Master Scheduling

Third Edition

A Practical Guide to Competitive Manufacturing

John F. Proud

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John Wiley & Sons, Inc.

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**This book is dedicated to manufacturing professionals worldwide,
especially those who have chosen master scheduling as a career.**

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Master Scheduling: A Practical Guide to Competitive Manufacturing, Third Edition
John F. Proud

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If you don't know where you are going, any road will get you there.

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Dick Ling, former Oliver Wight associate and former president of Arista Education and Consulting, exposed me to the real profession of master scheduling. If I had not crossed paths with Dick Ling and several other Oliver Wight associates, I would not have been able to write this book. I learned my master scheduling skills from the best in the industry—Dick Ling, Oliver Wight associates, and professional master schedulers working in Class A companies worldwide.

Dick Pugliese, while serving as general manager of a Xerox plant, gave me the opportunity to be part of a Class A Manufacturing Resource Planning system implementation. It was during this time that I learned how a manufacturing company should work if it is to be successful and achieve Class A results.

Other colleagues and associates have also taught me much about this complex subject. John Dougherty literally spent hours with me discussing and developing concepts that we hope furthered the industry's understanding of how important master scheduling is to the

manufacturing environment. Walt Goddard, John Sari, and Al Stevens also developed numerous master scheduling concepts over the years and were kind enough to share them with me. Oliver Wight associates Tom Gillen, who helped me with the engineering issues, and George Palmatier, who made sure I did justice to the demand side of the business, also deserve recognition.

Several other people whom I would like to thank and acknowledge are: Dick Luecke, who was instrumental in taking my thoughts and structuring them into sentences and phrases that actually make sense; Lori Stacey, who spent hours upon hours typing, correcting, re-typing, and re-correcting the lengthy manuscript; the Oliver Wight Publications staff, who have been effective, cooperative, patient, and understanding throughout this book's entire process; and the John Wiley & Sons, Inc. staff who added the professional flavor.

Once the manuscript draft was available, Mike Bales, former vice-president operations, G & W Electric; Dick Pugliese, retired executive; John Sari, Oliver Wight Alliance; and Larry Wilson, Oliver Wight Americas Principal worked their way through the many pages, challenging my thoughts and recommending changes as appropriate. Without their critical input, this book would be less than the book that it is today. My "severest and best critic" was former Oliver Wight associate Darryl Landvater, who challenged not only content but organization. A special thank you goes to Darryl for his effort, time, and patience.

Another special thanks goes to my original editor and publisher, Jim Childs, as well as my current editor, Matt Holt, whom I am sure I caused great grief when I missed several milestones along the way—what, the person who wrote the book on valid master schedules was "past due?" If you ever doubt how important it is for a manufacturing company to create valid schedules and then perform to these schedules in order to satisfy its customers, just give my publisher a call. In addition to Jim Childs, Dana Scannell was the first to give me the chance to write this book and encouraged me to keep going when my frustrations were high and my stamina was low.

My final thank you goes to my lovely wife, Darlene, who gave me the time necessary and seldom complained about being left alone while I

worked in the office. Darlene is truly my best friend, and without her understanding and encouragement, I would never have found myself in a position to write these acknowledgments for what I still believe is the first and only definitive book covering the subject of master scheduling.

Foreword

Planning comes before performance and performance comes before success.

It took someone with knowledge, understanding, breadth of experience, and passion for the subject to write this book.

A book that fills a gap in the literature of manufacturing.

A book that took tremendous effort to produce.

I have known John Proud for more than fifteen years. I have worked with him, taught with him, and debated concepts with him, developing a respect that he deserves both personally and professionally.

John has accomplished a monumental task in writing the definitive work on master scheduling. There are very few people who have the combination of user experience, software understanding, and consulting and teaching experience in a variety of industries that would enable them to present master scheduling in both an understandable and readable format.

This is not a theoretical book. John has taken great pains to help the reader to thoroughly understand the application of the principles of master scheduling, describing what works in great detail. When first reading the book, the reader could become mired in the technical detail of an environment that is different from his or her own company. My suggestion is to concentrate on those areas that apply to your environment and, at a later time, return to those areas that have no direct bearing on your experience for further understanding.

The manufacturing community, academia, and professional organizations will need to look very seriously at this work. It has the characteristics to make it the standard text for any course on master scheduling and the standard resource for all manufacturing companies who desire to do master scheduling well.

John, my sincere congratulations for writing such a definitive book on master scheduling.

Richard C. Ling
President, Richard C. Ling, Inc.

Introduction

The Master of All Schedules

I seek not to know all the answers,
but to understand the questions.

The 1960s were times of radical change in America; the youth of the country challenged almost every traditional value, rebelling in ways unheard of in previous generations. In manufacturing, a much quieter, though no less dramatic, revolution also was taking place. Traditional means of production and inventory control went by the boards as companies like Twin Disc and J. I. Case made effective use of Material Requirements Planning (MRP) a reality. Though crude by today's standards, these early attempts at MRP gave manufacturing professionals their first real weapons in the war on production inefficiencies.

When companies first began using MRP, they drove it with a forecast and/or customer orders (demand). In other words, to calculate material requirements, computers multiplied the latest demand numbers by the quantities required in the bills-of-material (BOM). The problem with this approach was that it blindly assumed that the resources would be available to manufacture a product in sufficient quantities just as it was sold. Unfortunately, manufacturing rarely produced each product as it was sold. And as demand numbers inevitably changed over time, material requirements changed with them. With computer-driven tools, it was very possible to generate overwhelming change to schedules that plants and suppliers could not handle. This meant that the information in the system was often in chaos. And so was the production line. The frequent result was an overloaded schedule, underutilized resources, or both.

Some of the MRP pioneers quickly realized that their formal systems were of little value if they failed to predict and control the resources needed to support the way production was actually scheduled. They also realized that they had left the computer too much decision-making power; nowhere in the process was there a human being who ensured a true balance between supply (manufacturing and supplier resources) and demand (customers). These insights led to the development of a "master schedule" that controlled all other schedules: plant, mill, suppliers, and so forth. Equally important, a new position was created: that of the master scheduler. These developments really marked the birth of Master Production Scheduling (MPS), or to use the term favored in this book, master scheduling. (The acronym MPS will be used throughout the book when referring to master scheduling.)

Master scheduling is the pivotal point in a manufacturing business when demand from the marketplace is balanced with the capabilities and capacities of the company and its suppliers in real-time terms. As the modern manufacturing environment has grown more complex in terms of products and product options, and more demanding in terms of the competitive requirements for quality, fast and on-time delivery, low prices, quality service, and technology enhancements, this balancing mechanism has been a vital tool for management at many levels. At the executive team level, sales and operations planning has become the integrator of all top-level plans: sales, marketing, quality, engineering, financial, and production. At middle-management levels, and on the plant or mill floor, master scheduling spells out in detail what needs to be produced so that the company can ensure that capacity will be available, that materials will be on hand when needed, and that customer requirements will be satisfied on dates specified by the customers.

Master Scheduling as Part of Enterprise Planning Systems

Like all other enterprise planning systems, master scheduling is geared to satisfying market demand. It coordinates that demand with resources in the company to schedule optimal production rates. To help management make decisions about aggregate production rates, companies developed a process called Sales and Operations Planning (S&OP) — sometimes called Integrated Business Management. In the S&OP process, the leaders of each major function meet at least once a month and develop a company game plan that synchronizes planned supply output with marketplace demand.

The sales and operations planning team considers products by aggregate families, and it is the job of the supply manager or master scheduler to break down those aggregate build rates into detailed, weekly and/or daily production schedules for each item. In this way, S&OP drives and guides the master schedule.[1]

The expansion of the original material requirements planning technique into a set of functions encompassing demand management, supply management, sales and operations planning, master scheduling, material requirements planning, capacity planning and control, and supplier and plant scheduling has become known as Manufacturing Resource Planning (MRPII).[2] It's fair to say that the addition of MPS

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[1] For a complete discussion of Sales and Operations Planning, see George E. Palmatier with Colleen Crum, *Enterprise Sales and Operations Planning* (Boca Raton, Fla.: J. Ross Publishing, Inc. 2003) Richard C. Ling and Walter E. Goddard, *Orchestrating Success* (New York, N.Y.: John Wiley & Sons, Inc., 1988).

[2] For a complete discussion of Manufacturing Resource Planning, see Darryl V. Landvater, *World Class Production and Inventory Management* (New York, N.Y.: John Wiley & Sons, Inc., 1993), and *Manufacturing Resource Planning: MRPII, Unlocking America's Productivity Potential* (New York, N.Y.: John Wiley & Sons, Inc., 1981), Appendix 1, pp. 403–17.

was a key ingredient in the evolution of MRP to MRPII to ERP (see chapter 2 for schematics of the MRPII and ERP processes).

Just having a master schedule does not ensure success. As with all processes and tools, the master schedule must be managed. Failure to manage the master schedule results in the company's manufacturing and supplier resources being poorly deployed. This in turn means that the company may be unresponsive to customer needs or wasteful in its use of resources. Ultimately, the company risks losing its competitive position. Moreover, if the master schedule is improperly managed, many of the benefits from the sales and operations planning process will be lost.

Managed well, the master schedule provides the basis for good customer order promising and good resource utilization. By maintaining an up-to-date picture of the balance between supply and demand, master scheduling allows each customer to get the best service possible within the constraints of inventory, resources, and time. And by providing updated information about the current status of company schedules and their ability to support customer commitments, the master schedule focuses the company's leaders' and management's attention where it is needed. In short, master scheduling plays a major role in helping companies stay responsive, competitive, and profitable.

Who Should Understand Master Scheduling?

This book is not intended solely for master schedulers, but also for those who should participate in designing their company's approach to master scheduling. For master schedulers—both new to the job and those who have been doing it for years—this book can help them to do their jobs more effectively. Beginners will find a complete framework for understanding the MPS process and how it connects with the rest of the business. Seasoned professionals will be challenged into rethinking master scheduling at their companies. And all readers will benefit from numerous tricks of the trade, drawn from years of practice management, consulting, and teaching experience.

Leaders and managers in sales, marketing, manufacturing, materials, design, engineering, information technology, and finance will also benefit from knowledge of master scheduling, which is, after all, the integration point for other planning, analysis, prioritizing, and performance measurement. They will find the chapters that cover the general principles of the MPS process useful reading.

Executive team members should familiarize themselves with the basic concepts of this book and should understand the later chapters, which cover sales and operations planning, rough cut capacity planning, demand and supply management, and effective implementation. This is because master scheduling balances resource utilization and customer satisfaction while supporting the strategic as well as tactical directions determined in the sales and operations planning process. As one manufacturing manager put it, "No one ever got to Class A without doing MPS well."[3] It therefore behooves everyone of authority in the company to understand what goes into and comes out of the master schedule.

The master scheduler and people in special environments will benefit from the middle chapters, which cover specific environments and advanced techniques. Overall, the book has been designed to have something for just about everyone connected with competitive manufacturing.

How This Book Is Organized

Master scheduling involves many functions of business and crosses most departmental lines. This is the first and only book designed to pull together a comprehensive body of knowledge about master sched-

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[3] The term "Class A" refers to the top rating a manufacturing company can achieve, based on the Oliver Wight ABCD Checklists for Operational and Business Excellence. The original checklist was developed by Oliver Wight in 1977 and has been updated since to reflect the evolving standards of performance achieved by world-class manufacturing companies. (See the Appendix, page 573.)

uling and to discuss the MPS process within the context of various manufacturing environments. It not only paints a broad perspective across the whole canvas of manufacturing but provides the fine details needed to understand MPS in specific types of businesses. Whether you make finished goods to stock, assemble or finish to customer order, or design and build products to customer specifications, you will find information and tools relevant to your business.

Chapters 1 through 6 of *Master Scheduling: A Practical Guide to Competitive Manufacturing* define the master scheduling process by explaining why and what to master schedule, the basic terminology, calculations, formats, mechanics, and how to manage change using master scheduling. Chapters 7 through 12 cover specific tools and techniques used in various manufacturing environments (make-to-stock, make-to-order, engineer-to-order, make-to-contract). Chapters 13 through 16 describe the supporting functions of MPS, such as sales and operations planning, rough cut capacity planning, supply management, and demand management. The book's chapters conclude with chapter 17 and the appendices—guidelines for implementing and operating a successful master scheduling process across the entire enterprise and supply chain.

Master Scheduling is not intended to be read cover to cover in one sitting. Rather, the general sections should be covered first, followed by those chapters that address the reader's manufacturing environment.

This book is intended to impart a thorough understanding of the master scheduling process, how it interfaces with other manufacturing processes, the roles various people play, and the technology as well as other tools necessary to support it. It aims to arm the reader with the knowledge required to fine-tune the master schedule process to the needs of his or her own company with the goal of improving customer satisfaction and enhancing competitiveness.

No company ever gets to Class A without managing the master scheduling process well, nor does anyone ever perform master scheduling well without having a firm grasp of the basic concepts and principles underlying the process. In the manufacturing arena, knowledge is truly power. Use that knowledge well, and you and your company will prosper.

Master Scheduling

Third Edition

1

Chaos in Manufacturing

Don't mistake activity for accomplishment.

The Place: A typical North American manufacturing company
The Time: 10:00 A.M.
The Date: Friday, the last day of the month

What had been a quiet and sporadically busy area three weeks ago has turned into a three-ring circus. Lift trucks careen through the stockrooms at full tilt, barely avoiding head-on collisions. Every inch of the shipping department is piled with partially completed products waiting for missing components. Normally neat and orderly work areas now resemble obstacle courses as excess materials clog the aisles.

Outside the supervisor's office an angry manager berates an expediter, demanding to know why the night shift ran the wrong size product. The expediter shifts his weight from foot to foot as he explains that the required product had been at the top of the hot list—and maybe the night supervisor did not get that revision of this week's list (of which there had been three).

Over in one of the assembly areas a worker complains that she has gone as far as she can without the next skid from the processing department. A supervisor moves from worker to worker, asking people to sign up for weekend overtime. A chart on the wall shows that 30% of the month's shipments still need to be made.

The cost variance reports that were the burning issue of the manufacturing meetings just two short weeks ago are now buried under a stack of quality control reject reports. Management has temporarily waived the rejects so that needed materials can be used to meet this month's numbers.

Off in a corner by the coffee machine, a gray-haired foreman shakes his head and mumbles: "So this is the manufacturing of the future that the guys in corporate promised. It looks like the manufacturing of the past to me."

This scene plays itself out in many manufacturing companies today. Worse, like a recurring nightmare it returns to haunt companies month after month. It happens, in part, because many companies still operate in a reactive mode, in which all decisions, priorities, and schedules are driven by the day-to-day fluctuations of the marketplace, momentary changes in the plant, and the performance of individual suppliers. It is a cycle of action and reaction, and until companies break the cycle, they will never rid themselves of the end-of-the-month crunch and nightmare.

Breaking the cycle entails four steps:

1. Admitting that serious problems exist, and that the current situation is not healthy for the company or the people who work in it
2. Identifying the specific problems—not just the symptoms
3. Determining the cause of the problems
4. Creating and acting on effective solutions

Problems in Manufacturing

Consider the scenario again, this time through the eyes of the plant manager, who sees that although everyone is attempting to do a conscientious job, the efforts are often misdirected. The use of hot lists to set priorities in getting products out the door causes major disruptions and confusion in manufacturing. Schedule changes prompted by these hot lists satisfy some short-term requirements but throw a monkey wrench into others. Shipment dates are missed, the customers complain to the sales force, and the sales manager vents his anger onto the production manager.

Although there appears to be much work in process, the reality is that most of the work is sitting in queues. In addition, staggering amounts of unplanned overtime and quality problems are mounting. After inventorying the problems, the plant manager begins to look for their underlying causes. The hot lists, he finds, are used because of frequent part shortages, some of which result from late deliveries from engineering (specifications) and suppliers (materials), late ordering by the company, and the poor quality of materials actually delivered by

Symptoms of Master Scheduling Problems

Uncontrollable costs
Disruptions on the shop floor
Late deliveries to customers
Late deliveries from suppliers
Unplanned overtime/off-loading
High work-in-process
Mismatched inventories
Over-/under-utilized resources
Hot lists
Frequent schedule changes
Many full-time expediters
Customer complaints
High “past dues”
Long queues
End-of-month crunch
Finger pointing/low morale

manufacturing (inside supplier) or outside suppliers in general. Other part shortages result from inaccurate bills-of-material and inventory record inaccuracies that report materials as being in stock when they are not.

Schedule change problems often stem from the lack of a priority mechanism, or from following the wrong priorities—such as keeping a machine busy rather than satisfying a customer. (It is not unusual for a company that has just purchased a new piece of expensive equipment to believe that its first priority is to keep the machine running, even if there are no customer orders for the machine's output.)

Missed shipment dates may result from part shortages or problems with capacity. Some companies are not ever sure what their capacity is, nor do they have a process in place to measure it. In other companies, measuring processes may be available, but they may not be accurate.

Additionally, material can sit in queues on the manufacturing floor because of material shortages, because of the capacity issues just described, or because plant priorities and work flows are driven by an overly optimistic sales forecast that is used to communicate priorities to people on the manufacturing floor.

Still other problems on the manufacturing floor have their source in inaccurate forecasts of demand—forecasts that instruct the plant to build either too much or too little.

THE INACCURATE FORECAST

It seems to happen all the time. Marketing forecasts customer demand at one level, while actual demand turns out to be something different—sometimes more, sometimes less.

The difficulty of scheduling production in the face of forecast inaccuracies should be obvious: Materials and capacities are planned for one level of demand, but the demand that actually finds its way to the production facility is something different. Consider the simple case

Periods	April	May	June	Quarterly Total
Forecast	100	100	100	300
Demand	140	65	120	325
Variance	+40	−35	+20	+25

shown in the graph. This company's quarterly forecast was off the mark by 25 units (about 8%). Not bad. Its forecast for individual monthly periods, however, was greatly off target. This is typical, as forecasting aggregate demand (such as quarterly) is always easier and tends to be more accurate than forecasting more detailed demand (such as monthly or even shorter periods).

Unfortunately, most production is scheduled in these shortened (or even smaller) periods, where grousing about inaccurate forecasts is commonplace but does little to alter the fact that forecasting the future will never have the precision of rocket science. Forecasts may be improved, but never guaranteed. Besides, any forecaster who could really see the future clearly would be in the next limo headed toward Wall Street or Las Vegas, where rewards for accurate forecasting are mind-boggling!

Management Issues

People in the day-to-day business of manufacturing must learn to live with the variances between anticipated (forecasted) and actual customer demand, and with the problems they create. For company leaders and managers, forecast inaccuracies create a number of important issues. First among these is the fact that when someone creates a forecast, real things happen: Materials and components are ordered or canceled. If current capacity isn't up to the forecast, people start thinking about increasing it with new equipment and new personnel. If current capacity is greater than the forecast, people start thinking about decreasing it by shutting down production centers, laying off employees, or even closing entire manufacturing operations. In other words, forecasting demand is not an intellectual exercise done for its own sake, but an activity that triggers a number of other costly actions within the company.

Unfortunately, forecasts are not always taken seriously. Salespeople may be tempted to overstate the forecast as insurance against possible stockouts. The forecast itself is generally uncritical of the estimates submitted by each salesperson and contains no rewards for accuracy or penalties for inaccuracy. The task of management is getting all parties involved in the forecasting process to work together and take accountability for its accuracy. Production and finance need to understand the concern of sales personnel about stockouts and lost commissions. Sales and marketing need to understand the cost of excess inventory to the profitability and survival of the company.

There is now a large body of knowledge and experience indicating the heights of customer satisfaction and profitability that result when teamwork replaces hostility among engineering, production, finance, marketing, and sales personnel. Management can and should act as the catalyst in team-building efforts.

While the team-building activity may be the greatest contribution of the executive team, other issues merit its concern:

- *What about inventory?* If a plant is scheduled to build 100 units and orders for 140 appear, is there enough inventory to satisfy the unexpected demand? In the reverse case, when demand fails to appear, should the plant keep running and building inventory?

- *What alternatives exist on the manufacturing floor?* When forecasted orders fail to appear, equipment and trained people are idled—unless alternative work is found. Moving up an order might keep some hands busy; maintenance or training might occupy others. When demand exceeds scheduled supply, can more supply be created through overtime or outsourcing of part of the workload?

- *What are some of the real costs of forecast inaccuracy?* An overloaded schedule creates overtime expenses. The production floor and its personnel are stressed and, perhaps, made less productive. Overforecasted demand creates idle hands and capacity, and inventories of unused materials.

- *How are customers affected?* When actual demand is underestimated, management becomes a traffic cop, directing the company's limited output to certain customers and withholding it from others. This is known in the industry as placing the customer on allocation (such a nasty word). If allocation of product is necessary, how should it be allocated when there isn't enough to go around? Which customers have priority? Remember, all customers are equal; it's just that some are more equal than others.

As management ponders these issues, the fallout of forecast inaccuracies has other minds working. Marketing observes the discrepancies between its forecasts and actual demand and wonders if these indicate a trend. If the forecast is usually on the high side, manufacturing thinks about discounting the forecast as a matter of policy. The corporate controller jokes about just tossing the manufacturing budget out the window. Out in the field, the individual salesperson grows apprehensive about guaranteeing delivery on firm orders; when push comes to shove, another sales representative's customer may have priority.

Knowing that forecasts will never match actual demand, except on rare occasions, experienced master schedulers understand that they must be flexible in shifting capacity and materials from one period to another. They must know whom to call about splitting a customer's delivery over two or more periods. And they must have the courage to look beyond the forecasted numbers as they plan production. Indeed, many top managers would be stunned to know that the solution to many of their production headaches is in the hands of the master scheduler, who either solves them with skill and ingenuity or allows them to fester due to inexperience or indifference.

And the Solutions

The search for solutions to these problems should begin with a fundamental question: Why is this company in business? And the answer should be this: To safely make a profit and satisfy customers. This answer entails ensuring an adequate product supply to meet the demand for the company's products. If a product is not in inventory to satisfy demand, the company must have the material, labor, equipment, capital, and time to produce it. This is where Master Scheduling (MPS), Enterprise Resource Planning (ERP), and Supply Chain Management (SCM) play such a critical role in the purpose of the business.

Supply Chain Management and Enterprise Resource Planning are integrated demand-driven supply planning processes. This demand can consist of a forecast, customer orders (which may or may not be part of that forecast), contracts or long-term agreements, engineering prototypes, branch warehouse requirements (e.g., replenishing a distribution center), or orders from another division within the company if the product in question is, in turn, a component of that division's products. Demand can also originate in the need for specials (industry shows, samples), service parts or spares, increase in safety stock requirements, or lot sizes.

To satisfy these demands, the master scheduler needs to consider the availability of materials and capacity resources. These materials include those being produced internally as well as those being procured from outside sources. Besides the item itself, quantities, dates, and lead times must be taken into account. Capacity involves people and equipment—both of one's own company and of its suppliers. Time, space, and money are also important considerations.

As mentioned in the introduction, the challenge the master scheduler faces is to effectively balance product supply with product demand. One way to envision the situation is to imagine a seesaw like the one shown in Figure 1.1. In a perfect world, the seesaw is parallel with the ground; supply is always an equal counterweight to demand. When demand changes, supply instantly adjusts in a way that keeps the system in perfect balance. In the real world, however, demand rises or falls in unpredictable ways, and imbalances occur. These occasions require a master scheduler to make adjustments to the system in order to get the demand and supply back into balance.

When a company has more demand for its products than it has supply, it has two options for returning to a balanced condition:

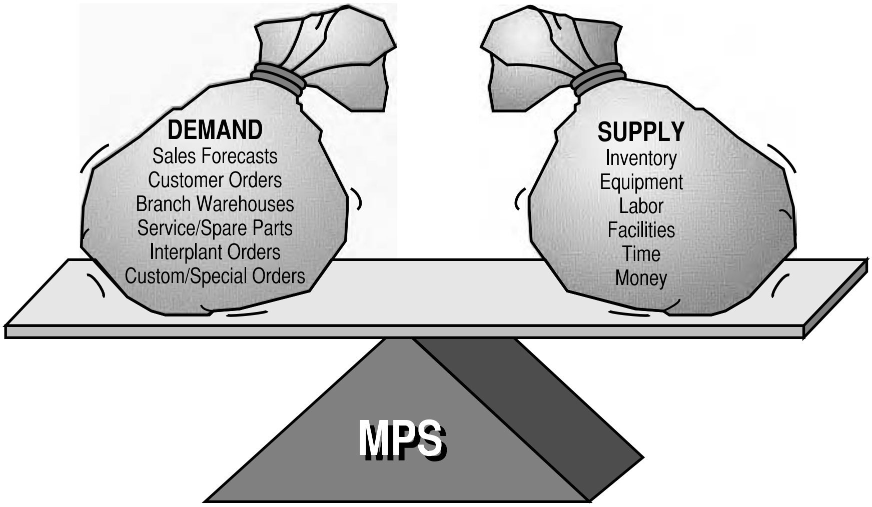


Figure 1.1 Balancing Supply and Demand

1. Increase the supply of product—get more material and resources.
2. Decrease the demand—turn away or reschedule some demand orders.

The situation in which there is more supply of the product than demand also creates two choices:

1. Increase demand—energize the sales force, run a promotion, discount the price, and so on.
2. Decrease the supply of the product or the material/capacity needed to produce it—cut back on production, people, and equipment.

Even though these situations can be solved only by one or both of the choices described here, some companies nevertheless believe that if they ignore the situation it will go away—an approach to problem solving called *ostrich management.*

The periodic imbalances between demand and supply are represented in Figure 1.2, which shows inventory's constant fluctuations over time between high, medium, and low demand as well as high, medium, and low supply, resulting in a sawtooth curve. In profitable manufacturing companies, the goal is generally to stabilize production by level-loading the plant while smoothing out the demand. The situation shown—stockouts as well as excess inventory—is certainly not the objective; the objective is to have just enough inventory to satisfy demand, thereby satisfying customers and making a profit.

In the presence of sawtooth demand, manufacturing will be a seesaw in constant motion, with all the stockouts, hot lists, and confusion that characterize the company profiled at the beginning of this chapter. If the company is not experiencing stockouts, it is experiencing excess inventories. What is known for sure about this environment is that it continually goes back and forth. Companies that try to smooth out sawtooth demand through artificial contrivances usually fail. Tactics like enforcing schedule freezes and placing limits on the volume of orders salespeople can take cause more problems than they solve. Telling a sales force to limit its sales for a particular period, for example, is a sure way to torpedo the important relationship that must exist between sales and manufacturing if a company is to grow and prosper. Using these types of approaches is like installing welded struts onto the bottom of the seesaw: nothing moves. A better approach may be to

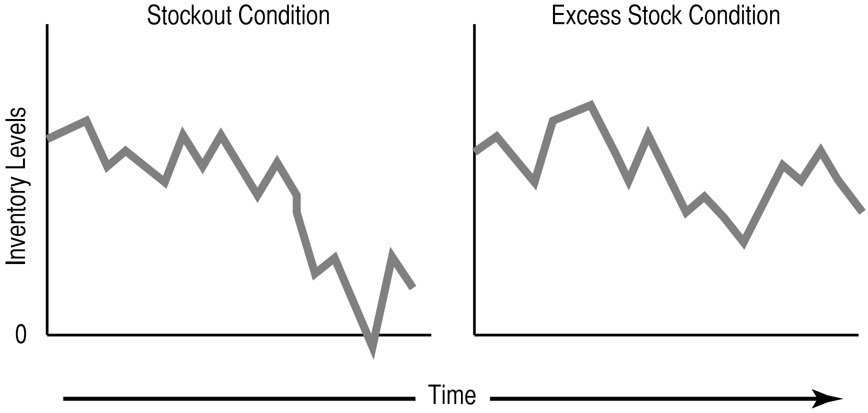


Figure 1.2 The Sawtooth Curves

install shock absorbers under the seesaw, to dampen expected fluctuations in supply and demand (see Figure 1.3).

Inventory in the form of finished goods, for example, is one traditional type of shock absorber. Inventory helps the company to accommodate changes in both supply and demand. Another type of shock absorber is flexibility in the supply chain, which allows the company to alter the activity rate on the plant floor in order to satisfy demand fluctuations without severe disruption. Flexibility can also be extended to sales and marketing. If the customer orders a red item, will a blue one work? If the customer requests the product for a next-month delivery, would that delivery better suit the customer's business purpose if it arrives in this month or in two months? If the customer cannot be so swayed, discounts or other sales inducements may give the customer reasons to cooperate with your demand and supply balancing problem. The point is, don't be afraid to ask. In any case, the company should identify whether it wants its greater flexibility in demand (sales and marketing) or supply (manufacturing and engineering). It should decide whether it wants to "sell the products manufacturing makes" or "build the products that sales sells" (further discussion regarding these

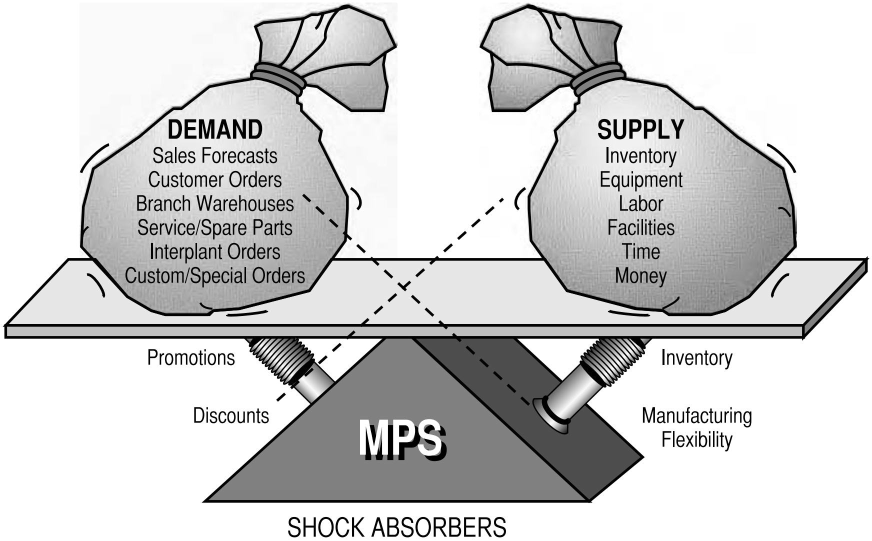


Figure 1.3 Dampening Supply and Demand Fluctuations

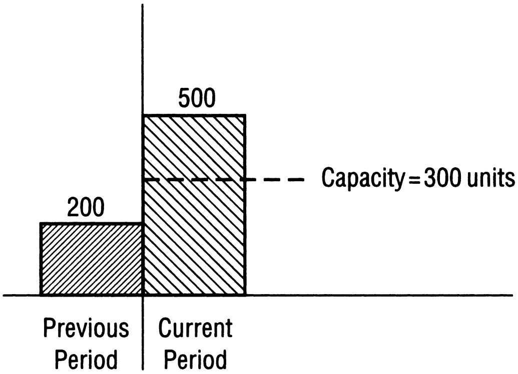
choices appears in Chapter 4, "Managing with the Master Schedule"). Once that decision is made, the company can move on to the task of balancing product supply with market demand. This effort takes place in demand management, sales and operations planning, supply management, and master scheduling.

It's this effort to balance supply and demand that drives a company to improve its master scheduling process and capability. The job ahead certainly is not an easy one. However, Class A and world-class companies face uncertain demand and supply in a controlled and managed way. The next chapter addresses the issue of why companies that wish to formally establish Class A planning and control processes elect to tackle the master scheduling function right from the start. Most Class A and world-class companies believe it's never too early to start to improve their master scheduling processes. However, before we move on, consider the following situation, which is all too typical of today's manufacturers.

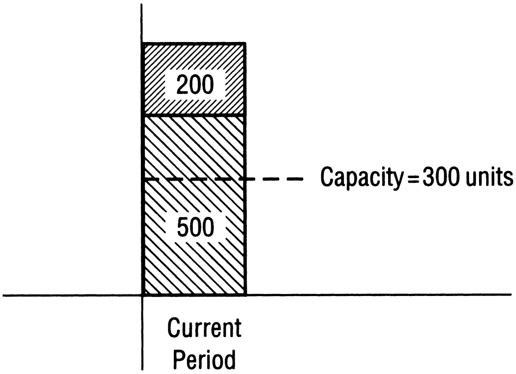
THE CASE OF THE OVERLOADED MASTER SCHEDULE

Some companies are always behind schedule on production and shipment. If Friday afternoons are a hellish race to whittle down the mountain of late manufacturing orders, Monday mornings are even worse. On Monday morning, the manufacturing manager and master scheduler face the dismal prospect of starting the new week under a load of past-due orders. It is tough enough to run a smooth operation when each week begins with a clean slate; but when you are faced with the normal scheduled orders *plus* all the work that failed to get done the previous week, the outlook is far from rosy. Yet this is how some companies operate—many on a continuing basis. Like a football or soccer team that starts the second half three touchdowns or goals behind its opponent, the manufacturer that carries past-due orders into the next period plays a desperate game of catch-up.

Here is a typical scenario. Spectrumatic Paint Company, which has a weekly capacity of 300 units, begins the current week with 500 units to produce—the result of inept scheduling, arm twisting by salespeople to accept orders, and so forth. To compound its current problem, Spectrumatic ended the previous week sitting on past-due orders totaling 200 units.



There is one unfortunate principle about past work periods, however, and this is *inalterable:* Time that passes is gone forever. Once a current production period expires, there is no retrieving it, and any orders left undone must either be done in a future period or be dropped entirely. Many companies simply move them into the current period. In the case of Spectrumatic Paint Company, its inexperienced scheduler simply piled the 200 past-due units on top of the 500 units currently scheduled, resulting in a total burden of 700 units in a period with 300 units of capacity. As the next figure shows, this is what the company was faced with on Monday morning.



This is like packing your family station wagon to the rain gutters for a summer vacation, only to find that—*oops!*—you forgot the bicycles, fishing gear, and canoe. Chances are that with all this new stuff loading down the wagon, you and your passengers are destined for an uncomfortable ride. Therefore, this scenario suggests an ironclad law for master schedulers to obey: The master schedule cannot be past due.

Management Issues

Past-due MPS orders and overscheduled current work periods are two major sources of the overloaded master schedules that plague so many companies. And these overloaded schedules create a host of *internal* problems for management.

- *Production efficiency decreases.* "Drop what you're doing and start order 247. We have to get this customer taken care of or we'll lose their whole account!" Poorly timed line changeovers, downtime due to material shortages, and stress take a toll on efficiency in the manufacturing facility. Production supervisors and cell leaders also get mixed signals as to real priorities.

- *Products do not get shipped.* An overloaded master schedule results in material stockouts; partially built products are taken off line, where they sit as work-in-process until missing materials are received. Products built but not shipped increase inventories while reducing current revenues, thereby creating financing problems for the entire company.

- *Costs go up or out of control.* As production efficiency decreases, financial managers see costs rising. Dependence on overtime, expedited material purchases, air freight charges on late orders, concessions to irate customers, and other compensations drive up unit costs and cause havoc in cost planning and budgets.

- *Widespread confusion makes it difficult for management to identify the real problems.* Why are products not being shipped? Lack of coordination of materials and production scheduling? Capacity problems? Credit holds? Engineering specifications not available?

- *Product quality suffers.* Production is pressured to work faster and faster to complete work in less than planned lead time, possibly causing quality to drop.

Given all of these negatives, we have to ask: Why would anyone allow the master schedule to be overloaded? Very often, the answer comes down to some basic human behaviors in situations where trust and confidence are absent.

Consider the sales representative who must ensure delivery of 100 units of Model 5B3 refrigerators to an appliance distributor on October 15. If the company's history is such that production is *always* late, or *always* short, or the stockroom *never* has enough components to complete an order, this sales representative has every incentive to inflate the size of the order and to ask that the order be moved up in the schedule. "One hundred twenty units delivered to the customer on the first of October" becomes his entry in the order book. Discounting production's capabilities is a natural response to past lack of performance, and deliberately overloading the schedule is often seen as a way of ensuring that enough materials will be on hand and that enough units will be built. Naturally, production schedulers learn to play this game and begin discounting orders as they appear. In no time at all, no one can trust anyone else's numbers.

The unfortunate part of this dysfunctional charade is that all the players are motivated by a desire to do the right thing: for the sales representative, to fill the customer order with the right quantity at the right time; for the purchasing department, to have just enough materials on hand; for the production facility, to meet *real* demand in an efficient and timely manner.

The net result of all these fine intentions in an atmosphere of distrust, however, is an overloaded master schedule and profit- and energy-sapping people problems, the most deadly being the blame game. Sales blames manufacturing for lost orders due to shipment delays. Manufacturing points the finger at the sales representatives, who "promise anything to get an order." Everything is a crisis. Finance yells that "costs are out of control" because of overtime and air freight. In this atmosphere, the refusal to recognize the seriousness of the problem naturally becomes a survival trait. Why admit that there *is* a problem? You can only be blamed for it and, maybe, fired ("If you can't get the job done, we'll find someone who can!"). Avoidance or denial of the problem becomes the course of least resistance. Sweep it under the rug. Park it at someone else's door.

Ultimately, all the people problems come to rest at the doorstep of the management team. Management must create an environment in which all concerned can be honest about their numbers. Sales and production must be motivated to be frank with one another and to operate in a mutually beneficial partnership. Very often, the key to developing this environment of cooperation is, as W. Edwards Deming noted, to "drive out fear."[1] Management must end the blame game and create a climate in which people can admit to problems and past mistakes without fear of blame or retribution. Lacking this climate, problems will simply continue being swept under the carpet.

Once fear is driven from the workplace, the next step toward dealing with an overloaded master schedule is a top-down analysis that does the following:

- Lists sales and production priorities
- Seeks practical remedies to production constraints
- Prioritizes and allocates production to customer demands
- Establishes a strategy to get out of—and stay out of—the over-scheduled condition
- Implements and communicates the chosen strategy
- Monitors and measures the strategy's success

The ultimate goal of this analysis, or course, is to give management the knowledge and the tools to shake off the oppressive burden of the overloaded master schedule and to reschedule production with completion dates that are realistic and that satisfy customer needs to the company's best ability.

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[1] W. Edwards Deming, "Fourteen Points," in *Out of Crisis* (Cambridge: Massachusetts Institute of Technology Center for Advanced Engineering Study, 1982), 23.

Getting Out of the Overloaded Master Schedule

One of the primary responsibilities of the master scheduler is to create a valid master schedule. A valid master schedule is one in which the material due dates equal the material need dates, and the planned capacity equals the required capacity. Look at Figure 1.4. As you can see, a master schedule item has gone past due. This item is used to drive the material requirements for all lower-level items as well as the capacity requirements for all manufacturing and engineering resources. If the master scheduled item is past due, what does that say about all the material that still needs to become part of the scheduled item? All this material is also past due. If we start with a past-due master schedule date, all the material and capacity still required, by definition, is past due. And how valid is a past-due date? How do you answer manufacturing, suppliers, or engineering when they ask, "Which past due do you want me to work on today?"

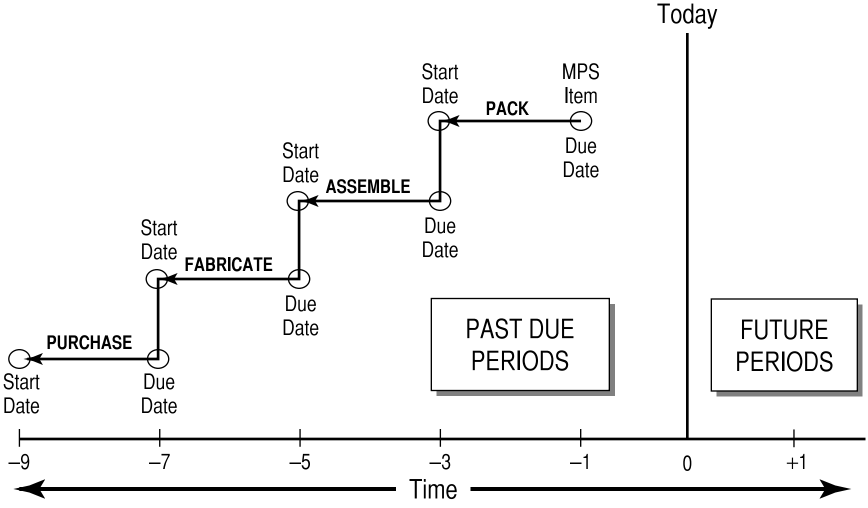


Figure 1.4 Past-Due Master Schedule

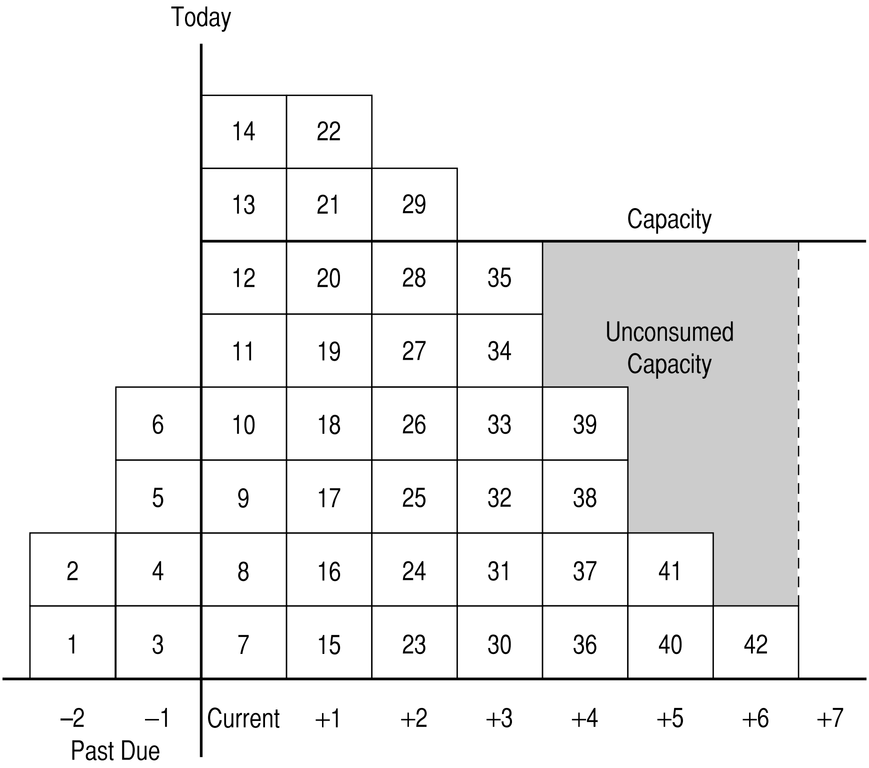
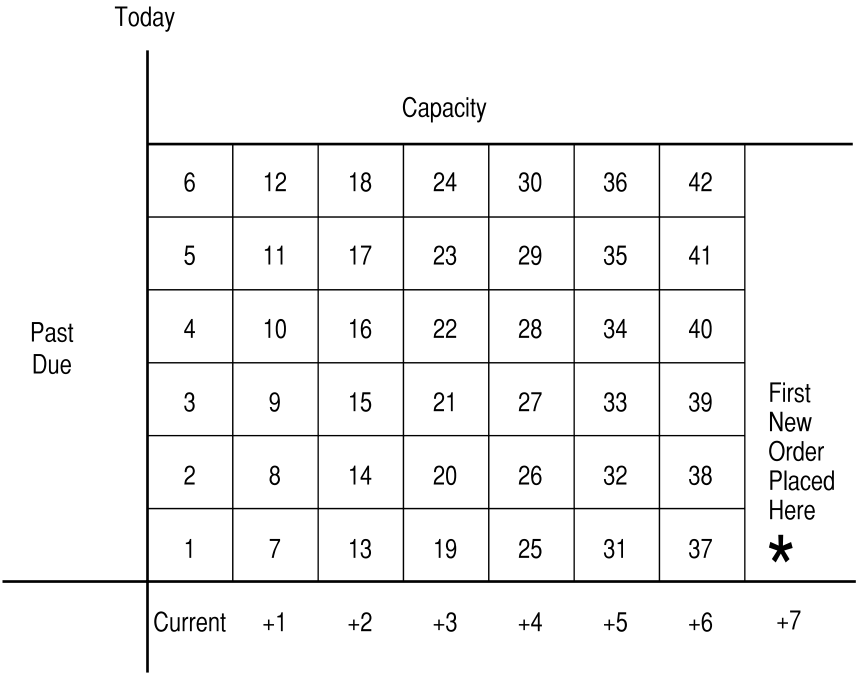


Figure 1.5 Overloaded Master Schedule

The job of creating a *valid* master schedule is not an easy one. It certainly is harder to do than to create an *invalid* schedule. In fact, it is not difficult at all to create an *invalid* schedule. Just about anyone can do that! The real challenge is to create a schedule that balances supply of resources and materials with the demand for those resources and materials. So, when in an overloaded condition, how does a master scheduler successfully orchestrate getting out of this inevitable situation?

The first step is to admit that the master schedule is overloaded. With this acknowledged, an assessment of the situation and identifying the constraints facing the company become necessary. Can overtime be used? Can work be subcontracted? Can more people be hired? Can material be expedited? Can premium air or ground freight be used? With these opportunities and constraints in mind, the master



6	12	18	24	30	36	42	
5	11	17	23	29	35	41	
4	10	16	22	28	34	40	
3	9	15	21	27	33	39	
2	8	14	20	26	32	38	
1	7	13	19	25	31	37	*
Current	+1	+2	+3	+4	+5	+6	+7

Figure 1.6 Correcting the Overloaded Master Schedule by Freezing Incoming Orders

scheduler needs to identify a rescheduling strategy. Other approaches to the rescheduling strategy have been tried, most of which have been unsuccessful. Look at the example presented in Figure 1.5, which illustrates a situation where 42 orders have been scheduled over a seven-period (current plus six periods) horizon. As the figure shows, 6 of these scheduled orders are past due, while 5 others have been committed over the planned capacity. Clearly, this represents an overloaded master schedule.

Over the years, three approaches have been tried to correct this situation. The first might be ostrich management—ignore the situation and it will simply go away. History has shown that this approach has never worked and probably never will.

The second approach is to freeze the schedule: No more orders are taken until a period well into the horizon. This will allow the company to work its way out of the overloaded condition. Refer to Figure 1.6

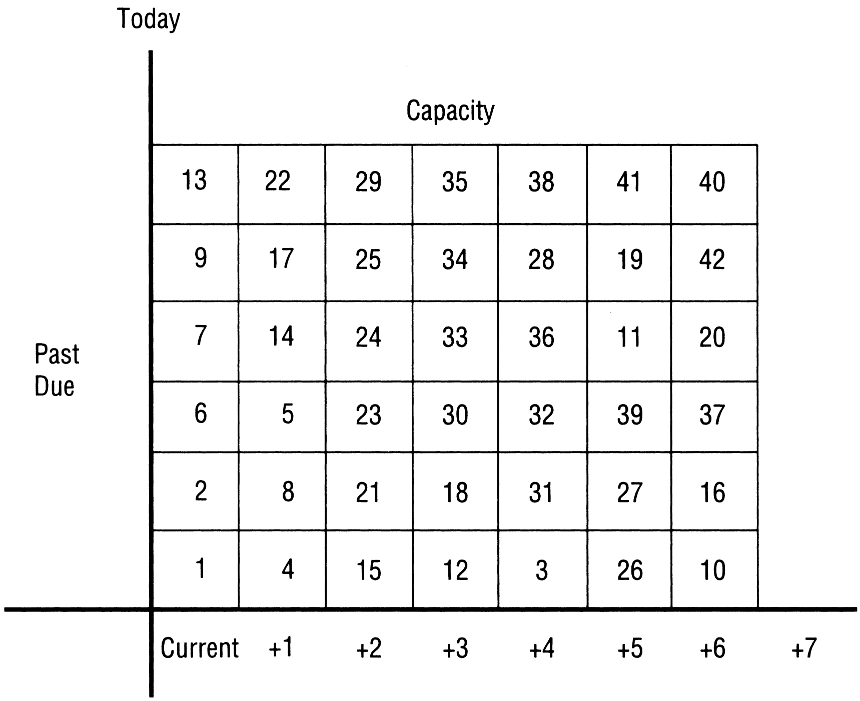
for a visual of this approach. What management or the master scheduler has done in this example is to inform everyone that no orders can be committed for delivery inside of seven periods. By doing this, the master scheduler expects to use the unconsumed capacity in periods current plus four through current plus six (see Figures 1.5 and 1.6) to work off the overload. In other words, the orders keep their same priority and just shift to the right, as seen in Figure 1.6.

How long do you think this directive will last? Maybe about 17 seconds—or until the next customer order that must be committed within the seven-period freeze zone! Another drawback of this approach is that it fails to recognize that these orders are not shipping because of some problem; this could be material, capacity, quality, credit hold, missing engineering specification, and so on. This approach ignores the fact that these problems may exist, and the product cannot be completed as scheduled, or cannot be completed even in the first or second periods, no matter how much pressure is put on the people or the facility.

A better approach, although it requires more work initially, is to reschedule. Using the reschedule strategy requires that the right mix of people—people who have the authority to make decisions—participate in an exercise to put achievable and realistic dates on all orders needing rescheduling. This process may require properly scheduled products to be moved out (or in some cases in) due to another product's being rescheduled into its committed time slot. Using Figures 1.5 and 1.7, let's review how this rescheduling process takes place.

Caution! Before beginning the actual rescheduling process, the company should be sure to identify a more realistic approach to booking customer orders in the future. This is important so that when the rescheduling exercise is complete, the company will not find itself right back in the same overloaded condition. Not only does the company need to identify how it will book orders in the future (using available-to-promise and realistic lead times), it must also implement the changes necessary to ensure that this more realistic approach is followed.

To start the rescheduling effort, a few key people must be available. The first and probably most important players are sales and marketing.



13	22	29	35	38	41	40
9	17	25	34	28	19	42
7	14	24	33	36	11	20
6	5	23	30	32	39	37
2	8	21	18	31	27	16
1	4	15	12	3	26	10
Current	+1	+2	+3	+4	+5	+6

Figure 1.7 Correcting the Overloaded Master Schedule by Rescheduling Commitments

In fact, when it comes to determining customer priorities, sales and marketing, working with the facts known as well as within the identified constraints, should have the final say. Manufacturing and materials management also should be included in the session to answer questions on capacities, capabilities, and materials. Other requested functions may include finance, quality, engineering, and general management. For obvious reasons the president, general manager, or managing director should speak last: It's called *people empowerment* and getting the people close to the situation to solve the problem. Of course, general management always has the right to make the final call. General management is also responsible for breaking ties when sales, marketing, manufacturing, engineering, and finance cannot agree.

Figure 1.5 on page 18 identifies an overloaded condition. Before starting the exercise, the status of each order (why it is past due or scheduled beyond the capacity limits) needs to be known. Once this information is on the table, the painful process of deciding a realistic and valid promise date begins. Looking at order number 1 and reviewing the problems associated with it, the group determines the new, realistic date. In the example, order numbers 1 and 2 remain as the highest priorities. Order number 3 has been rescheduled into the current period plus four, while orders number 4 and 5 have been rescheduled for a period 2 (current plus one) delivery. Order number 6 is designated as the number-three priority and rescheduled into the current period. This process continues until all orders have new expected delivery dates.

The next step in the process is to secure approval for the new plan from sales, marketing, materials, manufacturing, engineering, finance, and general management. Once this is done, it is time to implement the reschedule and make it happen. This is when the sales and marketing people really earn their money. Someone with sales and marketing responsibility must tactfully notify the customer of the anticipated delay and reschedule. It's generally not a pleasant task. Remember, many of these orders are already late and the customer is now being told that the expected delivery has been pushed out even further. No, it's not a pleasant task, but someone needs to do it. The challenge now is to ensure that the new delivery dates are met. Although implementing a rescheduling strategy is difficult, when coupled with the implementation of the promising new strategy, it works—and the benefits are many.

As you can see from the scenario, guarding against an overloaded master schedule is one reason why companies need to pay attention to how they master schedule. The next chapter discusses the whys of master scheduling and the framework into which this master scheduling process must fit.

2

Why Master Scheduling?

Success in business is easy if you do two things well:
plan your work and work your plan.

All manufacturing entities have a set of cornerstones—markers that define who they are, whom they serve, and the resources they draw upon. If they have been in operation for any length of time, they have customers, products, internal resources, and a set of suppliers. These are their cornerstones, and getting these cornerstones to fit together profitably is one of the challenges of manufacturing.

This view of the manufacturing business is represented in Figure 2.1 on page 24. Here, each of the cornerstones is disconnected, and in the center are the two qualities that must bring them together: vision and competence. Vision is the creative element that sees new and effective ways to combine the resources of the organization (human, material, equipment, and financial) with those provided by suppliers to create products that serve customer needs. Competence is the sum total of organizational and technical skills that transform the intangible vision into tangible plans and then into the activities that make the vision a reality. These competencies include innovation, sales and marketing, design and engineering, manufacturing, and so forth.

Both the vision and the competencies that exist to fulfill the vision express themselves through plans. All businesses have plans. Planning is first among the four essential functions of management, along with

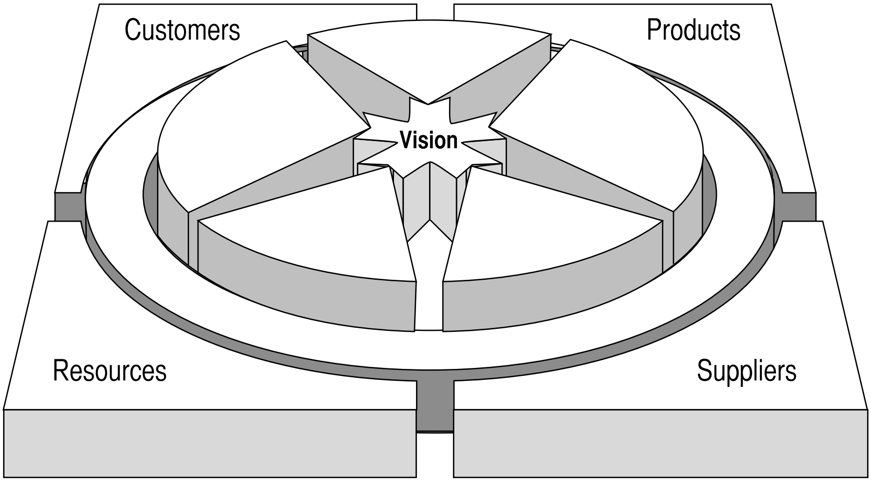


Figure 2.1 The Four Cornerstones of Manufacturing

organizing, motivating, and controlling. Without a plan there will be no control. Vision expresses itself through strategic plans determined by the executive team, painted in broad strokes, and addressed to the fundamental goals of the company. Strategic plans inevitably speak in the language of finance: "revenues of $240 million," "pretax earnings of $30.5 million," "a return on shareholder equity of 14%." At other times they present a market share goal.

But strategic plans cannot accomplish anything by themselves. To be fulfilled, they must be broken down into tactical operating plans—*plans that define what must be done.* These focus on business problems at operational levels and include:

- *The sales plan:* the number of units the sales team will sell
- *The marketing plan:* markets to target; product, pricing, promotion, and distribution schemes that will be used
- *The engineering plan:* programs and projects on the drawing board
- *The financial plan:* target revenues, expense budgets, and profit margins

- *The manufacturing plan:* how much the plant or mill will make, when it will be made, and at what rate

These operating plans must be linked with one another and with the strategic plans of the company. The financial plan, for example, establishes target revenues, but this target is meaningful only when plans to make and sell the product are considered. Likewise, manufacturing cannot independently determine what it will make and in what quantities: Manufacturing quantities must be determined in consultation with sales, which has its thumb on market demand; with engineering, which knows what is on the drawing boards; and with the financial department, which must pay for materials, labor, and carrying inventory.

Between Strategy and Execution

The broad area between strategic plans and their execution at the tactical level is the domain of middle management. Middle managers or key influencers of the company are charged with the development of lower-level plans and their execution. In this sense, middle management couples the broad strategies of the company to the details of execution. As detail execution takes place, middle management is responsible to ensure linkage of the detail work to the executive team's or top management's aggregate plans. Figure 2.2 on page 26 represents the integration between top-management plans and execution.

The master scheduler is, or certainly should be, one of these important midlevel management members. This individual (or individuals) operates as a buffer between one set of activities in the company—demand (sales and marketing)—and another—supply (engineering and manufacturing). Customer demand for the company's products can vary from period to period, and that variation is difficult to forecast with anything resembling certainty. Suffice it to say here that varia-

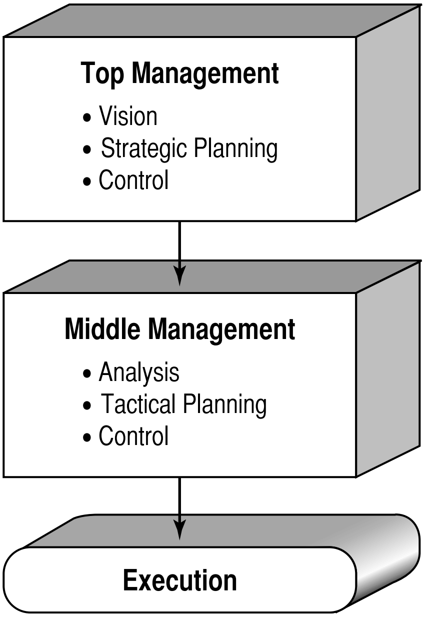


Figure 2.2 Middle Management as a Decoupler

tion can be greater than manufacturing's ability to respond. Nor is it generally in the company's best interests to have production fluctuate in lockstep with incoming sales. The frequent result of direct linkage between demand from customers and supply from the production floor is the kind of manufacturing chaos and sawtooth production rates described in the preceding chapter. What's needed is a way to decouple the direct input of incoming demand from the company's valued resources until the analysis process that is required can be completed. The decoupling capability in master scheduling gives a company the opportunity to avoid both chaos on the manufacturing floor and uneven production rates.

Figure 2.3 shows two different planning environments. Company A, on the left, has no middle-management buffer (master scheduling) function between its sales forecast and the production floor. Its sales forecast drives production directly; there is no intermediate gearing, no decoupler, to keep the forecast from causing gyrations in production. Company B, on the right, has interposed a middle-management

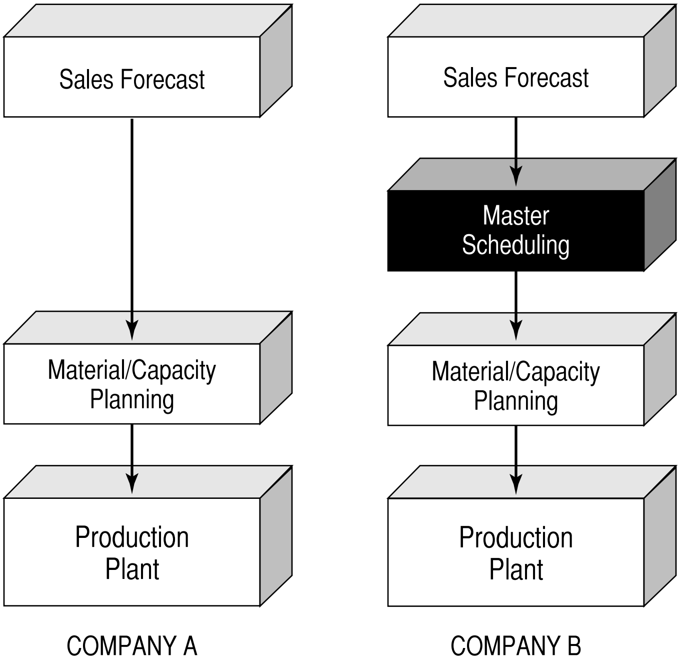


Figure 2.3 Master Scheduling as Buffer Between Sales Forecast and Production

(master scheduling) function between the sales forecast and production. This function has the intelligence and experience to interpret the signals it gets from sales and the forecast, to think of alternative means of satisfying anticipated customer needs, and to make the adjustments necessary in capacity, inventories, and so forth that allow the company to serve the customer without causing supply and demand imbalance. In so doing, it helps the company avoid manufacturing chaos and fulfills the overarching strategy of profitably satisfying customers.

Both sides of Figure 2.3 show material/capacity planning perched atop the production function. Material/capacity planning is shown here for a simple reason: Without the buffer provided by master scheduling, material/capacity planning takes the full shock of every fluctuation in the sales forecast. It, in turn, causes production fluctuations, sometimes 2, 3, even 10 times faster than the initial change in the sales forecast.

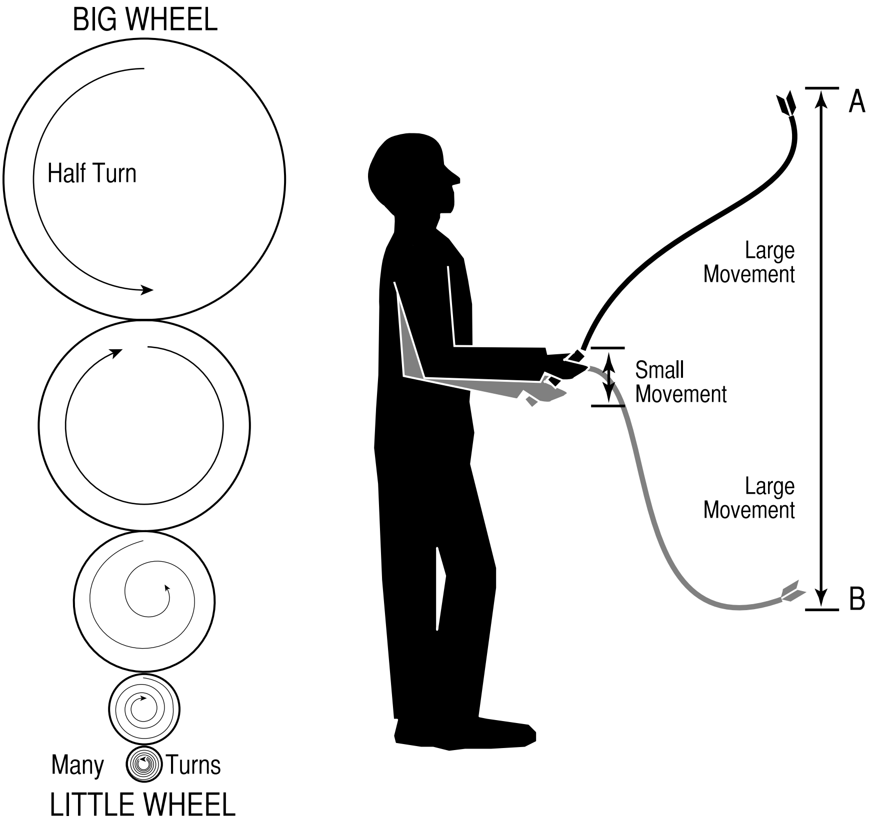


Figure 2.4 Big-Little Wheel and Whip Analogies

Figure 2.4 presents a couple of analogies to this situation. In the first (left side), a big wheel makes a half turn to the left; its movements cause the small wheel geared below it to make a full turn in the opposite direction. The still smaller wheel attached to it makes two full turns . . . and so it goes, in escalating fashion down to the very smallest wheel, which spins at high speed in response to the slightest movement of the first, largest wheel. In the second, a small movement of the whip's handle causes the end of the whip to move a considerable distance.

Early practitioners of material requirements planning (MRP) discovered how disastrous the unbuffered linkage between production activities and the sales forecast could be and developed master scheduling as the solution. This development allowed material requirements planning to work very effectively. In fact, it was not until the advent of the initial master scheduling computer software in the mid-1970s and the practical implementation of the master scheduling process that material requirements planning (MRP), Enterprise Resource Planning (ERP), and Supply Chain Management (SCM) started to achieve their full potential.[1] Material requirements planning users in the early 1970s were unsuccessful because of the missing link of the master schedule.

What Is the Master Schedule?

The master schedule is an operational plan, a subset of the larger production plan created in sales and operations planning. And like any plan, it is integral to the plans of other functional areas within the company. It must be linked to sales, marketing, engineering, finance, materials, manufacturing, transportation, and in some sense it is in a pivotal position between these and other important functions. The eleventh edition of *The Association for Operations Management (APICS) Dictionary* (2005) defines the master production schedule and master schedule definitions as follows:

> (1) The master production schedule is a line on the master schedule grid that reflects the anticipated build schedule of those items assigned to the master scheduler. The master scheduler maintains this schedule, and in turn, it becomes a set of planning numbers that drives material requirements planning. It represents what the company plans to produce expressed in specific configurations, quantities, and dates. The master production schedule is not a sales item forecast that represents a statement of demand. The master production schedule must take into account the forecast, the production plan, and other important considerations such as backlog, availability of material, availability of capacity, management policy and goals.

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[1] Oliver Wight could not have defined Class A performance (which first appeared in 1977) without the master scheduling function.

(2) The master schedule is a format that includes time periods (dates), the forecast, customer orders, projected available balance, available-to-promise, and the master production schedule. The master schedule takes into account the forecast; the production plan; and other important considerations such as backlog, availability of material, availability of capacity, and management policies and goals.

The key words in these definitions are *anticipated build schedule.* The master schedule is a statement of supply that drives the detailed material and capacity processes, and that statement is based upon expectations of demand—present and future—and of the company's own as well as outside estimated resources.

Other key points are *specific configurations, quantities,* and *dates,* all of which are specified in the master schedule. Finally, the master schedule is not a sales forecast; rather, it takes the sales forecast into account, along with the production plan (again, created in the sales and operations planning process), backlog position (orders booked, but not shipped), and availability of material and capacity.

Maximizing, Minimizing, and Optimizing

Many books tell us that manufacturing companies should have these objectives: maximize customer service, minimize inventories, and maximize the utilization of company resources as well as the entire supply chain. Ideally, this means running the plant at or near capacity at all times. Inventory should be at or near zero. When the customer calls to order a product, that product should be just coming off the line for shipment.

Practical considerations of the real world, however, tend to obscure this perfect world of manufacturing. Fast customer response usually requires some inventory, and manufacturing plants cannot be run at constant, level rates when demand for the product goes up and down on an irregular basis. So instead of being maximizers on service and plant utilization, and minimizers on inventory and other costs, master schedulers must be optimizers—finding the best middle course, the one that best satisfies conflicting goals in demand and supply as well as the strategies of the company.

Ultimately, master scheduling is an important part of the competence that, along with vision, unifies the four cornerstones of the manufacturing business. Taking its cue from customer demand, master scheduling sets the pace at which internal and external resources are drawn upon. In other words, master scheduling touches all the cornerstones in a manufacturing company.

The Challenge for the Master Scheduler

Ask someone in the sales function what the demand for digital televisions is and the likely answer will be something like $10,000,000 or "forty-eight hundred units per year—about four hundred each month." This way of thinking about sales—in broad terms—suits the sales department just fine. Its planning is most likely done in monthly, quarterly, and annual terms; sales forecasts, commission structures, and sales quotas are usually expressed in monthly, quarterly, and annual figures; marketing budgets are expressed in annual spending. If sales in some months are 300 and others are 500, this may be just fine for the sales department, as they average out to 400 a month, or 4,800 a year.

Down on the production floor, however, demand painted in broad, *average* strokes will not do. The production floor needs disaggregated information: How many should we build today? . . . This week? . . . This month? In this sense, the production floor is more on the customer's wavelength than is the sales department. The customer does not want 1,000 *this year.* The customer wants 100 this week, 125 the next

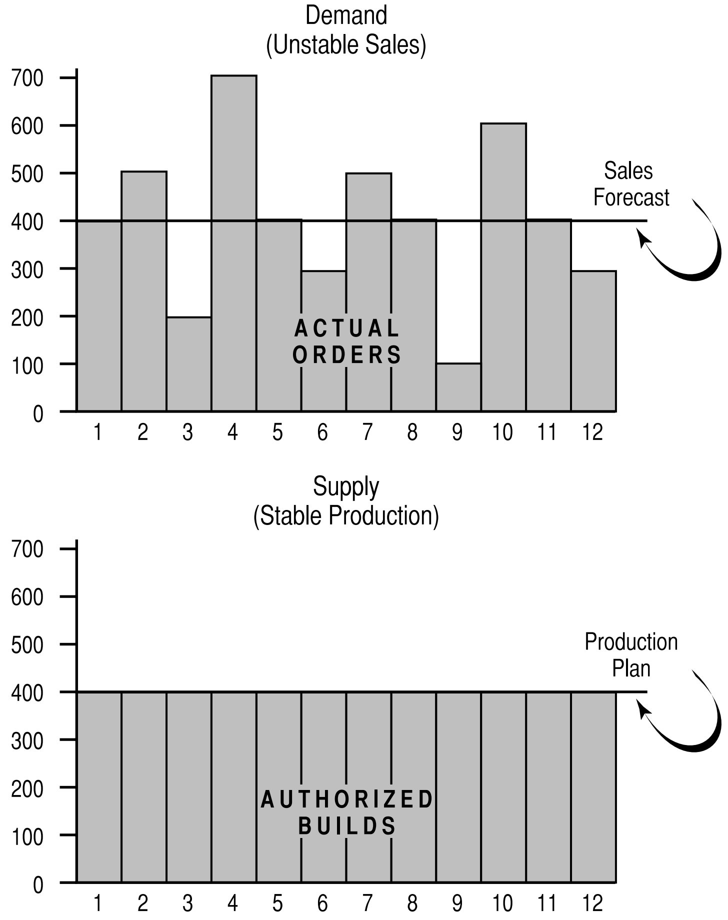

Figure 2.5 The Real World—Varying Demand Versus Desired Supply

week, 90 the following week. Take a look at Figure 2.5. Customer demand is just as the sales department would likely express it: 4,800 per year, an *average* of 400 per period. On a period-by-period basis, however, the production department sees volatile demand: 400 in period 1, 500 in period 2, 200 in period 3, and so forth. This kind of volatility is difficult to manage in a manufacturing facility.

For the master scheduler, the challenge is to plan production to approximate the stable master schedule shown at the bottom of Figure 2.5. In a nutshell, the challenge the master scheduler faces to take the chaos out of manufacturing is to balance the real world.

But how do the master scheduler and a company smooth out the peaks and valleys of demand while stabilizing the master schedule? Here are several available choices:

- Use of inventory and safety stock strategies
- Managing the supply through the use of overtime, off-loading work to other facilities, adding a shift, and so forth.
- Managing demand by running promotions, offering extras for customers who take early delivery, price breaks for customers willing to delay delivery, and so on.
- Varying the lead time when quoting delivery dates to customers or varying internal lead times by prioritizing orders
- A combination of the above—managing supply, demand, and lead time
- A modern heresy: turning away customer orders that cannot be delivered as requested—or, put another way, choosing the business you want
- Design for manufacturability—a long-term method for coping with supply/demand imbalances

MPS, MRPII, ERP, and SCM

In essence, four important functions must be fulfilled if the company expects to operate effectively:

1. Planning priorities (quantities and dates)
2. Planning capacity (internal and external resources)
3. Controlling priorities (execution of function number 1)
4. Controlling capacity (execution of function number 2)

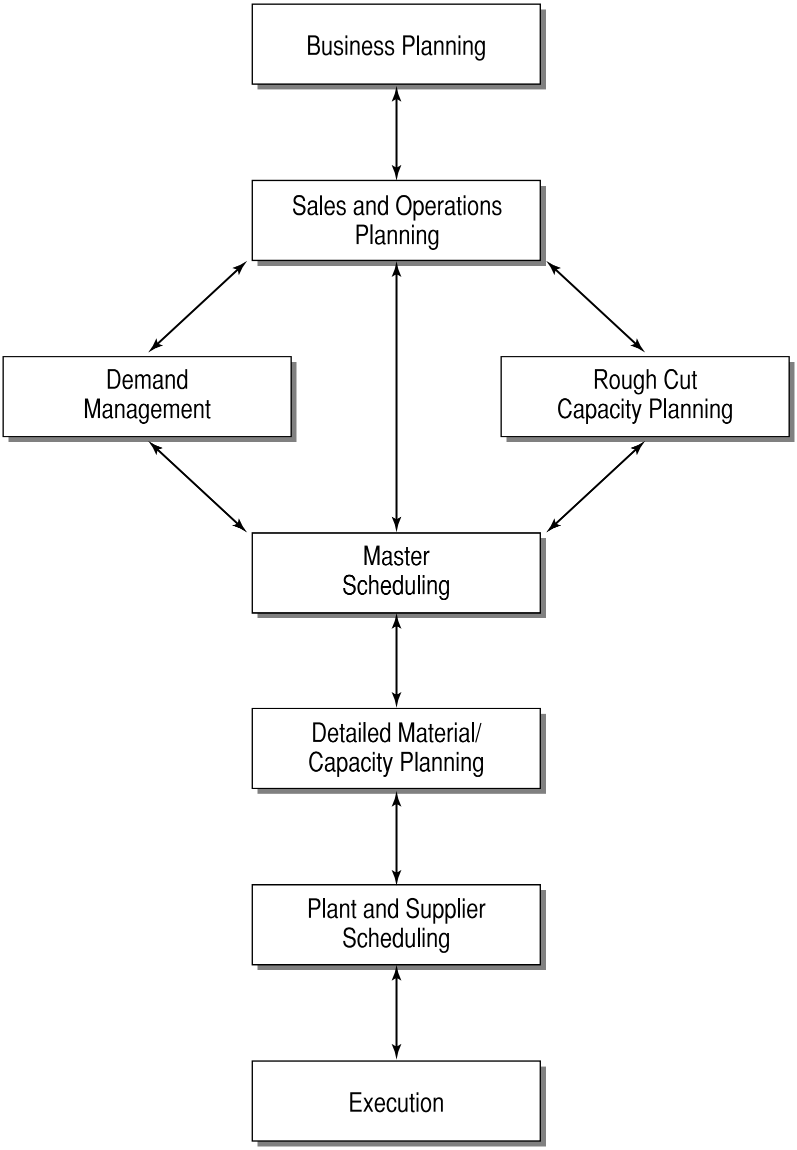

Figure 2.6 Manufacturing Resource Planning (MRPII)

To help manufacturing companies perform these functions, a formal integrated process, generally supported by computer hardware and software, is available. Some readers may recognize this process and software as Manufacturing Resource Planning (MRPII), while others may refer to it as Enterprise Resource Planning (ERP). Master scheduling is an important element of that these processes and the system or systems that support it. To understand just where master scheduling fits, see Figure 2.6 for MRPII (p. 34) and Figure 2.7 for ERP (p. 36). Here master scheduling is one of the four (MRPII) or five (ERP) central boxes—along with sales and operations planning, demand management, rough cut capacity planning, and supply management—which, collectively, form the basic content of this book. Within the closed loops of MRPII and ERP, master scheduling is a vital link to these and the rest of the process.

For those who are not familiar with an MRPII or ERP system, it is useful here to discuss some of its main parts.[2]

Business Planning

Business planning acts as the brains of this system. As a function of top-level tactical and financial plans of the company, it is the driver of all other activities. Business planning communicates through both annual and monthly financial budgets that project revenues and expenses for all major elements of the business. Being a top-level function, business planning is done by the president and other executives of the company and their staffs.

Sales and Operations Planning

Sales and operations planning (S&OP) is concerned with sales, production, inventories, backlog, and shipments. A sales and operational plan is designed to execute the strategic objectives represented in the

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[2] Here we rely heavily on the very fine description of the MRPII loop provided by Thomas F. Wallace in pages 131–135 of *Customer-Driven Strategy* (New York: John Wiley & Sons, 1993) and the author's interpretation of Enterprise Resource Planning (ERP).

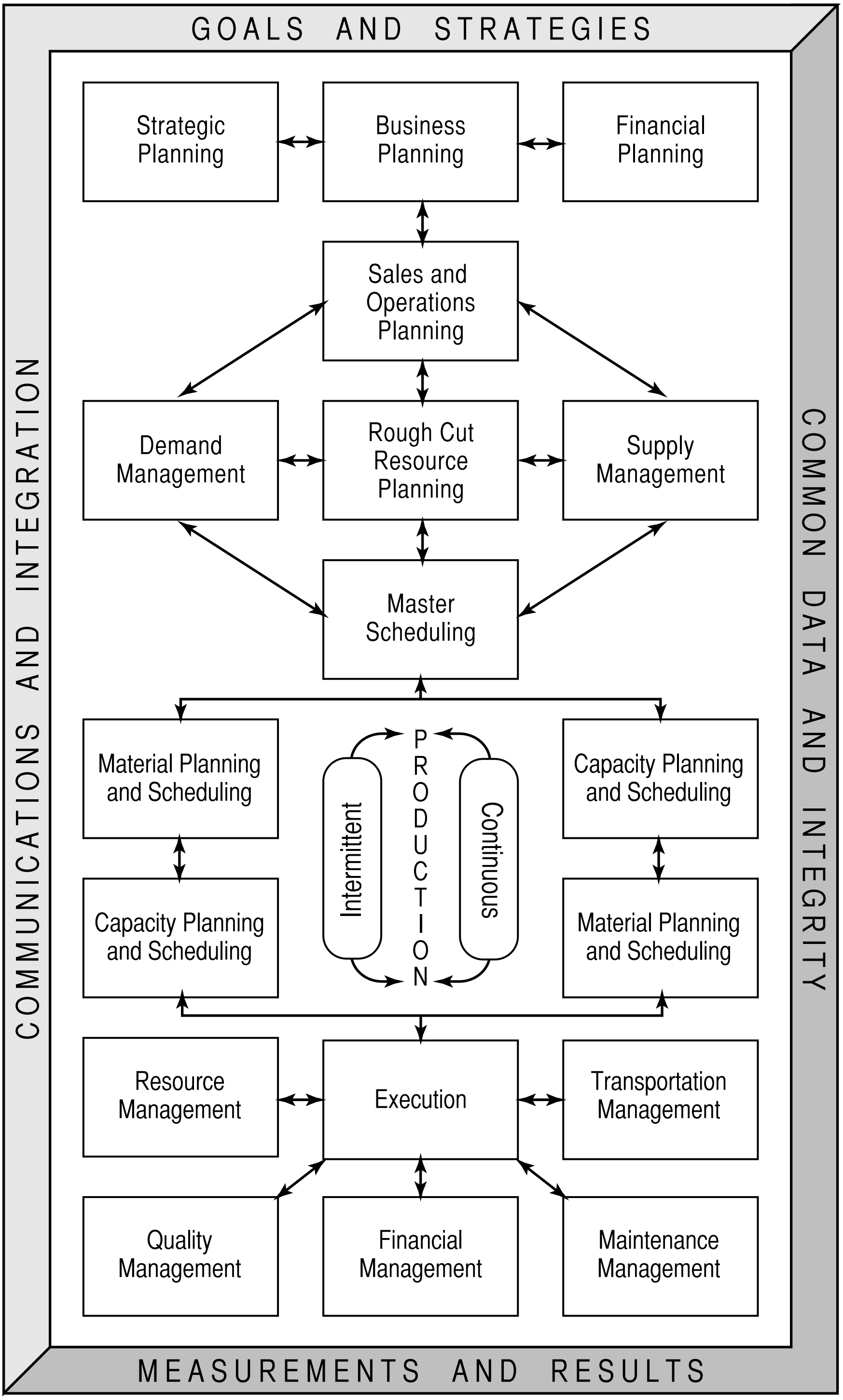

Figure 2.7 Enterprise Resource Planning (ERP)

business plan. It's generally expressed in financial as well as nonmonetary terms: units, tons, hours, and similar quantitative measures. Sales and operations planning is conducted within the broad framework of product families, rates, volumes, and monthly/quarterly periods.

Sales and operations planning is an important link between the top and middle levels of management. The process is typically conducted by means of several formal meetings that bring together the company's various functions in order to create a single game plan. In these forums, the participants thrash out conflicting expectations about demand and manufacturing's capability and capacity to meet that demand.

Master Scheduling

Master scheduling in the closed-loop system has already been discussed. The master scheduler must develop a plan that makes it possible, given the resources available to the company, to meet the requirements articulated by sales and operations planning. This plan takes the form of items, quantities, and specific dates. But here the level of planning is not within the broad context of product families but takes place among individual product family members; and here the dates are not expressed in months but in days and weeks. Furthermore, master scheduling must meet those requirements with a plan (schedule) that makes optimal use of the company's valued productive resources and time. This is the balancing act described earlier.

In developing that schedule, three other disciplines are brought to bear:

ROUGH CUT CAPACITY PLANNING (RCCP) addresses the question "Do we or will we have enough equipment, enough people, enough materials, and enough time to meet the sales and operations plans as currently written?" It is a sanity check on the quantities and dates developed by the S&OP process. If the answer is no to any of those questions, some rethinking is required. Rough cut capacity planning is also used to sanity check and validate the quantities and dates in the master schedule before it is released by the master scheduler.

DEMAND MANAGEMENT is the function of recognizing and managing all demands for products to ensure that the master scheduler is aware of them. It encompasses the activities of forecasting, order entry, order promising, branch warehouse requirements, interplant orders, and service parts requirements. Many companies do not pay sufficient attention to this important part of the process. That's a mistake! Manufacturing Resource Planning and Enterprise Resource Planning are demand-driven processes, and therefore the demand aspect of these processes needs full attention.

SUPPLY MANAGEMENT is the function of pulling together the company's overall supply planning efforts as well as the successful execution of the aggregate plans. Replenishment quantities are created in response to anticipated and firm demands for product. It encompasses supply planning in pre-S&OP, rationing out the production plan to the manufacturing facility or facilities, coordinating finished goods inventory levels, managing production to satisfy customer demand, establishing competitive lead times, and counseling with plant and mill master schedulers.

Many companies do not have the supply management function formalized as stated in regard to the demand management function. Ignoring this critical function in a multiple-plant, multiple-business, or global-business supply chain could be an error. As Figures 2.6 and 2.7 suggest, Manufacturing Resource Planning, Enterprise Resource Planning, and Supply Chain Management (SCM) all require that supply and demand be in balance at all levels within the global supply chain.

The remainder of the closed loop, *detailed material/capacity planning* and *scheduling*, is very much a part of the MRPII, ERP, and SCM systems. Full discussion of these important interfaces with master scheduling is, however, beyond the scope of this book. Suffice it to say that once the master schedule is created by item, quantity, and time, its items are "exploded" using bills-of-material, recipes, and formulations to determine the gross requirements for all lower items. Combining master scheduling with detailed capacity planning, plant scheduling, supplier scheduling, and execution ensures that the materials and the capacity to build all of the items planned by the master scheduler are available at the right time and in the right quantities.

Not shown in Figure 2.6 or 2.7 are other important functions that make master scheduling, MRPII, ERP, and SCM possible. For example, inventory records with a high degree of accuracy (95% minimum; in some cases, as high as 99.5%) are required to support the master scheduler's most basic decisions and bills-of-material that define the contents of products in detail must be at least 98% accurate (in some cases, as high as 99.5%). The routings that identify the sequences of events that a product goes through must be at least 95% accurate (in some cases, as high as 99.5%) in regard to structure, sequence, manufacturing centers, and times (within tolerance) for setup and run. Besides the routing data, a manufacturing center database identifying demonstrated and planned capacities must be available to support the overall MRPII, ERP, and SCM processes for many environments.

Enterprise Resource Planning

Through the years, Manufacturing Resource Planning has expanded its scope. When industry integrated the operational plans with the financial plans, it was called *Manufacturing Resource Planning II* or MRPII. Now it's time to start thinking about the next iteration of that development cycle.

Driven by hardware and software advancements, MRPII has been renamed *Enterprise Resource Planning* (ERP). Unfortunately, there are already several definitions of ERP throughout industry. For example, APICS defines ERP as an accounting-oriented information system for identifying and planning the enterprise-wide resources needed to take, make, ship, and account for customer orders. The definition goes on to say that an ERP system differs from the typical MRPII system in technical requirements such as graphical user interface, relationship database, fourth-generation language, and computer-aided software engineering tools in development, client-server architecture, and open-system portability. Based on this definition, one could certainly reason that ERP is nothing more than a technology enhancement.

Another source defines ERP as an integrated application software suite that balances manufacturing, distribution, and financial business functions. Enterprise Resource Planning is the technological evolution of MRPII through the introduction of relational database management systems, computer-aided software engineering, fourth-generation languages, and client-server architecture. When fully implemented, ERP can enable enterprises to optimize their business processes, and it allows for necessary management analysis and appropriate decision making in a quick and efficient manner. As more robust technology is implemented, ERP improves an enterprise's ability to react to market changes.[3]

According to the Piper Jaffray brokerage firm, ERP is any software application that automates and synchronizes the day-to-day operations of medium to large organizations. This includes both cross-industry operations, such as financial management and human resource management, as well as industry-specific operations, such as manufacturing, distribution, and merchandise management.[4]

These three definitions support the notion that ERP is a technologic evolution of MRPII. However, advancements in the areas of logistics, human resources, quality, finance, maintenance, and transportation management provide today's enterprise with processes to better plan and control the business. So the author believes that ERP is a term given to what might be called "advanced Manufacturing Resource Planning" or MRPIII (see Figure 2.7).

Reviewing the figure, the reader will note the addition of strategic planning, financial planning, supply management, human resource management, quality management, financial management, maintenance management, and transportation management to the Manufac-

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[3] "Computer Integrated Manufacturing," The Gartner Group.

[4] "Supply and Demand Management," Piper Jaffray Brokerage Firm.

turing Resource Planning diagram shown in Figure 2.6 earlier. These additions are not to imply that companies using MRPII fail to carry out these activities; they certainly do, especially in Class A MRPII companies. The intention of Figure 2.7 is to highlight the emphasis on other business processes that affect or are affected by the master scheduling process. It also can be seen in the figure that the manufacturing environment quite often affects the sequence in which business activities are performed. (For instance, intermittent production usually does material planning and scheduling before capacity planning, while continuous production does capacity planning and scheduling before material planning and scheduling.)

The last thing to note about the figure is that it all starts with the company's vision (not shown), which is supported by goals and strategies. To achieve Class A status in planning and control (according to the author's definition), a company must demonstrate clear lines of communications and integration, use a common database of the highest integrity, and measure performance results. Put it all together and the company becomes a Class A enterprise in what the Oliver Wight companies call "Operational Excellence" (*The Oliver Wight ABCD Checklist for Operational Excellence,* 5th ed.) or "Business Excellence" (*The Oliver Wight Class A Checklist for Business Excellence,* 6th ed.). From this point on, the terms *Enterprise Resource Planning* and *Supply Chain Management* will be used to refer to various processes that integrate the master scheduling process.

Supply Chain Management

Supply Chain Management is a process that brings together multiple companies to form a team or linked chain for the purpose of making products and providing these products and services to the customer (see Figure 2.8 on p. 42).

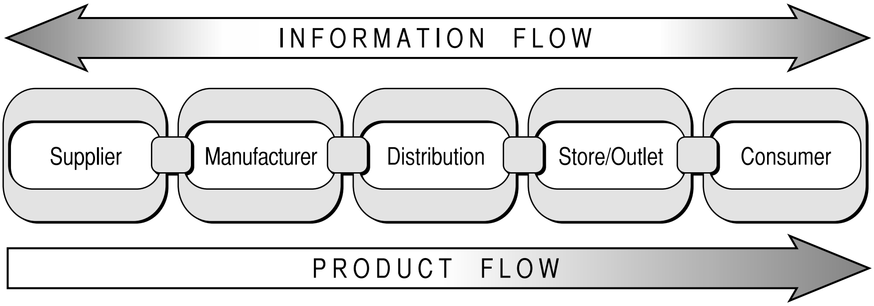

Figure 2.8 Supply Chain Management

An integrated supply chain is characterized by a smooth, continual product flow that is matched to consumer consumption. Additionally, information is exchanged in a timely, paperless flow. Supply Chain Management interfaces with all business and management processes that involve planning and scheduling in the supply chain. Companies involved in SCM seek to get better product to the customer, faster and for less money. If this is done properly, a win-win situation is created and maintained. Supply Chain Management is also known as *customer-supplier collaboration* and *partnerships.*

Master scheduling occupies a critical point in the MRPII, ERP, and SCM process—midway between the planning functions of top management and the detailed tactical and operational levels that turn those plans into products that satisfy customers. To better appreciate *why* master scheduling is such an important part of the entire process, consider the following scenario.

WHERE HAVE ALL THE ORDERS GONE?

"We really missed it this time," the marketing vice president sighed as the chief executive officer (CEO) and other managers stared glumly at his revised forecast. "Frankly, we were as surprised as everybody else that interest rates would spike upward as they have. And that single fact accounts for the dismal outlook for orders over the next few periods. The financing costs for the customers are just too unfavorable right now."

"So when do you expect things to pick up again?" the manufacturing vice president asked.

"When interest rates come back to Earth—and please don't ask me when that will happen. I don't know, and I doubt that any of the so-called experts know either."

Original Forecast	10	10	10	10
Actual Demand	7	4	3	1
Master Schedule	10	10	10	10

Indeed, the current outlook for the next four periods was dreadful. Almost as bad was the uncertainty. Because the company produced expensive machine tool equipment, sales were extremely sensitive to interest rates, and uncertainty as to future rates created a puzzle for production planners and schedulers. If rates came back down, demand for the company's products would quickly bounce back. As for correctly forecasting those rates, the firm's treasurer liked to say that "those who tell don't know, and those who know don't tell."

The current master schedule had undoubtedly already triggered the purchase of materials and components and building of other components of various lead times. These were either in the stockroom or somewhere in the pipeline. The production capacity was there; the skilled personnel were there; the fixed costs of the plant were there. All that was missing was the customer orders. What to do?

Lots of head scratching takes place in times like these. The marketing people wonder: "Why was our forecast so far off target?" The sales force beat the bushes for opportunities to fill the gaping hole in its revenue forecast. Manufacturing evaluates other ways to utilize unused capacity, fearing layoffs of experienced people who might never come back when business improves. The people in finance start having nightmares in which production keeps humming along—and keeps piling up expensive and unsold inventory.

Management Issues

The situation just described raises a number of management issues—both with respect to the current situation and with respect to a company's whole approach to the problem of operating in environments of unstable demand. In terms of the immediate situation, some would advocate pulling up three of the orders from the second period into the first. Perhaps some customers could be induced to take early delivery. This would keep all activities on course through the first period but would create a worse situation for the second.

An optimist would hope that a sudden uptick in demand would rescue the master schedule and might build inventory in the expectation of an order turnaround. Someone once said that the definition of an optimist is "a person who has no experience." A pessimist would begin reducing capacity and laying off labor. Someone also once said, "I'd be a pessimist, but it wouldn't work anyway." A pragmatist would think through alternatives for preserving the company's financial, productive, and human resources through a hostile period: building common parts for use in a variety of company products; rescheduling material purchase to later dates; redeploying personnel to other useful work.

What Kind of Company Are We?

The situation of slack demand provokes a larger question introduced earlier about a company's sense of itself: Are we in business to sell what we make or to make what we sell? A production-oriented company sells what it makes; it usually listens more closely to technical capabilities than to the voice of the customer and relies heavily on sales and marketing to move its steady output. In the face of slack demand, it may slow down, but it rarely stops. Instead, it invests heavily in a tool set that sales and marketing can use to clear its inventory: price flexibility, attractive financing terms, warrantee extensions, and so forth. A sales and marketing–oriented company makes what it sells. When sales are brisk, production responds; when order volume withers, its production responds accordingly—it is not in the business of just pushing product.

Which orientation is best? It probably depends on the product, the industry, and the time period (more discussion of this follows in Chapter 4, "Managing with the Master Schedule") But one thing is certain: Both require flexibility. The company that sells what it makes needs flexibility in the ability to move finished goods. The company that makes what it sells needs greater flexibility in production; for it, the model of lean production—the capability to produce at low cost in small batches and to economically switch production to other items—may be an important key to getting through periods of slack demand like that in our example.

The Four Cornerstones of Manufacturing Revisited

The first part of this chapter conceptualized the manufacturing business as four cornerstones—customers, products, resources, and suppliers—integrated by the unifying power of vision and competence. As the following chapters will make clear, master scheduling is a competency like engineering, financial management, and logistics. It represents a capability to get the job done, and to fulfill the larger vision and mission of the company. To see the core of vision and competence in more tangible terms, refer to Figure 2.9. Here the core of the company is represented by five people-based technologies that, when linked together, integrate the four cornerstones of the business. Starting at the top and moving clockwise, these pieces are:

- Customer-driven strategy
- New-product development
- Total quality management
- People and teams
- Planning and control

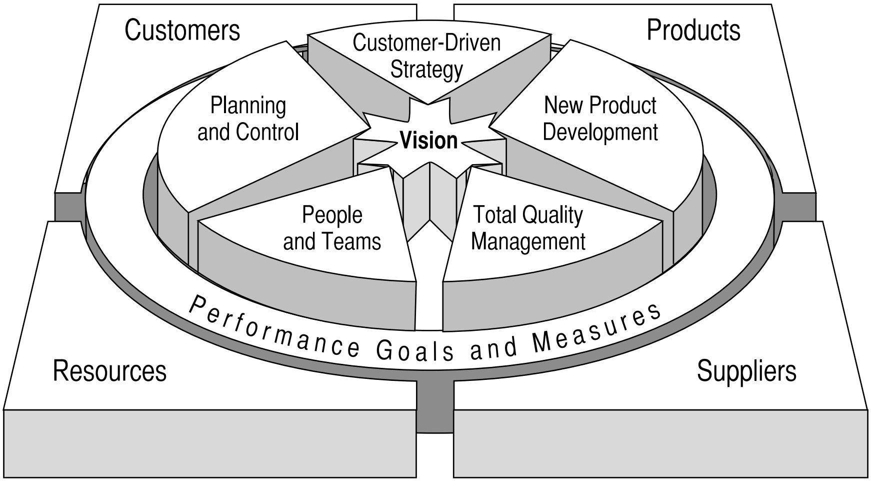

Figure 2.9 Integrating Elements of the Manufacturing Business

Each of these people-based technologies is critical to the success of a manufacturing company, and each is worthy of study. It is also a matter of convenience that each is represented separately, as if there were no links between them, or that somehow one piece—new product development, for example—did not have its own requirements for planning and control, or total quality management in the development process, and so on. Master scheduling, the subject of this book, resides in the planning and control wedge of the figure.

So, Why Master Scheduling?

At this point we can summarize a response to the question "Why master scheduling?"

1. To ensure integration and implementation of the business, sales, marketing, engineering, finance, manufacturing, and transportation plans

2. To manage inventory and backlog to a position desired by the company's executive team
3. To promise product deliveries and feel confident about our ability to keep these promises
4. To plan and commit resources to satisfy customer demands
5. To drive detail material and capacity requirements
6. To create a foundation for accountability within the company to customers, to suppliers, and to ourselves

The details of how a company goes about master scheduling are treated in the following chapters. There the reader will learn the basic mechanics of the process. Initially, this will appear to be a process better relegated to a computer than to a human being. Computers have proven to be excellent helpmates in the business of storing, displaying, predicting, calculating, and underscoring the numerical data that is essential to master scheduling. Indeed, the availability and improvement of master scheduling software introduced in the mid-1970s has done much to advance the implementation of master scheduling in the ranks of manufacturing, and in so doing has helped make ERP and SCM the powerful processes that they are today.

As a moderate-level expert system with built-in decision rules, modern master scheduling software can detect potential supply/demand imbalances and alert the master scheduler to their presence; the software can even recommend what action should be taken. As time continues to pass, the diagnostic, simulation, and actual scheduling abilities of master scheduling software are bound to increase.

However, as we move through the early days of the twenty-first century, this incredible computing power has not eliminated the need for the human judgments, or the insights and decision-making capabilities that a master scheduler brings to the job. Master scheduling is no cut-and-dried numbers game. The numbers are there in abundance, but understanding the assumptions behind them, how to use those numbers, and making decisions in an atmosphere of uncertainty is at least 75% of the master scheduler's job. No one said that this job was easy! In the author's opinion, master scheduling is more art than science.

This chapter has explained the "why" of master scheduling. The following chapter explains the "how," or the mechanics, of the subject. Once the mechanics of basic master scheduling are understood, discussion will move on to what the master scheduler does with the numbers and information available.

3

The Mechanics of Master Scheduling

You can definitely make mistakes,
but you can't make mistakes indefinitely.

The objective of master scheduling is to plan the impact of demand on materials and capacity. This is a vital function because every company must deploy its people, equipment, material, and capital in the most efficient way possible. Master scheduling (MPS) does this by ensuring that enough product is available for customers, while avoiding costly and unneeded inventories. This is the business of balancing supply and demand.

In addition, master scheduling lays out detailed build schedules in support of the aggregate plans developed during the sales and operations planning process. By ensuring that the detail plans are within the constraints of the overall aggregate plans, master scheduling implements the leadership team's directives. Finally, the master schedule is used to establish some degree of control and accountability: Who is accountable for the different inventory levels the company maintains? Who is accountable for managing capacity? Who is accountable for bringing the materials in-house? Who is accountable for managing the lead times that are used to buy and produce the product? Accountability is very important if a company is to successfully use Enterprise Resource Planning (ERP) and master scheduling.

The Master Schedule Matrix

One of the bottom-line goals of master scheduling is to balance supply and demand *by time period.* That means looking at all demand—from all sources—in discrete time segments and understanding the resources that will be necessary to satisfy that demand—again, in terms of time segments. This business of matching up supply and demand in time segments creates the need for a matrix that immediately reveals when supply and demand are in or out of balance. There are several different MPS matrix formats available, and the actual design is a matter of software choice. For purposes of illustration, this book uses the one shown in Figure 3.1.

The MPS matrix in the figure is a series of columns and rows that defines scheduled activities in terms of time and type (supply or demand). The time elements are arrayed across the top, and the activities are listed along the side. Each column contains all the master scheduling activity expected to take place within a specific time period (typically a week or day). The nature of the activity—either supply or demand—is determined by the row in which it appears.

Time Segments

The matrix displayed in Figure 3.1 on page 51 shows time periods 1 through 8 across the top. The number of periods is dependent upon the software and the company's choice of planning horizon. Each period could represent a day, a few days, or a week. In practice, the array is usually dated: for example, period starting 10/1, 10/8, 10/15, and so forth.

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		10	10	10	10	10	10	10	10
Option Forecast									
Actual Demand									
Total Demand		10	10	10	10	10	10	10	10
Projected Available Balance	12	2	12	2	12	2	12	2	–8
Available-to-Promise									
Master Schedule			20		20		20		

Figure 3.1 The Master Schedule Matrix

By convention, period 1 is the current period—the present—and remains so as time passes. Thus, one week period 1 would read 10/1; a week later it would read 10/8. The data in each column shifts to the left as time passes. The column just to the left of the current period is labeled *Past Due* (an explanation of this will come later). The columns to the right represent future time periods and are used to display data by identified activities. The cells in the master schedule matrix are for convenience of display when using a horizontal MPS format. Inside the computer, the quantities are stored by real dates—for example, April 11 or October 15—and therefore can be displayed using any time period arrangement that the master scheduler requires.

Demand Section

The top four rows of the MPS matrix show the components of demand for a master scheduled item: the *Item Forecast* or independent demand, the *Option Forecast* or dependent demand, the *Actual Demand* or customer orders, and the *Total Demand,* which is some combination of the previous three demands. (The total demand calculation is explained in Chapter 16, "Demand Management.")

ITEM FORECAST. This forecast row identifies the independent demand for the master scheduled item. An example of this would be an item such as a table saw motor sold directly to the customer. Besides selling the table saw to customers, the motor used in the table saw could be sold by itself and would appear on the motor's independent forecast line if the motor is an MPS item. Generally, demand of this type is to satisfy a service or spare part requirement. An item can, of course, have both independent demand and dependent demand (the motor is also required to build table saws). This situation explains why we have the option forecast line in the MPS matrix.

OPTION FORECAST. The option forecast row reflects the anticipated demand for an item that will be sold as part of something else. For example, suppose that the production of electric motors is master scheduled. Sale of the motor outright, as a service or spare part, would constitute independent demand. The same motor may also be used as a component in other products produced by the company, such as drill presses. Demand for these motors will therefore be dependent upon the volume of drill presses the company expects to sell as well as the demand for motors to be used as service parts. Consequently, demand for these motors will appear in both the service or item forecast and option forecast rows.[1]

ACTUAL DEMAND. Actual demand is concerned with customer orders that are booked or sold, but not yet shipped. A customer has

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[1] The scheduling literature has for years used the term *production forecast* for what is here called *option forecast.* The former is not an appropriate term in this case since the forecast is not of production but of demand. The master scheduling line represents production. Thus, the term *option forecast* is used in place of the more familiar term *production forecast* throughout this book, and hopefully it will become the standard term over time.

Naturally, when you are scheduling products that contain no option element, this line of the MPS matrix remains blank. Sometimes in a make-to-stock business (one that produces products to inventory in anticipation of customer orders), the option forecast line is used to display the requested inventory replenishment by time period.

placed an order for a quantity of motors. Because of company strategies, current schedules, material availability, plant capacities, or customer desires, these motors might not be ready for shipment for several weeks. These motors constitute actual demand, and the master scheduler must keep track of each order by customer, quantity, and promised delivery dates to ensure that the customer will receive the desired products as promised.

TOTAL DEMAND. This row in the MPS matrix reflects the combined demand for the item by time period. Total demand is calculated in various ways. Normally, it is the sum of the item forecast, option forecast, and actual demand. If the respective forecast row is reduced whenever orders are booked, then the total demand remains unchanged as demand is recorded. If, however, the forecast is not replaced with booked customer orders, then the logic used in the master scheduling system must take this into account when calculating the total demand. The process we are talking about is called *forecast consumption,* which is addressed in Chapter 16. For the purposes of this chapter, as demand orders are received, the forecasted quantity will be reduced by the quantity ordered. On the surface, this seems logical. Since the forecast is really an expectation of future demand orders, customer orders that are booked by the sales force may be seen as the fulfillment of that earlier demand forecast. However, what if the customer order was *not* thought of when the forecast was created? In this case the customer order would not be part of the forecast and should be treated as incremental demand. This type of demand is known as “abnormal demand” and will be covered later in the book. Until then, all demand in the examples will be treated as normal or expected demand.

Supply Section

Look again at Figure 3.1 on page 51. The rows in the matrix that indicate the level of demand for each time period have already been explained. It now remains to interpret the rows within which the supply and balancing of the two will appear. First, look at the bottom line, the *Master Schedule* row, or the total supply line.

MASTER SCHEDULE (MPS). This is the row in which the master scheduler and the computer place supply orders to meet the demand for each period. Each quantity on the MPS row represents a defined amount of the ordered item by due date.

Master schedule supply orders appear in the matrix in three different forms: released orders, firm planned orders, and computer planned orders. These various replenishment orders are identified on the MPS row by period. The sequence in which we would expect to see these orders as we move further out on the time line would be released orders first, firm planned orders second, and computer planned orders last. The nature of these orders, explained below, will make it clear why that sequence makes sense.

Released Orders. These orders initiate the production process by authorizing material, labor, and equipment to be used to manufacture a specific item. A released order has many aliases. Some of the names used are scheduled receipt, campaign, batch, manufacturing order, production order, shop order, work order, and purchasing order (if the item is purchased, not made).

Firm Planned Orders (FPOs). An FPO is an order that the master scheduler places to take control away from the computer. It is a placeholder that allows the master scheduler to firm a computer planned order in quantity and time. The computer software is restricted from changing an FPO; it is the responsibility of the master scheduler to change it. This technique can aid schedulers in planning materials and capacity by firming selected computer planned orders. Firm planned orders are the normal way of stating the master schedule. In effect, the master scheduler says, "I'm planning to produce so many units of this product, which will be due on this date, but I am not yet ready to authorize the work or issue a released order."

Generally, firm planned orders explode through the ERP system to plan materials and capacities. This explosion process is the same as the one used on computer planned orders. Released orders are not exploded via ERP because these orders create lower-level allocations for materials when they are placed, which are then treated as demand on the materials contained in the FPO's bill-of-material until that material is issued in accordance with the build plan.

Computer Planned Orders (CPOs). A CPO is an order created by the computer software rather than by the master scheduler. It is not a green light to manufacturing, but serves as a suggestion to the person doing the scheduling that a firm planned order of the indicated size will be needed if supply and demand are to balance. Generally, for a computer planned order to have a lasting effect on a master scheduled item, the master scheduler must convert the computer planned order into either a released order or a firm planned order. As stated above, the firm planned order takes control of the order away from the computer and firms the date and quantity. Chapters 4 and 5 discuss in detail when this action needs to take place.

The computer bases its creation of CPOs on demand need dates, predetermined lot sizes, and lead times to ensure that the release and production or procurement of material will satisfy the demand need date. Computer planned order creation rules are generally built into the MPS system's software and controlled by a *planning time fence* (a more detailed explanation of the planning time fence and how it is used in master scheduling is presented later in this chapter). This date-related boundary allows the computer to only generate CPOs with due dates *after* predefined dates, and not before. Inside the planning time fence, the master scheduler must control all the supply orders. By operating within the boundaries of the planning time fence, the computer software knows when it may or may not generate a CPO.

Each type of supply order plays a unique role in the master scheduling process. A released order is a manufacturing order against which material, labor, overhead, and other resources can be charged. Firm planned orders are also essential; without them, the computer software logic would assume responsibility for balancing demand with supply and would then attempt to rectify the situation by launching CPOs where needed, regardless of the actual material or capacity availability. Computer planned orders in effect represent the computer software's own version of a firm planned order. Once the master scheduler creates firm planned orders and balances supply to demand, the computer software will not attempt to create additional supply orders because they will not be needed.

Note that there can be many variations on the preceding supply order scheme; the movement from computer planned to firm planned to released order is only a generic approach. In fact, it is possible for the master scheduler to take a computer planned order and convert it directly into a released order without ever going through the firm planned order phase. Additionally, a computer planned order can be converted to a firm planned order that authorizes production (this is known as producing to a run rate). Regardless of how supply orders are used, each contributes to the MPS row in the computer format, which is the underpinning for an *anticipated build plan*—what we intend to produce.

PROJECTED AVAILABLE BALANCE. This row predicts what will be in inventory at a specific point in time. It is also the basis for the computer's critique of supply-and-demand balance. The outcome of the critique determines what action will be recommended. Action recommendations are sent to the master scheduler by the software in the form of "action" or "exception" messages.[2] Unless a company uses safety stock, the perfect supply-and-demand balance will be a projected inventory balance of zero (the supply of the product perfectly matches the demand for the product so that there is no projected inventory remaining). If a company uses safety stock of 100 items, for example, then the perfect balance is 100 units.

Rarely do we have a perfect balance in the imperfect world of manufacturing. Assuming that a company is not using any safety stock, a positive balance for any period of time in the projected available balance row suggests a potential surplus or excess stock condition. If there is a negative projected available balance, the system is projecting a potential shortage. In the case of a potential surplus, the computer system may recommend that the master scheduler move supply orders out or even cancel supply orders altogether. In the case of a

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[2] Action or exception messages are notes to the master scheduler made by the computer based upon data in the system. These typically appear beneath the formatted supply-and-demand information or on a separate screen or report. Chapter 4 explains action and exception messages in detail.

potential shortfall, the master scheduler will receive recommendations from the computer system to release new supply orders or move future supply orders in to cover the projected deficit. In summary, the projected available balance line is used for scheduling and causes the main action messages (reschedule-in, reschedule-out, order, cancel) to be generated.

AVAILABLE-TO-PROMISE (ATP). This row is used for customer order promising and displays the projected supply of product less the actual demand. The result of this calculation informs the sales and customer order entry of the products that still can be sold without modifying the current master schedule. This is an extremely useful piece of information because it identifies what can honestly be promised to a customer in terms of delivery. If available-to-promise indicates a total of 10 units by a particular period and we promise a customer 12 by that period, then we have made a bad promise. Anyone who books demand orders should be aware of ATP, how the computer system calculations are done, and what the company's policy is regarding the commitment of product to customers. Available-to-promise is discussed in depth in Chapters 9, 10, and 16.

Master Scheduling in Action

Now that the matrix for organizing master scheduling data has been presented, we need to understand how to use it as a scheduling tool for a simple product.

The product we will be looking at is a standard flashlight, with a bill-of-material consisting of the following: one head subassembly, one light subassembly, and one body subassembly (see Figure 3.2). While each of these subassemblies might in reality contain other subassemblies, fabricated items, and components, for simplicity's sake, we will ignore any secondary product structures at this time.

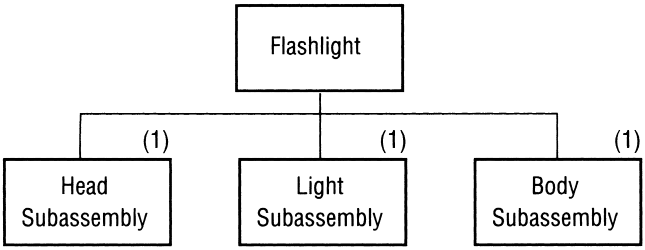
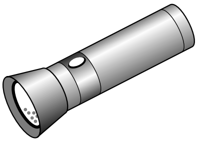


Figure 3.2 Flashlight Product Structure

In Figure 3.2, it is important to note that the numbers in parentheses indicate the number of items needed to build the parent item, the finished flashlight. In addition to knowledge of the specific product structure, several other pieces of information regarding the flashlight must be known before master scheduling can begin. We make the assumption here that the flashlight is being made-to-stock—that is, completed flashlights are placed in a finished-goods inventory. With that assumption in mind, consider the current status of flashlights:

On-hand inventory balance:	12
Planning lead time:	1 period
Minimum order quantity:[3]	20 units



Thus, 12 units already exist in inventory. A lead time of one period is required to complete the final assembly process. And the company has determined that flashlights should be built in order quantities, or lots sizes, of 20 units; this means that whenever the decision is made to build more flashlights, the *minimum* order quantity should be 20 units. In Figure 3.3 on page 59 we see how this data finds its way into the master scheduling matrix.

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[3] The terms *order quantity* and *lot size* are used interchangeably in this book. In the process industry, *lot size* is sometimes used in reference to a quality sample.

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		10	10	10	10	10	10	10	10
Option Forecast									
Actual Demand									
Total Demand		10	10	10	10	10	10	10	10
Projected Available Balance	12	2	12	2	12	2	12	2	–8
Available-to-Promise									
Master Schedule			20		20		20		

Figure 3.3 Flashlight Master Schedule Matrix Example

Computing the Projected Available Balance

For the purpose of this example, we assume a forecast of 10 units every period, and these appear in the forecast cells in each of the eight periods considered. No actual demand is present because the flashlights are being built to stock using the forecast of independent demand as the only demand input. Therefore, the total demand for each period is 10 units.

Notice that the column of the forecast row labeled *Past Due* is blank; this indicates that there is no past-due demand or unconsumed forecast. A past-due forecast is a forecast that was not consumed or satisfied. All unconsumed forecast should be analyzed and either rolled forward or dropped, depending upon company policy and the forecast consumption rules being used (more detail on forecast consumption is available in Chapter 16). Besides the demand, we know we have 12 units on hand, which has been placed where the past-due column and the projected available balance row intersect. This does not imply that the on-hand balance is past due; it is merely a convenient place to put the on-hand balance so that the MPS software can begin its calculation of the projected available balance line. Knowing the on-hand quantity (12), the forecasted quantities in the future (10 per period), and the expected supply orders (20 in periods 2, 4, and 6), the MPS computer system can project the expected quantity on hand for future time periods. Once this is done, the MPS system will be in a position to critique the balance of supply and demand.

Period 1. There are no supply orders (MPS row) due in period 1, so we have 12 units available to satisfy period 1's demand of 10 units. Therefore our projected available balance at the end of period 1 will be 2 units (12 – 10), a surplus reflected as projected available balance. This becomes, in effect, the projected beginning on-hand balance for the next period.

Period 2. Again, demand exists for 10 units. What about supply? There is a supply order or scheduled receipt of 20 units due in period 2. This scheduled receipt is a result of the master scheduler's having placed a supply order for flashlights prior to now. If this scheduled receipt is received as scheduled (MPS quantities are shown by due date), the 20 units can be added to the 2 already projected to be on hand and will equal 22 units available to satisfy period 2's demand. Since the total demand for period 2 is 10, a projected available balance of 12 units will be left at the end of period 2 (2 + 20 – 10).

Period 3 through Period 7. The master scheduling system has projected a positive balance of 12 units at the end of period 2. Demand again stands at 10 units in period 3, and no scheduled receipts are identified in the MPS row. In case the reader has not recognized this situation, it is the exact duplicate of period 1. Looking ahead, we can see that the same pattern of demand, projected available balance, and anticipated scheduled receipts repeats every other period through period 7. The reader may want to work through each period in turn to gain added practice in the projected available balance calculation, going back to the beginning on-hand-balance column and period 1 if he or she gets stuck.

Period 8. In period 8 the situation changes. Period 7 ended with a projected available balance of 2 units. Again, this constitutes a projected beginning on-hand balance for the next period. Demand in period 8 is again at 10 units. No additional units are scheduled for receipt in period 8 (see MPS row, period 8 cell). Given this situation, the system will correctly project a negative balance of 8 units (2 – 10) in period 8 if the master scheduler does not take corrective action and the demand occurs as planned.

Nature abhors a vacuum, cats hate water, and master scheduling software cannot stand the sight of a negative projected available balance. The computer will spot the potential shortage in period 8 and will automatically place a computer planned order to be received in period 8 to restore the projected available balance to zero or a positive number. Its order will be for 20 units (the minimum lot size or order quantity). If in the future the master scheduler chooses to accept the computer's recommendation, the computer planned order will be converted into a firm planned order or a released order and the projected negative available balance of 8 units will shift to a positive 12 units (the 2 units available from period 7 added to the expected receipt of 20 units less the total demand of 10). The result of the adjustment produces the MPS matrix in Figure 3.4.

In addition to determining where and for what quantity CPOs should be generated, the computer system also critiques the timing of the receipts in periods 2, 4, and 6, provided they are scheduled releases or firm planned orders, to determine if the orders are scheduled properly. The system will start its critique by going back to period 2 and asking, "Is this MPS order of 20 units scheduled properly?" In this case, the answer is yes. This is so because without the 20 units arriving as scheduled, the projected available balance will be negative (2 – 10).

The same logic is used in testing the supply orders on the MPS row in periods 4 and 6. The answer to the question will be yes in both cases since each MPS lot of 20 is properly scheduled and needed in the defined periods.

Analysis

This example not only illustrates how the projected available balance is calculated but underscores the fact that the computer's recommendations are just that—recommendations. The master scheduler

	Past Due	1	2	3	4	5	6	7	8
Service Forecast		10	10	10	10	10	10	10	10
Option Forecast									
Actual Demand									
Total Demand		10	10	10	10	10	10	10	10
Projected Available Balance	12	2	12	2	12	2	12	2	–8 12
Available-to-Promise									
Master Schedule			20		20		20		⑳
Released Order									
Firm Planned Order			☆		☆		☆		
Computer Planned Order									☆

(For purposes of illustration, the entries in the master schedule line have been specified as to the "types" of order they are. Thus, the orders in periods 2, 4, and 6 are firm planned orders, and the final order in period 8, the one circled, is a computer planned order.)

Figure 3.4 Flashlight Master Schedule Matrix with CPO

ultimately determines whether the computer's recommendations are valid for the particular situation at hand. There is a universal principle in master scheduling and ERP: Machines make recommendations; people make decisions. Accountability is the underlying issue.

The software system supports the master scheduler in creating a valid master schedule based on the availability of material and capacity. With respect to the availability of material, the issue is whether or not material *due* dates (dates placed by the master scheduler) match true *need* dates (dates calculated by the computer). With respect to capacity, it must be available in sufficient quantities to satisfy the resource requirements by specific time periods. This is a balancing job, and how well or how poorly a master scheduler does that job determines the real worth of the scheduler and the particular MPS system. The question now is what to do with period 8's computer planned order. To balance the supply and demand at the MPS level, this order for 20 flashlights is necessary. (Actually, only 8 are needed, but 20 is the minimum order quantity.) Therefore, the system will assume that the master scheduler will convert this computer planned order into a firm planned order when it is necessary (based on the lead time of the product). The next step in the process is to communicate this expected build plan to the schedulers and planners for lower-level materials to ensure that the required materials and capacities will be available when needed. Let's look at the integration between master scheduling (MPS) and material requirements planning (MRP).

How Master Scheduling Drives Material Planning

The basics of the MPS matrix, and how the software computer system and master scheduler together ensure a balance between supply and demand, should now be clear for the simple case just given. So far we have been dealing at the level of completed flashlights, ignoring the flashlight's underlying components. Yet we know that other scheduling issues may lie beneath the surface of the master scheduled item. The need to deal with the underlying components—and the materials, capacity, and build-time issues that each entails—requires an interface between master scheduling and material requirements planning. That interface is made via the flashlight's bill-of-material. To fully understand that interface, let us follow the flashlight example a bit further.

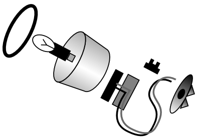
Given that it takes one period (planned lead time) to build the flashlight once the head, light, and body subassemblies are available, and since some flashlights are scheduled for completion in period 2, then there must be sufficient head, light, and body subassemblies on hand in period 1 to start building the flashlights required for completion in period 2. If the master scheduler expects to have 20 flashlights as scheduled receipts in period 2, then 20 head subassemblies, 20 light subassemblies, and 20 body subassemblies had better be available in period 1. Therefore, a *gross requirement* for 20 of each of these subassemblies exists in period 1. In other words, the master schedule row is what drives requirements down to the MRP level. Using the same logic, 20 head, light, and body subassemblies are needed in period 3 coming from the MPS lot due for completion in period 4, and 20 more in period 5 coming from the MPS lot in period 6. The computer planned order in period 8 also generates a gross requirement for 20 head, light, and body subassemblies, this time in period 7. Each of these subassemblies, then, needs its own MRP plan and schedule. Figure 3.5 represents the linkage of these schedules graphically.

To understand how MRP accommodates each of these subassemblies (and *their* various subassemblies, manufactured parts, components, and raw materials if they exist) and links them to the master schedule, we will follow just one of those subassemblies—the light subassembly—from the master schedule down to its own MRP matrix.

Material Requirements Planning

To get started on planning the light subassembly, some basic information about the subassembly is required.

On-hand inventory balance:	3
Planning lead time:	2 periods
Minimum order quantity:	25 units



For illustration purposes and to show just how the MPS and MRP matrices are linked via the computer software, the bottom rows of the MPS matrix (master schedule by due date and master schedule by start date) are shown in Figure 3.6 on page 66. The various orders for

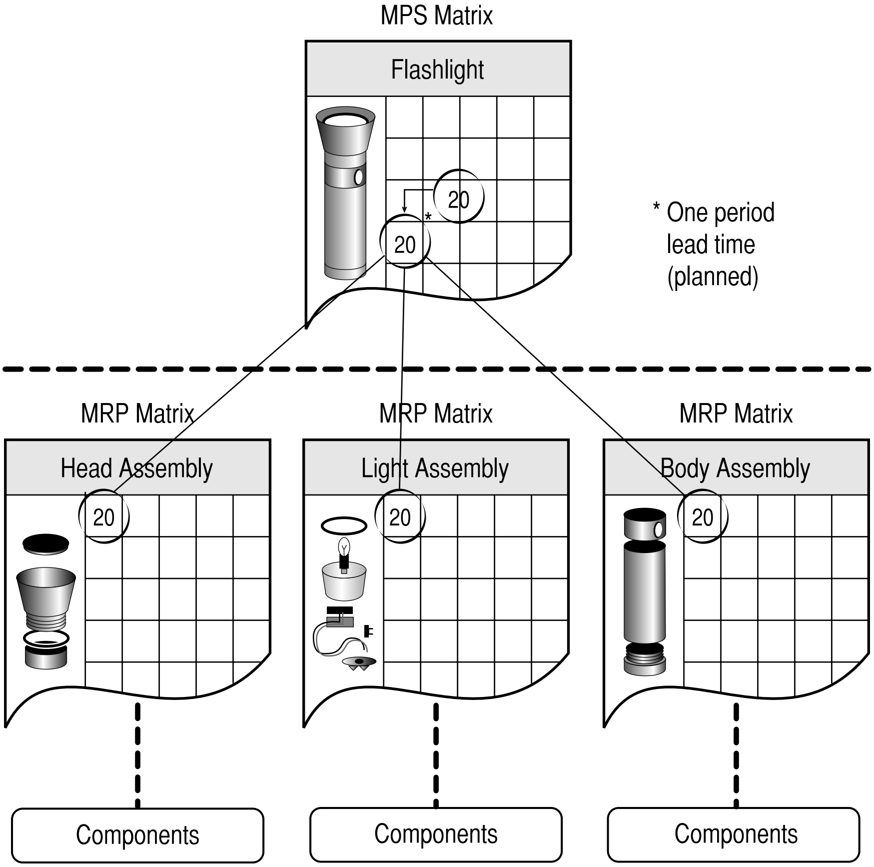
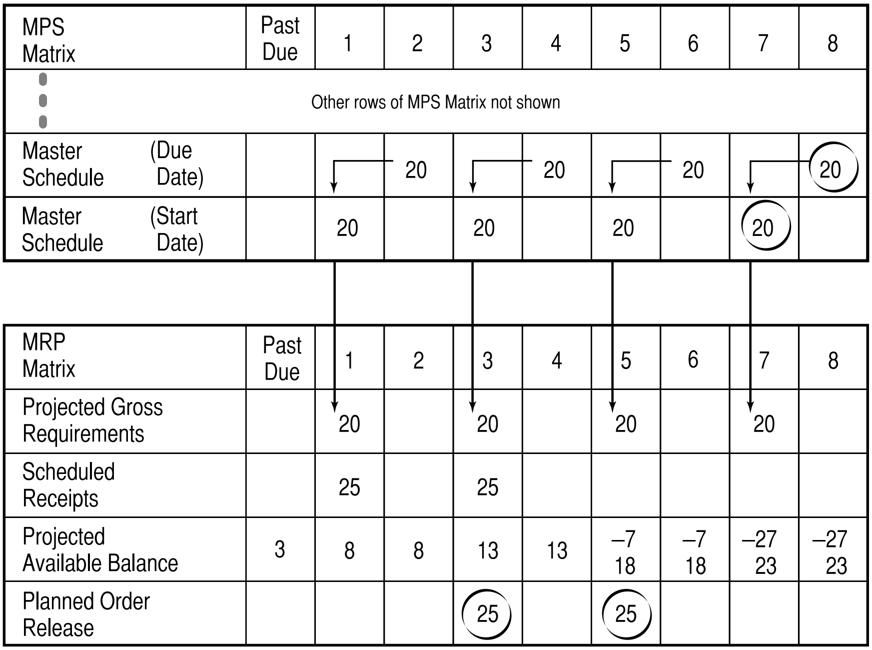


Figure 3.5 Master Schedule Linked to Material Requirements Planning

20 *completed* flashlights in periods 2, 4, 6, and 8 of the master schedule line are shown to trigger respective gross requirements for the same quantity one period earlier in the MRP matrix (MPS quantities by due date and offset by planning lead time to the start date).

The projected gross requirements row of the MRP matrix represents demand for the identified item, not from the final customer, but from the master schedule—specifically, from the MPS row. For instance, when the master scheduler placed a supply order for 20 completed flashlights in period 2 on the master schedule, that translated into a projected gross requirement of 20 light subassemblies in period



MPS Matrix	Past Due	1	2	3	4	5	6	7	8
⋮	Other rows of MPS Matrix not shown								
Master Schedule (Due Date)			20		20		20		20
Master Schedule (Start Date)		20		20		20		20	

MRP Matrix	Past Due	1	2	3	4	5	6	7	8
Projected Gross Requirements		20		20		20		20	
Scheduled Receipts		25		25					
Projected Available Balance	3	8	8	13	13	–7 18	–7 18	–27 23	–27 23
Planned Order Release				25		25			

(Circled values are computer planned orders.)

Figure 3.6 The MRP Matrix—Light Subassemblies

1 on the MRP matrix. Taking the lead time into account, the computer software system places this requirement of 20 units in period 1 of the MRP matrix.[4] The same process repeats itself whenever a supply order appears on the MPS row of the master schedule.

Projected gross requirements are the sum of all the demands over time for this item. In our simple example, the light subassembly is used only in the flashlight that's master scheduled. In a more complex environment, that same light subassembly might be used in other products manufactured by the company, in which case the demand for the light subassembly from many different master schedules would

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[4] Remember, the stated lead time to take the head, light, and body subassemblies and produce a flashlight is one period, which is not to be confused with the lead time of two periods that it takes to build the light subassembly itself.

accumulate in the various projected gross requirements time periods of the light subassembly's MRP matrix.

The scheduled receipts shown in the MRP matrix are supply orders that either MRP planners or schedulers have placed. (There are no computer planned orders here.) These scheduled receipts can go by many possible names—work orders, shop orders, production orders, manufacturing orders, campaigns, or run rates, to name a few—and are used for parts and items that the company builds or produces. Purchase orders or confirmed supplier schedules are used for parts, materials, or items that the company buys. It is important to understand that a scheduled receipt is expected to be received in the period shown and will be used in calculating the projected available balance, the next row in the MRP matrix.

Just as in the MPS matrix row of the same name, the projected available balance is where the projected inventory balance is reflected. The past-due column in this row contains the starting on-hand balance, but from that point forward, the projected available balance is the sum of on-hand balance for the prior period and scheduled receipts for the period being calculated less the projected gross requirements for that period. That figure, in effect, becomes the projected beginning on-hand balance for the next period. For example, in Figure 3.6 we see an on-hand balance of 3 light subassemblies, added to the 25 scheduled to be received in period 1; this represents an available supply of 28 in period 1, and since demand in that period (projected gross requirements) is 20, the projected available balance for the period is 8 (3 + 25 – 20).

The MRP system calculates the projected available balance quantity in much the same way as does the MPS system. The basic calculation in both systems is to take the projected ending available balance from the prior period and add scheduled receipts from the period being evaluated, then subtract the anticipated demand for that period. This yields the projected available balance for the period being calculated.

The planned order release row contains the equivalents of the computer planned orders found in the master schedule. It is the row in which the computer attempts to deal with any potential supply shortages that appear in the projected available balance row. For example, the MRP matrix for the light subassembly projects a negative available balance (the top row of numbers in periods 5 through 8) unless some action is taken. Anticipated demand from the master schedule outstrips the expected supply of light assemblies by a cumulative of 7 units in periods 5 and 6, and by a cumulative of 27 units in periods 7 and 8.

To avoid a deficit situation from developing in period 5, a computer planned order is needed to arrive in period 5, and therefore must be released in period 3 (remember, the lead time for light subassemblies is two periods). What should be the size of the order? Ideally, the computer would place an order for 7 units (assuming no minimum order quantity) in period 3 to cover the 7-unit deficit expected in period 5. However, the minimum order quantity for this item has been specified as 25, and that is what shows up in the planned order release row of period 3.

If the MRP planner or scheduler accepts the computer software's recommendation, he or she will convert the computer planned order into a scheduled receipt when period 3 becomes the current period (period 1), and a surplus of 18 units will be available in period 5, as reflected in the bottom half of the cell (13 + 25 – 20).

An important point is now being made. In order for a computer planned order to be recognized as a scheduled receipt, the scheduler or planner must take affirmative action. Remember, only supply orders placed by a scheduler or planner appear in the scheduled receipt row. It follows that once the computer planned order is converted into a scheduled receipt, it will be deleted when MRP is next run. Lower-level requirements are maintained when the system creates an allocation for each lower-level part or item required to support the scheduled receipt. These time-phased allocations are maintained automatically by the system's software and generally stored in a requirements file.

Looking ahead to future periods, no activity takes place in period 6, so the projected available balance remains at 18 units. In period 7 a demand for 20 units creates a projected negative balance of 2 units

(18 + 0 scheduled receipts – 20). The origin of this demand is the computer planned order for 20 flashlights in period 8 of the master schedule. Using the planned lead time of one period for the flashlight has resulted in this CPO generating a projected gross requirement in period 7 in the MRP matrix. The computer cannot abide a negative balance for the light subassembly, so another planned order must be released, this time in period 5 (taking into account the light subassembly's two-period lead time) to ensure sufficient supply of the light subassembly in period 7. If the computer's recommendation is followed and the computer planned order is converted into a scheduled receipt to be received in period 7, a projected surplus balance of 23 units will be available at the end of period 7 (18 + 25 – 20).

In period 8, the projected available balance will remain at either –27 units if no action is taken, or at 23 units if the CPO releases are converted to scheduled receipts when appropriate. The CPO scheduled for release in period 3 should be converted to a scheduled receipt two periods prior to the CPO scheduled for release in period 5.

The projected gross requirements (demand), projected available balance, and planned order release (supply) rows are automatically calculated by the MRP software system. Only the scheduled receipt row is maintained by MRP schedulers and planners.

Analysis

Using the on-hand balance, projected gross requirements, and scheduled receipts, the MRP system will project the available balance over each planning period, making it possible for the system to determine the true material need dates. If the projected available balance goes negative and then returns to positive, the system recognizes that a timing problem exists—that is, there is enough on order, but some of the orders are scheduled too late. If the projected available balance goes negative and stays negative, the system recognizes a volume problem and calls for additional supply orders.

Reviewing the MRP matrix for the light subassembly we observed in periods 5 through 8, the projected available balance went negative and remained negative (top set of numbers)—evidence of a volume problem. Some type of order action has to take place, and the computer software has suggested that two releases be made to put the supply and demand for light subassemblies back into balance. The scheduled receipts of 25 units in periods 1 and 3 are both necessary and scheduled properly to prevent the close-in projected available balance from becoming negative, which would have otherwise signified a timing problem.

Each time that MRP is run, this kind of analysis takes place within the computer and action messages are generated as appropriate. Based on the analysis just completed, the MRP system would not recommend that any action be taken until period 3 becomes the current period.

The flashlight example just given has explained the basics of both the MPS and the MRP logic, how internal calculations are made, and how the system—with the input of the scheduler or planner—maintains a balance of demand and supply. Just as important, the example showed the connection between the master schedule for the flashlight and how it is supported by the MRP system for each of the flashlight's components, examining one of those components—the light subassembly—in detail.

Experienced manufacturing people will be quick to recognize this as a very simplified case. Few manufactured products are as simple as the one just shown, and even a flashlight is more complex in its component makeup than this illustration has revealed. In fact, each of the flashlight components used in the example (head subassembly, light subassembly, and body subassembly) can be exploded into its components and their subcomponents. This complexity of detail, even for a simple flashlight, is more typical of the multilevel product structure that most schedulers experience.

This added detail is brought in here to make the point that MRP will continue to explode requirements through the defined bills-of-material in order to generate an MRP plan for every one of the items identified as part of the final flashlight.

The What, Why, and How of Safety Stock

Master schedulers and planners must understand safety stocks, why they are used, and their impacts on master scheduling and material requirements planning. In developing illustrations of a fairly simple master schedule and showing how it explodes down through the MRP system we have, thus far, made some convenient assumptions. We have assumed that our inventory records are accurate—that is, if the on-hand balance said 12 units, we assumed it reflected reality. We also assumed the demand at the MPS level, bills-of-material, and the projected gross requirements at the MRP level were valid and accurate. Based upon these assumptions, we constructed a master schedule, supported by lower-level schedules, and assumed that production as well as our suppliers would perform to a high standard of timely completion relative to those schedules.

However, forecasted demand is not always accurate, and non–Class A companies' inventory records are notoriously inaccurate—meaning that items we assumed to be on hand were not.[5] Even if the inventory records are accurate, other problems can occur. The production floor may run the number of items scheduled, but some of these may be found to be defective. Sometimes a purchase order for 100 parts will arrive with only 97 in the box; sometimes the parts arrive late.

A system in which one set of assumptions is layered upon others is bound to contain surprises. Often surprises do not work in our favor.

Safety Stocks as a Hedge

Safety stock inventory can be used as a hedge against unanticipated variations in both demand and supply. If the supplier delivers fewer

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[5] Class A companies have inventory record accuracy that exceeds minimum standards of 95% or, in some cases, 99.5%.

items than requisitioned, if the production floor builds items that fail to meet quality specifications, or if the demand forecast is for 10 and orders come in for 12, safety stock inventory, used with caution, can be strategically planned to fill out the difference.

What to Safety Stock

In a world where inventory had no carrying costs for the company, virtually every finished item, every parent part, and every component could be safety stocked—as long as there was room to store it. But why stop there? Why not have extra personnel on hand, just in case someone has to go home early? In the real world, however, this is impractical and expensive, so management teams may have to determine what is important to safety stock from a strategic standpoint. The immediate choices that come to mind are finished goods, subassemblies, intermediates, components, and raw materials. However, there are several other candidates for safety stocking, some of which are discussed in greater detail later in this book. Here, our concern is the mechanics of how MPS and MRP software accommodate safety stocks.

In the flashlight example, the company could decide to always maintain an inventory of 10, 20, or 40 finished flashlights. Additionally, it could also consider safety stocking certain components—like flashlight bulbs or even the raw materials used to make the components. Whichever level it chooses to safety stock, there should be a strategic purpose to offset the extra cost of inventory. Here are a few strategic purposes:

- Items with long lead times can add to the cumulative time needed to build the product. By strategic or safety stocking those items with the longest lead times, the cumulative lead time to build the product may be reduced.

- If a family of finished product is available in many options (colors, trim pieces, etc.), the forecast for the entire family is likely to be more accurate than the forecast for the specific configured product. Thus, the surprises in demand are likely to be most pronounced among the options; therefore, these semifinished options would be candidates for strategic stocking.

- For many businesses, customers expect that the producer will have certain items on hand *all of the time,* other items *some of the time,* and other items *occasionally.* Consider the analogy of the automotive service station. Its customers expect that gasoline and certain selected auto parts (fan belts, oil, oil filters, etc.) will *always* be available. It would be unacceptable for an auto service station to be out of these for any length of time. Customers would expect replacement batteries and spark plugs to be available, but they would not be shocked or terribly disappointed if the station was temporarily out of stock. They might be willing to wait a day or two for their replacement batteries or spark plugs (many companies have a one- or two-day restocking policy for items like these). These same customers, however, would *not* expect the service station to have a replacement transmission for a 1998 Ford, and would be prepared to wait for a special order on this part to come in. In this example, gasoline-like items are candidates for safety stock inventory if there is a reasonable chance for unexpected demand or a shortfall. This analogy applies to manufacturers who place a high premium on customer service for their basic, core products or service parts business.

The Mechanics of Using Safety Stocks

With modern MPS software, the desired stocking level for a master scheduled item is entered into the system, and the system flags any situation in which the projected on-hand balance falls below the safety stock level. Consider the example in Figure 3.7. This company desires, as a matter of policy, a safety stock of 50 units. Here, forecasted demand is also for 50 units per period. Seventy units are shown to be on hand—all but 20 representing safety stock (70 – 50). In the MPS line, the master scheduler has laid in four separate orders of supply to meet the anticipated demand. A quick glance at the projected available balance line reveals that in periods 1, 3, and 4, the projected number of units on hand is expected to fall below the safety stock level or turn

Safety Stock: 50 Units
On Hand: 70 Units
Lot Size: 125 Units

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		50	50	50	50	50	50	50	50
Option Forecast									
Actual Demand									
Total Demand		50	50	50	50	50	50	50	50
Projected Available Balance	70	20	95	45	–5	70	145	95	170
Available-to-Promise									
Master Schedule		←	125	←	—	125	125		125

Figure 3.7 Safety Stock Example

negative. For example, with 70 as a starting on-hand balance, less the 50 needed in period 1, only 20 will remain—less than the safety stock policy requirement. Here the master scheduler would receive an action message to shift the period 2 supply order in the MPS line to period 1, as indicated by the arrow. Following the same logic, the master scheduler would receive an action message to shift the 125 scheduled in period 5 to period 3 because the projected available balance falls below the safety stock policy of 50. If period 5's supply order is moved to period 3 or 4, the projected shortage in period 4 will not occur. These shifts would keep the projected available balances above 50 in all periods.[6] After these shifts in the timing of supply, the matrix for this master scheduled item would appear as shown in Figure 3.8. In this instance, none of the periods have a projected available balance less than the safety stock level.

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[6] The computer software would recommend these changes by means of action messages, which are detailed in Chapter 4.

Total Demand		50	50	50	50	50	50	50	50
Projected Available Balance	70	145	95	170	120	70	145	95	170
Available-to-Promise									
Master Schedule		125		125			125		125

Figure 3.8 Same Example After Shifting Supply Orders

Alternative Safety Stock Display Format

Many people today have checking accounts that may require a minimum balance of, say, $300. By agreeing to maintain this minimum balance, they are not charged the normal account service fees. While most of these people keep track of their checkbook balances in the normal way and avoid slipping below the $300 minimum, some people simply reduce their actual balance by $300. This way, when the checkbook register says $0, they know they cannot write any more checks—even though there is $300 in the account. Some MPS and MRP computer software handles safety stocks the same way. The MPS matrix for these systems does not reflect the safety stock in the projected available balance line. The inventory is there, but the computer software does not show it. This means that the master scheduler can take those balances down to zero without violating safety stock policy.

Planning Time Fence

As previously discussed, projected gross requirements, scheduled receipts, on-hand balances, lot sizes, and safety stocks affect the placement of computer planned orders. Also, each item's lead time is used to offset the placement (release date) of computer planned orders from the need date. In the flashlight example, we saw lead times of one period for flashlights and two periods for the light subassembly. But what would happen if the lead time for flashlights or light subassemblies was five or more periods? By definition, the planned order release for light subassemblies would be past due. Another way to say this is that there would be inadequate lead time for the proper placement of the light subassembly supply order. Of course, this is not a desired condition.

Fortunately, there is a way in master scheduling to control lead time issues. Modern software links master scheduling to material requirements planning, which schedules descending levels of materials. Material requirements planning efficiently performs the required calculations and recommends actions, freeing the scheduler from the drudge work and allowing him or her to focus on critical decision making.

One of the truly valuable features of master scheduling software is the *planning time fence* (PTF). A planning time fence restricts the computer software system from automatically adding to the master schedule within a specified zone. If, for example, the master scheduler wants to maintain complete control of all flashlight supply orders within periods 1 through 6, a planning time fence can be placed at the end of period 6 (Figure 3.9), forming a boundary within which only the master scheduler can place supply orders (by definition these orders then must be released orders or firm planned orders—no computer planned orders, which are created by the computer, being permitted inside the planning time fence). Outside the planning time fence, the computer can continue to place CPOs.

The planning time fence can be used to implement management policies and guidelines. For example, management may determine that changes to the master schedule can be accomplished easily beyond the cumulative lead time—that is, the total time needed to build the product from scratch—whereas making supply changes at points inside the cumulative lead time become progressively more difficult as they take on the characteristics of last-minute changes. The planning time fence can create a boundary between these areas.

← PTF

On Hand: 135 Units Lot Size: 130 Units	Past Due	1	2	3	4	5	6	7	8
Item Forecast		70	70	70	70	70	70	70	70
Option Forecast									
Actual Demand									
Total Demand		70	70	70	70	70	70	70	70
Projected Available Balance	135	65	125	55	115	45	–25	–95 35	–165 95
Available-to-Promise									
Master Schedule			130		130			130	130

Figure 3.9 Planning Time Fence Example

The planning time fence also satisfies the master scheduler's need to restrict the master scheduling software so that only released orders and firm planned orders can be created within close-in time periods. These are time periods within which the master scheduler's attention must be focused and within which the scheduler—not the computer—must make the decisions.

Areas of Control

To better understand how the planning time fence functions, look at Figure 3.9. Let's assume the cumulative lead time of this MPS item is six periods. The master scheduler has decided to place a planning time fence at the end of period 6.[7] The planning time fence (PTF) indicates

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[7] Where to place the time fence for various master schedule items is discussed in Chapter 4.

that the master scheduler controls all the supply orders up through period 6, while the computer can add or make changes in periods 7 and 8. With a cumulative lead time of six periods, the master scheduler may want these periods locked up and not subject to any mindless changes made by the computer software to balance out a deficiency in some period without careful analysis.

To understand the utilization of the planning time fence, consider again the problem represented in Figure 3.9. In this case, forecasted demand for the master scheduled item is 70 per period. The starting on-hand balance is 135 units. The on-hand balance plus the scheduled receipt of 130 units in period 2 is sufficient to cover the demand through that period and leaves a projected available balance of 125. That surplus supply is enough to meet the next period's demand, but not enough to meet that of period 4. However, a firm planned order of 130 is scheduled to be received in period 4, and this should leave a projected balance of 115. Taking this order into account, the projected inventory is sufficient to meet demand through period 5, but as we observe, a potential shortage appears in period 6. Here the projected available balance at the end of period 6 is 25 units short of meeting the demand of 70 in the period. In the absence of a released order or firm planned order in the MPS row of period 6, the MPS display shows a –25 projected available balance. That deficit would increase by 70 per period through the horizon if no additional orders were placed, which is indicated by the negative projected available balances in periods 7 and 8 (–95 and –165, respectively).

Maintaining Supply/Demand Balance Inside the Planning Time Fence

Since master scheduling software cannot tolerate a potential supply shortage (its circuits get upset when a negative available balance appears), it would normally place a computer planned order (CPO) in the MPS row of period 6 to cover the –25 projected available balance. However, the planning time fence restricts the computer software from any CPO activity through period 6. If it could speak (and it probably will some day), the computer software would shout to the master scheduler, "Wake up and fix that deficit in period 6!" Since it cannot do that, the computer software settles for piling enough CPOs into period 7 (the first period outside the planning time fence) to create a positive projected available balance, and informs the master scheduler by means of an action (or exception) message that a negative availability condition exists inside the planning time fence. With this action or exception message, the decision of what to do is dropped directly into the master scheduler's lap.

Converting a CPO to an FPO

The master scheduler must take some sort of action in period 6 if the potential supply deficit in that period is to be avoided. It would appear that the CPO of 130 in period 7 must be converted into an FPO with a due date in period 6. First, though, the master scheduler should be sure that this action is in the best interest of the company. Several questions must be answered:

- Can we get the material to produce these items in time?
- Does the capacity to produce these items exist?
- Will the forecast of 70 units really turn into customer orders?
- What will it cost to make this change?
- Does authorization exist to make this change?
- What is the business impact if the change isn't made?

Determining the answers to these questions takes master scheduling beyond the straightforward job of juggling numbers to keep supply and demand in balance. This is an area in which the computer can provide assistance but not a final judgment—at least not yet. What we are now talking about is the real job of the master scheduler.

Demand Time Fence

The challenge of master scheduling is to balance supply and demand. We have just concluded a discussion on the use of planning time fences to control the behavior of the computer and its ERP software. This begs the question: how about the demand side of the business?

Some master scheduling software has the capability to accept user defined rules on how the total demand is to be calculated. One of these capabilities is the use of a demand time fence, which is not to be confused with the demand management time fence described later in this book.

The use of a planning time fence (PTF) in the master scheduling software is only a mechanical means of controlling where the computer software can place computer planned orders. Some master scheduling software has another time fence capability: that of a demand time fence (DTF).

The DTF has basically one purpose, and it is strictly mechanical. Inside the DTF, the total demand will consist only of customer orders (actual demand). In other words, the forecast will be ignored between the current date and the DTF (Figure 3.10).

The forecast for this master scheduled item has been time-phased across periods 1 to 8. The actual demand line on the matrix shows committed customer orders (promised deliveries) in period 1 for 70 units, period 2 for 50 units, period 3 for 30 units, and period 4 for 10 units.

A DTF has been established between periods 3 and 4 using the DTF definition. The total demand for this item is calculated using only the actual demand line in periods 1 to 3 and a combination of forecast and actual demand from period 4 through the planning horizon.

Using the logic previously explained in this chapter, the projected available balance for period 1 is the sum of the on-hand inventory balance (135 units) plus the MPS in period 1 (zero), minus the total

← DTF ← PTF

On Hand: 135 Units Lot Size: 130 Units	Past Due	1	2	3	4	5	6	7	8
Item Forecast		0	20	40	60	70	70	70	70
Option Forecast									
Actual Demand		70	50	30	10				
Total Demand		70	50	30	70	70	70	70	70
Projected Available Balance	135	65	145	115	175	105	35	–35 95	–105 25
Available-to-Promise									
Master Schedule			130		130			130	

Figure 3.10 Demand Time Fence Example

demand in period 1 (70 units). This calculation creates an ending projected available balance for period 1 of 65 units. The projected available balance for periods 2 and 3 is calculated basically the same way. Take the projected ending available balance (65 units) from period 1, add it to the MPS in period 2 (130 units), and subtract the total demand for 50 units (this represents actual demand only. Period 2 is inside the DTF. The remaining forecast of 20 in period 2 is ignored), leaving a projected available balance of 145 units. Using the same calculation generates an ending projected available balance of 115 units in period 3 (145 + 0 – 30).

As we move into period 4, we are crossing the DTF. Therefore, the total demand calculation will take the forecast into account. The total demand in period 4 is the sum of the 60 units forecasted and 10 units of actual demand equal to total units. That total demand is subtracted from the ending projected available balance of 115 units in period 3 plus the MPS of 130 units scheduled for completion in period 4, carrying the calculation to its completion. We see a projected available balance of 175 units in period 4 (115 + 130 – [60 + 10]). The mechanical calculation continues. These calculations are why we have and need computers in master scheduling.

Before using the DTF, a company should understand how it works and its impact on total demand and scheduling. A policy should be in place defining the setting of the DTF by MPS item, maintenance of the demand fence, and its use in planning. Since this time fence affects the calculation of total demand, it needs to be under the control of the demand side of the business, perhaps by the demand manager/demand planner. A detailed description covering the role of demand management and its demand manager is given in Chapter 16.

This chapter has described what the master scheduling system mechanics do to support the master scheduler. The next chapter begins the discussion of how the master scheduler uses this data and information in order to manage the production plant or mill. But before this discussion begins, we must conclude this chapter with a discussion on some of the design criteria of the master scheduling process.

Master Schedule Design Criteria

In order to make ERP function properly, the master scheduling and material requirements planning system must be carefully linked. This linkage is done via bills-of-material. Besides tying the two processes together, the MPS process and system should adhere to a set of design criteria.

While there is some flexibility in the design of any MPS process, certain guidelines should be observed. These guidelines reflect the cumulative experience of many companies in many different industries. The following design areas need to be addressed.

Time Criteria

Basically all MPS software now on the market manages all supply and demand by dates. If the real dates are known, master schedule data can be displayed in any variety of ways. It is recommended that the maximum length of a scheduling display period be no greater than one week. In many cases, a daily time period will be preferred. Monthly increments are simply unsatisfactory; attempting to manage time blocks of this size increases the chances that the master scheduler will miss the details necessary to convert production rates into specific item or material numbers, quantities, and due dates. The result: completion dates not met and missed deliveries.

Planning Horizon

At the master schedule level, it is necessary to deal with two different types of lead times. One is the lead time required to produce the master scheduled item itself when all items one level down in the MPS item's bill-of-material are available. The second is the cumulative lead time—the longest planned length of time required to produce the master scheduled item from scratch. This takes into account *all* the lead times of *all* the items that go into the master scheduled item. In short, it is the critical path that recognizes some processes that can be done in parallel.

Many companies find it necessary to extend the planning horizon beyond the cumulative lead time if they need additional visibility for supplier planning and establishing supplier agreements. Extension of the planning horizon may also be required to properly assess capacity requirements. Thus, while some companies have a short material lead time, they may need to extend the overall horizon because of heavy equipment or other capacity needs.

Frequency of Review

Ideally, the master schedule will be reviewed continuously or daily using an on-line computer system. At a minimum, each item on the master schedule should be reviewed weekly. With today's technology it is possible to keep the master schedule constantly on-line, where changes can be seen on the MPS screen as they are made. As Chapter 16 on demand management and available-to-promise (ATP) will make clear, the ATP row of the master schedule screen needs to be analyzed in a real-time environment if customer orders are received on a regular basis.

This chapter covered the basic MPS matrix and the calculations used in the master scheduling process. Some basic guidelines on the design of the master scheduling process have also been addressed. The fact is, however, that we have only described how to get information into a format that the master scheduler can use. The next step is to understand how to manage with the information provided by the master scheduling system. This is discussed in the following chapters.

4

Managing with the Master Schedule

If you don't have time to do it right the first time,
when are you going to find time to do it again?

On Wednesday morning, just as she was preparing to go off to lunch, Judy Wilson, master scheduler for Criterion Electric Controls Company, received a call from the vice president of sales.

"Judy, I just got a call from our sales representative in Philadelphia. He has a chance of making an important sale of an A3 control system to a big company out there if we can beat Drumlin Electronics in making delivery."

"Well, that's good news," Wilson replied. "An A3 is a $120,000 unit."

"Right," said the sales vice president, "and this would be a new and important account for us—one that Drumlin has always controlled. Once we get our foot in the door, other business should follow."

Wilson knew that the sales vice president had not called just to announce some good news. The phrase "if we can beat Drumlin Electronics in making delivery" was to be the real reason for this conversation. The master scheduler braced herself for what was surely coming next.

"Here's the deal, Judy. Delivery is the big issue in the sale. Drumlin has promised to expedite the order and deliver in just four weeks—not their usual five." The sales vice president paused for just a moment, preparing to drop his bomb on Wilson. "We have to do better to get the business. Could we have an A3 unit for this customer in three weeks?"

Wilson had just looked at the master schedule for A3s that morning and knew that the production line was totally committed through the period in question. She also knew that the cumulative lead time for a finished A3 was six weeks. "Is that three weeks to ship?" she asked.

"I'm afraid not," the vice president responded. "That's three weeks to the customer's loading dock."

Both knew that the product was too heavy to air freight, and that express trucking would take a full two days.

"Let me work on it," Wilson said. "I'll call you back in a couple of hours. I need to check the schedule and talk with some other people."

While the sales vice president was off to a business lunch, the master scheduler went to work on the problem. She would spend the next hour or more reexamining the master schedule for A3s, several of which were on order and in various stages of production for other customers. She would consider current capacity and materials. And she would do whatever she could to make it possible for Criterion to deliver its A3 for the sales representative to open this important new account, and to ensure that all other customer commitments are satisfied. It was her job to make these things happen when she could.

By 1:30 that afternoon, Wilson was on the phone to the sales vice president. "Tell your sales representative in Philadelphia that he'll get his A3 three weeks from today . . . on the customer's loading dock."

"Great, Judy! How did you manage it?"

"Well, we had an A2 already in production. I had your assistant call the account representative for the A2's customer to determine if he could live with a two-week delay. We worked out a deal with that customer to offer a free extension on his warranty if he would take it two weeks later. The customer had no problem with it, and finance has approved the deal. I can upgrade that A2 to an A3 with available materials and capacity and deliver as promised. Tell your sales representative that he has a green light on this one, if we can solve one problem."

"What's that?" the vice president asked apprehensively.

"Your Michigan representative has an A3 on order that will be delayed by three to four days if we make these changes. Is that all right with you?"

The ball was back in the sales vice president's court. But he was used to this give-and-take with Wilson, who had educated everyone to the fact that when the production system was carefully scheduled, even the most creative rescheduling to satisfy customers usually carried some sort of penalty.

"Yes, I can deal with the customer on that delay," the vice president ended. "We'll forward the order to you in an hour."

As this story makes clear, there is much more to master scheduling than knowing how to move numbers around on the MPS matrix. Proficiency with the mechanics of scheduling is essential, but other skills are equally important: a sense of the company's overall business and its customers, knowledge of its products and production processes, and understanding of the reliability of its suppliers, to name just a few. These are areas in which judgment combined with a good business sense are critical, and they relate closely with the ability to use the mechanics of the MPS system to manage production operations.

In this story, the master scheduler used her master scheduling software tool to get a picture of current A3 production, capacity, and materials. But she went beyond this, thinking creatively about how the picture could be tactically rearranged to meet the interests of her company and its customers. Her knowledge of the company's products and how they are manufactured allowed her to see how an A2 could be converted into an A3 on short order. And she had the organizational skills to work through other parts of the company—sales, marketing, engineering, finance, manufacturing, and management—to create a solution in a way that would be supported by all affected parties.

The mechanics of master scheduling (described in Chapter 3) provide an important management tool, but the master scheduler must know how to use that tool, which is the focus of this chapter.

The Master Scheduler's Job

One way to understand how to manage with the master scheduling system is to consider the job requirements of the scheduler. (A detailed sample job description is supplied in Chapter 17.) Basically, the master scheduler is responsible for creating and maintaining a master schedule that satisfies all demands. This is not a task restricted to the factory, mill, or plant floor, but one that coordinates with other important functions of the company and its constituency of suppliers and customers:

- *Sales.* Sales personnel live to secure orders on which, hopefully, a profit can be made and commissions earned. Their task is made easier when the product can be delivered on the date the customer wants it and in the correct quantities. In a competitive world, stockouts, missed delivery dates, and the inability of the manufacturing facility to fill rush orders makes the lives of sales personnel more difficult. Conversely, the ability to avoid stockouts, meet promised delivery dates, and accommodate special customers with rapid delivery helps secure both sales success and the overall success of the company.

- *Marketing.* Marketing personnel are skilled in bringing product into the marketplace and communicating its features and benefits to potential customers. They work on forecasting issues, pricing strategies, distribution systems, product promotions, and so forth. Untimely production delays, stockouts, and unreliable service to distributors and dealers are issues that require regular interaction with the master scheduler. The better they can work together, the more effective their marketing and manufacturing programs will be.

- *Engineering.* Design engineers live for the day when development projects, which for months and years had been merely ideas or drawings, emerge from the plant as finished new products. Anything that reduces manufacturing and material complications or failures ranks high on their list of important issues.

- *Finance.* Financial managers measure the world in monetary terms. Inventory requires costly capital. Surpluses of materials and finished goods are nonproductive assets that create expense and no income. On the other hand, shortages of deliverable products and the materials from which they are made can result in expensive unplanned air freight, overtime pay, performance penalties, and lost sales. Finance wants the manufacturing facility to walk a fine line between too much inventory and stockout situations.

- *Manufacturing.* Plant and mill managers like to maintain an orderly flow of production—one that levels the load on the manufacturing facility over extended periods. An orderly flow facilitates optimal plant or mill usage, steers a course between layoffs and overtime, and eliminates the stresses that create the end-of-the-month nightmares described at the beginning of Chapter 1.

- *Transportation.* Transportation strives to optimize the loading of trucks, railcars, and marine vessels to reduce the total unit shipping costs. The objective is to secure the best use of the transportation vehicle by loading it with the proper mix of products needed by the customer or distribution center. It should be remembered that in many companies transportation makes up a large portion of the total product cost or costs of getting the product to the customer (sometimes, transportation accounts for the largest portion of the logistics cost). The better a company plans its transportation needs, the better its customer satisfaction and profits will be.

- *Top management.* The role of the executive team is to harness the capital and human resources of the company to a strategy that will result in economic prosperity for the organization and its owners. Top management has to steer the company into the future, and that is possible only when all the machinery of the organization is working together. The ability of management to lead and control is compromised with shipping delays, confusion on the manufacturing floor, excessive expenses in production, poor quality, and other internal emergencies.

The activities of the master scheduler are important to each of these functions of the company. Sales and marketing must be accommodated to the greatest extent possible to win orders, but undisciplined demands for large inventories and expedited production need to be balanced against other concerns. The desire of finance to reduce inventory expenses must be balanced against the requirements of the competitive marketplace and the needs of production to keep the plant or mill running in a sensible way. The desire of manufacturing to produce steady runs and level the load on the plant or mill must be judged in the context of foreseeable customer demand for the plant's or mill's output. And of course, the product must get to the customer in the most effective way.

In some respects, the master scheduler attempts to do from the middle management level of the organization what the executive team attempts to do from the top, namely, optimize the cooperation of the company's many functions in serving the needs of the customer. This is a job for which master scheduling software is clearly just one tool; a job for which an acute sense of manufacturing dynamics as well as negotiating and communication skills are critical. The following case illustrates how master scheduling is more than a mindless numbers tool, but one that requires finesse on the part of the scheduler.

MOVING A CUSTOMER ORDER TO AN EARLIER DATE

"We'd like to reschedule our order."

This is not the worst kind of message to get from a customer. It's certainly preferable to "We'd like to *cancel* our order." Still, it can present problems for manufacturing and challenge the ability of management to run the business in a way that delivers a profit to shareholders and satisfies customers—which are the two bases for being, and *staying,* in business.

Consider the case of Acme Glassworks, a producer of plate glass.

One of its major customers, a manufacturer of commercial windows and glass sheathing for buildings, has called to request a change in its scheduled orders, from 10 pallets in each of the next four weeks (40 pallets in all), to 10 this week, 14 next week, 6 the following week, and 10 the following week (again, 40 in all).

The master scheduler at Acme Glassworks recognizes this as a straightforward timing change, one that will require some shifting from week to week. If capacity and materials were no issue, this could be accomplished as follows:

PERIODS	WK 1	WK 2	WK 3	WK 4	MONTH
Customer Orders (pallets)	10	14 ~~10~~	6 ~~10~~	10 ~~30~~	40
Master Schedule	10	10	10	10 ~~30~~	40

On the surface, a request to move up an order would seem like a clear-cut opportunity for the manufacturer to please and satisfy the customer. But is it really? This move-up request may actually have some source other than the customer. The order might have been triggered by one of the company's own sales representatives. With the sales contest for the trip to Hawaii coming into the final stretch, the representative in Omaha might have pleaded with a customer to place the order early, thereby pushing his sales numbers up in the contest period.

In another situation, the order might originate on a clerk's computer screen. The customer in this case might be a clerk in the company's inventory control group whose computer software flagged the item, indicating a demand change due to arbitrary safety stock requirement.

If a great fuss is to be made in moving an order in, then we need to be sure that all the pain and suffering will have a positive result: that of profitably serving a paying customer.

Management Issues

Even the simple Acme Glassworks situation raises a host of important issues for managers and supervisors.

- *Can we get the capacity?* Sure, you want to satisfy the customer's request to move up an order! But it's often easier said than done. Will this gesture of customer satisfaction overload the schedule and throw a monkey wrench into the production facility?

- *Can we get the materials?* Even if the capacity problem is solved, a manufacturer might not be able to move up his own order for materials. With so many companies operating on razor-thin parts and materials inventories, the materials might not be obtainable.

- *How much will it cost?* If overtime is part of the capacity solution, and if expedited purchases and air freight of materials are part of the materials problem, then this order change may squeeze any profit out of the order that so many people will be scrambling to accommodate.

- *What will this change do to morale and teamwork on the floor?* Personnel close to the action may be working diligently to create a stable and smooth-running operation for management. Will this order change and disrupt the efficient routines and undercut the progress personnel has made in creating an orderly workplace?

These are important issues for management. Others in the organization will have their own issues of concern. Marketing may see the order change as important for market penetration. In the absence of any explanation, manufacturing may see the order change as just another headache. Finance may see a revenue opportunity. Of course, they may also recognize a cash-flow problem—namely, how will the company pay for the material and manufacturing costs that are now being moved up and out of its budget?

Typically, requests to move up an order in the schedule come from someone in sales, and they usually want an answer right away—while they are still on the telephone. "Well, can you do it or not?" We all like to please, but moving an order usually requires some checking: with the current manufacturing schedule, with the stockroom, and sometimes with suppliers. There is nothing wrong with saying, "I'll need to do some checking and call you back. It may take a day or two to get you an answer, depending on which suppliers we need to check with to see if we can get the materials." To imply otherwise is to send the signal that schedules are of no great importance and can be changed at will.

Sometimes we simply have to say no to change requests. But instead of an absolute no, we should say something like this: "I can't move that order up because the production schedule is currently booked. If you would be willing to move one of your other orders to a later date, however, I might be able to use that capacity. Do you want me to look into that?" This response helps the salesperson understand the limits of schedule flexibility, and conveys the important idea that trade-offs are often the answer.

For companies whose traditions have been to reflexively accept order changes, the greater care and study suggested here may not be agreeable to everyone—especially at first. Sales representatives who routinely telephone in order changes and get an instant answer will not like being told "We'll get back to you after we do some checking." One of management's challenges is to help these people see that a more thoughtful way of handling order changes is in the company's best interests.

Of course, computer software continues to get better and better in its support of demand and supply balancing. However, it's not just about computer software. The company must have solid processes that approach Class A to make use of the software available today. The movement in the twenty-first century is to customer and supplier collaboration and the sharing of information. This is what might be called *real* Class A integrated demand-driven Supply Chain Management.

Action and Exception Messages

The master scheduling computer system proposes; the master scheduler disposes. Chapter 3 explained that the computer looks for imbalances in supply and demand, and places computer planned orders where necessary, given product lead times, lot sizes, and safety stock requirements. We also observed how a planning time fence can be used to create a boundary between time periods in which the computer proposes and the master scheduler disposes.

One way in which computer and scheduler communicate is through *action messages* (also known as *exception messages*). Action messages are the master scheduling software's way of getting the master scheduler's attention and directing it to areas of potential problems. They identify the need for intervention to correct a current problem or to avoid a potential one. Examples of action messages are release an order, reschedule-in, reschedule-out, cancel, convert a computer planned order to a firm planned order, and so forth.

Figure 4.1 provides an example in which several of these action messages appear. Here, the planning time fence is somewhere beyond period 8; thus, all the numbers in the master schedule row represent firm planned orders (FPOs).

Demand for the product is stated as 50 units per period. With 70 units on hand, the MPS logic projects the available balance for each period. An FPO for 115 is scheduled to be received in period 2. (The lot size was 115 when the firm planned order was created, or the master scheduler had decided to override the lot size specification of 125 when the order was placed, or 10 have been received or scrapped, or the like.) The above discussion could be true if the company manufactures to a rate and expresses this rate using firm planned orders. It is the master scheduler's job to keep the master schedule line valid in quantity and due date. Remember, inside the planning time fence only the master scheduler can create orders and alter released and firm planned order dates and quantities. Additional FPOs for 125 have previously been placed in periods 5, 6, and 8.

A potential shortage of 15 units is projected for period 4, but a positive projected available balance reappears in the next period (60 in period 5). Subsequent periods project additional positive balances (135, 85, and 160). Because the projected available balance goes negative in period 4 and then returns to positive, the master scheduling system recognizes that a timing, not a volume, problem exists. The master scheduling system notes this and looks into future periods for

On hand: 70 units
Lead time (one level): 1 period
Cumulative lead time: >8 periods
Lot size:125 units
Safety stock: none

PTF →

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		50	50	50	50	50	50	50	50
Option Forecast									
Actual Demand									
Total Demand		50	50	50	50	50	50	50	50
Projected Available Balance	70	20	85	35	–15	60	135	85	160
Available-to-Promise									
Master Schedule			115		←	125	125	→	125
			Release			R/I	R/O		Cancel

ACTION MESSAGES:

1. Release FPO in period 2; start building in period 1.
2. Reschedule-in FPO in period 5 to period 4.
3. Reschedule-out FPO in period 6 to period 7.
4. Cancel FPO in period 8.

Figure 4.1 Action Message Example

orders that could be moved up. Since an FPO for 125 units is scheduled to be received in period 5 and really is needed in period 4, the system generates an action message recommending that the FPO in period 5 be rescheduled-in to period 4, thus solving the deficit problem.[1] The computer would also scan future periods and spot the larger than needed available balance of 135 in period 6. If the scheduled FPO for this period was not received, the 60 remaining from the pre-

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[1] Only 15 units are needed here, but most master scheduling and material requirements planning systems recommend bringing in the entire lot. However, the master scheduler has several options: Split the lot of 125 into 15 and 110; increase the planned order in period 2 to 130; do nothing; and so on.

vious projected balance would be more than enough to cover period 6's demand of 50 units; 10 units would, in fact, be left over. This being the case, the software would send an action message to reschedule-out the 125 units from period 6 to period 7.

Scanning still further, it would be clear that the FPO of 125 units in period 8 is not needed if the projected demand beyond period 8 is less than 35 units, and a cancel message would be sent to the master scheduler for his or her consideration.

In addition to the action messages discussed here, the master scheduling system would notify the scheduler that the FPO due in period 2 should be released (e.g., converted to a released order, such as a work order) since the item under evolution has a one-period lead time.

To review, a master scheduling system generally has the capability to analyze the supply/demand balance and to generate the following key action messages:

- Convert firm planned orders into released orders
- Convert computer planned orders into firm planned orders
- Reschedule released orders or FPOs into a closer time frame
- Reschedule released orders or FPOs into a future time frame
- Cancel a released order or firm planned order
- A negative projected available balance exists within the planning time fence
- Demand requirements are past due
- Scheduled receipts or FPOs are past due
- A planned order release has inadequate lead time to properly order material or secure the necessary capacity (past-due release)

Although the above listed action messages are considered the key ones, Enterprise Resource Planning and master scheduling systems today have the capability to generate far more exception-driven action messages.

Six Key Questions to Answer

Action messages are the recommendations made by the computer software system. These systems range in price from several thousand to a few million dollars and are terrific for making calculations and linking those calculations horizontally across time periods and vertically through the bills-of-material and material requirements planning systems. They are practically infallible in the black-and-white area of numeric logic, but even the best systems are not capable of dealing with the many gray areas that permeate the complex manufacturing environment. It is the gray areas in which the human master scheduler is superior to the machine, and in which his or her natural skepticism about demand forecasts, intuitions about risk, and so forth are essential. These gray areas may be defined in terms of six key questions that most computers cannot completely answer but that must be addressed before computer-directed reschedules and order launches are executed.

Question 1: Has Demand Really Changed?

The computer and its software can look up the demand number, compare it to the supply, and recommend action. However, it rarely challenges the validity of that demand number. If the demand number is seriously in error, the reschedule or order message may be invalid. Maybe a customer has just shifted an order out of one period and into another; the period demand has changed, but the aggregate demand remains the same. Before making changes in manufacturing, a human being must ask: “How realistic is this demand?” or “What caused the demand change?” or “Should we react to this demand?”

Consider a product that normally has demand for 50 units per period. A period with 80 units appears in the total demand row on the planning horizon. The master scheduler must make a decision with respect to creating supply to match this demand. Certain subtle clues may suggest that the high demand is not genuine. For example, if this high demand comes in just prior to the end of the annual sales bonus period, could the sales force be stuffing their regular customers with sales, robbing the next period just to enhance this period and reach their bonus requirements? Meeting this abnormally high demand might likely mean paying high overtime rates, costly special freight charges, and general stress on the factory. A telephone call or e-mail might determine how genuine the demand really is. Changes can then be made accordingly.

Question 2: What Is the Impact on the Production Plan?

A computer-generated action recommendation may put the master scheduler at odds with one or more executive plans. In a Class A Enterprise Resource Planning and Supply Chain Management environment, aggregate monthly production rates by product family are reviewed and authorized by top management; these constitute a production plan that the master scheduler must support in aggregate. This means that individual line item master schedules can be altered only in a way that preserves the validity of the overall monthly production plan totals. One master schedule change may have to be counterbalanced by an equal but opposite change for another item in the same product family. If this is not possible, higher-level approval may be needed for a change that would disrupt the monthly production plan volume.

Question 3: Is Capacity Available?

The desire to make a change to the master schedule may be constrained by available resources. A manufacturing facility is like a piece of rubber: You can stretch it in a number of different directions to accommodate production level changes (overtime, extra shifts, outsourcing, etc.). However, when action recommendations appear, capacity must be ensured before taking the recommended steps.

Question 4: Is Material Available?

Capacity alone does not manufacture products; the right materials in the right quantities are also essential to making schedule changes. If the recommendation is for a supply increase, there probably is a need for additional materials. Conversely, if demand is being reduced, it may be necessary to consider added space requirements for materials inventory.

Question 5: What Are the Costs and the Associated Risks?

In many cases, extra capacity can be found and more materials can be obtained to accommodate changes made within the lead time. Almost everything is possible—but at a cost. Express delivery companies have multibillions of dollars in annual revenues, much of it earned from companies and individuals rushing documents and materials around to meet deadlines and schedules. But revenues to express delivery companies are expenses to companies that use their services. In manufacturing, freeing up capacity, shifting work, and expediting materials delivery and product shipments all raise the cost of producing product. They also increase the risk of producing poor-quality products and damaging important customer relationships due to failure to keep delivery promises.

Question 6: What Is the Impact in the Marketplace?

If the master scheduler does not reschedule, the company risks becoming vulnerable to losing an important customer order, getting a reputation in the marketplace for being inflexible, being seen as an arrogant supplier, or worse. Here we want to know the pain of not changing the schedule. Many times the answer to this question becomes a tiebreaker when deciding whether the schedule should or should not be changed.

From a management viewpoint, the costs and risks of master schedule changes have to be measured and compared to the benefits of these changes. Does management understand the impact on financial performances due to these changes? Will the changes impact support for other customers and products? In the end, management needs to ask the question: "Is it a smart business decision to make this change?"

Answering the Six Questions

Each of the six questions should be answered before any master schedule change is made. Obviously, in complex environments involving many materials and many products, answering each question in complete detail would be enormously time consuming. In these cases, time-saving tools like rough cut capacity planning (explained in Chapter 14)—which focuses attention on only critical or key resources and materials—are invaluable. Also, operating on a computer platform that can generate simulations in minutes or even seconds is desirable. However, no matter how difficult the task, answers to these questions need to be determined if sound business decisions are to be made.

Equally invaluable is the master scheduler's experience and judgment. That experience and judgment will make answers to some of the questions intuitively obvious. In other cases, hours and days of investigation by the master scheduler and other personnel may be required to gather the data on which analysis and an informed decision can be made.

A good master scheduler satisfies demands from forecasts, contracts, customer orders, and other sources, along with the demand variations that inevitably occur, through the use of effective schedules, safety stock, safety capacity, and selective overplanning. Building a good master schedule, however, is just half of the challenge; operating a master schedule within 95%–100% (sometimes as high as 99.5%) of plan is the other half. This is as much art as science, because the master scheduler must balance materials, resources, and time against the goals and needs of other parts of the business.

Time Zones as Aids to Decision Making

The example given in Figure 4.1 on page 95 allowed the master scheduler to use judgment in rebalancing the master schedule through change orders. For a number of reasons to be discussed soon, it is beneficial to have a set of guidelines, or rescheduling time zone rules, to aid master schedulers and management in making decisions. These rules are linked to management policies that determine what kinds of changes can be made to the master schedule at certain points in time. Figure 4.2 is an abridgment of the MPS matrix, and shows how the time horizon of periods can be grouped into zones for managing schedule changes.

The meaning of these time zones for management is fairly intuitive. Zone A includes the current period and close in periods, and is one in which the master scheduler and management must carefully investigate all suggested changes. Because these periods are almost always within the cumulative and possibly the finishing or final assembly lead time of the master scheduled item, any changes will be somewhat disruptive and probably costly. Generally, safety and emergency changes are honored here. All others need high-level approval.

Zone B is one within which caution should be exercised with respect to changes. Capacity and material availability for changes need scrutiny here, and prioritizing of different orders may be required. Generally, this zone is known as the *trading zone*—material has been

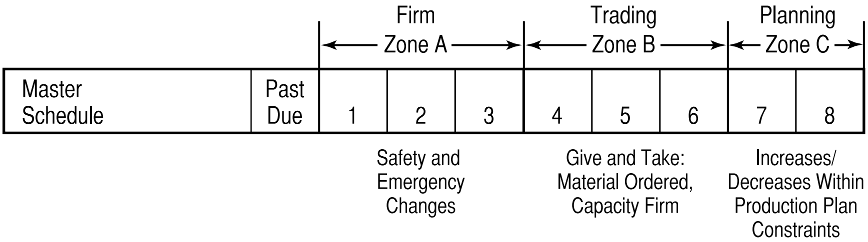


Figure 4.2 Rescheduling Time Zones

ordered, capacity is firm. Changes that cannot be traded with other demand need some level of approval.

In zone C the master scheduler, and often computer software, are free to make changes as long as the schedule remains within the production plan constraints. This period is by definition far enough into the future that the master scheduler can modify the master schedule without affecting the procurement of material or the process of getting the product to market. Generally, this zone is known as the *free* or *future planning zone.* Changes in this zone can generally be approved by the master scheduler without further management analysis or discussion.

Guidelines for Establishing Zones

There are no hard-and-fast rules for establishing where each zone starts and stops. These are totally dependent upon the nature of the product and the market and manufacturing strategy of the company. As a general rule, it is useful to think about the boundary separating zones A and B as a point at which the production process is highly locked in—where changes will be quite costly and disruptive (zone A) and in which a certain amount of careful trading can take place (zone B). The boundary between these two zones often coincides with the final assembly or finishing process.

The next step is to determine the boundary between zones B and C. When in doubt, the product's cumulative lead time is a logical candidate for this boundary. The logic here is that beyond the cumulative lead time, the master scheduler has the time necessary to obtain the required lower-level materials and move capacity around as required. In some cases, however, zone B could extend beyond the cumulative lead time. This happens when management wants more control over the schedule and schedule changes. The down side of this, however, is the human effort required to approve and make changes within this zone.

The opposite is also possible—management might make zone B smaller, thereby extending the area of zone C. If a scheduled item had, for example, a cumulative lead time of two months, and fewer approvals and less control were wanted near the end of that period, the boundary could be brought *inside* the cumulative lead time. This provides less people and more computer empowerment in making changes. However, the risk of not making the time, capacity, materials, and financial resources come together as necessary is certainly there due to changes occurring inside of lead time.

Before leaving this subject, let's consider the following case of an order change.

MOVING A MANUFACTURING ORDER TO AN EARLIER DATE

The new production facility of Bordertown Salsa Company had not only been able to meet its scheduled production load but had actually gotten ahead of the game. It now felt capable of taking on more work. For a new production facility this was an encouraging development. The general manager, however, was cautious and reluctant to push the new plant to the limits. "No sense in giving them so much that they choke themselves," he thought.

Bordertown's production manager told the general manager that he would like to move in 2 units of scheduled output from period 3 to period 2. This would provide a test of the plant's productive capacity in period 2 and, if that went well, would open up some slack time in period 3 to do some line adjustments. The general manager agreed.

PERIOD	1	2	3
Demand	10	10	10
Supply	10	12 ~~10~~	8 ~~10~~

Pulling work forward is not always a bad idea. In this case, it is done for a rational purpose: to test the limits of a new production facility and to create future slack time for line adjustments. Another instance might involve the opportunity to fill unused production capacity. Likewise, a company may find that its parts or materials inventories are too large, and moving orders in can help reduce these inventories and associated carrying costs if the product built can be sold, shipped, and invoiced. The reasons to move a manufacturing order to an earlier date are numerous. However, moving up an order involves more than just a change in the due date.

Management Issues

Some orders are moved in because they *must* be moved: a batch of finished product was damaged and must be quickly replaced, preshipment product testing found many defective units, a cycle count found an inventory error placing the company out-of-stock on a popular product, a new safety stock level has been approved, and so on. Other move requests may have less merit, and part of management's job is to create a working environment in which necessary and frivolous change requests can be sorted out on a rational basis.

It takes very little effort to request an order change, but implementing the change is often difficult, disruptive, and costly. Management needs to determine if a change request is frivolous or essential to the goals of the business, and whether it can be justified from a cost standpoint. If the move-up request is simply to satisfy some internal convenience—such as an arbitrary safety stock requirement—that might not represent a genuine business need. If the move is to satisfy an important customer, we should measure the benefit of greater customer satisfaction against the cost of making the change. We need to ask: "What would happen if we didn't make the change?"

Here are some other issues that the master scheduler and management must think through:

- *The order movement may be inside the lead time.* One or more components needed for this stage of production may not be available at the newly scheduled date. This could create a materials problem as well as a credibility problem for the scheduler (i.e., by asking manufacturing to make product without materials).

- *Is there sufficient capacity?* Whoever approved the move-in order may not have checked (or had the experience to determine) that the capacity was available. If the factory cannot respond, what purpose would be served by moving the order?

If an order *must* be moved forward, yet the plant cannot respond, then management must make hard choices. Being between a rock and a hard place is a dilemma that is common in the business world. Management's job is to exercise judgment and creativity in dealing with these dilemmas.

Naturally, management is not the only party concerned when the idea of moving in a manufacturing order is considered. If manufacturing resists, sales and marketing may respond: "You've done it before. Why not now?" Manufacturing may counter with: "We are flexible—to a point—and can handle this one moved-up order. But we cannot handle three, five, or ten such orders." Manufacturing rightfully wonders why they are seldom notified of opportunities to move *out* orders to make room for the orders in question. Finance, as always, is concerned with the costs of the change and how it will enhance or reduce profits. The master scheduler, whose job it is to satisfy customers within the capabilities and capacities of manufacturing, may rightfully muse that "nothing seems impossible to the person who doesn't have to do it."

Two other time fences are sometimes used by companies to help in managing the business. The capacity time fence (for example, see Figure 10.7, pp. 284–285) reminds the master scheduler that changing capacity within this boundary is difficult. The material time fence (for example, see Figures 10.8 and 10.9, pp. 294–295 and 302–303) reminds the master scheduler that changing the material requirements inside this boundary is difficult. Both of these time fences are warning-type fences and don't affect the MPS software (ERP) logic.

Planning Within Policy

Chapter 3 described the use of planning time fences, which is a system technique in which the master scheduler interacts with the computer. It is not unusual to see the planning time fence (PTF) established at a product's cumulative lead time. In fact, if you do not know where to put the PTF, this is where to start. The master scheduler may, however, want to take more control of the horizon. This can be done by putting the PTF further out onto the horizon. This gives the master scheduler more control but also requires more effort since there may be more FPOs to control. The master scheduler could also decide to take less control. This can be done by putting the PTF *inside* the cumulative lead time. While this requires *less* effort, the master scheduler is turning over more control of the product to the computer software. Care is needed here since any time the PTF is placed inside the cumulative lead time, some strategic stocking of long lead time items should also be taking place in order to ensure material availability. Company policy needs to define where the planning, material, and capacity time fences are to be placed and which functions within the company are responsible for their maintenance. In addition to the planning time fence and computer logic, we must also consider the relationship between the managerial decision zones just described and the position of the rescheduling timing zones.

The Hierarchy of Change Approvals

As time passes, a company's ability to make changes to the product becomes increasingly more difficult. Actually, the closer the change is to the product's due date, the more disruptive and costly it will be to make that change. Less than Class A companies choose to ignore these simple and important facts. It should be obvious that changes in zone A will be more difficult, disruptive, and costly than changes in zones B and C. (See Figure 4.3.) Likewise, changes in zone B will be more

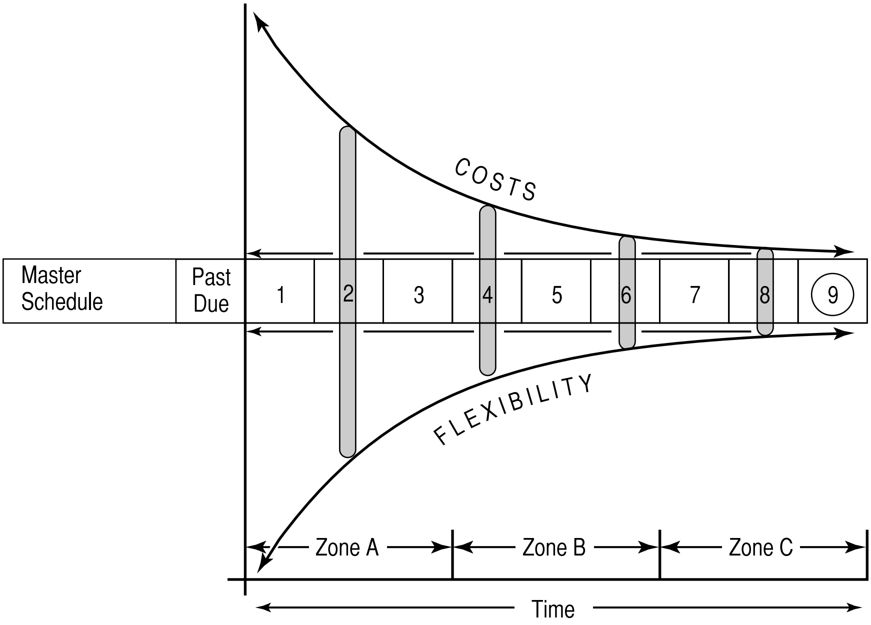
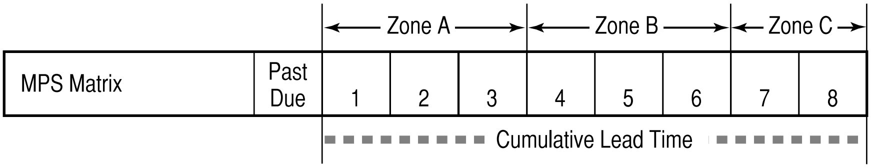


Figure 4.3 MPS Change Gap Analysis

difficult, disruptive, and costly than changes in zone C. In fact, as steps in the manufacturing process are completed, a company's flexibility to even change the product diminishes.

Thus, changes that cause minor disruption and cost increase can be made by individuals lower in the hierarchy of authority, while changes that cause major disruptions as well as significant cost increases should be scrutinized and approved at a higher level. This is the sort of policy that prevails in Class A companies and is analogous to other corporate policies that involve commitments of resources.

A caution in the development of a change-approval policy is that the list of people needed to approve a change should not be so formidable as to make needed changes overly difficult to implement. If a master scheduler has to run around to seventeen people to get approval for necessary changes, one of two things will happen: (1) the changes will never be made, or (2) the master scheduler will ignore the policy and make changes arbitrarily. There is a fine line between overburdening the approval process and giving out too much authority to lower-level functions.



Zone A	Zone B	Zone C
Approvals by:	Approvals by:	Approvals by:
Pres., VP Manufacturing, VP Sales, and/or VP Finance	Manufacturing Dir., Plant Mgr., and/or Sales Dir.	Master Scheduler and/or Materials Mgr., Demand Mgr.

Figure 4.4 Time Zones and Approval Policy Example

Figure 4.4 illustrates this hierarchy of authority to approve changes against the background of the schedule time horizon and zones A, B, and C previously mentioned. The exact location of the zones in the figure is hypothetical and strictly for illustration purposes. In any Class A organization, however, these demarcations are thoroughly thought out and communicated through written policies.

The Placement of Approval Zones

While approval policies that govern the domain of humans are divided into three or more time zones, the domain of the computer software is generally broken in two by means of the planning time fence: one area in which the computer software has no control (can recommend changes) and another in which it operates freely. The point has already been made that in the absence of any other guidelines, a good place to put the PTF is at the end of the cumulative lead time.

In the development of a formal policy with respect to the reschedule approval zones, a good place to put the break between zones C and B is also at the end of the cumulative lead time. A logical place for the break between zones A and B is at the finishing or final assembly process. These are not hard-and-fast rules by any means, but they are good rules of thumb when the company has insufficient information to place the decision points elsewhere.

No Past Dues

It should be against the law to permit the master schedule to go past due and remain there. In Chapter 1, we discussed the impact of a past-due master schedule. Effective and competitive manufacturing relies on valid scheduling. There simply is no other choice. Several things can be done to encourage valid schedules while discouraging invalid ones.

First of all, an executive policy needs to be written and put into effect that clearly states that there will be no past dues when it comes to the master schedule. Second, there needs to be an understanding of what the policy means and why adherence to it is so important. Third, the people affected by the policy must have the discipline to follow it. Fourth, a performance measurement program that rewards valid schedules while penalizing invalid (past-due) schedules needs to be implemented. (More detail on past dues and performance of the master schedule is included in Chapter 17.) Fifth, a corrective action process should be put into place just in case any MPS item does go past due and remains past due.

Doing these five things and paying attention to the validity of the master schedule will greatly enhance a company's ability to satisfy their customers while maintaining a profitable business.

Managing with Planning Time Fences

It is now useful to return to planning time fences to discuss how the master scheduler can use them to more effectively manage production schedules. Consider again the MPS matrix used to introduce the concept of planning time fences, reintroduced here as Figure 4.5. Let

On hand: 135 units
Lead time (one-level): 2 periods
Cumulative lead time: 6 periods
Lot size: 130 units
Multiples: 130 units

← PTF

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		70	70	70	70	70	70	70	70
Option Forecast									
Actual Demand									
Total Demand		70	70	70	70	70	70	70	70
Projected Available Balance	135	65	125	55	115	45	–25	–95 35	–165 95
Available-to-Promise									
Master Schedule			130		130			130	130

Figure 4.5 Managing with Planning Time Fences

us consider this to be the master schedule for an A3 unit manufactured by Criterion Electric Controls Company, introduced earlier in the chapter.

Criterion has forecasted level demand at 70 units per period. The master scheduler, Judy Wilson, has placed a PTF at the end of period 6, and as before, the computer has spotted the potential deficiencies beginning in period 6 and generated two CPOs of 130 each to counteract the deficiencies. However, since a PTF has been established between periods 6 and 7, the first of these CPOs has been placed in period 7 with an action message (negative availability inside the PTF) being sent to the master scheduler. Moving the first of those CPOs into period 6 as a firm planned order is necessary from the vantage point of the computer software. However, additional analysis must be done before taking action. To learn something new from this situation, consider the following scenario.

The sales group has just returned from a major trade show where customer response to the A3 unit has been extraordinary. Each of the regional sales managers has told the national sales vice president that its sales representatives will be submitting new and higher forecasts for A3 units within the near term. This is truly good news for the company, and the sales vice president is anxious to ensure an adequate supply of A3 units to meet the tremendous demand he expects to materialize soon. Normally, he would have consulted with the vice president of finance on any major change in the sales forecast, but today he was so excited by future sales prospects and so uneasy about the company's ability to satisfy orders, that he picked up the telephone and called Judy Wilson first.

"Judy, this is Phil. Good news on the sales front. We have big orders ready to come in on A3s, so we are increasing the forecast in period 4."

"I'm glad to hear about the big sales, Phil, but could you give me a figure for how much higher your forecast will go?"

"Sure," said Phil, proudly. "Right now it is 70 units in period 4. We plan to knock that up to 270. Wait, on second thought, let's go to 370. No sense in getting caught short, is there?"

Wilson knew immediately that she would earn her paycheck this day. Several things would happen if she entered this forecast change as requested. The obedient computer software would place a series of CPOs for 130 units in the MPS row of period 7, along with an action message to convert three CPOs for 130 units to FPOs and move them into period 4. Figure 4.6 demonstrates just what Wilson's computer screen would show her.

The large new demand forecasted for period 4 would create a projected deficit in periods 4, 5, and 6. The computer software would never dial the sales vice president to ask how realistic this demand forecast was. Rather, it would respond in the only way available to it: by placing a very large computer-generated supply order—520 units, four complete lot sizes (multiples of 130 specified)—in period 7, just outside the planning time fence. These large CPOs, which have been aggregated to a larger CPO, would solve the volume problem for Wilson, but

On hand: 135 units
Lead time (one-level): 2 periods
Cumulative lead time: 6 periods
Lot size: 130 units
Multiples: 130 units

PTF

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		70	70	70	370	70	70	70	70
Option Forecast									
Actual Demand									
Total Demand		70	70	70	370	70	70	70	70
Projected Available Balance	135	65	125	55	–185	–255	–325	–395 125	–465 55
Available-to-Promise									
Master Schedule			130		130			520	

ACTION MESSAGES:

1. Convert CPO to FPO.
2. Negative availability inside PTF.

Figure 4.6 MPS for A3 Units, with Increased Demand in Period 4

certainly not the timing problem in periods 4 through 6. An action message would recommend firming the CPO of 520 units into an FPO and moving the FPO into period 4, or moving two FPOs of 130 each into period 4, one of 130 to period 6, and creating one for 130 in period 7 (dependent upon the software logic).

Keeping the CPOs outside the planning time fence has the benefit of avoiding unexamined new demand forecasts from automatically exploding downward through the material requirements planning system, where materials would be ordered and expected as well as capacity called for on short order. The planning time fence permits the master scheduler to keep this change in suspension while she considers its consequences on the entire production and materials system.

As an experienced master scheduler, Judy Wilson knew that she would not be changing the master schedule on the sales vice president's request alone. A few things were out of order:

1. This change would take place within time zone B, and Criterion's company policy required the approval of *both* the sales vice president and the plant manager. The reason for this policy was to avoid the chaos that normally resulted from unauthorized changes made within the cumulative lead time. Wilson would first check to see if the plant manager had signed off on this proposed schedule change.

2. Wilson's natural suspicion was aroused by both the timing of this request and the sales vice president's initial tentativeness with respect to the number of orders he expected to receive. Saying "on second thought, let's go [from 270] to 370" was not reassuring to Wilson. Also, forecasted demand increases typically followed the annual trade show attended by the company and, historically, many of these sales failed to materialize in the forecasted period—if at all.

Aside from these two concerns, Wilson knew intuitively that if she brought the CPOs into period 4 that the magnitude of the increased supply would create material and capacity problems below the level of the master schedule. Completing this volume of A3 units would require evening shifts at double-time wages, rushed materials purchased at premium prices, and expedited shipments to customers—all very costly to the company. "Has anyone even spoken with the vice president of finance?" Wilson wondered aloud.

In the case described, the master scheduler earned her pay by being both open-minded and tough-minded. She had to be open to the possibility of increasing shipments by considering possible alternatives to the computer action messages, like bringing some of the 520 units into periods 4 and 6—capacity, materials, and costs permitting.

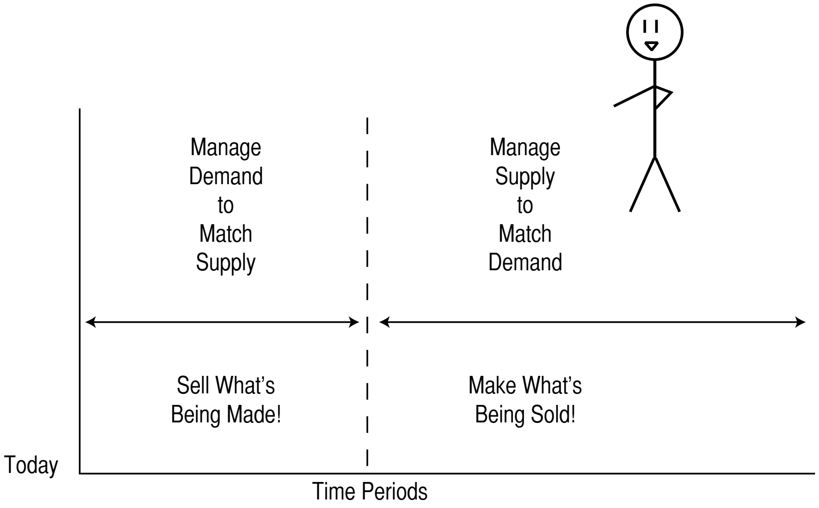


Figure 4.7 Demand and Supply Management Time Fence

She also had to be tough-minded in observing change policies that support smooth operations and collaboration of different functions of the company. Finally, she needed to answer the six questions with respect to demand, the impact of demand changes on production, materials and capacity availability, costs, risks, and opportunities.

Planning time zones help master schedulers manage this difficult process. Planning time fences hold automatic MPS changes outside of zones A and B, where unexamined changes invariably cause problems, and they prompt the master scheduler with action messages to either implement its suggestions or think of better alternatives.

Management is often asked whether the company should "sell what it makes" or "make what it sells." The answer should always be *"yes." That's a good idea!* What the company needs to do is add time to the question. Refer to Figure 4.7. In the close-in time periods, the company should make the demand equal to the supply—sell what's being produced. Beyond a defined timeline, the company's planned supply should be equal to the planned demand (aggregate planning taking lot sizing into account). The reader may be asking where this timeline appears. Again, there are no hard-and-fast rules, but the finishing or final assembly time is a good starting point.

Load-Leveling in Manufacturing

Every plant or mill manager's dream is to run the manufacturing facility at a steady pace—that is, at a level load. Ideally, this level load is very close to peak operating capacity yet provides enough slack for periodic repairs and maintenance. In a perfect world, overtime and expediting costs are eliminated, and workers are spared the scourge of forced periodic plant shutdowns and/or layoffs. The top half of Figure 4.8 represents this idyl-

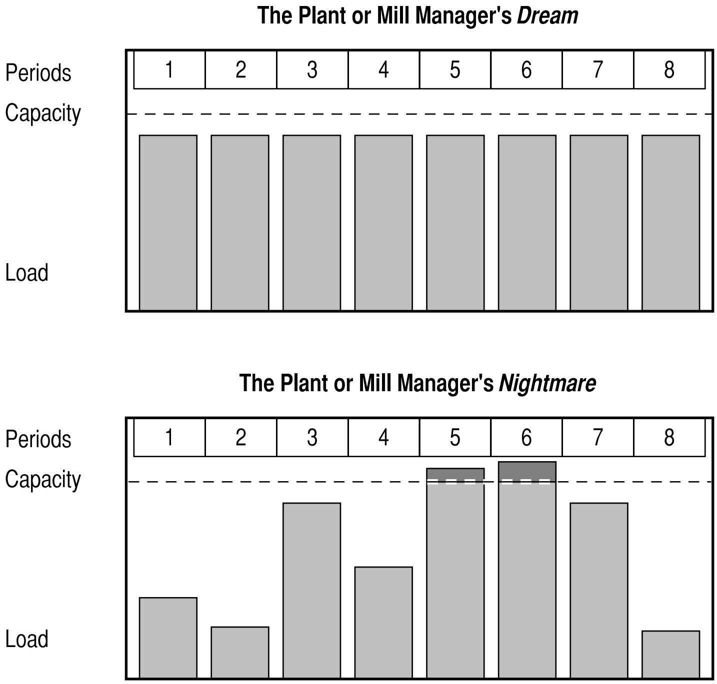


Figure 4.8 Load-Leveling

	Past Due	1	2	3	4	5	6	7	8	Total
Total Demand		30	80	60	70	20	20	80	40	400
Projected Available Balance	0	+20	–10	–20	–40	–10	+20	–10	0	0
Master Schedule		50	50	50	50	50	50	50	50	400

Figure 4.9 A Naive Approach to Load Leveling

lic condition. The bottom half, however, represents every plant or mill manager's nightmare and a condition all too common among traditional production plants. In the bottom half, the plant or mill load varies widely: underutilizing capacity in some periods and demanding more than the plant or mill can deliver—except with costly overtime—in others. These variations may be attributed to fluctuating demand, equipment downtime, or just poor scheduling. The master scheduler cannot always make the plant or mill manager's dream come true, but he or she can even out some of the peaks and valleys of production.

Since a major cause of load-level problems is demand fluctuation, consider the following situation. The company forecasts total demand for 400 units at a very uneven rate over the next eight weeks. One approach to leveling production is to plan orders for 400 units at a level rate of 50 per week (400 ÷ 8 = 50). Figure 4.9 demonstrates the result of this naive approach. Assume that the company starts with a zero on-hand balance and that the scheduler has effectively leveled production at 50 units per week. The resulting projected available balance line indicates that promises to customers may be broken in five of the eight weeks. The first-cut level load will not work.

Several possible solutions present themselves:

1. Anticipating this situation, the master scheduler might build up inventory to a point where the company would start week 1 with an on-hand balance of 40 units. This would render projected available balance positive in all subsequent weeks. The negative side of this approach is inventory costs for certain periods.

	Past Due	1	2	3	4	5	6	7	8	Total
Total Demand		30	80	60	70	20	20	80	40	400
Projected Available Balance	0	30	10	10	0	20	40	0	0	0
Master Schedule		60	60	60	60	40	40	40	40	400

Figure 4.10 Level-Loading by Blocks

2. Work with the sales department to manage demand so that it takes on a more level profile. Discounts or other inducements could be effective in this effort.

3. Break the eight-week time span into blocks that can be level-loaded. A quick review of the demand figures indicates that the first four weeks is a block of fairly high demand (30 + 80 + 60 + 70 = 240); weeks 5 through 8 have less demand (20 + 20 + 80 + 40 = 160). By simply scheduling orders for 60 units in each of the first four weeks (240 ÷ 4 = 60), and 40 units in each succeeding week (160 ÷ 4 = 40), as demonstrated in Figure 4.10, two level-loaded blocks of production are created that satisfy all anticipated customer orders with a minimum of excess inventory. This might not be the perfect solution of 50 units per week, but it is close. Of course, the master scheduler must evaluate the impact of the reduction in the MPS between weeks 1–4 and 5–8 (what are we going to do with the people and equipment?).

The company can come closer to the perfect solution if it implements a continuous improvement program with lean manufacturing characteristics that possibly makes use of mixed-model scheduling.

Lean Manufacturing and Continuous Improvement

Over the past two to three decades much attention has been paid to improving the manufacturing process, largely as a result of the continuous improvement, Just-in-Time, and lean manufacturing movements. As manufacturers learned more about these movements, they came to realize that improving their processes involved more than simply getting material to arrive at the factory every two hours. They began to see lean manufacturing in a broader sense—as a continuous improvement program that has as its objective the elimination of waste—where waste is defined as any activity that does not add value to the product.

Consider a three-step process that produces a plastic part (Figure 4.11). In step 1, the part is formed in a mold; this step adds cost (machine, material, labor, electricity, etc.). This step also adds value. Step 2 moves the molded part some 100 feet to the packaging line. Again, this step adds cost (material handling equipment, labor, etc.). But does step 2 add value to the final part? Absolutely not! The customer is no better off for the fact that the part moved 100 feet across the manufacturing floor. Step 3, part packaging, adds both cost and value.

The principles of lean manufacturing and continuous improvement suggest that the non-value-adding activity of step 2—physically moving the molded part around the facility—should be eliminated. One

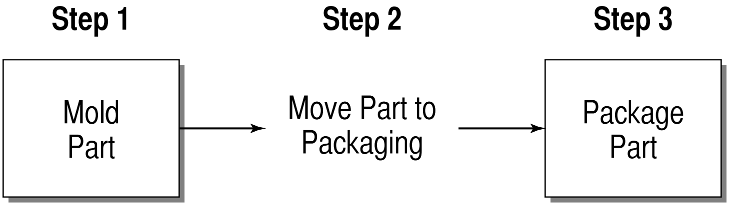


Figure 4.11 Value-Adding and Nonvalue-Adding Operations

way to do this would be to place the packaging line next to the molding machine. Besides this obvious candidate for elimination, there may be other, less obvious non-value-adding activities associated with this molded part: the preparation of schedules, dispatch lists, hot lists, shortage reports, work orders, and so on. The use of these traditional control mechanisms continue to be challenged by many manufacturers today. Those activities that cannot be shown to add value are being eliminated.

The same scrutiny is being applied to traditional lot sizes and safety stocks, two factors that produce inventory. Inventory does not *directly* add value for the customer, even though the company may have reason to maintain it. However, any increments of inventory that can be reduced without impairing customer service and satisfaction may legitimately be viewed as waste. Lot sizes are generally the result of long setups and/or complex changeovers. Continuous improvement programs suggest that the way to reduce lot sizes is to reduce setup times. Safety stocks are used as protection against demand/supply variation. Continuous improvement programs suggest a way to reduce inventory is to reduce safety stocks, and a way to reduce safety stocks is to reduce or eliminate the supply/demand variations. As this book intends to demonstrate, careful management of supply and demand is effective in reducing the need for wasteful safety stocks.

Mixed-Model Scheduling

Traditionally, manufacturers have attempted to build products in large lots to take advantage of cost savings associated with volume. Today, the cost savings associated with volume production are being challenged. As companies move closer to the lean manufacturing environment, they are discarding the ideas of large production runs in favor of smaller ones that match incoming customer orders. Since demand for many different products or models may require shipment of many

Traditional Approach

Periods	1	2	3	4	5	6	7	8	9	10
Item	151	151	151	151	151	152	153	154	154	155

Mixed-Model Approach

Periods	1	2	3	4	5	6	7	8	9	10
Item	151	154	151	152	151	153	151	155	151	154

Figure 4.12 Weekly Production Schedule for Golf Carts

products on the same day, a growing number of companies are implementing a technique called *mixed-model scheduling,* which allows/ forces them to reduce order quantities, build less of a product at one time, build the product more often, and provide better customer satisfaction and service. Paradoxically, they can do this without increasing costs.

Mixed-model scheduling means building a small volume of each product every day or every week. Consider, for example, a company that produces a five-member family of golf carts—types 151 through 155—with a mixed-model sequence. For this producer, 50% of its unit business is represented by type 151; the other types normally account for sales as follows: type 152, 10%; type 153, 10%; type 154, 20%; and type 155, 10%. Under traditional methods, the company would produce each type of golf cart in a batch to minimize production costs. The mixed-model method, however, schedules each type of cart as needed. Figure 4.12 represents the schedule of a company that builds 10 units per week. The top part of the figure is the traditional approach, and the bottom is the mixed-model approach.

In the traditional approach, the customer who orders a type 154 cart at the beginning of the week must wait until Thursday for shipment (assuming that two golf carts are produced per day). In the mixed-model approach, that cart can be shipped on Monday or in the worst case, on Friday. This method reduces the chance of a stockout and the overbuilding of inventory. As a scheduling method it is not perfect, but manufacturers that use it have reported good results.

One such manufacturer is Tennant Company, which makes industrial floor sweepers. Tennant implemented mixed-model scheduling years ago to improve delivery times and reduce the need to carry large finished goods inventory. To accomplish this, Tennant needed to reduce setups, lead times, and cycle times (from four weeks to one week).

The three parts of Figure 4.13 show the company's transition from a traditional economic order quantity (EOQ) producer—one that optimizes lot size relative to carrying costs—to a mixed-model producer. Section A of the figure identifies Tennant as an EOQ producer. Looking at the assembly line starts and the parts-kitting activities supporting those starts, we see an unbalanced load on the people doing the kitting—21 kits to be pulled in week 1; 17 kits in week 2; 49 kits in week 3; no kits at all in week 4; and so forth. Section B of the figure shows Tennant still as an EOQ-based product producer, but level-loading the kitting area at 17 pulls per week. Section C of the figure indicates that Tennant has completed the transition to a mixed-model producer, building a small amount of everything every week, *and* level-loading the kitting area. The secret to the company's transition was regular, incremental process improvement.

Mixed-model scheduling and lean manufacturing are important parts of being a Class A company. They require good communication among sales, marketing, engineering, finance, and manufacturing. There is just no substitute for people working together as a focused team to eliminate waste. Companies that have not adopted mixed-model scheduling and lean manufacturing are advised to consider them as methods for improving the customer satisfaction process.

A. Economic Order Quantity Producer

	WEEKS														
Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
A	21 →							21 →							42
B		17 →							18 →						35
C			49 →							49 →					98
D						21 →							21 →		42
E							11							10	21
Total # of Units Kitted per Week	21	17	49	—	—	21	11	21	18	49	—	—	21	10	238

B. Level-Load Producer

	WEEKS														
Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
A	17	4						17	4						42
B		13	4						13	5					35
C			13	17	17	2				12	17	17	3		98
D						15	6						14	7	42
E							11							10	21
Total	17	17	17	17	17	17	17	17	17	17	17	17	17	17	238

C. Mixed-Model Producer

	WEEKS														
Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
A	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42
B	2	3	2	3	2	3	2	3	2	3	2	3	2	3	35
C	7	7	7	7	7	7	7	7	7	7	7	7	7	7	98
D	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42
E	2	1	2	1	2	1	2	1	2	1	2	1	2	1	21
Total	17	17	17	17	17	17	17	17	17	17	17	17	17	17	238

Figure 4.13 Tennant Company Transition from Traditional Economic Order Quantity Producer to Mixed-Model Producer

Planned Plant Shutdowns

In many industries, customer demand is fairly continuous, yet production facilities are shutdown periodically for vacations, scheduled maintenance, refitting, and other purposes. Accommodating demand when the plant is idle is a regular and important responsibility of the master scheduler and is usually accomplished by a steady buildup of inventories in the periods prior to the shutdown. To demonstrate this process, consider Minuteman Electronics Company. Minuteman has planned a shutdown of its Boston production facility during the weeks beginning 7/12 and 7/19 to accommodate annual maintenance and cleaning. Many of its regular production workers will take those weeks as vacation; those who do not will assist the maintenance and cleaning crews.

Demand from customers and from its two regional distribution centers is forecasted at 3,000 units per week during the period before and during the shutdown, meaning that Minuteman must go into the shutdown period with a reserve quantity of 6,000 units if it hopes to satisfy all forecasted orders. Thus, the company's master scheduler must plan to build enough product to cover the regular forecasted demand *and* build up the reserve quantity during the weeks prior to shutdown.

Figure 4.14 shows the situation at Minuteman, where the master scheduler has created three firm planned orders of 7,500 each in periods 6/8, 6/22, and 7/5 to complete the reserve quantity. By the end of period 7/5, the projected inventory balance is 9,700, enough to cover the shutdown as well as any demand in 7/26, while the plant is coming back up. However, as the master scheduling software analyzes the projected available balance line, it will notice that the firm planned orders in 6/22 and 7/5 can be rescheduled-out (the projected available balance will remain positive if this is done), and will signal the master scheduler with action messages.

Reserve quantity: 0
Cumulative to date: 0
On-hand balance: 5,200 units
Start build: 6/8
Stop build: 7/5
Release date: 7/12

								Shutdown	
	Past Due	6/1	6/8	6/15	6/22	6/29	7/5	7/12	7/19
Forecast		3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Projected Available Balance	5,200	2,200	6,700	3,700	8,200	5,200	9,700	6,700	3,700
Master Schedule			7,500		7,500	→	7,500	→	

Reschedule Out

Figure 4.14 Plant Shutdown Planning

The master scheduler may want to get rid of these correct, though unwanted, action messages. There are three approaches to this:

1. Use a nonmovable firm planned order if the master scheduling software offers this capability.
2. Create artificial demand by placing a reserve requirement in the system over the course of the buildup period.
3. Modify the software so that it will create artificial demand equal to the amount needed during the shutdown period.

Figure 4.15 indicates how the artificial demand suggested in the last two alternatives may be implemented.

As the figure indicates, an artificial demand equal to the forecasted demand for the shutdown period has been created and placed in the master scheduling matrix under the *Reserve Quantity* line. As each period's projected available balance is calculated, the shutdown demand is taken into account. This process continues until period 7/5, when the entire buildup quantity is released (7/12) and recorded in the inventory balance. The projected inventory balance in 7/12 is determined by summing the 3,700 projected to be available in 7/5 and the reserve quantity of 6,000 (3,700 + 6,000 = 9,700). From this the forecast of 3,000 units is subtracted, leaving a projected available bal-

Reserve quantity: 6,000 units
Cumulative to date: 0
On-hand balance: 5,200 units
Start build: 6/8
Stop build: 7/5
Release date: 7/12

								Shutdown	
	Past Due	6/1	6/8	6/15	6/22	6/29	7/5	7/12	7/19
Forecast		3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Reserve Quantity			1,200	1,200	1,200	1,200	1,200	–6,000	
Projected Available Balance	5,200	2,200	5,500	1,300	4,600	400	3,700	6,700	3,700
Master Schedule			7,500		7,500		7,500		

Figure 4.15 Plant Shutdown Planning with Artificial Demand

ance of 6,700, which will be used to satisfy demand in periods 7/19, 7/26, and so on.

Of course, plant shutdowns can also result from the termination of a particular product or from a corporation's need to reduce overall manufacturing capacity. Witness, for example, the continuing efforts of a large automobile manufacturer to slash its auto- and part-making capacities. The following case situation speaks to a similar situation, and one that points out the important implications for both top management and the master scheduler.

THE PRODUCTION SHUTDOWN

In 1976 a leading medical group announced its conclusion that women below the age of 55 should *not* have regular mammograms. The danger of repeated radiation exposures, in its view, outweighed the benefits of regular mammograms in the detection of breast cancer among younger women.

For Xerox Corporation's Xeroradiography Operations Unit, this announcement struck like a torpedo amid ships. Almost overnight, a large chunk of the market for its expensive mammography machines was blown out of the water. Although some of its backlogged orders held firm in the wake of the announcement, many were canceled, and few new customers appeared. With the demand forecast sinking quickly, managers and production schedulers in the Xerox unit had to make new estimates of future demand and reflect these in dramatic revisions of the production plan.

In the fast-paced business environment, when products are quickly undercut by new technology and new competitors, the situation faced by Xerox in 1976 is not uncommon, and just about everyone in the affected business unit—including the master scheduler—is forced to make dramatic course corrections. Consider the following set of numbers for a hypothetical operation. The original forecast had been for 100 units per period, but new developments have cut deeply into that figure. With future demand slowed to a trickle, and the future of the product clearly in doubt, management sees a shutdown of the production line as its best option. But how should that shutdown be scheduled?

Original Forecast	100	100	100	100
New Forecast	30	10	10	10
Master Schedule	60	0	0	0

In this simple example, management decides to keep the production line open during the next period, building for *all* demand anticipated over the next four periods. This plan will result in heavy initial inventory, but financial managers determine that the inventory carrying costs will be less than the costs associated with maintaining a low-volume production line over time. Once its inventory of built products is exhausted, the product will be terminated due to insufficient demand.

In the case of Xerox, the Xeroradiography Operations Unit determined that the combination of existing finished goods, current production scheduled through the next several months, and machines sent back for refurbishing would be sufficient to satisfy reduced market demand for a period of two years—an estimate that proved to be remarkably accurate. Current work was completed and the line was shut down. Two other developments occurred within two years: Medical opinion on the risks and benefits of mammograms for women under 55 made an about-face, and engineering changes at Xerox were successful in reducing the radiation levels of the next generation of mammogram machines.

Management Issues

Production shutdowns can result from several causes: a dramatic reduction in market demand (as described above) or recall of the product because of safety or sabotage problems (e.g., Johnson & Johnson's recall of Tylenol), among others. Whatever the cause, a number of important issues confront management:

- Should we continue production and simply build inventory until the horizon is clearer, or should we shut down the line?
- If we reduce or halt production, what will we do with materials in inventory and on order, with production personnel, and with the production facility itself?
- Should we fight the issue and rebuild demand by pumping resources into public relations and advertising?

If our leaders and managers are paid to make decisions, they *really* earn their pay during episodes like these, when the stakes are high and the future is uncertain. Worse still, the best solutions may only *reduce* the financial damage to the company. For business leaders and managers, all the choices may be undesirable, but choices nevertheless must be made.

Abrupt production shutdowns affect everyone, not just top management. Financial managers analyze the costs of the alternative solutions and project their effects onto the bottom line. Sales and marketing personnel must deal with affected customers and wonder what other products they should be selling. Manufacturing personnel contemplate line changeovers to other products as they await the decision of top management. Engineers and quality people scramble for solutions that will put the product back into the market.

The two preceding chapters should have imparted a general understanding of master scheduling and materials requirements planning mechanics, planning time zones, action messages, and what the master scheduler needs to do in order to successfully guide the company. The next two chapters deal with how to use the master scheduling system output in the make-to-stock environment and *what* to master schedule. The mechanics discussed so far are important, but not nearly as important as how the master scheduler makes decisions using the computer software generated information.

5

Using the MPS Output in a Make-to-Stock Environment

It requires a very unusual mind to make an analysis of the obvious.

This chapter examines the computer software output—reports or screens—used by the master scheduler in managing supply and demand, timing as well as quantities. Understanding its many elements and how they interact is essential in this important management task. Once the master scheduling (MPS) data and information are introduced, we will see how they can be used in scheduling an actual product—an industrial winch.

The manufacturer of the winch in our example follows a *make-to-stock* manufacturing strategy. This is a fairly common strategy followed by companies that make everything from felt-tipped pens to books like the one you are holding in your hand. Make-to-stock companies build products to put directly on the shelf—either in their own stockrooms or in those of their distribution centers. The relative simplicity of the make-to-stock strategy versus the make-to-order strategy makes the chore of explaining the MPS output straightforward. Subsequent chapters will show you how to work the MPS output in other manufacturing environments, such as make-to-order, engineer-to-order, and design-to-order.

The Master Schedule Screen

Previous chapters have presented matrices for the master schedule. Hopefully, these have been useful to the reader in learning the mechanics of the scheduling process. Here we encounter a computer-generated master schedule screen typical of those used in modern manufacturing facilities and whose elements should now be familiar to the reader (see Figure 5.1).

This screen is divided into three major sections:

1. Item information
2. Planning horizons
3. Detail data

Item Information Section

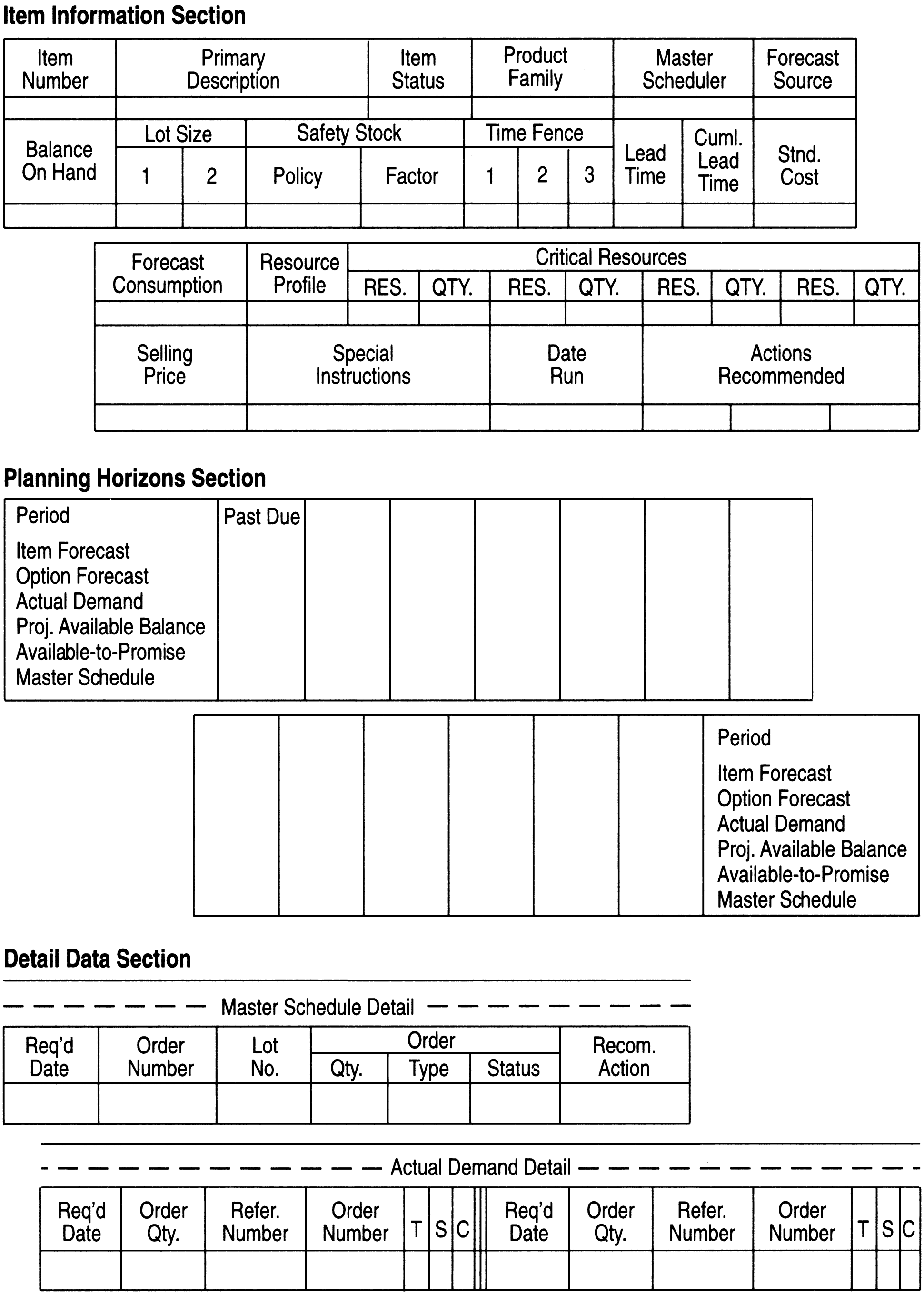
This section occupies the top portion of the screen and contains information about the product, planning data, and production policy guidelines. Here is a brief description of each data element of this section.

Item Number: The unique identification assigned to the master scheduled item.

Primary Description: Provides a brief description of the scheduled item and can include name, model number, or other data.

Item Status: Describes the item by stocking status (e.g., indicates whether the part is a stocked, pseudo, or phantom).

Product Family: The product family to which the item belongs. For example, an AM radio might be part of a family that includes AM/FM radios, AM/FM radios with cassettes, AM/FM radios with CD, and so on.



Item Information Section

Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source

Balance On Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cuml. Lead Time	Stnd. Cost
	1	2	Policy	Factor	1	2	3			

Forecast Consumption	Resource Profile	Critical Resources							
		RES.	QTY.	RES.	QTY.	RES.	QTY.	RES.	QTY.

Selling Price	Special Instructions	Date Run	Actions Recommended		

Planning Horizons Section

Period Item Forecast Option Forecast Actual Demand Proj. Available Balance Available-to-Promise Master Schedule	Past Due						

						Period Item Forecast Option Forecast Actual Demand Proj. Available Balance Available-to-Promise Master Schedule

Detail Data Section

Master Schedule Detail

Req'd Date	Order Number	Lot No.	Order			Recom. Action
			Qty.	Type	Status	

Actual Demand Detail

Req'd Date	Order Qty.	Refer. Number	Order Number	T	S	C	Req'd Date	Order Qty.	Refer. Number	Order Number	T	S	C

Figure 5.1 Sample Master Schedule Screen

Master Scheduler: Contains the initials or name of the individual scheduler responsible for this master schedule item. The data also allows the master scheduling system to sort reports for distribution of hard copies.

Forecast Source: Indicates the source of forecasted demand (i.e., demand from a statistical forecasting system, developed through an explosion using planning bills, or a manually input judgmental number).

Forecast Consumption: Shows the master scheduler how the forecast is consumed when orders are booked.

Resource Profile: Indicates the resource profile to which the item is tied (to its own profile, to the product family profile, or to a similar item). This resource profile is used in rough cut capacity planning, which is discussed in detail in Chapter 14.

Critical Resources: Four critical resources could be displayed for this item. These include the name of the resource and the required quantity/time, depending on how the profile was designed.

Balance on Hand: The quantity of the master scheduled item in the warehouse as of the date the MPS data was run.

Lot Size: Indicates the preferred ordering practice for the item. This category contains two fields. The first field includes the lot sizing rule used (discrete or lot for lot; a fixed quantity; a period order quantity; etc.). The second field contains the modifier attached to whatever lot size rule is used. For example, if period order quantity is used, a modifier of 2 specifies that enough material to cover two periods of demand should be ordered. If a fixed quantity is used, the modifier might be, say, 100, indicating that 100 is the minimum order amount.

Safety Stock: This displays two types of information: (1) the policy, which refers to a quantity or time; and (2) a factor, which describes the lower limit (e.g., “never less than 100 units”) or how many periods early the recommended order release and receipt will be specified (e.g., “two periods earlier than required”).

Time Fences: This field shows where the planning time fence is set (e.g., between periods 6 and 7). If a demand, material, capacity, or release time fence is used, this, too, is indicated.

Lead Time and Cumulative Lead Time: The first data element is the planning lead time for one level of this MPS item. It shows how long it should take to get the product on the shelf once all the subassemblies, intermediates, and materials required one level down are available. The second data element, cumulative lead time, indicates how long it should take to build this MPS item from scratch (the longest leg or critical path of the item).

Standard Cost: Cost can be derived by other methods, but here the standard cost refers to the target cost of the item (material content, labor content, direct overhead, outside processing, etc.). The information in this field is helpful in determining the impact on cost resulting from changes in the master schedule.

Selling Price: Indicates the list price of the item in the marketplace. Selling price is useful in determining operating margins and in quantifying the impact of master schedule changes on total revenues.

Special Instructions: These include reminders such as "See note 11." Note 11 in turn might instruct the master scheduler to check with engineering before releasing another FPO because of a planned engineering change.

Date Run: The date on which the computer system prepared the screen or report.

Actions Recommended: A summary of recommendations, such as reschedule-in or -out, release the order, convert a computer planned order to a firm planned order, and so on. (Refer to Chapter 4 for a discussion of the various action messages.)

Planning Horizons Section

The planning horizons section describes supply and demand data for a specific time period, typically one day or week. The format in the screen is almost identical to the format used in previous chapters. The first period is generally the past-due period, the second is the current period, and each subsequent period extends the time line into the future. (Note: The number of periods shown varies from company to company. Also, the master scheduler can often define how many days are in each period; the scheduler may, for example, define the first 5 periods in individual days, the next 11 in half weeks, and the 6 following these in weeks.) Each period includes the following information:

Item Forecast: Generally independent demand. This line is used to display spares or service forecast for the master scheduled item.

Option Forecast: Generally dependent demand. The option forecast is the quantity directly forecasted for the item or the result of forecasted requirements from a top-level model exploded through a product family planning bill (see Chapters 8 and 9 for an explanation of this process).

Actual Demand: Indicates customer orders already held by the company. In a make-to-stock environment, the interval between the receipt of a customer order and its ship date is relatively short; therefore, it is not uncommon to see little unshipped actual demand reflected on the master schedule screen.

Projected Available Balance: The quantity expected to be available at the end of each planning period. This is the balance between supply and demand. A positive number identifies potential surplus stock, negative numbers show potential shortages, and zero reflects perfect balance. (Note: A positive value can also reflect potential perfect balance if safety stock is being used and the positive value equals the desired safety stock level.)

Available-to-Promise: Shows the amount of product that can be committed to customers (not used extensively in make-to-stock environments). It is equal to the master scheduled quantity less the actual demand for all periods, except period 1, where the quantity on hand is added to the master scheduled quantity less the actual demand (noncumulative in all examples in this chapter).

Master Schedule: Shows the anticipated build quantity per period and consists of scheduled receipts, released orders, and firm planned orders within the planning time fence. Beyond the planning time fence, the computer can place its own orders, which are called computer planned orders. All MPS quantities in this chapter's example are shown in the period in which they are due.

Detail Data Section

This section of the master schedule screen shows actual data by date and is subdivided into *Master Schedule Detail* on the left side and *Actual Demand Detail* on the right. All data appearing here is linked to the planning horizons data above it and constitutes the supporting detail for the master schedule.

MASTER SCHEDULE DETAIL. This portion of the detail section is found in the lower left corner of the screen. It supplies detail information on each expected master schedule receipt that appears in the master schedule row. Action messages are printed for any expected receipt that requires scheduling, rescheduling, cancellation, and so on.

Required Date: Shows the actual date the scheduled receipt is expected to be completed or received. This date is the one used to place the quantity on the master schedule row of the planning horizon.

Order Number: Shows the manufacturing, firm planned, or purchase order number assigned by the master scheduler.

Lot Number: Is a suffix applied to manufacturing, firm planned, or purchase orders that further defines the expected receipt by lot, run, campaign, or other unique characteristic.

Order Quantity: Indicates the quantity remaining open on the scheduled receipt.

Order Type: Distinguishes between manufacturing and purchase receipts or orders.

Order Status: Indicates whether the expected receipt is released, firm planned, or computer planned.

Recommended Action: Displays the computer's recommendation for each receipt (e.g., reschedule-in or -out, release, etc.).

ACTUAL DEMAND DETAIL. This portion of the detail section occupies the lower middle and lower right area of the MPS screen. Like the master schedule detail, it provides important details on the demand figures that appear in the planning horizons section. This information is provided in terms of the following categories:

Required Date: Displays the ship date or final assembly start date (depending on which date is being used to synchronize the planning) for the customer order.

Order Quantity: Shows the amount of product remaining open for the customer order.

Reference Number: Is the particular customer name (which in a make-to-stock environment may just be "finished goods").

Order Number: Indicates the actual customer order number for the make-to-order environment and the manufacturing order or run number for the make-to-stock environment.

Demand Type (T): Indicates the type of demand, such as assemble-to-order (A), finished goods (F), and so on.

Demand Status (S): Notes whether the demand is a released requirement (R), a customer order in the quotation state (Q), an on-hold customer order (H), a shippable item (S), demand that has been generated from an upper-level item (F), and so forth.

Demand Code (C): Indicates whether the demand is abnormal (A) or normal (blank). If abnormal, it is added to the forecast amount in the period in which it occurs.

Working a Make-to-Stock Master Schedule

Now that the basic components of the master scheduling screen are understood, it can be used in master scheduling an actual manufactured product, in this case an industrial winch.[1] But first we need to understand this product in terms of its product family, product structure, and cumulative lead time. These are best understood by examining the bill-of-material (see Figure 5.2 on p. 138).

The top portion of the figure is a hierarchy representation of the WA01 winch and its underlying components and subassemblies. The winch has four levels: a finished-item level (L0) and three lower levels (L1, L2, and L3).

The bottom half of the figure is called an *indented* or *multilevel* bill-of-material (BOM). This bill reveals all the items necessary to produce the WA01 winch from scratch. The various column headings in this indented BOM, however, require some explanation:

LVL: Refers to the level in the BOM. Level 3 items are components of level 2 items, level 2 items are components of level 1 items, and level 1 items are all components of the finished item—the level 0 item.

ITEM #: Refers to the specific identification number of the raw material, component, machined part, subassembly, or any other item.

DESCRIPTION: Provides a brief description of the raw material, component, intermediate, subassembly, parent assembly, or finished item.

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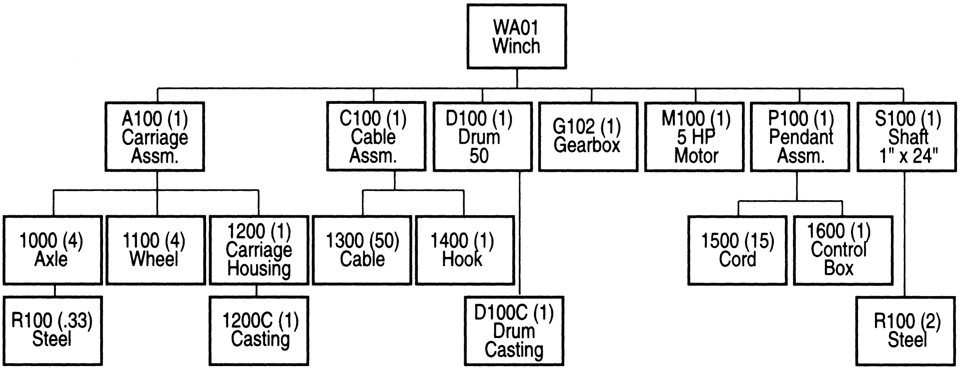
[1] The winch product structure example used in this chapter and Chapter 10 was created and published in the initial APICS *Bill-of-Material Training Aid* (Falls Church, VA: American Production and Inventory Control Society). The master schedule and material requirements planning examples were originally developed at Arista Manufacturing Systems by a number of people. The intention of these two chapters is not to perform mechanics on the numbers, but to discuss what a master scheduler does with data once it is available. For this purpose these examples work well.



LVL	Item #	Description	Source	QPU	U/M	Ext. QPU	Lead Time	Cumul. Lead Time
0	WA01	Winch, 1000# 4FPM	ASSM	1	EA	1	2	18
.1	A100	Carriage Assm.	SUB	1	EA	1	2	16
..2	1000	Axle	MCH	4	EA	4	1	9
...3	R100	Hard Steel	RAW	.33	FT	1.32	8	8
..2	1100	6" Wheel	PUR	4	EA	4	8	8
..2	1200	Housing	MCH	1	EA	1	2	14
...3	1200C	Housing Casting	RAW	1	EA	1	12	12
.1	C100	2000# Cable Assm.	SUB	1	EA	1	1	11
..2	1300	1/4" Cable	PUR	50	FT	50	8	8
..2	1400	4000# Hook	PUR	1	EA	1	10	10
.1	D100	Drum-50', 1/4"	MCH	1	EA	1	3	15
..2	D100C	Drum Casting	RAW	1	EA	1	12	12
.1	G102	Gearbox	PUR	1	EA	1	12	12
.1	M100	5HP Motor	PUR	1	EA	1	12	12
.1	P100	Pendant Assm.	SUB	1	EA	1	1	7
..2	1500	3- Wire Cord	PUR	15	FT	15	4	4
..2	1600	Control Box	PUR	1	EA	1	6	6
.1	S100	1" Shaft	MCH	1	EA	1	1	9
..2	R100	Hard Steel	RAW	2	FT	2	8	8

Figure 5.2 WA01 Winch Multilevel Bill-of-Material

SOURCE: Describes where the item comes from. These sources may be any of the following:

RAW: Raw materials or components, which are used to create machined parts or subassemblies.

PUR: Purchased materials.

MCH: Machined or fabricated items, in which raw materials are converted into other intermediates (in some cases, the machined or fabricated items may be end items in themselves).

SUB: Subassemblies, which consist of a configuration of parts, components, machined items, or raw materials.

QPU: Stands for "quantities per unit" and defines the quantity needed at the next higher level. Thus, the carriage assembly consists of four axles, which in turn require .33 feet of hard steel (see next column for units), four purchased wheels, one machined housing, and one housing that is machined from a housing casting.

U/M: Indicates the unit of measure for each quantity in the preceding column. The units in this example are feet (FT) and each (EA).

EXT. QPU: Is the extended quantities per unit. For example, as we saw in the QPU column, four axles are needed for each carriage assembly. Each axle in return requires .33 feet of hard steel, so four axles will require 1.32 feet of hard steel (4 × .33).

LEAD TIME: Refers to the amount of time it takes to procure or make the individual item (hours, days, weeks).

CUMULATIVE LEAD TIME: Indicates how long it takes to build the item from scratch. Note that it is *not* the sum of the individual lead times below it; rather, it is based on the critical path—the longest path in time that it takes to produce the referenced item from scratch. The difference is that many of the processes will be done in parallel operations.

In Figure 5.2 it can be seen that each intermediate has its own cumulative lead time. In the case of the pendant assembly, that time is 7 periods. For the carriage assembly, the lead time is 16 periods.

The carriage assembly, in fact, has the longest lead time of any of the intermediates. Since the final winch assembly requires two periods to build once all the intermediates are in place, the cumulative lead time for the WA01 winch is 18 periods.[2]

Time Phasing the Bill-of-Material

With the information contained in the BOM, the master scheduler knows the items, levels, quantities, and lead times. Using this information, he or she develops a time-phased bill-of-material that shows the relationship of each item in the winch to each other in terms of level and in terms of when work on it must be started if the final winch is to be built within the planning lead time—18 periods (Figure 5.3).

The time-phased BOM in this example makes it visually clear that to produce the WA01 winch, the carriage assembly (A100), cable assembly (C100), drum (D100), pendant assembly (P100), and shaft (S100) must be completed and available two periods before the WA01 winch is scheduled for completion. In addition, the gear box (G102) and motor (M100) must be received from the supplier. This is true because of the two periods of lead time associated with the WA01 winch. Looking at just one of the subassemblies for the winch, the A100 carriage assembly, it is easy to see that work on its component items must be initiated still earlier if the carriage assembly is to be ready in time for work on the final WA01 winch to begin. To pick just one of A100's component parts as an example, work on item 1100 (the six-inch wheel) must begin 10 periods before the A100 carriage assembly is due to be

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[2] If a winch is to be completed 18 periods from today, a material planner must order the housing casting today, because it requires 12 periods to procure the raw material, 2 periods to machine the housing, and another 2 periods to include the housing casting in the carriage assembly—a total of 16 periods. Add the 2 periods for putting the finished winch together, and the total time is 18 periods.

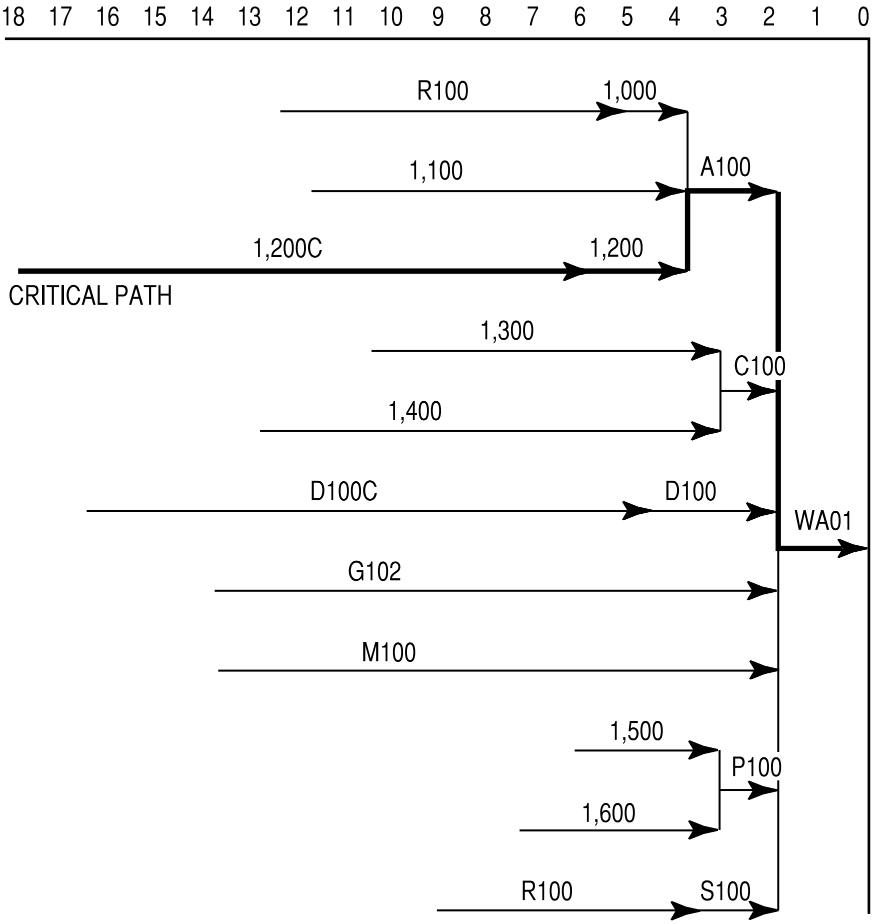

Figure 5.3 Time-Phased Bill-of-Material

finished (8 periods to secure the wheel and 2 periods to complete the carriage assembly).

The term *critical path* is used by schedulers and project managers alike to describe the longest path in the entire operation. As long as other work can be done in parallel to this critical path, it defines the cumulative lead time to build the entire item. In this particular example, the critical path travels from housing casting (1200C), to housing (1200), to carriage assembly (A100), and to winch (WA01) itself.

Understanding the Action Messages

Figure 5.4 (see pp. 144–145) is the master schedule screen for the WA01 winch. This screen will be our tool in learning how the master scheduler integrates the information available about the winch with company policies, demand, supply, and the master scheduler's strong desire to satisfy the customer with competent, businesslike judgments concerning manufacturing stability, inventories, capacity constraints, schedule change costs, and the like.

Item Information Section

In the WA01 example, 138 units are on hand, and the lot size method chosen is period order quantity (POQ) for two periods of demands. The safety stock policy is by quantity, and the factor is 100 (the company desires not to drop below 100 winches in stock at any time). The planning time fence is set at 20 periods.

"Since the cumulative lead time is 18 periods," one might ask, "why set a planning time fence at 20 periods?" In this case, the answer may simply be that the master scheduler has elected to gain an extra 2 periods of control. Remember, inside the planning time fence, the master scheduler has control of the planning horizon and creates or places released or firm planned orders. Outside the planning time fence, the computer software generates computer planned orders.

Finally, the actions recommended in the WA01 example include a reschedule-in, a computer planned order that needs to be converted to a firm planned order, and a firm planned order that needs to be released. Those actions are reflected in the master schedule detail section of the screen, as explained below.

Planning Horizons Section

In the past-due column of the planning horizons section, there is an unconsumed forecast of 22 items. This means that the item probably started with a forecast of 100 for the period, 78 of which were sold and consumed, leaving 22 units unconsumed.[3]

The second number in this column is the projected available balance (PAB) of 116 units. The system calculated this as follows: 138 units are on hand and 22 are still forecasted to be sold (the unconsumed forecast). Here the system assumes that the forecasted 22 will in fact be sold, leaving 116 (138 – 22) as the PAB to start the first period.

Now consider that first period (the current period) during which 200 units (on the master schedule line) are scheduled to be received. Combining those 200 units with the 116 opening projected available balance creates a total supply of 316 units. The demand for this period is 100 units, as shown in the forecast line. Assuming that those will be sold, the system subtracts 100 units from the 316 units available, leaving a projected available balance at the end of the first period of 216 units. This same logic is used to calculate the projected available balance throughout the entire planning horizon.[4]

The Reflection of Supply and Demand in the Details Section

Supply and demand activities throughout the planning horizon are illuminated in the details section. For example, the 200 units in the master schedule line of period 1 are reflected as the first entry under master schedule detail. Here, the master scheduler can see that this is more than just a supply of 200 scheduled WA01 units, which is all the planning horizon data reveals. In the master schedule detail section, it is defined as lot number 012. Its required date is period 1; it is a manufacturing work order (MFG); and it has been released to the

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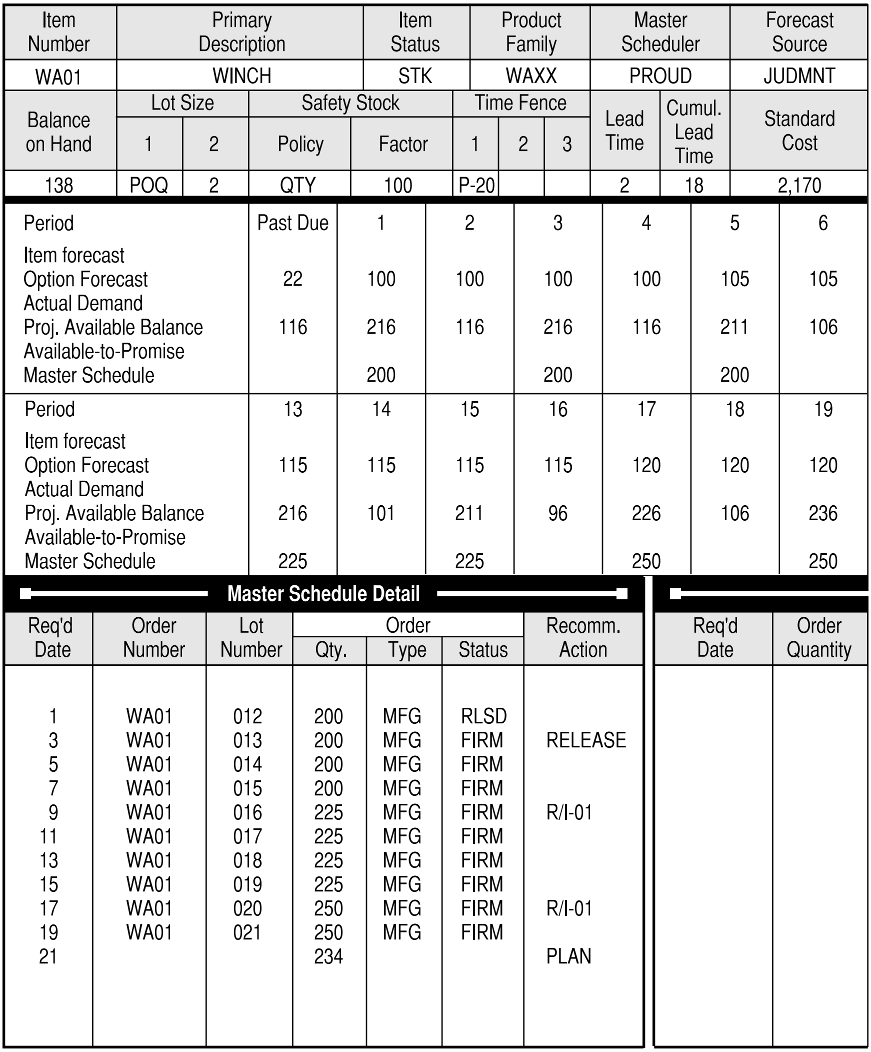
[3] Different master scheduling systems would display that 22 in several ways—either as shown here or added to the first period's demand of 100, making it 122 (refer to Chapter 16 for a discussion of forecast consumption).

[4] Note: If you have trouble understanding the basic calculations and mechanics, refer to Chapter 3 for a review.



Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source
WA01	WINCH	STK	WAXX	PROUD	JUDMNT

Balance on Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cumul. Lead Time	Standard Cost
	1	2	Policy	Factor	1	2	3			
138	POQ	2	QTY	100	P-20			2	18	2,170

Period	Past Due	1	2	3	4	5	6
Item forecast							
Option Forecast	22	100	100	100	100	105	105
Actual Demand							
Proj. Available Balance	116	216	116	216	116	211	106
Available-to-Promise							
Master Schedule		200		200		200	

Period	13	14	15	16	17	18	19
Item forecast							
Option Forecast	115	115	115	115	120	120	120
Actual Demand							
Proj. Available Balance	216	101	211	96	226	106	236
Available-to-Promise							
Master Schedule	225		225		250		250

Master Schedule Detail

Req'd Date	Order Number	Lot Number	Order			Recomm. Action
			Qty.	Type	Status	
1	WA01	012	200	MFG	RLSD	
3	WA01	013	200	MFG	FIRM	RELEASE
5	WA01	014	200	MFG	FIRM	
7	WA01	015	200	MFG	FIRM	
9	WA01	016	225	MFG	FIRM	R/I-01
11	WA01	017	225	MFG	FIRM	
13	WA01	018	225	MFG	FIRM	
15	WA01	019	225	MFG	FIRM	
17	WA01	020	250	MFG	FIRM	R/I-01
19	WA01	021	250	MFG	FIRM	
21			234			PLAN

Req'd Date	Order Quantity

Figure 5.4 Master Schedule Screen, Winch WA01

Forecast Consumption	Resource Profile	Critical Resources							
		Res.	Qty.	Res.	Qty.	Res.	Qty.	Res.	Qty.
ADJUST	WAXX	MCH	5.0	SUB	3.0	ASSM	14.0	PKG	2.0

Selling Price	Special Instructions	Date Run	Action Recommended		
3,100	NONE	XX-XX-XX	R/I	PLAN	REL

7	8	9	10	11	12	Period
						Item Forecast
105	105	110	110	110	110	Option Forecast
						Actual Demand
201	96	211	101	216	106	Proj. Available Balance
						Available-to-Promise
200		225		225		Master Schedule
20 P	21	22	23	24	25	Period
P						Item Forecast
120 P	125	125	125	125	125	Option Forecast
P						Actual Demand
116 P	–9	–134	–259	–384	–509	Proj. Available Balance
P						Available-to-Promise
P	234		250		250	Master Schedule

Actual Demand Detail

Refer. Number	Order Number	T	S	C	Req'd Date	Order Quantity	Refer. Number	Order Number	T	S	C

NOTE: All demand in this make-to-stock example is for finished goods inventory.

Figure 5.4 ***Continued***

manufacturing floor. And if it's on the floor, the assumption is that the material required to make it is likewise on the floor, unless an allocation or shortage shows up on the WA01 components' material requirements planning screens.

In period 3, 200 units are also shown on the MPS line. In the master schedule detail for period 3, an action message to release indicates that it's time to convert the firm planned order into a released order. The reason for this action is that the winch has a lead time of two periods, and period 3 is within one period of that lead time. That means it is time to create a work authorization and send it out to manufacturing.

Further down in the master schedule detail is lot 016, a firm planned order of 225, with a required date of period 9. Here, the system is recommending a reschedule-in of the order by one period, back to period 8. To the master scheduler, this message is a cue to examine the supply/demand situation in the planning horizon for periods 8 and 9. In period 8, the projected available balance is 96 units, 4 short of the company's desired safety stock requirement of 100. Therefore, the firm planned order of 225 in the MPS line of period 9 needs to be moved back into period 8. The same logic applies to the order in period 17, where another reschedule-in recommendation appears in the master schedule detail (the same situation: the projected available balance has fallen below the desired safety stock level of 100 units).

To ignore the computer's recommendation on the basis that "we need only 4, not 225 units" would be a legitimate response to the potential safety stock shortfall in period 8. The experienced master scheduler would understand that the forecasted demand in each period between 1 and 8 is only a prediction or request for product, and that actual demand may easily fall short by 4 or more units over that period, entirely eliminating the need for an early resupply of WA01 winches. Additionally, the experienced master scheduler will check the status of the unconsumed forecast discussed at the beginning of the chapter. And even if the demand does materialize, the company would still have an inventory of 96 units.

Besides the alternatives of slavishly following the computer software's recommendation to reschedule-in 225 units from period 9 to period 8, or simply ignoring the recommendation for action altogether, the master scheduler has at least two other alternatives to choose from:

1. Split the lot of 225 scheduled for period 9 into two orders: one for 4 units in period 8, and another for 221 in period 9.
2. Simply change the order of 200 in period 7 to 204.

Either of these options would eliminate the action message. The first, however, might be somewhat costly in that an extra order involves extra paperwork, reporting, material issuing, and possibly changeover costs. In fact, the changeover cost to build just 4 units may, in itself, be sufficiently high as to disqualify this as a viable solution. The second solution might cause less paperwork, reporting, and changeover but could still disrupt manufacturing.

Both cases contain other issues that need to be addressed before changing the schedule. Chapter 4 discussed six important reschedule change questions that should be answered before any rescheduling is done. It is worth reviewing them here:

1. *Has demand changed?* The screen merely represents a snapshot of the master schedule and does not provide the data necessary to answer this question. However, a working master scheduler in the plant or mill would be able to secure the information necessary. We want to know if we *should* change.

2. *What is the impact of the change on the production plan volumes?* The production plan is created and approved during the sales and operations planning process. The master scheduler has a responsibility to work within the constraints of approved production plan volumes. If a change is made, will the master schedule still summarize up to the approved rates? Here we want to know if we are *authorized* to make the change.

3. *Can the capacity be obtained?* In both cases we need to know if there is enough capacity in period 7 or period 8 (depending upon choice) to do the work. If the capacity is not available or cannot be

available, then it will do no good to reschedule. We want to know if we are *able* to change.

4. *Can we obtain the material?* In both cases we must know if the required material can be produced or procured in time. To determine what material, we would refer back to the time-phased BOM (Figure 5.3 on p. 141). Drawing a line on the WA01 winch BOM, at period 7 through 9, we see the material that is affected: hard steel (R100), wheel (1100), housing casting (1200C), cable (1300), hook (1400), drum casting (D100C), gear box (G102), motor (M100), and control box (1600). It may not be easy to cut one or two periods of lead time from these items. Again we want to know if we are *able* to change.

5. *What is the cost of changing?* Changing schedules generally costs money, in fact, the closer the change comes to the completion date, the greater the cost in overtime, subcontracting, extra shifts, premium payments to suppliers, air freight, expediting, and so on. We want to know the *cost* of changing.

6. *What is the impact on the marketplace? How painful will it be for the company if the master schedule is not changed?* Since the origin of this action message is a 4% drop below the safety stock level, it is hard to imagine much pain in the marketplace. However, if this MPS item is under a contractual agreement to maintain an inventory balance of 100 units or else penalties would apply, the decision takes on a different perspective.

Only after the master scheduler has the data to answer these reschedule change questions can an informed decision be made. No one ever said master scheduling was easy. This is why Class A companies have very creative, organized, and knowledgeable people doing the job.

Finally, period 21 details a system recommendation to convert a computer planned order to a firm planned order (PLAN). Here's why: The system shows a projected available balance of –9 in period 21. The lot sizing rule tells the master scheduling system that any time a computer planned order is placed, it must cover the next two periods of demand. So, in period 21, nine units are needed, and in period 22 the demand is 125, leaving a projected deficit of 134 (9 + 125). A total of 134 units will thus cover demand in periods 21 and 22, but the safety stock rules specify that 100 units should always be in stock, so the MPS system recommends releasing an order for 100 additional units, for a total of 234. Since in this example we chose a dynamic lot sizing rule (period order quantity), the computer software will recommend that orders be placed outside the planning time fence equal to the requirements for two periods plus safety stock.

Bridging Data and Judgment

This computer-driven reporting system projects what the plant, mill, or factory will look like in the future. It provides supply and demand information, summaries of company policies about lot sizes and safety stocks, and asks the master scheduler to intervene in situations where imbalances and policy violations occur. This is the mechanical or scientific part of master scheduling; the remainder is art—or, more accurately, judgment formed with experience. Armed with the information and recommendations provided by the system, the master scheduler uses judgment in making decisions on a multitude of quantitative *and* qualitative factors.

Seeing the Big Picture

The computer software's posting of demand data over long periods allows the master scheduler to see patterns in the ebb and flow of demand. In the case of the WA01 winch, for example, demand grows steadily in stepwise fashion (100, 105, 110, 115, etc.) every four periods. As a percentage of total demand, however, each step is smaller than the one before. From the MPS line of the screen, we observe that the master scheduler has not responded to the steady antici-

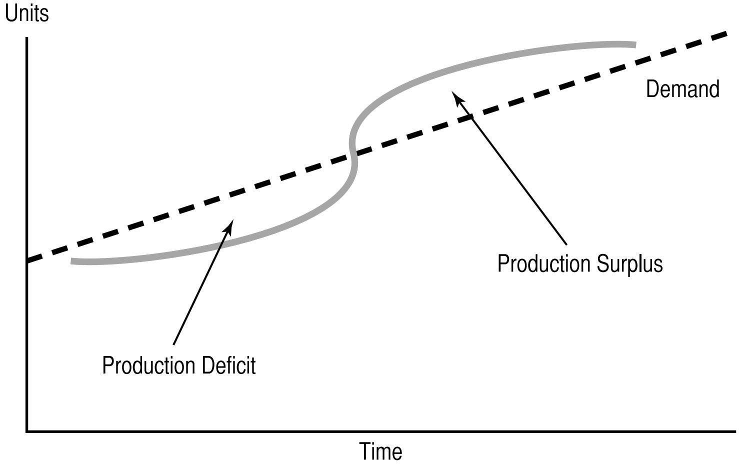


Figure 5.5 Supply Deficit Turns to Supply Surplus

pated growth in demand with an equal increase in supply—at least not at first. Instead—perhaps to better manage growth in output, perhaps owing to production constraints not revealed here—the master scheduler builds supply gradually, but deliberately. Over the periods shown in the screen, demand exceeds supply in periods 5 through 8 and in periods 13 through 16, but supply exceeds demand in periods 9 through 12 and periods 17 through 20. If we were to represent this situation conceptually, ignoring the step-wise changes, it would appear something like Figure 5.5. Here, a small supply deficit develops in the early periods, but that deficit turns into a surplus in the intermediate periods, which then turns back into a supply deficit in later periods. So how can this be possible? And why would the master scheduler, whose first responsibility is to balance supply and demand, do this?

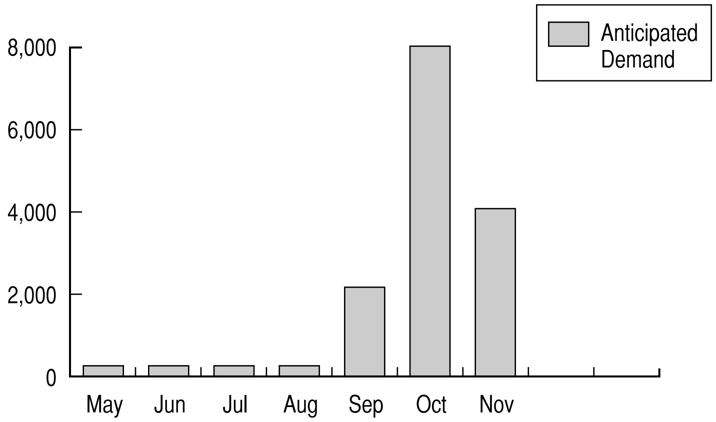
As to *how*, the answer is safety stock. Safety stock is not there to be worshipped or admired, but to provide some utility to the company. Sometimes this utility takes the form of a supply bank from which the master scheduler can do a little judicious borrowing. In the example, the master scheduler has borrowed a little supply in the early periods, but like any savvy borrower, he or she pays back what he or she owes. Thus, in later periods, any reduction in safety stock is redressed with a supply surplus.

Conceptually, this is how farmers finance their seasonal businesses and how manufacturers maintain manageable loads on their plants and mills in the face of seasonal demand cycles. While on this topic, let's look at a seasonal business and address some of the management issues involved.

SEASONALITY AND INVENTORY BUILDUP

Bernard Baruch once said that the way to get rich was to "buy straw hats in January"—the presumption being that you could buy them cheaply and resell them at a premium in July and August. Mr. Baruch was a wizard at the investment game of buying low and selling high, but he probably didn't know much about the cost of holding inventory.

For businesses with strong seasonal demand, planning production to meet anticipated demand while minimizing current inventory and possibly unsold units is a tremendous challenge. Consider the case of Datebook Publishing Company, whose main products are calendars and appointment books. It experiences strong demand during the late fall months and virtually no demand for the rest of the year, as shown below. Any calendars not sold during the period between October and December most likely end up at the paper shredder.



Fortunately, this company has other contract printing and publishing work during other seasons. Still, to meet anticipated demand, it must begin production and start building inventory as early as May.

Forecasted Demand	0	0	0	0	2000	8000	4000
Master Schedule	2000	2000	2000	2000	2000	2000	2000

Management Issues

For companies like Datebook Publishing, seasonality of demand creates a number of management issues to which ingenuity and judgment must be applied.

- *Demand forecasting takes on greater importance.* In most businesses, if you are caught short on product availability, the customer might be induced to delay the order while more products are built. In seasonal businesses, you either have product or miss the sale entirely. Conversely, building too many products generally leads to obsolete inventory, particularly if a shelf-life or model-year issue is involved. This means that everyone in the organization must understand the importance of accurate forecasting and must have an incentive to provide good numbers and continuous monitoring of anticipated demand.

- *Inventory and fixed capacity are major concerns.* Management faces an important trade-off between building large manufacturing capacity or building large inventories. Large amounts of capacity make it possible to meet the seasonal demand spike without reliance on inventory. It is the difference between being a make-to-order and a make-to-stock business. The problem is using that expensive capacity during the rest of the year. By contrast, keeping fixed capacity low forces the company to build and hold expensive inventory. Finding the optimal condition demands the collective attention of managers in all functions.

- *Can the either/or dilemma of capacity versus inventory be altered through design?* For years, managers subscribed to the idea that you either produced in high volume at low cost or in low volume at high cost. The notion that high quality costs more to build was also universally accepted. The experience of the past ten years has shown that both of these "iron laws" of manufacturing were wrong. Quality *can* cost less to produce, and short production runs are *not* absolutely synonymous with high costs.[5] The either/or dilemma of high capacity or high inventory for the seasonal business may be equally antiquated. Managers need to step outside of these constraints and think creatively about alternative ways of producing. They may be able to break out of this dilemma through redesigning products or processes: by creating unique products from a combination of common and unique parts that are configured *after* receiving the customer order; and, by implementing manufacturing processes with the flexibility to respond to seasonal spikes in demand as they occur.

Executives are not the only ones who should be concerned with these issues. Marketers have to think deeply about the validity of their demand forecasts. Errors are expensive when you have just one shot at the customer. Salespeople are naturally concerned about their booked orders being filled in the event that the company builds too few products. Financial managers are justly concerned with the cost of building and carrying inventory, some of which might never be sold. They need to communicate those concerns to others in the organization and to work with the executive team in creating incentives for all concerned to forecast, build, and inventory only what can be sold.

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[5] See James P. Womack, Daniel T. Jones, and Daniel Roos, *The Machine That Changed the World: The Story of Lean Production* (New York: Rawson Associates, 1990), and Joseph Pine, *Mass Customization: The New Frontier in Business Competition* (Boston: Harvard Business School Press, 1992).

The Six Key Questions Revisited

Computer-generated data and the ability of MPS software to create action recommendations give the master scheduler every opportunity to bring judgment to bear in managing the supply and timing of production. Managing change is, in fact, the master scheduler's highest responsibility. Like other managers, the master scheduler must make decisions on the basis of factual information that is often incomplete, ambiguous, or reflective of conflicting goals within the company. The choice of accepting or rejecting a computer software–generated reschedule-in recommendation to cover a potential supply or safety stock problem is typical of the hard decisions the master scheduler must make. To the computer software, the answer is clear: A safety stock violation exists, therefore reschedule-in; to the master scheduler, violation of this simple decision rule merely provokes a number of questions for which there may be no simple answers. A good start is to secure the answers to the six questions previously discussed. Thinking through each of those questions is the first step toward reaching an informed scheduling decision.

Scheduling in a World of Many Schedules

The detailed example of winch WA01 should not lull the prospective master scheduler into the illusion that the real world of manufacturing is this simple. WA01, it should be remembered, is just one of many members of the WAXX winch family, each of which has its own time-phased bill-of-materials, its own ordering policy, its own scheduling requirements, and so on. Like the game of chess, there are many different types of players on the board at the same time. And as in a chess game, we cannot play each item in turn—that is, we cannot deal exclusively with the pawns first, then the bishops, then the knights, and so forth—but we must know how to move them about as part of a single game. This makes master scheduling a *dynamic* as opposed to a *linear* process. Thus, in scheduling the WA01, we must realize that other product family members may share the same manufacturing floor, the same materials stocking area, and possibly the same production line.

Figures 5.6 and 5.8 (see pp. 156–157 and 162–163, respectively) are master schedule screens for WA01's cousins, winches WA04 and WA06, respectively. A quick glance at these screens indicates that they have much in common with WA01: the same family, the same lot size and safety stock policies (but not the same factors), the same lead times and planning time fences. Because WA01 is forecasted to account for two-thirds of all winch sales, all demand and supply figures for WA04 and WA06 are proportionally less.

An experienced master scheduler who knew nothing about these winches—who had in fact just walked in off the street—would nevertheless spot an important relationship among these three different winches. He or she would notice that all MPS quantities for WA01 are due in odd-numbered periods, and MPS quantities for WA04 and WA06 are due in even-numbered periods. To the veteran scheduler, this would suggest that all three winches share an important critical resource: the same production line. This can also be seen by evaluating the critical resources noted on the top of each master schedule under *Critical Resources.* Therefore, a schedule change for any one winch may affect a resource required by the other two. Rough cut capacity planning is one of the useful tools for testing the viability of schedule changes that impinge upon other schedules.

Working the WA04 Reschedule-In Action Message

Referring to period 10 master schedule detail in Figure 5.6, notice a reschedule-in message for lot 306. Reviewing period 9 of the planning horizons data section, we see that the MPS system is recommending that the master scheduler pull in the lot of 75 by one period to stop the

Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source
WA04	WINCH	STK	WAXX	PROUD	JUDMNT

Balance on Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cumul. Lead Time	Standard Cost
	1	2	Policy	Factor	1	2	3			
82	POQ	2	QTY	30	P-20			2	18	2,310

Period	Past Due	1	2	3	4	5	6
Item Forecast							
Option Forecast	4	30	30	30	30	30	30
Actual Demand							
Proj. Available Balance	78	48	68	38	73	43	63
Available-to-Promise							
Master Schedule			50		65		50

Period	13	14	15	16	17	18	19
Item Forecast							
Option Forecast	34	32	32	32	35	35	35
Actual Demand							
Proj. Available Balance	39	82	50	93	58	98	63
Available-to-Promise							
Master Schedule		75		75		75	

Master Schedule Detail

Req'd Date	Order Number	Lot Number	Order			Recomm. Action
			Qty.	Type	Status	
2	WA04	302	50	MFG	RLSD	
4	WA04	303	65	MFG	FIRM	
6	WA04	304	50	MFG	FIRM	
8	WA04	305	50	MFG	FIRM	
10	WA04	306	75	MFG	FIRM	R/I-01
12	WA04	307	75	MFG	FIRM	
14	WA04	308	75	MFG	FIRM	
16	WA04	309	75	MFG	FIRM	
18	WA04	310	75	MFG	FIRM	
20	WA04	311	75	MFG	FIRM	

Req'd Date	Order Quantity

Figure 5.6 Master Schedule Screen, Winch WA04

Forecast Consumption	Resource Profile	Critical Resources							
		Res.	Qty.	Res.	Qty.	Res.	Qty.	Res.	Qty.
ADJUST	WAXX	MCH	6.0	SUB	3.5	ASSM	15.0	PKG	2.0

Selling Price	Special Instructions	Date Run	Action Recommended		
3,300	NONE	XX-XX-XX	R/I		

7	8	9	10	11	12	Period
						Item Forecast
30	30	34	32	32	32	Option Forecast
						Actual Demand
33	53	19	62	30	73	Proj. Available Balance
						Available-to-Promise
	50		75		75	Master Schedule

20	P	21	22	23	24	25	Period
	P						Item Forecast
35	P	35	35	35	35	35	Option Forecast
	P						Actual Demand
103	P	68	33	–2	–37	–72	Proj. Available Balance
	P						Available-to-Promise
75	P			67		70	Master Schedule

Actual Demand Detail

Refer. Number	Order Number	T	S	C	Req'd Date	Order Quantity	Refer. Number	Order Number	T	S	C

All demand for this make-to-stock example is for finished goods inventory.

Figure 5.6 ***Continued***

projected inventory balance from falling below the safety stock level (19 units as opposed to the required 30). That is what the system says to do. However, pulling in the entire lot might overload the production line or critical resources in period 9, the period the WA01 winch is planned to run. So here are the master scheduler's alternatives:

- Ignore the action message. By doing this, the master scheduler will use safety stock inventory to satisfy expected demand.
- Split the lot and pull in only the required 11 units. Of course, there is nothing sacred about the 11 units except that 11 are needed to bring the projected available balance up to the desired safety stock.
- Increase the firm planned order in period 8 to 61 units (the master scheduler is planning to increase the schedule by 25 units in period 10 anyway). Again, the only reason for choosing 61 is that this is the quantity required to satisfy the safety stock policy.
- Some combination of the above. The master scheduler could choose to pull a few items forward, increase the quantity in period 8, and still be projected to drop below safety stock policy.
- Follow the computer software's recommendation.

In order to determine the best course of action, the master scheduler must first decide whether he or she is comfortable cutting into safety stock by approximately 35%. If the answer is yes, then the best action would probably be to take *no action.* However, if this cut into safety stock disturbs the master scheduler's comfort level, a different course of action should be taken.

One of the challenges of master scheduling is to balance supply and demand while maintaining as much stability as possible. Therefore, looking at the example, the master scheduler may not wish to disrupt the production flow of running the WA04 and WA06 across two periods with completion dates in the even periods. Figure 5.7 shows what the production of WA01, WA04, and WA06 might look like. Let us assume all winches require four operations to complete the last level of the build process. These operations are equally spread over two

	PERIODS					
	7	8	9	10	11	12
WA01	3 4	1 2	3 4	1 2	3 4	1 2
WA04	1 2	3 4	1 2	3 4	1 2	3 4
WA06	1 2	3 4	1 2	3 4	1 2	3 4

Figure 5.7 Winch Schedule by Operation

periods of planning lead time. As we look at WA01, we see the first two operations are done in periods 8, 10, and 12, while the last two are planned for completion in periods 7, 9, and 11. Looking at WA04 and WA06 (see Figure 5.8 for WA06 master schedule), we observe that the first two operations are being run in periods 7, 9, and 11, while the last two operations are scheduled in periods 8, 10, and 12.

Assuming Figure 5.7 is an accurate display of the planned production load, one can see why the master scheduler may be hesitant to change the schedule as recommended by the MPS software (reschedule-ins for WA01 in period 9 and WA04 plus WA06 in period 10) because of the capacity issues it might cause. If the WA01 lot scheduled for completion in period 9 is rescheduled to period 8, an overload of the last two operations would occur in period 8 while period 9 most likely would experience a significant drop in production requirements. If WA04 and WA06 are rescheduled (completion dates change from periods 10 to period 9), a major drop in production requirement would occur. If this is the case, a change in the quantity for period 8 seems like the best alternative. However, the six important reschedule change questions must be asked—and answered—before making a change.

Since the recommended schedule adjustment is for periods 9 and 10, several items in the WA04's bill-of-materials are affected (refer to Figure 5.3 on p. 141) and assume the WA04 product required materials are similar to WA01's). So, if any change is to be made, a lot of homework must be done to ensure that the change is not only made in the master scheduling system, but also is successfully made on the plant or mill floor and in purchasing. A good rule for the master scheduler to follow is "Don't change the schedule any faster than engineering, manufacturing, and purchasing can economically respond."

One last point on this example: Period 11 projects an inventory balance of 30 units, exactly the desired safety stock quantity. This is only two periods away from the projected problem. This might be another reason for the master scheduler to use some safety stock if necessary and leave the schedule as currently written.

Working the WA06 Reschedule-In Action Messages

Two back-to-back reschedule-in messages appear in periods 8 and 10 (Figure 5.8 on pp. 162–163). Using the same logic as with WA04, there seems no point in pulling up the 50 units in period 8 to period 7 because of a projected 8% dip into safety stock. Why disrupt the production line for 2 units of safety stock? Besides, we are halfway through the lead time and any change to the master schedule will affect many material items as well as capacity. And then there is the cost associated with every change at the MPS level within the product's lead time. The best choice seems to be to let the schedule stand.

Consider the next message. The suggestion of pulling up the 75 units in period 10 to period 9 requires more analysis. If we let the schedule stand, we anticipate going into planned safety stock by approximately 40%. If this is no problem, then the best choice is again to opt for stability by leaving the schedule alone. However, if depletion of safety stock threatens our ability to satisfy variable future demand, then raising the quantity in period 8 to, say, 64 units would take care of the action message and meet management's objective of holding one period's worth of safety stock (demand is increasing from 25 to 30 through period 9). If the master scheduler plans to make this change, the six reschedule change questions must again be asked. Again, the only magic about 64 is that an increase of 14 is required to bring the company's projected available balance position back in line with safety stock policy.

Given the expected deep cut into safety stock, it would be worth the master scheduler's time to consider the history of the product. A new product might call for greater caution, since demand patterns are unknown. An established product whose demand patterns are stable or more predictable, however, may make it more feasible to use safety stock in lieu of schedule changes.

These simple examples again demonstrate the need for a knowledgeable master scheduler; left to its own devices, the computer software would initiate the reschedule actions, disrupting the production line and possibly frustrating many. Worse still, the computer software cannot be held accountable for its reschedule decisions. Of course, this is not true when it comes to the master scheduler and his or her decisions. The master scheduler is accountable for creating and maintaining a realistic, valid, and achievable master schedule.

Working the WA06 Reschedule-Out Action Messages

For WA06, the system recommends moving lot 412, a firm planned order of 75 units, out one period, from period 18 to 19. It also recommends moving lot 413 from period 20 to 21. The reason for this message in period 18 is the projected ending balance of 101 units in that period. If the 75 units do not arrive as scheduled, we would still have a projected inventory balance of 26 units, 1 more than the current desired safety stock level of 25. Thus, it is not necessary to have the lot for 75 arrive in period 18. The same logic applies to period 20; if the 75 units do not come in as scheduled, we will still end period 20 with a balance higher than the current desired safety stock.

The cumulative lead time for WA06 is 18 periods. This means that any action taken by the master scheduler on the FPO in period 18 will affect purchasing, which will be starting to acquire the long-lead-time items. If the lot is pushed out to period 19, the potential overstocking problem will be solved. Of course, another problem may be created by doing this: Period 19 may become capacity constrained.

Another possibility is not to run as many as planned—perhaps 65 units instead of 75 (the right lot size is, in fact, 67 or 68) starting in period 10. Therefore, knowing the product, the best approach might

Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source
WA06	WINCH	STK	WAXX	PROUD	JUDMNT

Balance on Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cumul. Lead Time	Standard Cost
	1	2	Policy	Factor	1	2	3			
74	POQ	2	QTY	25	P-20			2	18	2,450

Period	Past Due	1	2	3	4	5	6
Item Forecast							
Option Forecast	3	25	25	25	25	29	27
Actual Demand							
Proj. Available Balance	71	46	71	46	56	27	50
Available-to-Promise							
Master Schedule			50		35		50

Period	13	14	15	16	17	18	19
Item Forecast							
Option Forecast	34	32	32	32	35	35	35
Actual Demand							
Proj. Available Balance	42	85	53	96	61	101	66
Available-to-Promise							
Master Schedule		75		75		75	

Master Schedule Detail

Req'd Date	Order Number	Lot Number	Order			Recomm. Action
			Qty.	Type	Status	
2	WA06	404	50	MFG	RLSD	
4	WA06	405	35	MFG	FIRM	
6	WA06	406	50	MFG	FIRM	
8	WA06	407	50	MFG	FIRM	R/I-01
10	WA06	408	75	MFG	FIRM	R/I-01
12	WA06	409	75	MFG	FIRM	
14	WA06	410	75	MFG	FIRM	
16	WA06	411	75	MFG	FIRM	
18	WA06	412	75	MFG	FIRM	R/O-01
20	WA06	413	75	MFG	FIRM	R/O-01

Req'd Date	Order Quantity

Figure 5.8 Master Schedule Screen, Winch WA06

Forecast Consumption	Resource Profile	Critical Resources							
		Res.	Qty.	Res.	Qty.	Res.	Qty.	Res.	Qty.
ADJUST	WAXX	MCH	6.5	SUB	4.0	ASSM	16.5	PKG	2.0

Selling Price	Special Instructions	Date Run	Action Recommended		
3,500	NONE	XX-XX-XX	R/I	R/O	

7	8	9	10	11	12	Period
						Item Forecast
27	27	30	30	30	30	Option Forecast
						Actual Demand
23	46	16	61	31	76	Proj. Available Balance
						Available-to-Promise
	50		75		75	Master Schedule
20 P	21	22	23	24	25	Period
P						Item Forecast
35 P	39	37	37	37	40	Option Forecast
P						Actual Demand
106 P	67	30	–7	–44	–84	Proj. Available Balance
P						Available-to-Promise
75 P			69		80	Master Schedule

Actual Demand Detail

Refer. Number	Order Number	T	S	C	Req'd Date	Order Quantity	Refer. Number	Order Number	T	S	C

All demand for this make-to-stock example is for finished goods inventory.

Figure 5.8 ***Continued***

be to reduce the FPOs in periods 10, 12, 14, 16, 18, and 20 to some lower amount. This action would stop the projected inventory buildup, thereby eliminating the two action messages.

From Master Scheduling to Material Requirements Planning

Now that it is understood how the MPS system recommends actions for individual items, and how the master scheduler must analyze these recommendations, the next step is to test changes to the master schedule using rough cut capacity planning. This technique is described in Chapter 14. Only when the rough cut capacity planning step has been completed and the master scheduler is satisfied that changes to the schedule are reasonable are those changes passed down to the material requirements planning (MRP) system, where materials are ordered and capacity and components are earmarked for availability.

Figure 5.9 on pages 166–167 shows the MRP computer-generated screen for the A100 carriage assembly, a common item in the WAXX winch family. Like the MPS screen, it has three main sections. The top section contains information about the item itself. The middle section contains planning horizons data. The bottom section contains details: *Scheduled Receipts Detail* on the left; *Requirements Detail* on the right. While many features of the MRP screen are shared with the MPS screen already explained, others are unique and in need of explanation here.

Item Information Section

ITEM TYPE: Here SUB is "subassembly."

COMMODITY CODE: A code indicating the basic characteristics of a purchase order.

VALUE CLASS: Refers to a hierarchy of dollar cost among parts in which "A" is high cost and "C" is low cost. This hierarchy can connote either high unit cost or high total cost (as in the case of a low-priced but high-usage item).

SCRAP FACTOR: A bit of information that allows the scheduler to figure gross production needed to yield an after-scrappage net production equal to product demand (sometimes referred to as shrinkage).

ANNUAL GROSS REQUIREMENTS: Strictly memo information.

TOTAL RELEASED REQUIREMENTS: Summary information computed by aggregating data from the requirements detail section.

CUMULATIVE LEAD TIME: Cumulative lead time is calculated as in the master schedule system. In the case of the carriage assembly, this is 16 periods—the time needed to build A100 from scratch. This lead time number is determined from the time-phased BOM. Here cumulative lead time is two periods less than the finished winch, which makes sense in that the final assembly of the winch from A100 and the other required items requires two periods.

TOTAL SCHEDULED RECEIPTS: Summary information computed by aggregating data from the scheduled receipts detail section.

Planning Horizons Section

This section contains five lines of data for each period. The first two lines reflect requirements; the third, scheduled receipts; the fourth, the projected available balance; and the fifth, the planned order releases. Each is worth examining in some detail.

SERVICE REQUIREMENTS: If an item is sold as an independent item, and orders are taken directly against the item, then these orders show up here. If marketing and sales forecasted that some of the carriage assemblies would be needed as spares, that forecast would also appear here.

Item Number	Item Status	U/M	Primary Description	Item Type	Comm. Code	MRP Planner	Value Class
A100	STK	EA	CARRIAGE ASSM	SUB		SMITH	A

Balance on Hand	Safety Stock		Scrap Factor	Annual Gross Requirement	Total Released Requirments
	Policy	Factor			
0	NO	NONE	NONE	10,400	0

Period	Past Due	1	2	3	4	5	6
Service Requirements							
Production Requirements		200	100	200	100	200	100
Scheduled Receipts		300					
Proj. Available Balance	0	100	0	–200	–300	–500	–600
Planned Order Release		300		300		375	

Period	13	14	15	16	17	18	19
Service Requirements							
Production Requirements	225	150	250	150	250	150	234
Scheduled Receipts							
Proj. Available Balance	–1,950	–2,100	–2,350	–2,500	–2,750	–2,900	–3,134
Planned Order Release	400		400		234		386

Scheduled Receipts Detail

Req'd Date	Promised Date	Order Number	Lot No.	Rem. Qty.	Received	Type	Status	Recomm. Action
1		A100	26	300		MFG	RLSD	
3		A100	27	300				ORDER

Req'd Date	Req'd Quantity
1	200
2	65
2	35
3	200
4	50
4	50
5	200
6	50
6	50
7	225
8	75
8	75
9	225
10	75
10	75
11	225

Figure 5.9 Material Requirements Planning Screen, Carriage Assembly (A100)

Lead Time	Cumul. Lead Time	Order		Minimum Order Qty.	Maximum Order Qty.	Multiple Order Qty.
		Policy	Qty./Time			
2	16	POQ	2	100		

Total Sceduled Receipts	Special Instructions	Date Run	Action Recommended
300	NONE	XX-XX-XX	ORDER

7	8	9	10	11	12	Period
						Service Requirements
225	150	225	150	225	150	Production Requirements
						Scheduled Receipts
–825	–975	–1,200	–1,350	–1,575	–1,725	Proj. Available Balance
375		375		375		Planned Order Release

20	21	22	23	24	25	Period
						Service Requirements
0	386	0	400	0	0	Production Requirements
						Scheduled Receipts
–3,134	–3,520	–3,520	–3,920	–3,920	–3,920	Proj. Available Balance
	400					Planned Order Release

Requirements Detail

Refer. Number	Order Number	Lot	T	S
WA01	A100	013	M	F
WA04	A100	303	M	F
WA06	A100	405	M	F
WA01	A100	014	M	F
WA04	A100	304	M	F
WA06	A100	406	M	F
WA01	A100	015	M	F
WA04	A100	305	M	F
WA06	A100	407	M	F
WA01	A100	016	M	F
WA04	A100	306	M	F
WA06	A100	408	M	F
WA01	A100	017	M	F
WA04	A100	307	M	F
WA06	A100	409	M	F
WA01	A100	018	M	F

Req'd Date	Order Quantity	Refer. Number	Order Number	Lot	T	S
12	75	WA04	A100	308	M	F
12	75	WA06	A100	410	M	F
13	225	WA01	A100	019	M	F
14	75	WA04	A100	309	M	F
14	75	WA06	A100	411	M	F
15	250	WA01	A100	020	M	F
16	75	WA04	A100	310	M	F
16	75	WA06	A100	412	M	F
17	250	WA01	A100	021	M	F
18	75	WA04	A100	311	M	F
18	75	WA06	A100	413	M	F
19	234	WA01	A100		P	P
21	250	WA01	A100		P	P
21	67	WA04	A100		P	P
21	69	WA06	A100		P	P

Figure 5.9 ***Continued***

PRODUCTION REQUIREMENTS: Indicates dependent demand for the item caused by the master schedule or a higher-level MRP item. All dependent requirements for the carriage assembly are summarized and appear on this line.

SCHEDULED RECEIPTS: Identifies actions taken by the planner or scheduler for the carriage assembly. When the planner or scheduler creates a job order, work order, manufacturing order, production order, purchase order, or run rate, the order quantity appears on this line.

PROJECTED AVAILABLE BALANCE (PAB): Displays the projected inventory balance for each period in the item's MRP horizon. The PAB line is used to critique the balance between supply and demand.

PLANNED ORDER RELEASE: All computer planned orders are shown on this line. When MRP recognizes an imbalance between supply and demand, and the supply is projected to be short, the computer places its own orders in the form of CPOs to restore the balance. These orders are placed by the MRP system logic in the time period in which they are scheduled to be released or started. Some MPS systems put CPOs in the period in which they are due, and some may reflect both.

Detail Data Section

The detail data section of the MRP screen, like that of the MPS screen, is divided into two major parts, here called *Scheduled Receipts Detail* and *Requirements Detail.*

SCHEDULED RECEIPTS DETAIL: In the lower left corner of Figure 5.9 (see p. 166), the first line indicates that in period 1 300 units remain to be received (remaining quantity) for lot 26. Lot 26 is a manufactured item (MFG) that has already been released (RLSD). The next line indicates that a computerplanned order (lot 27) for 300 has been created by the computer; an action message, prompted by the two-period lead time, recommends that the planner/scheduler convert this CPO into a scheduled receipt.

Looking briefly at the requirements detail, we see that the first date with a requirement is period 1, which has a demand of 200 carriage assemblies, which we know originates from the WA01 winch. Two quantities totaling 100 units are required for period 2 (the 65 necessary to start building WA04s and 35 to start building WA06s). Back in the first line of the scheduled receipts detail is an entry for 300 units, which is scheduled for receipt in period 1. Since there is no on-hand balance for carriage assemblies, the scheduled receipt of 300 is expected to be used to satisfy the demand in period 1 of 200 units, leaving a projected available balance of 100 units. This quantity is expected to be used in period 2 to satisfy the demand for 100 carriage assemblies needed to support the build plan for the WA04 and WA06 winches. In period 3 there is a PAB of –200. Recognizing a two-period lead time, MRP logic recommends in period 1 the releasing of an order for 300 units to be due in period 3. This amount is 100 over the requirement for that period, but since the order policy is to order enough to cover two periods of demand, the 300 are just enough to satisfy the 200 required in period 3 and the 100 required in period 4.

Requirements Detail: As the requirements detail shows (p. 167), a quantity of 200 is needed in period 1 to satisfy a demand from the WA01 winch. A quick look back at the MPS schedule for WA01 (Figure 5.4 on pp. 144–145) shows an FPO for 200 in period 3, lot 013 (remember, the lead time to build the WA01 when all items one level down are available is two periods). This FPO is both the trigger for this 200-unit requirement at the carriage assembly MRP level and the ultimate destination of the completed A100 items. This linking of item requirements to the source of demand is an example of *pegging* and is an essential part of any MRP system.

The next two lines in the requirements details indicate quantities of 65 (from WA04), and 35 (from WA06). The MPS screens for those two different winches indicate that those quantities are needed at the completed winch level in period 4, which means that they are required to be started in period 2—two periods earlier. This is when the carriage assemblies are needed.

As this chapter's discussion should make clear, it is important that the master scheduler and material planner understand the relationship between what appears on the master schedule screen and the underlying material requirements planning system. Less obvious, but just as important, are the productive working relationships among master schedulers, planners, and production schedulers. However, there is another level of understanding that the master scheduler must possess. We have discussed in some detail how the master schedule itself drives requirements down to lower levels. But where does the master schedule get its data? We have mentioned the likes of a production plan, which is a volume plan by product family. To be effective, a master scheduler must understand the ins and outs of the sales and operations planning process (discussed in Chapter 13), which is the source of the production plan.

However, there is another issue to address: that of *what* to master schedule. This chapter has reviewed the process of master scheduling in a make-to-stock environment, where finished goods are often the items master scheduled. But what about the make-to-order, assemble-to-order, design-to-order, engineer-to-order, and make-to-contract products? What items do we master schedule in these environments? This question is the subject of our next chapter.

6

What to Master Schedule

When you think you have all the answers,
it may be time to reask the question.

Like any tool, master scheduling software is useful only if it is applied in the right way. Here, the right way begins with knowing *what* to master schedule. In the case of a simple product, like the flashlight in Chapter 3, it may be the final assembly of the flashlight that needs master scheduling. In a more complex product, like an automobile, master scheduling may be done at a number of intermediate steps—engines, transmissions, radios, and so on.

Knowing what to master schedule presupposes a clear understanding of the process by which the product is transformed from either raw materials or purchased components into a shippable configuration. Generally, that process begins with the ordering of the raw materials to be available when the product is to be built. In traditional manufacturing, these materials are inspected by the receiving department as they arrive to ensure their conformance to order specification and quality standards. Items that pass muster are then stored and issued to the manufacturing floor as needed. At the point of issue, the conversion of raw materials through the processes of mixing, forming, machining, assembling, and so forth, to final product begins to take place. The item may move into a subassembly or filling area and then into a final assembly, finishing, or packaging area. The last step typically involves crating and shipping the finished product either to a warehouse or directly to the customer.[1]

Manufacturing Strategies

The master scheduler's company adheres to one or more manufacturing strategies deemed most appropriate for its business. Each of these strategies is defined in terms of *the point in the manufacturing process at which the customer enters the picture.*

Make-to-Stock

Company A makes a very simple family of products—plastic wall plates to cover electrical outlet boxes. With just a few exceptions, its products are manufactured by continuous processes of plastic molding, with no assembly except packaging. This company has determined that it must follow a make-to-stock strategy—that is, a strategy in which raw materials are ordered and the final product made in advance of any orders by the final consumer. From the customer's perspective, these are off-the-shelf products. Fasteners, note pads, photographic film, and countless other commodity-like items are typically made on this basis.

Companies follow this strategy when the market dictates that their products be finished and available for immediate purchase and use.

Engineer-to-Order

Company B designs and builds process equipment for the chemicals industry. Its products are large, complex, and very expensive; most are built on a base of standardized liquid and dry materials, mixing and moving equipment, with computerized monitoring systems. Because each piece of its equipment is expensive and specially tailored to the

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[1] *Finished* is a relative term. In some cases the finished product of manufacturer X is a component in the finished product of manufacturer Y.

requirements of the individual customer, work can begin only when a customer order is received and detailed specifications are developed.

Company B follows an engineer-to-order or design-to-order strategy, which is at the opposite end of the spectrum from the make-to-stock company. While make-to-stock products tend to be generic and easily substituted within a product class, engineer-to-order or design-to-order products are, by definition, either unique (as in custom-made) or very complex and produced only in small quantities. Aircraft, special-purpose machine tools and other process equipment, as well as space shuttles are all engineer-to-order or design-to-order products. In engineer-to-order companies, no product is engineered and/or manufactured until the company has at least a letter of intent, a contract, or a customer order. At that point the design process can begin, after which material is ordered and the product is produced and delivered to the customer.

Make-to-Order

Between the extremes just cited is the make-to-order company, in which *some* material may be ordered and *some* items of the product may be produced before receipt of a customer order. With a pure make-to-order strategy, product is designed, but the company does not start manufacturing until a customer order is received. Highly customized products are generally made in this fashion.

Three variations on the make-to-order theme are finish-to-order, assemble-to-order, and true make-to-order. In the case of the first, the company may build product through all but the finishing stage and may proceed only when a customer order has been received. The basic product, a conference room table, for example, may be completed, but the customer's logo etched in the middle of the table is not done until the order is received. Furniture makers often use a finish-to-order strategy, building product up to the point of applying the customer's choice of finishing stain or fabrics as the last step. Assemble-to-order is an analogous manufacturing strategy. Automobiles, with their many options, are good examples of assemble-to-order products.

Company C follows an assemble-to-order strategy. It is a leading producer of elevators for commercial buildings. It offers an array of elevator products, featuring dozens of capacities and hundreds of possible car interior decors. Because its customers—architects and building contractors—have long planning schedules, Company C does not need any off-the-shelf items (except for replacement parts), but the economics of its business encourages it to produce most of the components from which its product variety can be fabricated within three weeks.

Make-to-Contract

Whereas all of the above strategies generally apply to commercial businesses, another variant of the make-to-order strategy applies to government contractors. Like make-to-order, make-to-contract companies wait until a contract is issued before ordering material (many government contracts specify when the company can procure materials). The make-to-contract strategy can thus be thought of as a make-to-order or engineer-to-order approach in which the contract takes the place of the customer order.

Choosing the Right Strategy

The right strategy for a particular company depends on where it intends to meet the customer, which is largely dictated by the demands of the marketplace and the company's competitive position within its own marketplace. The strategy chosen determines where, in the product structure, master scheduling will take place. In addition, where a company chooses to meet the customer influences the actual structuring of the bills-of-material.

The choice of where to meet the customer really depends on a company's competitive position, which is determined by a balance of delivery, service, price, quality, and technology. If a company's service, price, technology, and quality are competitive, its delivery performance may be the deciding factor. The tremendous impact of master scheduling on meeting schedules and customer delivery dates is therefore an important competitive weapon.

Before examining the master scheduling component, though, we need to re-examine the options for meeting the customer, which are represented in Figure 6.1. The stair step diagram indicates the many points in the manufacturing process at which the actual order may be received—that is, where the company meets the customer. Each step up the stairway represents a higher degree of product completion or "cost/value added." In selecting "ship finished goods," a company has, by definition, chosen a make-to-stock strategy. The company that meets its customer at the engineering level has chosen a design- or engineer-to-order strategy. At the purchasing, fabricating, mixing, or intermediate assembly step, it has chosen one of the make-to-order approaches. Some examples of make-to-order are buy-to-stock and make-to-order, assemble-to-order, and finish-to-order.

Inventory and Capacity Requirements

In selecting a strategy, other factors, such as a willingness to invest in inventory and the capacity required to complete the product from the stocking point within the necessary lead time, should be consid-

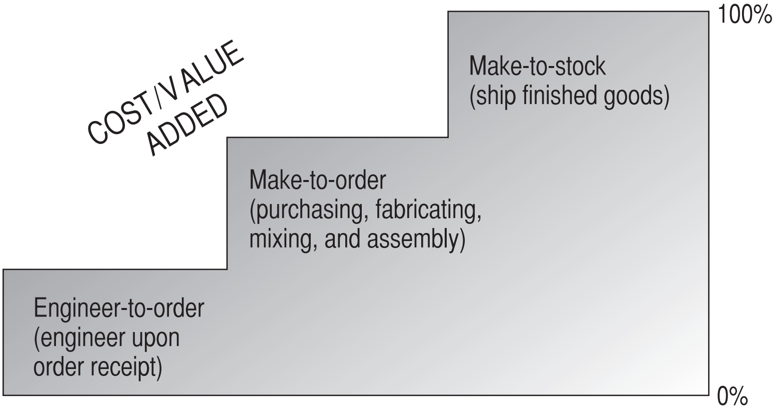

Figure 6.1 Strategies to Meet the Customer

ered. Any company that chooses to meet the customer at the finished-goods (make-to-stock) level, must be willing to make an investment in finished inventory. This company must be prepared to ship finished goods as customer orders appear (minimal lead time available). In contrast, the engineer-to-order company has minimal or zero inventory requirements, since no product building takes place in the absence of an order. But it must have the engineering, manufacturing, and/or finishing capacity necessary to complete the order within a quoted or promised lead time and generally by a specified date.

In the make-to-order strategy, particularly finish- and assemble-to-order situations, companies must be willing to invest in inventory up to the point where they plan to meet the customer (stocking level), such as intermediates or subassemblies, and must secure the capacity necessary to complete and ship the defined products as required.

It is important to understand that wherever a company chooses to meet the customer, its objective must be to provide timely delivery, first-class service, competitive pricing, high quality, and leading-edge technology. The next section demonstrates how master scheduling can greatly enhance at least two of those critical components of success: timely delivery and competitive pricing.

Manufacturing Strategy and Product Life Cycles

Like living organisms, products experience life cycles of growth, maturity, and decline. Business scholars have described this process (as shown in Figure 6.2 on page 177). Here, the introductory stage (measured in sales revenues or units) is fairly flat until such time as the product catches on. At this point it enters a period of rapid growth, followed by a maturity period of large but flat sales, followed by a period of decline.

Obviously, not every product experiences each of these cycles. Many new products never get beyond the introductory stage, and a fortunate few products forestall decline for extended periods through the introduction of product enhancements ("new and improved") and long-term growth of their markets.

A company may treat the same product with different manufacturing strategies at various stages of its life cycle. Thus, in the introduc-

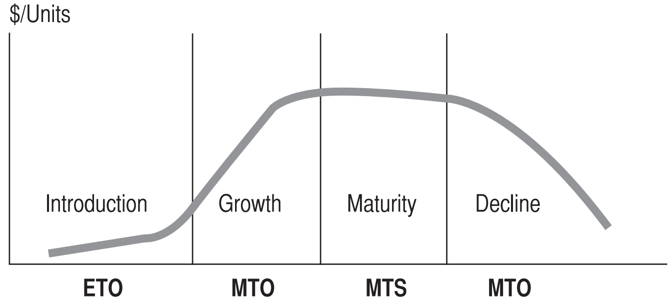

Figure 6.2 Product Life Cycles

tory stage, when demand is largely unknown, an engineer-to-order or design-to-order strategy may be most appropriate (more on this aspect of engineer-to-order follows in Chapter 11). As the product enters its rapid growth period, a make- or assemble- or finish-to-order strategy may be ideal. Once the period of rapid growth gives way to a long stretch of flat, but predictable demand from established customers, make-to-stock may be most suitable. As the product goes into decline and customer orders become less reliable, going back to finish- or assemble- or make-to-order may be sensible.

Master Scheduling and Product Structures

In making the determination of *what* (or where) to master schedule, it is necessary to consider the different possible types of product structures (see Figure 6.3). In each of the product structures, the top portion represents finished goods, and the bottom represents raw materials.

PYRAMID STRUCTURE. Part A of Figure 6.3 represents a business that makes a limited number of standard items from many semifinished items, components, or raw materials. Small appliances, staplers, ballpoint pens, watches, lamps, and telephones fit this type of product structure.

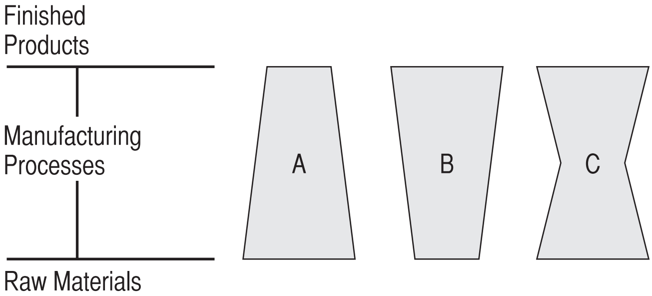

Figure 6.3 Product Structure

INVERTED PYRAMID STRUCTURE. Many items are made from a limited number of raw materials. Steel, for example, is used to make everything from shopping carts to scaffolding. Nylon thread is the main ingredient in thousands of fabric products. Part B of Figure 6.3 shows this product structure.

HOURGLASS STRUCTURE. Many items are made from common, semifinished items or part or material sets. The automobile is a classic example (see part C of Figure 6.3). At the top level is the car; at the pinch point is the semifinished product (the engine, the chassis); at the bottom level are the thousands of components or materials used to make the semifinished parts.

The Optimal Point to Master Schedule

In each of the preceding product profiles, the idea would be to master schedule at the *narrowest* part of the diagram; doing so provides the greatest flexibility and control. The reason for this is that at this narrow point there are the fewest number of items to forecast, and desired customer requirements can be configured from this point using the fewest number of master scheduled items (a point expanded upon during the discussion of make-to-order environments in Chapters 8 and 9). With fewer items to deal with, the narrowest point is also the *easiest* place to master schedule. Besides, master scheduling at the top level will require an investment in inventory at all subsequent levels. Of course, the marketplace, customer, and competition still have a lot to say about what a company master schedules.

If a product has the pyramid structure, the top of the pyramid—where the product is finished into a limited number of end items—is probably the place a company would like to master schedule. If, for instance, a company was in the business of selling electric coffeepots off the shelf, it might decide to master schedule the various standard colored pots.

The inverted pyramid presents the opposite situation, and the master scheduler may want to focus at the bottom, the pinch point. Of course, master scheduling at this level would mean that material requirements planning would be of little assistance in the planning process. This fact is probably obvious since the master schedule would be for the lowest level in the structure, leaving little for material requirements planning to do. To get more help from material requirements planning, the master scheduler may decide to move up into the structure and master schedule at some higher level, even though control may be more difficult. In moving to a higher level, common product groupings that use like resources and common base stocks should be considered. By doing so, the master scheduler can plan the common materials, schedule focused resources, and get some help from the material requirements planning logic.

The pinch point in the hourglass structure provides a useful master scheduling point. Consider how difficult it would be to master schedule automobiles at the top level: Millions of option permutations are possible at the top (e.g., two doors, V6, air conditioning, and special interior features, to name just a few). Two issues immediately surface when discussing this environment. The first relates to the possible number of bills-of-material for a company that offers several configurations; it would be nearly impossible to structure and maintain all the possible bills-of-material. Without a bills-of-material database, material requirements planning is also impossible to implement. The second issue is that of securing a reasonable forecast (statement of demand) for each and every possible detailed configuration.

These are general guidelines, and the optimal place to master schedule within a product structure ultimately depends upon the needs of the company and where it intends to meet the customer.

Depending on specific needs, each of the following is a candidate for the status of a master scheduled item:

- End items or finished products
- Intermediates or subassemblies
- Options or features
- Add-ons or attachments
- Purchased raw materials or components
- Service or spare parts
- Capacity or resources
- Activities or events

The point is this: One can master schedule *anything that makes sense to the business.* All of the factors and issues discussed above must be taken into consideration when a company is identifying what it plans to master schedule. And we're not done. To say that a company's decision about where to master schedule is a key to master scheduling success is certainly an understatement. To make this an even more complex decision, a company can elect to master schedule at multiple levels in its product structure.

Multilevel Master Scheduling

We have seen above that there are times when it may make sense to master schedule at levels other than the final product. An item that is expensive, difficult to obtain, or difficult to manufacture may need the kind of attention that a master scheduled item deserves and gets. Thus, since there are no hard-and-fast rules for deciding *what* to master schedule, the management team and the master scheduler may elect to master schedule not only end items, but other items one, two, or three levels deep in the product structure. This approach is known

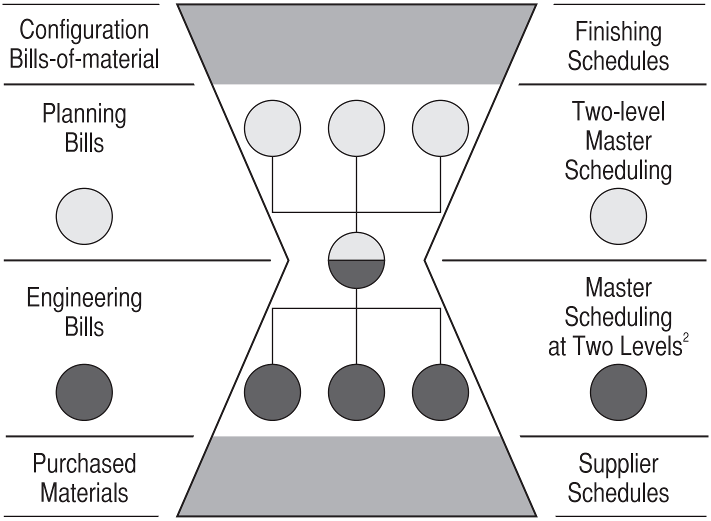

Figure 6.4 Master Scheduling Terminology

as *master scheduling at multiple levels,* or sometimes as *master scheduling at two levels;* it is shown in Figure 6.4.[2]

There are also times when two-level master scheduling, which is technically different from multilevel master scheduling, is necessary. For example, the first level in two-level master scheduling logic might be at the product family level (shown in Figure 6.4), as stipulated in the sales and operations planning process. At some point, the discrete demand and due dates for lower-level members that make up that product family need to be determined; one could drive the product family demand through a planning bill in order to forecast demand for the product family members. When a company uses a planning bill to predict demand at a lower level, it is using a two-level master scheduling approach.

We will get into two-level master scheduling and planning bills later, but for now think about the issue raised in the following situation.

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[2] Master scheduling at two levels (or multiple levels) uses engineering bills or bills-of-material for planning.

TYING THE MASTER SCHEDULE AND THE PRODUCTION PLAN TOGETHER

No business can operate for long without coordination between its functional parts. All must coordinate their efforts if a company is to survive and prosper. For the manufacturing company, sales and operations planning serves as an important coordinating function, bringing together customer demand, product design, financial capabilities, operational capacity, and the goals of management in a quantitative form, describing—in aggregate—what needs to be built and sold in future periods.

Consider the case of Deskmasters Corporation, a manufacturer of office furniture. As its managers emerge from their monthly sales and operations planning meeting, the manufacturing vice president hands the master scheduler a copy of the new approved production plan, which, for simplicity's sake, we will describe as covering only the month of April. April's plan authorizes the production (volume) of 1,200 desks.

The master scheduler takes this *aggregate* sales and operations plan and uses it to create a more specific build plan—breaking it into different types of desks (mix) to be produced in varying quantities in each week of the month. In this simple example, the desk product family has just two members: oak and pine.

	April Production Plan = 1,200 desks				
	Week 1	Week 2	Week 3	Week 4	Total
MPS oak	200	200	200	200	800
MPS pine	100	100	100	100	400
Total	300	300	300	300	1200

You will notice that the various master scheduling quantities *total* 1,200 desks, pointing out an important principle: *The sum of the mas-*

ter schedule must equal the production plan plus or minus any approved tolerance set by the executive team. This principle is discussed in greater detail in Chapter 13, which covers sales and operations planning.

Management Issues

For management, the supply (operations) or production plan serves as an important control mechanism over manufacturing resources, indicating the authorized level of overall production. For those who do the work, and who may have more intimate knowledge of current inventories, work in process, plant capacities, and material availabilities at any given moment, the master schedule provides specificity and direction, namely, how many of *which* products need to be built and *when.* The requirement that master scheduled quantities equal those of the production plan provides an important check against unauthorized and ill-directed activities on the plant or mill floor. Without this check, the master scheduler would, in effect, be in sole control of the plant or mill and its various costs. When product families contain dozens of different members, the damage done by uncontrolled master scheduling can very quickly get out of hand.

For practical purposes, there may be times when it makes sense to *exceed* supply or production plan limits in a particular period. Perhaps production wants to build up inventory in advance of a previously unscheduled maintenance shutdown or pending strike? Perhaps the master scheduler wants to overplan unique options and features in some product family because of product mix uncertainty? Management needs to have a clear policy concerning these situations and the link between the master schedule and the supply or production plan.

Master Scheduling Capacities, Activities, and Events

Thus far, our discussion has concentrated on master scheduling only one of the productive resources of the company—materials. Equally important to the production process is another resource—capacity.[3] Master scheduling techniques can be applied to capacity as well as to parts or items. Understanding this point is especially important for those companies whose business is that of selling capacity. For example, job or machine shops that make buildings, irrigation, and other large-scale products fall into this category. For such businesses, it is critical to know what machinery will be required so that customer orders can be booked against the uncommitted—or unconsumed—capacity of that machine. Another example is a production line that is constrained by one or more pieces of equipment, such as a mixer. When the next customer places an order, the plant needs to know how much capacity is left or uncommitted on those pieces of equipment so that product completion can be properly quoted and delivered on the promised date. In these cases a company may choose to master schedule capacity.

Other situations may require a company to master schedule not items or capacity, but activities and events. A testing lab, for example, sells a service that can be broken down into a series of activities. The product that the testing lab sells is capacity, and that capacity is spread among several events that must occur. Chapter 11 will detail how activities and events can be harnessed within a structure analogous to that of a bill-of-material and show how points within this structure can be scheduled and capacity can be planned.

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[3] Here we should not think so narrowly as to construe capacity as applying solely to labor, machine time, and production space on the manufacturing floor. As master scheduling becomes more broadly applied within companies, capacity can also be construed (and scheduled) in the context of services.

This chapter has explained the importance of knowing *what* to master schedule. It has shown that this "what (or where)" is not preordained as the last step in the cost/value-adding process, but may focus elsewhere, depending upon the manufacturing strategy selected by the company.

Manufacturing strategies are largely geared to where a company intends to meet its customers, and this is determined by customer needs, competition, market requirements, lead times, willingness to invest in inventory, and the company's position on employing resources and capacity. Besides these elements, where the company's product is on its life cycle and what the product structures look like have a good deal of impact when choosing what to master schedule.

The important point to carry forward from this discussion to succeeding chapters is that the master scheduler must be fully versed in the nature of his or her company's products, how they are built, and the competitive constraints under which the company operates. A simpleminded default to end-item master scheduling may work in some competitive environments, but in most will be inappropriate, resulting in loss of control of the schedule and its underlying levels of materials and capacity management. In addition, succeeding chapters will help the reader determine what (or where) to master schedule in any given manufacturing environment. In fact, not until the reader completes reading this entire book will all the decision points and master scheduling techniques be on the table. At that point, answers to the question of what (or where) to master schedule can be obtained.

So far, we have discussed why manufacturing companies need to master schedule, the mechanics of master scheduling, managing with the master schedule, using the master schedule in a make-to-stock environment, and what (or where) to master schedule. In the next five chapters we will turn our attention to master scheduling in other environments, starting with a flow environment and moving to the assemble-to-order, finish-to-order, and make-to-order worlds. In these environments upside-down and planning bills are usually necessary to aid the master scheduling process. Planning and scheduling in the process and repetitive manufacturing industries offer additional challenges and opportunities. These flow environments are the subjects of our next discussion.

7

Scheduling in a Flow Environment

All models are wrong, but some are useful.

Thus far, all of our examples have described products assembled from parts or components such as a flashlight and winches. Many readers, perhaps a majority, may be working in environments that produce these types of products, though their situations may be more complex than those used in our examples. Turbines, aircraft, photocopiers, washing machines, microwave ovens, desktop computers, and machine tools are other examples. The list is practically endless. For lack of a better term, we call this *intermittent manufacturing.* Other readers work in repetitive or process environments: chemicals, food, cosmetics, containers, semiconductors, petroleum distillation, brewing, paint manufacturing, textiles, lumber, glassmaking, and so forth. These readers may be wondering if the principles of master scheduling are applicable in the world of nonassembled products.

The answer to this question is "yes." As a general statement, everything we've described in earlier chapters applies to the flow manufacturing environment. However, some aspects of master scheduling in this environment are uniquely different, some are much simpler, and others add a new dimension of complexity.

Master scheduling in the world of intermittent manufacturing is primarily concerned with one main objective: getting purchased materials, plant equipment, and people ready to build the product when the orders come in. In other words, master scheduling is really a full-fledged planning process. From that point forward, everything else is execution through plant and supplier scheduling. With a few exceptions, flow environments shift much of the master scheduler's work from preparing to build the product to actual execution. The reason for this shift in emphasis is simple: Most intermittent manufacturing operations involve dozens (if not thousands) of components, all with different lead times. Machine tools provide an excellent example. Modern drill presses and lathes are assembled from thousands of parts sourced from hundreds of suppliers. Component parts, labor, and finished goods are expensive, and *optimizing their availability against customer demand* is essential for profitability.

The flow environment, on the other hand, is dominated by the optimization of the manufacturing process. Here, pipes, tanks, and vessels of various sorts are physically arranged to simplify, facilitate, and accelerate the flow of raw materials through the process, making the end product in a very short time—a few days or even a few hours. Since many of the products of this environment are commodities or commodity-like items (such as gasoline, paints, industrial chemicals, or processed foods) sold on the basis of price, the *efficiency of the process* has a major impact on profitability. Thus, the goal of scheduling in the flow environment is less about matching up materials and resources against customer orders than about assuring the efficiency of a manufacturing process that will produce high quality output at the lowest possible cost. In other words, it's the process that matters. Also, where perishability of raw ingredients is an issue—as it so often is in this type of environment—the scheduler may find economic reasons to run the process until all of a newly opened batch of ingredients has been used up, customer orders notwithstanding. In other situations the matter of government-mandated lot traceability takes on larger significance.

Different Manufacturing Environments

The different manufacturing environments just described are really extreme ends of a continuum of manufacturing practices. One end of that continuum is marked by the traditional job shop. There, the inputs of production are provided by suppliers and follow a route that takes them, by disconnected steps, to several work centers with specialized machines for bending, drilling, assembling, testing, painting, packing, and so on (Figure 7.1). The work *comes to the machine or assembler.* And when one machine or assembler has completed the task at hand, the work-in-process is transferred to yet another machine or assembler, perhaps sitting in queues along the way.

For the scheduler, the job shop environment demands a heavy emphasis on the following:

- multilevel and often complex bills-of-material;
- detailed routing of work through various work stations and holding areas; and
- work orders tied to stock or customer orders authorizing the entire process of manufacturing to begin.

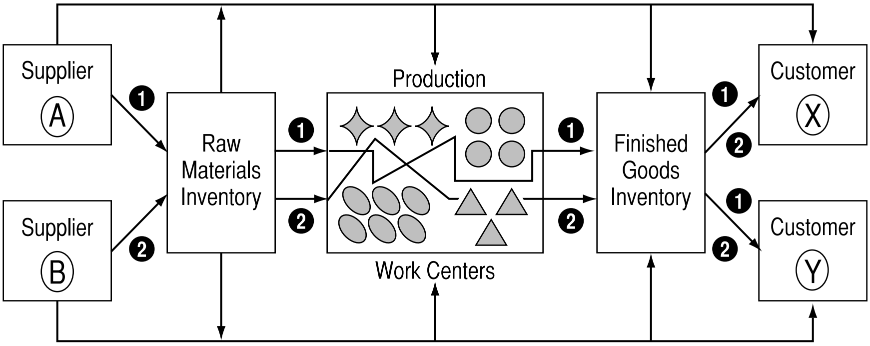

Figure 7.1 The Job Shop Environment

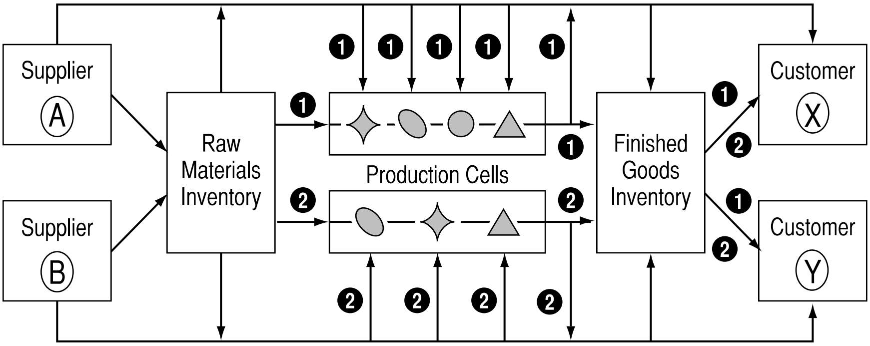

Figure 7.2 The Flow Manufacturing Environment

On the other end of the manufacturing continuum we find the pure flow environment, in which raw materials (usually few in number) are fed into a highly automated and continuous process for created finished output. There are no intermediate work stations, queues, or handling equipment (queues and handling add no value; they only add cost). And there are usually fewer people. Machinery and the movement of work-in-process are integrated into a generally seamless, continuous process. Together, these elements reduce manufacturing cost and the amount of time that work remains in the process. In the perfect process, raw materials are dumped into a hopper at one end of the line, and finished goods emerge from a pipe or packaging machine at the other (Figure 7.2).

Few operations, however, fit the ideal image just described. Many are still characterized by the processing of batches that must be queued from one step of the operation to the next.[1] This makes some manufacturing highly sensitive to the sequencing of work put into the line. For example, the scheduler of salsa would probably want to run a batch of mild salsa through the series of vats and mixers before sending a batch of hot salsa through them. Doing the reverse would require that the equipment be flushed out between batches so that the mild salsa would not pick up any residual spicy ingredients.

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[1] In food and pharmaceutical industries, regulations often force companies to operate in batch mode as a way of creating identifiable lots.

Many manufacturing processes, of course, operate in the vast middle ground between the two extremes just described. Some assembly operations—particularly those characterized by moving assembly lines that do rapid, repetitive work—share many characteristics of the flow environment. Indeed, the history of manufacturing of all types of products has followed an evolution from a discrete set of separate operations to a continuous flow of work. In some cases, this has been accomplished by a simple reconfiguration of the manufacturing facility, in which machines are arranged to eliminate transfers, queues, and storage areas. In others, process innovations have eliminated and/or combined some operational steps. An excellent example is found in the plate glass industry. A century ago, plate glass was manufactured in batches through an expensive and time-consuming series of discrete steps:

1. Mixing and melting ingredients
2. Casting the liquid glass into molds
3. Annealing the glass in a lehr (an oven)
4. Grinding
5. Polishing

Decades of innovations have converted what was once a job-shop operation to a near-perfect flow operation by reducing the former five steps to a single operation: continuous casting of a ribbon of glass that requires neither grinding nor polishing.[2] The parallel development occurred in the steel industry when Nucor built the first plant capable of continuous casting of sheet steel. Readers may recognize similar evolutions in their own industries. Others are bound to follow.

Differences in the job shop and flow environments extend to the language used by company associates, the length of production runs, and other factors. Figure 7.3 itemizes just a few.

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[2] See James M. Utterback, "Innovation in Nonassembled Products," in *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1994), 103–144.

	Job Shop Environment	Flow Environment
Production attributes	• Low volume; low speed; short to long runs • Longer lead times • More different inputs (parts)	• High volume; high speed; long runs • Shorter lead times • Fewer different inputs (ingredients)
Schedule basis	• To meet stock or customer orders • Scheduled to the week or to the day • Schedule materials first, then balance capacity	• Primarily to optimize production utilization • Finer grained scheduling—often schedule to the hour • Schedule capacity first, then balance materials
Materials inventory adjustments made	• As material issued and product completed	• Via "backflushing" (i.e., materials used deducted by the recipe or formula and the number of finished products)
Terminology	• Factory vs. • Bills-of-material vs. • Routings vs. • Work orders vs. • Fabricate, assemble vs. • Parts, sub-assemblies vs.	• Plant • Recipes or formulas • Process sheets • Campaigns, batches • Fill, pack, or finish • Bulk, intermediates
Level of scheduling paperwork	• High	• Low

Figure 7.3 Job Shop vs. Continuous Flow

Similarities between Intermittent and Flow Environments

Despite the differences just noted in the two manufacturing environments, many of the tasks that involve the scheduling of work remain the same. To identify these, let's revisit the diagram introduced in

Chapter 2 as Figure 2.6 (p. 34). This is a thumbnail sketch of what must go on in any commercial manufacturing environment (seen here as Figure 7.4). Each activity in the figure is essentially the same, down to the level of master scheduling.

Business and Sales and Operations Planning

As before, everything begins with business planning and sales and operations planning, and this is equally true for *both* manufacturing environments. Whether a company is making paint or computers, both of these important aspects of planning must be addressed.

Demand Management

Demand management is also equally important in both environments. Without demand forecasting, no company can hope to put the right mix of material, plant equipment, and human resources into play. The company that doesn't forecast will either find itself at some state of under- or overloaded capacity; the same is true of its inventories. With forecasting, however, the job shop or intermittent manufacturer will allocate those resources on the basis of stock or customer orders. In contrast, the flow-oriented company, being more inclined to optimize its productive capacity, will tend to produce its products and then use sales inducements to reduce any overstock that occurs.

Rough Cut Capacity Planning

Rough cut capacity planning was explained briefly in Chapter 2.[3] It is used to answer the question: "Do we have a chance to meet the production plan and/or master schedule as currently written?" It answers that question for both modes of production. However, it is even more important in the flow environment as a basis of scheduling decisions. The detailed capacity planning block shown in the figure is often bypassed entirely by the scheduler of flow-type and highly repetitive

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[3] A detailed treatment is found in Chapter 14.

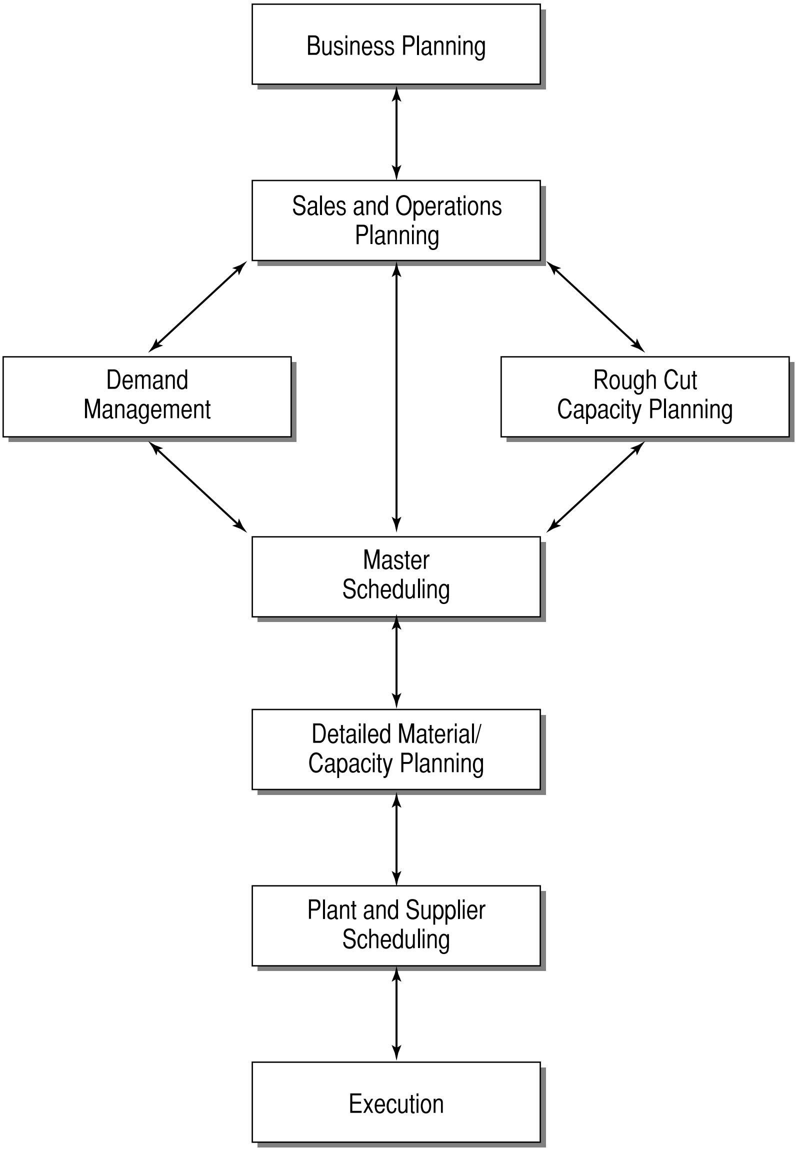

Figure 7.4 The Planning and Control Process

production. After a rough cut is conducted, if it can be determined that the scheduler can get 100 thousand units per day down a certain line but has a requirement for 120 thousand units, production time for 20 thousand of those units will have to be shifted elsewhere. If the requirement is for only 80 thousand, the scheduler would ask, "What else can I put though this line to utilize its full capacity?" Proper sequencing, as described previously, is an important aspect of the master schedule when coupled with rough cut capacity planning since it determines how much time, if any, must be set aside for tasks such as equipment changeovers and cleaning.

Master Scheduling

Important differences begin to appear once we reach the master scheduling activity block. Here we find that master scheduling in the flow environment is simpler in many respects, but more complex in others. We mentioned earlier that the bills-of-material used in most intermittent manufacturing are more extensive and complicated by lead times than are the lists of ingredients used in most flow environments. A prime example is a Boeing 777 or 787 compared to a jar of peanut butter. On the other hand, the flow environment contains lots of variables that must be factored into scheduling decisions—especially when capacity is tight. Temperature, humidity, variations in raw materials—even variability in the process itself—are a few examples.

Consider raw materials as just one illustration. Food companies that use milk as a key ingredient generally find that the composition of this raw material varies significantly from batch to batch and from season to season. At some times of the year, milk purchased from suppliers has a lower fat content than does milk purchased at other times. Adjustments to the recipe must be made to bring the final product into specification. These adjustments may take several forms, such as the addition of another ingredient or a shorter or longer period of processing.

As the number of variations increase for the same operation, the level of scheduling complexity escalates, making the scheduler more reliant on sophisticated master and plant scheduling software, such as finite-capacity scheduling and advanced supply-planning software capable of thinking through simultaneous variations and producing an optimized plan for the scheduler. These softwares can be loaded with the known data and variations experienced by the company in past operations. Scheduling parameters also include the time needed to accommodate line changeovers associated with many sequencing situations.

Detailed Material/Capacity Planning

Given the relatively few materials used in most or certainly many flow environments, detailed material planning is only needed to translate the master schedule products into raw material supplier schedules. Detailed capacity planning used in the intermittent production environment can often be skipped in the flow environment. In these cases, rough cut capacity planning—sometimes coupled with finite-capacity scheduling or advanced supply-planning—is what's necessary.

Plant and Supplier Scheduling

In the job shop environment, dispatch lists are used to tell each work center the order in which it should work on different jobs. Meanwhile, job routings coupled with the dispatch list direct work-in-process from one location on the manufacturing floor to another. The flow environment generally has no dispatch lists and no detailed routings. Instead, plant schedules, which are derived from the master schedule, direct the start of work.

Supplier scheduling is likewise minimal, as fewer suppliers and materials are used. Both environments, however, can assure material planning and replenishment through supplier scheduling and kanban agreements with suppliers.

Execution

A key difference experienced by the master scheduler in this stage between the job shop and flow manufacturing environments is found in the process of adjusting inventories once the products have been finished. As noted in Figure 7.4 on page 193, the job shop environment reduces raw material inventory as parts and components enter production. Work-in-process inventory is increased as these parts and components are issued to the line. The work-in-process inventory is reduced as work is completed and finished goods are increased upon receipt from production. In contrast, the flow environment is more inclined to use a method called *backflushing*. In this method, the operator knows from the recipe or formula that each finished product requires the consumption of a specified (or average) amount of inventoried material: for example, so many gallons of pureed tomatoes and so many ounces of diced jalapeños per gallon of finished hot salsa. Working back from the final output, then, the amount of inventoried materials used can be estimated with some accuracy.

In some cases, flow environments actually also produce items for inventory. These are commonly known as by-products and coproducts of the production process. For example, the petroleum refining processes or lumber manufacturing that aim to create one product generally produces several others. Many of these by-products go into inventory as feed stocks for still other petroleum-based or wood final products.

Product Definition

Product definition includes both a description of the materials that constitute the product to be built and the sequence of activities through which it is produced. In the job shop or intermittent manufacturing arenas, a product is defined in terms of a bill-of-materials and detailed routing. The bill-of-material itemizes every one of the parts and subassemblies that go into the final product; the routing indicates the various steps through which the product will be put together, including operations, description, work center, tooling, setup times, and run times.

Products in the flow environment are, in contrast, defined in terms of a recipe and a process sheet. The recipe is a list of ingredients or a formula. Like a cook in the kitchen, the manufacturer looks to the recipe book for a definition of the salsa, dog biscuits, latex paint, or whatever product he or she is about to make. The process sheet indicates when and at what stage the ingredients will be added to the product being manufactured. Once the process starts cooking, the outcome may not, as in job shop or intermittent manufacturing, be a single product. Instead, the flow operation may produce by-products, coproducts, or products representing several grades of quality. Some of the output may even be recycled back into the recipe for the next production run. Each of these outcomes has implications for master scheduling.

Structuring Recipes for By-Products and Coproducts

Many chemical processes result in one or more by-products. For example, paper pulping produces calcium lignin sulfonate. Some of these by-products are usable as ingredients in other products made by the company, in which case they go into inventory. Others are marketable either as a final product or as an ingredient for some other company's manufacturing process. The calcium lignin sulfonate just mentioned, for example, is sold as an additive in the making of concrete, tile, and brick, and as a binder for animal foods.

Other operations produce coproducts. A meatpacking operation offers a good example. A hog operation produces not just ham, but bacon, tripe, pig knuckles, and a handful of other marketable items. As the saying goes, modern meatpackers sell "everything but the squeal."

If we were to represent by-products or coproducts graphically, as we sometimes do with a traditional bill-of-materials, it would look something like Figure 7.5 on page 198. On the left we see how several raw materials are brought together to produce a single product. On the right-hand side of the figure, we see that a group of several raw materials (the recipe) has produced several unique products—A, B, and C. This situation is sometimes referred to as an *upside-down bill-of-material.* A petroleum refinery encounters this type of situation,

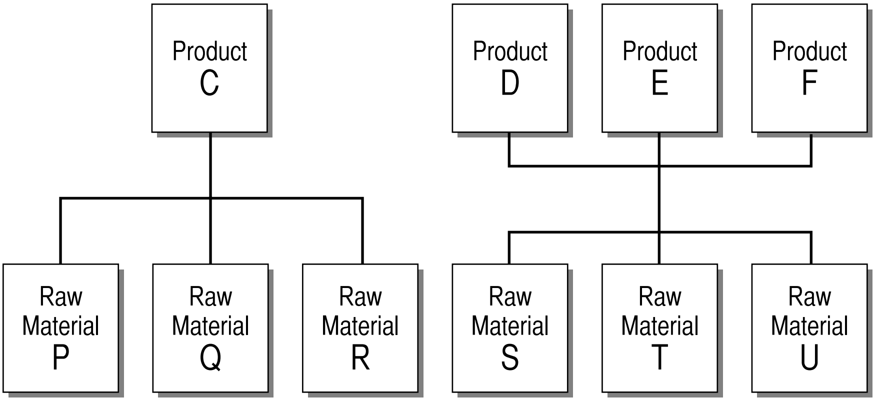

Figure 7.5 Single Product and Upside-Down Bills-of-Material

producing several marketable products from the same ingredient. In many cases, by-products or coproducts are ingredients for other products manufactured by the company, and the scheduler needs to create linkages between the output of one operation and the raw materials used for another.

The several products in the upside-down bill-of-material may also be different *grades* of a single product. Because of variations in the raw materials, in the manufacturing process, or even in the weather, different grades of output may result. For instance, if 1,000 units were produced by the process, 700 might be grade 1, 200 might be grade 2, and the remaining units might be grade 3. These must be sorted at the end of the line. In this case, the scheduler must rely on historical experience and personal insight to hit supply and demand targets. The different grades may also be manufactured by design depending on the grade of the raw materials.

Recovered Products

Some manufacturing operations that fall within our description of the flow environment actually recover some of the raw materials put into the front end of the process. These are generally counted as an output product and entered into inventory by production, where they constitute part of that on-hand inventory. A good example of this situation is found in the glass-making business. Broken glass is one of the ingredients of glassmaking. Thus, scrap or breakage that occurs in manufacturing is recycled as inventoried raw materials. Catalysts used in chemical reactions often exhibit the same behavior.

Process Sheets

As mentioned earlier, flow environments generally use process sheets instead of the detailed routings used in job shop and intermittent manufacturing. Both indicate the course that various inputs and outputs will follow during manufacturing. For example, a routing for a fabricated metal product may say to move the output of work center A to work center D, from there to work center G, and from there to the finished stock room. A start-stop date and time for each activity would be stated. A process sheet is similar, but it more closely resembles a diagrammatic representation of the manufacturing process itself. It may be a one-step routing: start the manufacturing cycle and finish it. This is true since setup for each part of the operation is generally done simultaneously (not sequentially) and the work flows in a continuous stream. Product specifications are also a part of the process sheet.

Figure 7.6 on page 200 demonstrates the difference between the multistep routing characteristic of job shop and intermittent manufacturing and the simpler, single-step routing seen on process sheets used in flow environments.

Accuracy Requirements

Assembly and job shop manufacturers apply a variety of quality controls to assure that finished products meet specification. These include the inspection of items in the bill-of-materials as they come in from suppliers, in-process monitoring, and statistical methods that keep equipment operating within acceptable limits. Flow manufacturers assure the quality of their ingredients and conduct monitoring to verify that in-process activities are within target specifications.

We've already noted how natural variations in raw materials (like the butter fat content of milk, the viscosity of a particular vegetable

Multiple Step Routing			
Operation	Description	Set-Up	Run
10	Mix	1.5 hours	0.2 hours/batch
20	Fill	0.5 hours	1 hour/1,000 cases
30	Pack	0.75 hours	1 hour/1,000 cases

Process Sheet (Single Step Routing)			
Operation	Description	Set-Up	Run
Line 1	Mix, fill, pack	1.5 hours	1.1 hours/1,000 cases

Figure 7.6 Routings Versus Process Sheets

oil, the sweetness of a patch of peaches, or dye potencies) and environmental factors can create variations in the final product. These can sometimes be reduced by interventions: holding a batch in the cooker for a bit longer; adding more sugar to a processed food or more pigments to a batch of paint; and so forth. When output is not within acceptable limits, plant personnel and schedulers need to determine if the problem was in the accuracy of recipe, in the particular batch, or in the production process. Once this analysis is complete, adjustments are made as required.

The Planning Process

In the planning process—in any environment—the master scheduler (and sometimes planners) anticipates what will be produced in the future. In the job shop, the scheduler plans the arrival and storage of the many raw materials and semifinished parts required for the manufacturing and/or assembly of the final product. Once the material priority plans are in place, the scheduler plans the capacity needed to do the job. If capacity is less than required, the scheduler will look for constraints or bottlenecks, find a way to increase the capacity of particular work centers, offload some of the work to other lines or plants, or find some other way to balance demand with the available capacity or the planned available capacity.

Schedulers in the flow environment begin by scheduling available capacity, since capacity is usually the dominant constraint. Only then do they turn to scheduling materials. The rationale for this sequence is the fixed nature of most plant capacity and the general availability of raw materials (safety stock inventory is often carried) for the products made in this environment.

Most flow operations are, in fact, capacity constrained. For example, for the last three decades the world has been awash in crude oil, but refining assets are limited. If demand for gasoline were to suddenly go through the roof, Exxon could probably pump or purchase all the crude it needed to meet its share of demand, but expanding its refining capacity would take years. Process industries are often characterized by commodity-like materials (like wheat, vegetable oil, sand, lime, or paint pigments).[4] Thus, in many cases, the scheduler can have all the materials needed within a day or two of a call from the purchasing department. Increasing capacity, on the other hand, requires a major financial commitment and years of design and construction to bring the increased capacity online.

The high cost of most processing plants also dictates that they be run at full capacity. Few companies can afford to idle a multimillion-dollar plant or allow it to operate far below its rated capacity; these generally must run at about 65%–70% capacity to break even. As a result, utilizing plant capacity is the first order of business for most schedulers.

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[4] Obviously, there are exceptions to this general statement. Some materials are very high cost and their availability represents a primary constraint on production.

Planning Capacity

In the flow environment, this is the order of process planning:

1. Understand the anticipated demand.
2. Develop a master schedule using finite-capacity scheduling or advanced supply planning software, if available.
3. Check the feasibility of that schedule using rough cut capacity planning, if required.
4. Forward the master schedule to detailed plant scheduling as work is ready to be released.

If the production process is highly integrated in the flow of activities, there is no need for detailed capacity planning. Experience will tell the scheduler (whether this is a person or finite-capacity scheduling software) the lower, optimal, and upper limits of a line's capacity. Because fully utilized capacity is a crucial goal, the scheduler also looks for underloaded conditions. As these are identified, work may be shifted to correct the problem.

Once the operation begins, changing the schedule can be difficult and costly, necessitating breaking down the line, cleaning it out, reheating furnaces, and so forth. Urgent customer orders that arrive during production cannot always be accommodated; therefore, careful planning of what to run and when to run it is very important. It is hard to control what hasn't been planned!

The software currently available is an invaluable aid to the planning process. When line capacity data is entered into the scheduling database, the master scheduling software will not recommend a load plan that exceeds or greatly underloads the current or planned capacity. It will instead shift loads around to fit and, perhaps, prioritize orders to accommodate preferred customers. It is also capable of optimizing the production of different products once all the data for those products are loaded into the database. The software will recommend which sequence of products should be run (as optimized through algorithms such as linear programming, mixed integer programming, artificial intelligence, simulation/heuristics, etc.).[5] This type of software, then, can handle what we call finite-capacity scheduling. Using a stated level of plant capacity as its starting point, it tells the scheduler, "Given the stated capacity, this is how you can optimize the schedule." Some companies can, and do, literally use this software to schedule their production; others prefer to have an override option in the system so that adjustments can be made.[6]

The finite-capacity scheduler described above is quite different than the infinite-capacity planning software used in many job shop environments that says, "Given the finished units you need to build by this date, this is the capacity you must have in particular time periods." The chore of finding that capacity or changing the demand is a job left to the master scheduler.

Planning Materials

Once the flow environment scheduler has taken care of capacity issues, he or she shifts attention to plan for the materials used to build the product, as well as materials that will result from building the product (like by-products). Here, two methods are useful: negative gross requirements and special scheduled receipts.

NEGATIVE GROSS REQUIREMENTS. One of the unique aspects of some flow environments is the fact that they can create one or more of the materials used in the process itself. We first observed this in earlier discussion of by-products, coproducts, and recovery. Production of these ingredient materials produces what we might call a negative gross requirement. To understand this term, consider our earlier example of glass production.

[5] This type of software is referred to as a *finite-capacity* planning or scheduling system, since it creates a schedule based upon existing, finite capacity. *Infinite-capacity* planning or scheduling systems begin with the order requirements and tell the operator how much capacity will be needed to produce it.

[6] For an excellent treatment of finite-capacity scheduling, see James Correll and Kevin Herbert, *Gaining Control,* 3rd ed. (New York: John Wiley & Sons, 2006).

The glass-making process produces a certain amount of scrap (or *cullet*) that, in effect, is a raw ingredient of the glass-making process, along with sand, lime, and soda. This scrapped glass can be reused and is, therefore, planned as recovery material. Those raw materials are positive gross requirements of the glass-making process. We need certain quantities to make the product, and we master schedule and material plan accordingly. The scrap produced in making one batch of glass reduces the raw material requirement for making the next batch. (We will need less raw material because we will use the cullet produced during the first batch.) The scheduler must adjust the recipe and process sheet accordingly.

Negative gross requirements sometimes create an important timing problem for the scheduler. The material that emerges from the process as a by-product must be time-phased with its availability; that is, we must indicate when this by-product is available for use. The requirements of the by-product for use in the next batch must also be time-phased. For example, scrap glass can be recycled into the glass-making process, but the scheduler must know when it will be available, enter that information into the planning software, and schedule accordingly.

SPECIAL SCHEDULED RECEIPTS. In planning material requirements, the flow environment scheduler looks to two sources: incoming new materials obtained through purchasing and the by-products and coproducts generated within the manufacturing process itself, as just described. Both represent scheduled receipts. When many by-products, coproducts, and different grades result from manufacturing, coordination between schedulers, sales, and marketing personnel is extremely important. To appreciate why, consider this example:

> Y is a by-product of a distillation operation whose main product is X. On average, the production of two barrels of X results in the production of one barrel of Y; the company has developed distribution channels for the sale of both products. Suddenly, the market demand for Y increases, prompting marketing to send the following urgent request to production: "Our customers will need twice as much Y next month as the 1,000 barrels we had projected. Please increase your output of Y to 2,000 barrels in anticipation."

Of course, complying with this request will have an important consequence: 4,000 barrels of X must be produced to get the 2,000 barrels of Y requested. Will the company be able to move this increased X output? Does it have the capacity to store it until new customer orders can be generated?

In this case, the master scheduler should work closely with marketing, reminding its managers that two barrels of X will hit finished goods for every barrel of Y requested. Unless they can develop a plan for offloading that inventory—through discounts, sales promotions, or other means—the company's bottom line may suffer. If the profits generated through by-product Y are low, it may be smart to develop another high-margin product for which Y would be an important ingredient.

The fact that several grades of output may emerge from a production process further complicates the job of scheduling receipts, especially when these must be predicted statistically. For example, a manufacturer knows that natural variability in raw materials, weather, and the production process will result in three grades of output: good, better, and best. These are sorted separately at the end of the production cycle. Based upon its experience, this manufacturer expects that, *on average,* 20% will be good, 30% will be better, and 50% will meet the standards of "best." However, every average—by definition—contains some level of variability.[7] For instance, if three men picked at random weighed 120 pounds, 180 pounds, and 270 pounds, we'd have an average weight of 190 pounds. But the high variability around that average (from 120 to 270 pounds) doesn't tell us much about the weight of the next man picked at random. Likewise, in manufacturing, if variability is high from receipt of one raw material to the next, or from one process batch to the next, averages won't have much predictive value for the person planning scheduled receipts. This is one reason why many flow manufacturers use safety stock or buffer inventory—it protects them from these sources of variability.

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[7] In statistics, variability of outcomes around the mean (or average) is measured in terms of standard deviations.

An Extended Example

Now that the elements of scheduling in a flow environment have been explained, let's jump into an example, using the kind of planning matrix produced by commercially available scheduling software.

Jelly Giant is a processed foods company specializing in fruit jams and jellies. Its products are produced in cases using batch operations in which different ingredients are added at different times. (We've altered and simplified this process for demonstration purposes.) One of the company's popular products is grape jelly, which is made from a handful of ingredients: grape mash, sugar, corn syrup, pectin, and citric acid.

The matrix shown in Figure 7.7 is representative of the information a scheduler might see on a computer screen. The top part represents the master schedule for grape jelly; the bottom part is a material plan for one ingredient: grape mash. Other ingredients have their own material plans. Let's start at the top.

The Master Schedule Matrix

As mentioned earlier, the master scheduler in many flow environments uses finite-capacity planning and scheduling software. This software takes all the known data about forecasted demand, expected lead times, desired safety stock or buffer levels, preferred sequencing, and so forth, and indicates how much should be scheduled and when, given customer preferences, inventory objectives, and supply constraints. Reviewing some of what we learned in Chapters 3 through 5, here is the known data for this master scheduled item:

- Item being produced (grape jelly)
- On-hand inventory (220 cases)
- Desired safety stock or buffer (10 cases)

GRAPE JELLY
Lot Size: 200
Lead Time: 2

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		50			90			200	
Option Forecast									
Actual Demand		110	30	10	40	20	50		
Total Demand		160	30	10	130	20	50	200	0
Projected Available Balance	220	60	30	20	90	70	20	20	20
Available-to-Promise									
Master Schedule (Receipt Date)					200			200	
Master Schedule (Release Date)			200			200			

GRAPE MASH
Lot Size: 1,000
Lead Time: 5

	Past Due	1	2	3	4	5	6	7	8
Projected Gross Requirements			1,200			1,200			
Scheduled Receipts		1,000					1,000		
Projected Available Balance	1,300	2,300	1,100	1,100	1,100	–100	900	900	900
Planned Order Release									

Figure 7.7 Master Schedule for Grape Jelly; Material Plan for Grape Mash

- Batch or lot size (200 cases)
- Lead time, or time required to complete a batch once the material is available (two days)
- Cumulative lead time, or time required to complete a batch from scratch (six days)

- The planning time fence (PTF), which is six periods (days, in this case)[8]

Previous chapters have acquainted you with the various elements of data in the left-hand column. Let's review them.

The *Forecast* row indicates predicted demand for grape jelly: 200 cases in each of the periods 1, 4, and 7. *Actual Demand,* however, departs from the forecast. Here we see *Actual Demand,* or orders in hand, for 110 cases in period 1; 30 cases in period 2; 10 cases in period 3; and so on. The total actual demand for the first three periods is 150 cases (110 + 30 + 10). Since these orders were forecasted, they "consume the forecast," reducing forecasted demand in period 1 to 50 and in period 4 to 90.[9] *Total Demand* is then the sum of the unconsumed forecast and actual demand.

The next important line of the matrix is the *Projected Available Balance,* which indicates (in this example) the number of finished cases of grape jelly expected to be available at the end of each period. Here, for example, Jelly Giant has 220 cases on hand as it begins period 1. The available balance satisfies some of the demand in subsequent periods. Ideally, the projected available balance should not fall below the stated safety stock level.

A finite-capacity scheduling system informs the scheduler what the production process is capable of handling at any given time by creating firm planned orders and computer-planned orders on the *Master Schedule* line of the matrix. It will not schedule a run or campaign that the process cannot accommodate. Using the information provided by the software, the master scheduler has authorized (in this example) the start of production of a batch of 200 cases of grape jelly in period 2. Production of these cases will finish in period 4 (with two days' lead time), where they appear as a "scheduled receipt," and just in the nick of time to prevent a stockout. The master scheduler has authorized

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[8] Everything to the left of the fence is within the control of the scheduler; the computer generates computer-planned orders outside the fence, indicating batch sizes it assumes will be produced.

[9] See Chapter 16 for details on forecast consumption.

another release of 200 cases in period 5, to be completed and received in period 7.

The Material Plan Matrix

In many flow environments, scheduling is driven by its most critical resource: plant capacity. As a consequence, orders may be arranged for the plant *first;* after the plant is scheduled, the scheduler turns to the materials or ingredients needed to make the product, getting them when they are needed and in the right quantities.

The bottom section of Figure 7.7 is the material plan matrix for the first of several grape jelly ingredients: grape mash. There we see that there are fixed order quantities (1,000 units), safety stock (250 units) for this material, and a planning lead time (four periods). There is also an on-hand inventory balance of 1,300 units, which has been put into period zero, the starting value for the projected available balance calculation. It should also be noted that 6 units of grape mash (indicated in the recipe) are needed to build one case of grape jelly. Thus, we need 1,200 units of grape mash to produce a batch of 200 cases of grape jelly. This number appears as a projected gross requirement in period 2 and again in period 5 at exactly the time—to the day in this example—that orders for 200 cases of grape jelly are to be released to production.

Our materials plan also indicates anticipated scheduled receipts of 1,000 units of grape mash in periods 1 and 6. These are based on orders placed by Jelly Giant's purchasing group. The scheduler can see from the *Projected Available Balance* line that this second order will have to be moved up to period 5; otherwise, there will not be enough grape mash on hand to meet the demand for that ingredient in that period. A simple telephone call or e-mail to the supplier may be all that's needed to speed up that scheduled receipt.

Each of the other ingredients of the grape jelly process (not shown here) has its own plan and its own matrix, and each must be periodically checked—and adjustments made when necessary—to assure that the plant will have all the ingredients it needs to produce the primary product. Some of these ingredients will not be needed until the middle or end of the process; thus, the scheduler and planner need to time-phase their availability and release.

Planning By-Products and Coproducts

The product definition of by-products was discussed earlier in the chapter. Many flow environments create by-products that are either sold or used as ingredients for other products. A material plan should be created for each of these by-products, especially if they will be recovered for use in other products, or if they will be sold as products in their own right.

In the case of Jelly Giant, the production of 200 cases of grape jelly creates a residue of 180 gallons of grape pulp. For years, Jelly Giant paid thousands of dollars each month to get rid of what it considered worthless sludge. Then one of its marketing geniuses discovered that grape pulp could be sold to Asian food processors, who would pay high prices for as much grape pulp as Jelly Giant could produce. To them, Jelly Giant's waste by-product was a highly valued ingredient in a popular aphrodisiac.

By-products create an interesting problem of signs for the scheduler (see Figure 7.8). If a by-product is expected to be produced, a negative quantity is put on grape mash within the grape jelly recipe. When the master schedule of 200 cases of grape jelly is exploded through its recipe, the negative quantity is multiplied by the MPS quantity, which creates a negative gross requirement for grape mash in periods 2 and 5. The software must show these gross requirements as negative quantities in the materials plan. When the scheduling software subtracts these negative quantities, they become positive values and are added to the *Projected Available Balance* line of the planning matrix.[10] One of the problems with this technique is timing the by-product's receipt into inventory. Most of the time, the by-product will be received on the due date of the main item being produced, in this case, grape jelly. If the lead time of the master scheduled item is short, this problem is not a major concern.

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[10] Companies that use a by-product as an ingredient in another product will often show additional quantities of material in the *Scheduled Receipts* line of the matrix. These represent quantities purchased to add to the inventory of the by-product.

MPS Matrix	Past Due	1	2	3	4	5	6	7	8
Master Schedule (Receipt Date)					200			200	
Master Schedule (Release Date)			200			200			

MRP Matrix	Past Due	1	2	3	4	5	6	7	8
Projected Gross Requirements			–180			–180			
Scheduled Receipts									
Projected Available Balance	500	500	680	680	680	860	860	860	860
Planned Order Release									

Figure 7.8 Material Plan for a By-Product or Coproduct

If the lead time is long, then the master scheduler needs software capable of exploding selected recipe items by due date, using component/ingredient lead-time offset capability (explained in Chapter 12), or else the scheduler must use the special scheduled receipt method. Another problem with the negative gross requirement is the negative quantity on the recipe—this bothers some people because of recipe accuracy issues. Of course, software designed specifically for the process industry may handle these situations. A similar procedure is applied when a material used in the process is recovered for use in the future. Catalysts, broken glass, and chocolate are among the materials recovered for reuse.

Catalysts and Recovered Material

Some chemical manufacturing situations involve a catalyst that is needed for a period of time and then recovered in whole or in part for

MPS Matrix	Past Due	1	2	3	4	5	6	7	8
Master Schedule (Receipt Date)					200			200	
Master Schedule (Release Date)			200			200			

MRP Matrix	Past Due	1	2	3	4	5	6	7	8
Projected Gross Requirements			1,200			1,200			
Scheduled Receipts		❶ 1,000			❷ 480			❷ 480	
Projected Available Balance	1,300	2,300	1,100	1,100	1,580	380	380	860	860
Planned Order Release									

❶ Purchased Material ❷ Recovered Material

Figure 7.9 Material Plan for a Catalyst or Recovered Ingredient

reuse. Other processes recover ingredients. Consider, for example, a candy bar maker that mixes ingredients, forms bars, and then coats them with chocolate. Then 1,200 gallons of liquid chocolate is added. As this chocolate is applied to the bars, however, an average of 480 gallons (40%) fails to adhere and can be recovered for use with the next batch. The result is that the process has both a chocolate *requirement* and a chocolate *receipt.* Figure 7.9 describes the master schedule and material plan for this example.

Reviewing the figure, we see the master schedule for the candy bars and the material plan for chocolate. Here, the scheduler has decided to produce two 200,000-unit batches of candy bars. The first batch will run across days 2 and 3, while the second batch is scheduled for days 5 and 6. The recipe indicates a requirement of 1,200 gallons of chocolate to be issued for each batch of 200,000 bars in periods 2 and 5. At the end of each campaign, the plan anticipates that 480 gallons of the issued chocolate material will be recovered. To plan for this recovered material, the scheduler uses either the negative gross requirement (placing a negative quantity on the recipe) or the special scheduled receipt. Both of these techniques were discussed earlier. The figure shows a special scheduled receipt for recovered material in addition to what has been ordered from the supplier.

Line Scheduling

The level of fixed overhead represented by process equipment in most flow environments is so high relative to labor, materials, and other costs that every effort is made to keep that equipment fully utilized. That is straightforward when there is only one production line, but it gets more complicated when two or more exist under the same roof. And as we will see in Chapter 15, "Supply Management," having many roofs in different parts of the country or world increases complexity still further.

Schedulers in these highly capitalized plants are responsible for keeping several production lines fully utilized. They generally attempt to do so through finite schedules. They shift products around from line to line where feasible in an attempt to minimize downtime, and they must do so within constraints imposed by equipment adjustments, tank capacities, raw material availability, customer orders, safety stock or buffer replenishments, labor, and so on. Figure 7.10 on page 214 provides an example of how one plant with two lines and many products to make might schedule the flow of work. The top part is a simple table of products and times; the bottom portion is the type of graphic representation that a finite-capacity scheduling system can produce. Here, the dark bars are nonproductive times (changeover, maintenance, crew meetings, and so forth). Both line schedules, top and bottom, come from the same data.[11]

As the reader reviews the information contained on the line sched-

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[11] Inventory levels, customer demand levels, potential stockouts, and so forth can also be graphically represented.

Line #1				Line #2			
Product	Quantity (cases)	Date	Time	Product	Quantity (cases)	Date	Time
A	10,000	15 Sept	8 am–2 pm	X	7,000	15 Sept	9 am–12:30 pm
Changeover		15 Sept	2 pm–2:30 pm	Changeover		15 Sept	12:30 pm–2 pm
B	20,000	15 Sept	2:30 pm–12:15 am	Y	18,000	15 Sept	2 pm–3 am
Changeover		16 Sept	12:15 am–1 am	Changeover		16 Sept	3 am–4:45 am
C	12,000	16 Sept	1 am–6 am	Z	6,000	16 Sept	4:45 am–8:30 am

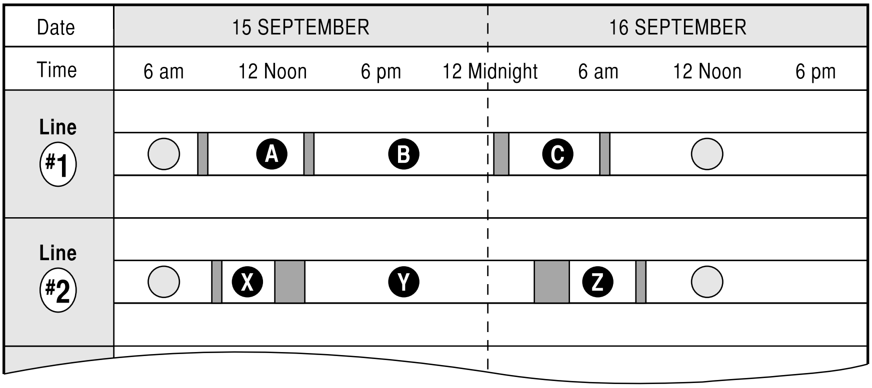

Figure 7.10 Line Schedules

ule, he or she should note the precision of these schedules—products A, B, C, X, Y, and Z are scheduled to fractions of an hour. The line schedules shown in the figure have been created using a vertical format (top portion) and a horizontal format (bottom portion). Although the graphic display is the most popular, both formats are available using commercially available scheduling software.

This chapter shows how master scheduling and material planning concepts can be used in all manufacturing environments, especially in the flow environments that produce so many goods used in our economy. It should also be recognized that scheduling concepts and techniques used in repetitive and flow environments apply equally to intermittent manufacturing. Besides being knowledgeable about the various production environments, the master scheduler must understand how to schedule these environments using the chosen manufacturing strategy (make-to-stock, make-to-order, or design-to-order). The next chapter covers planning bills, which are most often used in the make-to-order environment. However, there are several applications of planning bills in the make-to-stock and multiple plant supply management worlds as well.

8

Planning Bills

An assumption is the first step toward a screwup.

Imagine a company that sells conference center chairs off the shelf. To remain competitive, the company determines that it must expand its product line—customers want a variety of colors beyond the current black-only model. To accomplish this product expansion, the company must evaluate both its marketing and manufacturing strategies. Under its current make-to-stock strategy, the customer simply asks for a chair, and that item is shipped from finished goods. This system works fine for a product family with a limited number of members. But if a company is going to offer greater product variety without a change in its manufacturing strategy, it will be very expensive to maintain a finished-goods inventory for off-the-shelf shipment. Its forecasting job will be much more difficult, too; if it guesses wrong on demand for its variety of products, it risks having obsolete inventory. As the company continues to offer more options to the customer in order to remain competitive, the problem becomes more significant. Therefore, it may be necessary to choose a new manufacturing strategy.

The make-to-stock manufacturing strategy has already been discussed. This chapter deals with an alternative strategy—make-to-order (MTO). First, though, we review the potential strategies at our disposal, using the familiar fast-food industry as a model. At one extreme, a fast-food restaurant can make-to-stock ready-to-eat hamburgers and keep them hot under heat lamps. Some would have ketchup, some mustard, some pickles, others lettuce, and some combinations of the various condiments. The advantage is that the customer gets instant gratification; some of the disadvantages, of course, are the high cost of finished inventory, possible waste due to shelf life, and the difficulty in forecasting the mix requirements. Some items would move quickly, but others would grow stale and have to be discarded.

At the other extreme, the restaurant could wait for the customer's special order and then do the following: determine the proper wheat to use, bake the buns, run to the grocery store for some ground beef, prepare sliced pickles and other condiments from scratch, and cook and prepare the order as given. Such a design-to-order or engineer-to-order approach would, of course, be impractical for a "fast-food" restaurant. The customer would grow tired of waiting.

In between these two extremes, the restaurant could maintain certain items in a finished state—the burgers and the buns. Condiment options could be added on request. This is a form of a make-to-order, or assemble-to-order or finish-to-order situation. The customer walks in and says, "I'll have a hamburger with mustard, lettuce, pickles, and tomatoes." The hamburgers are sitting on the grill and the buns are in the warmer; the restaurant simply adds the requested options.

Whether a company makes hamburgers or chairs, the production issues and master scheduling techniques needed are basically the same for the make-to-order business. However, these product configurations must be planned prior to receipt of the order to avoid high inventory investments and to reduce delivery time to the customer.

While make-to-order approaches to manufacturing offer significant advantages in terms of reducing finished-goods inventory costs, they have the potential disadvantage of creating unwieldy and complex bills-of-material as the number of product options grows. They also create potential forecasting problems in terms of estimating the right mix of options. This chapter is concerned primarily with the bill-of-material (BOM) or list-of-ingredients aspects of make-to-order strategies, demonstrating how to set up the product structures in a database so that master scheduling in a make-to-order, assemble-to-order, and finish-to-order environment is feasible.

The Overly Complex Bill-of-Material

Earlier in the book it was explained that to gain a strategic edge a company must match or surpass its competitors in terms of delivery time, price, quality, service, and technology. If product quality, technology, service, and price are equal among competitors, then the battle for customer allegiance must be won on the grounds of delivery performance, a factor of competitiveness that falls squarely in the domain of the master scheduler.

With proper scheduling techniques, it may be possible to meet the customer at a prefinished stage yet still provide product within a competitive time frame. If so, a competitive advantage will have been gained by offering the same or better delivery times but with substantially lower costs. Since the producer will have the opportunity to carry less inventory, its operating costs will be lower, making it possible to either reduce product price or increase margins or both.

From the master scheduler's perspective, a change to a make-to-order strategy means, first, deciding where to meet the customer. ("Come in and we will hand you a burger. . . . Give us two minutes and we will put it together for you. . . . Give us two hours and we'll run to the store for the ingredients and prepare it from scratch.") The decision about where to meet the customer impacts the decision of *what* will be master scheduled. Recalling a previous chapter, any of three types of product structures are possible within a company's framework (Figure 8.1). In the case of the finish-to-order or assemble-to-order environment, the hourglass structure (C) is the relevant shape.

The hourglass structure represents a situation in which the customer buys a certain item from a product family, then selects additional options—like a hamburger, which can be configured in any number of ways. But whether the customer buys a plain hamburger or a cheeseburger with the works, he or she still must buy a hamburger (which, here, is one item represented in the pinch point of the hour

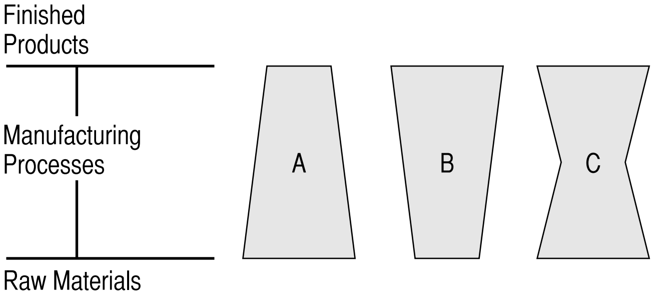

Figure 8.1 Standard Manufacturing Configurations

glass). The bun, lettuce, tomatoes, and pickles are options added later. The automobile offers a similar example: No matter which radio is ordered (AM/FM, CD player, or cassette player) or which type of seats, the customer is still buying a car with bumpers, wheels, chassis, and so forth.

The hourglass is the structure most relevant to the assemble- or finish-to-order environment, and it addresses a key question for the master scheduler: How many bills-of-material must be created to accommodate all the possible options? Consider the BOM for a hypothetical product shown in Figure 8.2.

As Figure 8.2 makes clear, the purchaser of one of the products has a choice of ten different A options. Assuming that all options are mutually compatible, the buyer then needs to select from among eight B options. This equates to 80 possible configurations just among the A and B options. But there are more! Option C lists two choices. A quick calculation of all possible options A through E reveals a staggering 9,600 possible configurations (10 × 8 × 2 × 12 × 5). The job of creating and maintaining separate bills-of-material for each configuration would be staggering. Now, what if a single new option E was added to the list of choices? How many *new* BOMs would need to be created? Answer: 1,920 new bills-of-material (10 × 8 × 2 × 12 × 6 = 11,520 minus the earlier 9,600) each time a change is made to option E.

This situation requires the master scheduler to work with sales and marketing to create the best forecast of demand for the various options—no easy task. Imagine the novice master scheduler approaching the marketing manager and saying, "I need to know how many

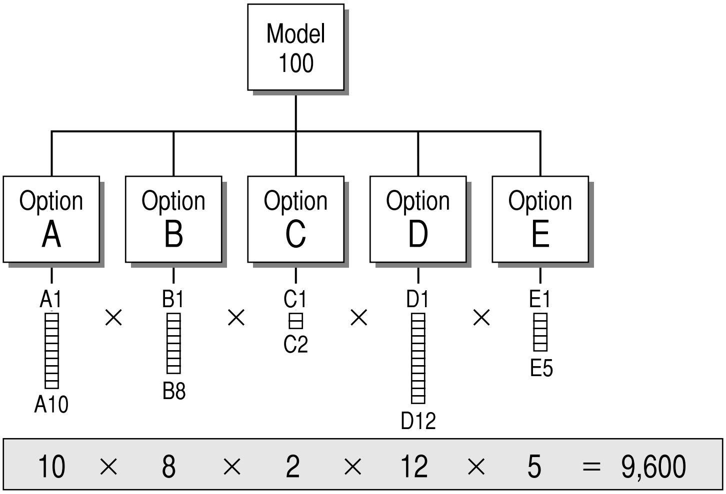

Figure 8.2 Options Availability for Hypothetical Product

Model 100s you're going to sell with the A1, B1, C1, D1, and E1 options next August." The marketing manager, a savvy veteran of the manufacturing world, rubs his chin, looks the new master scheduler straight in the eye, and says with great deliberation, "Seventeen."

Of course, the marketing manager has absolutely no idea of how many Model 100s will be sold with those options some months from now, and perhaps the master scheduler will catch on to his little joke. The point is, there has to be a better method for getting a handle on products that have a potentially enormous number of BOMs. One solution is to figure out a way to master schedule one level below the finished product level—at the A1 and A2 and B1 levels, and so on. How many BOMs would be needed if this approach was followed? Answer: a total of 10 BOMs for A, 8 for B, 2 for C, 12 for D, and 5 for E. In other words, 37 BOMs would be needed (Figure 8.3). This represents quite a difference from the 9,600 BOMs for the full product!

Dropping down a level also could benefit the design engineers in BOM maintenance. If an engineer wants to add a sixth E option, he or she needs to create *one* new BOM instead of having to gin up 1,920 new ones.

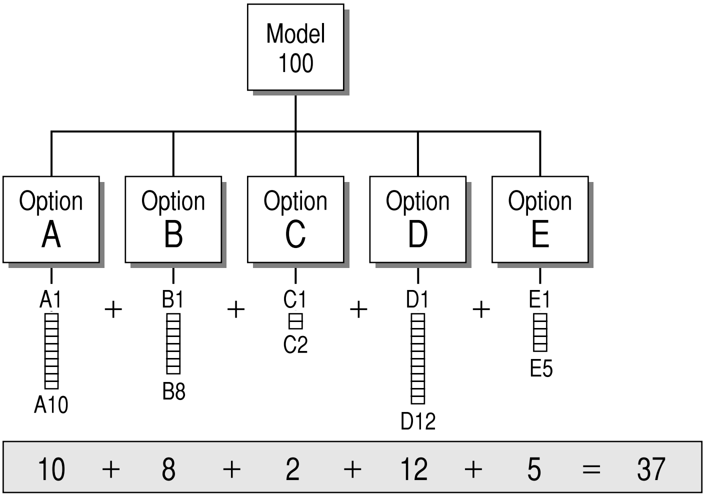

Figure 8.3 Effect of Master Scheduling One Level Down in the Product Structure

Of course, it is still necessary to determine how many Model 100s will be sold in a given month. Once the aggregate number is determined, another key question must be answered: For every Model 100 sold, what is the probability that it will be shipped with the A1 option? With the A2 option? And so forth. Sales and marketing can answer these questions by saying something like this: "Whenever we sell a Model 100, we anticipate that 20 percent of the time we'll sell it with option A1." This is essentially a forecast for the requirement of the option, and being a forecast, it is bound to be inaccurate to some extent. But for the time being, it may be the best number available to the master scheduler and will be used to estimate demand at the product mix level.

After the mix percentage has been determined, the next step is to forecast demand at the lower levels. The following discussion covers a tool for doing just that—the *planning bill.* A planning bill is an artificial grouping of items or events in a bill-of-material (BOM) format (see Figure 8.4, p. 222).

Planning bills are in the category of *pseudo bills*—false or artificial bills. They cannot be used directly to actually build any configuration

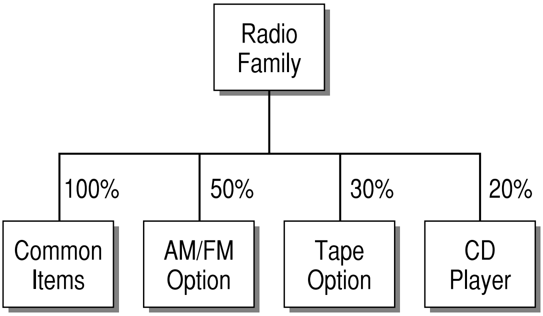

Figure 8.4 Sample Planning Bill

of the product. The reason is twofold. First, the product in our example cannot be built with less than 100% of a given item. In other words, you cannot take 50% of an AM/FM radio, add it to 30% of a radio with a cassette player, and then add this to 20% of a radio with a CD player. Second, it takes more than just unique items to build the product—common items are also needed. However, a pseudo item with a pseudo bill attached to it can be master scheduled. Once this is done, the planning bill can then be used to predict what items may be needed to produce the product the customer may request.

An Example

Consider this simple example. If we know that we will sell 1,000 Model 100s, we also know that 1,000 sets of the common items (those used in *all* Model 100s, no matter which options are selected by the customer) will be needed. Nothing could be more simple. The difficulty comes in determining the mix of the *unique* items. Suppose that 20% of the Model 100s sold in any given month are expected to contain option A1. In this case we would convert the 20% to a decimal (.20) and enter that value into the BOM quantity field (some master scheduling software has a probability field as well as the quantity field—in this case the value is entered in the probability field) for the A1 option, as shown in Figure 8.5. The same would be done for each of the other options—say, .15 for the B1 option, indicating that 15% of the Model 100s are expected to contain the B1 option.

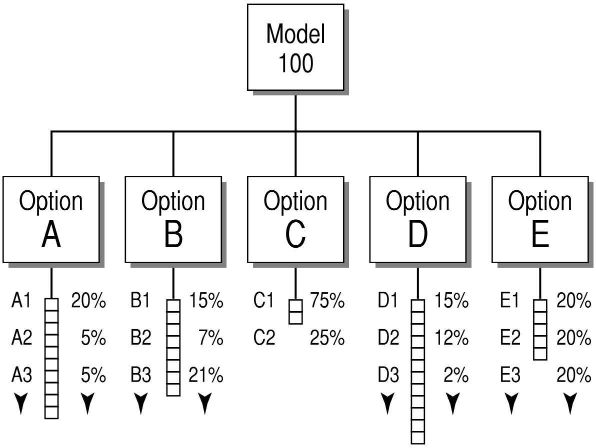

Figure 8.5 Planning Bill with Percentages of Options

These numbers are best obtained through a mixture of science and art. The process begins by asking the right people, who in this case happen to be individuals in marketing and sales—who, after all, has a more complete knowledge of the product, the market appeal of its options, and the intentions of customers? Their information comes through sales and delivery (demand) history and what might be called *future history*—that is, orders booked for future delivery. At some point, what is booked for future delivery becomes sales history. Sales and marketing personnel also keep close tabs on their list of current and prospective accounts, often compiling lists of expected orders months in advance of when those orders are actually received. These lists are used by marketing to focus sales attention on near-term orders that need to be closed, but they can also be used in forecasting. The bottom line in planning bill accuracy is that sales and marketing must be accountable for creating and maintaining the planning bill percentages.

Once the percentages are obtained, they are entered into the option planning bill. But should they add up to 100%? If the options are required, the answer would be yes. But if the options are add-ons, then the percentages or probabilities of sales may be less than or greater than 100%. For example, consider a bicycle with numerous configurations—different frame sizes, a rear derailleur (gear assembly), pedals, and so on. No matter what size frame, what gear ratios, or what style of pedals are selected, every bicycle *must* have a frame, a gear assembly, and a pedal set. On the other hand, it is not necessary to have a front derailleur (which doubles or triples the number of available gears). The front derailleur is therefore an add-on option, and the total forecast for units with this option could be equal to, less than, or greater than the number of bicycles to be sold.

As more options are added, the complexity of the bicycle increases, creating a more difficult situation for manufacturing and the master scheduler. One technique for managing this complexity is to group common items (those that are always needed, such as wheels, brakes, seat stems, wire cables, etc.). Every bicycle in a given family will have common items, though these may be unique to the product family. One family, for example, might always have an eight-inch seat stem and a standard front axle, regardless of frame size, wheel size, and so forth. Those items would be listed together on a common-items bill. The common-items bill is also a pseudo, since nothing can be built with just a seat stem and front axle. But the common-parts bill can be married with an option bill-of-material to build the bicycle. Why do this? Because of the existence of common items, certain probabilities remain constant; the probability that common items will be needed is 100%. That fact is very important. If a set of common items for every bicycle is needed, the job of forecasting the mix is certainly reduced. All that is needed then is to get enough sets of common items to match the demand forecast generated in the sales and operations planning (S&OP) process.

Now consider handlebars. Perhaps option C1 represents dropped bars, and C2 represents upright bars. According to marketing, 75% of the bicycles sold will have dropped bars, and the remaining 25% will have straight bars. In the planning bill C1 would be indicated as .75, and C2 would be listed as .25. Manufacturing cannot produce a handlebar using .75 of a dropped bar and .25 of a straight bar. Again, for this reason, the planning bill is called a *pseudo bill-of-material* and is used for planning purposes only. To build the product, manufacturing must use an actual configured bill-of-material and process instructions generally created by sales and/or engineering.

How does the pseudo bill work? Suppose that marketing predicts 1,000 bicycles will be sold in the next month. By exploding 1,000 through the planning bill and multiplying the aggregate quantity by the projected percentages, one can forecast how many unique and common items will be needed. In this case, if the dropped bars are forecasted at a 75% probability, and upright bars at 25%, then 750 bikes with dropped handlebars and 250 with upright bars will be needed. Naturally, the number of common items needed will equal the number of bicycles required—1,000, assuming one set of common items per bicycle.

With this understanding, consider a familiar product and how the planning bill assists the company and its master scheduler in getting the job done in the assemble- or finish-to-order environment.

Soft Seat Listens to Customers, Expands Product Offerings

The Soft Seat Corporation designs and manufactures a successful line of conference center chairs that it sells off the shelf throughout North America and parts of Europe and parts of Asia. During a monthly sales and operations planning meeting, the chief executive officer (CEO) announced that market research indicated that to remain competitive the company must expand its product line to provide models in colors other than its traditional black. "Customers are telling us that they want a variety of colors to coordinate with modern office decors. The increasing success of the one competitor that does provide color choices confirms the research."

Soft Seat had built a successful business on just one product in one color. This simple product situation made planning fairly straightforward. Since the company's market forecast was generally reliable, it could satisfy customer orders by keying production to the market forecast. There was no need to guess how many orders there would be for various model options.

The announcement by the CEO would make life more difficult for just about everyone. Marketing would find forecasting more challenging; they would have to estimate demand not just for chairs, but for black chairs, red chairs, and so forth. If estimating demand for plain black chairs was difficult from month to month, breaking that total forecast into segments represented by different colors would prove more difficult—and surely less reliable.

The chief financial officer would surely find the new strategy troubling. This was a "get the order and ship it" business. Soft Seat had to have a sizable finished-goods inventory to meet the competitive requirement for fast delivery. Now he feared he would be required to finance not one inventory, but several, one for each color plus the various mixed colors—a red back with a black seat is quite fashionable.

The manufacturing manager was even less thrilled by the announcement because it would greatly complicate what had been a fairly simple and routine manufacturing operation. Nevertheless, he knew that he and his staff were up to the challenge.

The sales force was entirely behind the color idea. Since the other competitive parameters of their business—price, delivery, quality, service, and technology—were closely followed by everyone in the business, this color-option strategy gave them one more piece of selling ammunition. The manufacturing and finance issues were not their concern.

Until now, Soft Seat merely had to secure the customer order and ship from its finished-goods inventory. It followed a classic make-to-stock manufacturing strategy, typical of businesses in which either (1) the competitive environment requires rapid order fulfillment, or (2) simple, low-priced products prevail. Manufacturers of office supplies, tire companies, and small appliances fit this description. When a customer wants a box of ten computer memory sticks, she wants them now, not two weeks from now. She will not submit an order to the manufacturer to begin production.

The make-to-stock manufacturing strategy works well in the environment just cited, but if a company adopts a new product strategy—as Soft Seat has—then a new manufacturing strategy logically follows.[1] Here we describe a make-to-order strategy. Recall from Chapter 6 that a make-to-order strategy occupies a middle position

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[1] Over the past 15 to 30 years, the business strategy of competing on the basis of rapid introduction of new and varied products has gained many adherents. Japanese companies have led the way in this: Honda with literally dozens of new motorcycle model introductions in just a few years; Casio with over 100 different watch models (on less than a dozen

between the extremes of make-to-stock and engineer-to-order. According to APICS, a make-to-order product is one that is finished after receipt of a customer order. In make-to-order, *some* material may be ordered and *some* parts of the product may be produced before receipt of a customer order. With a pure make-to-order strategy, the product is designed, but no manufacturing occurs until a customer order is received. Highly customized products are generally made in this fashion. Finish-to-order and assemble-to-order are variants of this strategy, in which the company may build product through all but the finishing stage, which is triggered by a customer order.

Anatomy of a Planning Bill

Figure 8.6 on page 228 shows a planning bill for the new Soft Seat chair product family. Here, four different color options are available. (Note: Colors are coded using a significant item number scheme in the form of a suffix. For example, the basic conference center chair is model 260; the suffix BL indicates the color black; RD indicates red; GR indicates green; and BB indicates blue.)

In a make-to-stock environment, all four colors of conference center chairs would be built and held as finished goods pending the receipt of customer orders. Looking at the chair one level down (Figure 8.7), we see that the following items are needed: a seat assembly, a back splat assembly, a left leg assembly, a hardware kit, and a right leg assembly. Notice that neither the hardware kit nor the leg assemblies have a color designation. This means that these are common to all chairs, regardless of color, and *not* unique.

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internal cores); Sony with multiple varieties of its popular Walkman cassette player. Business scholars have written extensively on the competitive advantages to be gained by this strategy; almost none, however, have focused on the manufacturing issues that underlie the strategy and, in fact, make it possible.

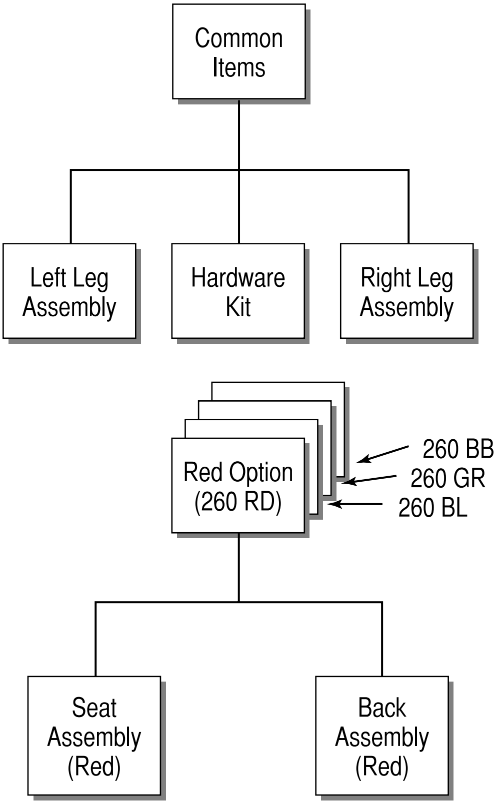

Figure 8.6 Soft Seat Planning Bills for Options and Common Items

Time Phasing

At this point we need to *time phase* the BOM, as shown in Figure 8.7. In a make-to-stock environment, chairs would be stocked at the *zero* time line. In switching to a make-to-order or assemble-to-order strategy, however, time phasing would become critical, since completed chairs would no longer be stocked. Instead, we may stock seat assemblies (color sensitive), back splat assemblies (color sensitive), hardware kits (common), right leg assemblies (common), and left leg assemblies (common). The ability and decision to do this depend on where the company intends to meet its customers. The capacity to

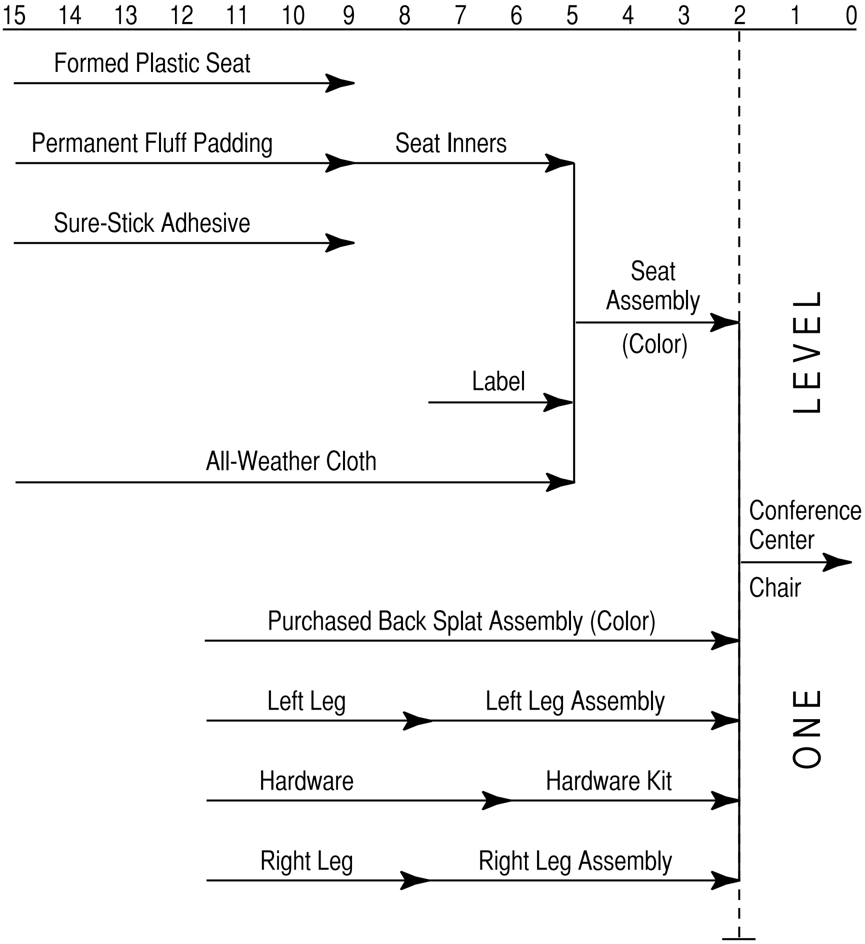

Figure 8.7 Time-Phased Bill for the Conference Center Chair Product Family

configure these stocked items into customer-defined requirements would also be required within the defined time period. For illustration purposes, let's assume we plan to meet the customer with the defined modules, which means that we would need two periods to complete the product once the customer order is placed.

To deploy to an assemble- or finish-to-order strategy, BOMs need to be structured for the common components as well as for each offered option. This means that the red option bill will contain a red

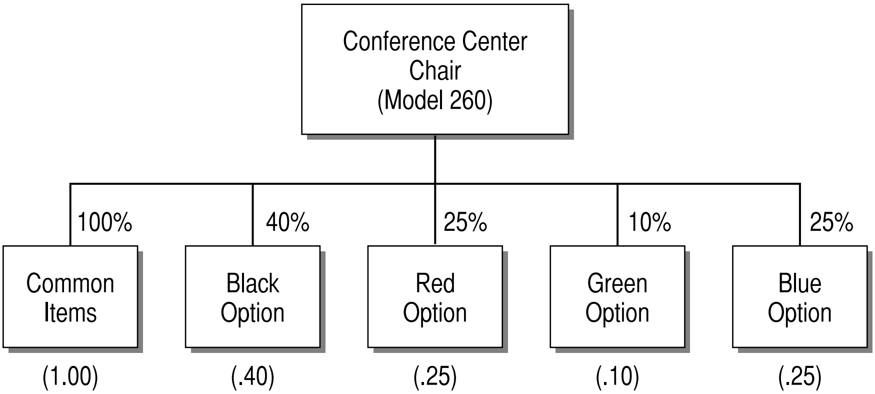

Figure 8.8 Planning Bill for the Conference Center Chair Product Family

seat assembly and a red back assembly. The black option will likewise contain a black seat assembly and a black back assembly.

Figures 8.6 (see p. 228) and 8.8 show the planning bills for the entire conference center chair family. The common-items planning bill is shown at the top of Figure 8.6, while the lower portion of the figure contains the unique items: red option, black option, and so on. This bill restructuring makes it possible to greatly reduce the number of bills in the data file. With this done, another pseudo bill is created for the conference center chair family itself (Figure 8.8). In this planning bill we structure the common items plus the unique options that we desire to plan. By so doing, we have made it possible to tie the output of the sales and operations planning process to the lowest component and material in the chair product family. To see how, follow it all the way to the bottom. The conference center chair calls out the red option, which calls out the red seat assembly, which calls out the seat inners (see Figure 8.7 on p. 229), which call out the formed plastic seat, permanent fluff padding, and sure-stick adhesive. The chair also calls out the common items, which call out the left and right leg assemblies, which would call out the left and right legs as well as the hardware kit, which would call out the hardware.

The key concept here is that the forecasting done during the sales and operations planning process is done at the product family level (conference center chairs) and the top-level planning bill is also structured at the generic chair level. This provides the vital link needed to tie the aggregate planning to the detail planning.

During the master scheduling process, the numbers created during the S&OP plan are exploded through the planning bill. Since every conference center chair requires a set of common items, the percentage attached to the common-items kit is 100 (or 1.0). Now, according to sales and marketing, every time a chair is demanded, there is a 40% chance that it will be black. If you planned to sell 1,000 conference center chairs, you would anticipate needing 1,000 sets of common items (1,000 × 1.0), 400 black seat assemblies (1,000 × .40), and 400 black back splat assemblies (1,000 × .40). The other 600 conference center chairs would require red, blue, and green options. In this way the master scheduling software using the planning bills can calculate the expected mix demand at the next lower level, which is where master scheduling would take place.

What we have done in this example is create pseudo bills-of-material: one for the common items and one for each of the unique options. When a customer orders a chair, that customer will indicate a color preference. If the order is for three red chairs, then the company needs to configure a customer order comprised from three sets of red options and three sets of common items.

Knowing that, the company will structure the five pseudo bills into a conference center chair family (Figure 8.8). The purpose is to tie all the option bills to the sales and operations planning process output—that is, to the level where executive management creates the product family plans that includes the conference center chair family.

The chair family's pseudo bill is also known as a *super bill* or the *top-level planning bill.* The master scheduler can take the S&OP output and explode it through the planning bill by time period to determine the expected demand at the master scheduling mix level (the demand for different color options). Demand for the common items is determined at the same time. With that demand determined, a master schedule can be created at the common-items and option levels, and that master schedule data can be passed down to lower levels via material requirements planning logic.

Another way to structure a planning bill is to have the unique items (options) be the components (ingredients) of the common items. This

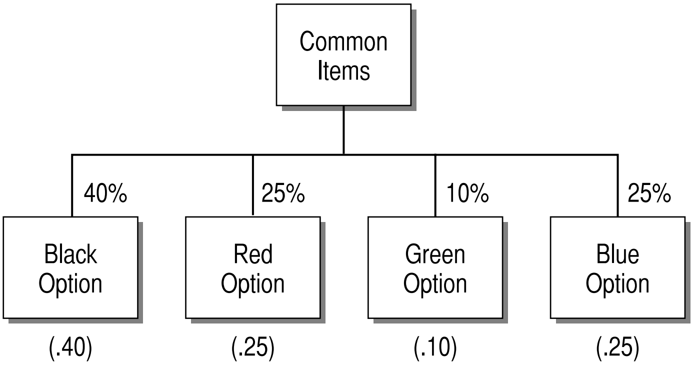

Figure 8.9 Planning Bill with Unique Options Structured into Common Items

structure is displayed in Figure 8.9 since the common items and the product family are the same or a one-for-one relationship exists. (Common items are planned at 100% of the product family.) There is really no need to plan and maintain both. By doing this, the master scheduler (or supply manager) is saved the effort of maintaining master schedules for both the product family and common items. However, structuring the planning bill this way can cause some problems when abnormal demand is introduced into the process (see Chapters 10 and 16).

Deciding how to structure the planning bill in make-to-order or package-to-order environments is a matter of choice. Both techniques work well in environments when abnormal demand is not present. The opposite is true when abnormal demand is present, especially if such demand is significant. An example of abnormal demand is discussed in Chapter 10. For now, we need to understand that there are two structuring methods.

Creating Demand at the Master Schedule Level

The next step is to calculate demand for the various options. Here our novice master scheduler (who has since been educated on make-to-order scheduling techniques and is now a journeyman), must go back to marketing and sales with some questions. But the questions will now be quite different. Instead of asking how many of a particular configuration (such as red, green, blue, or black chairs) will be sold in future periods, the first question is: How many chairs are anticipated to be needed to satisfy anticipated demand in August, *regardless* of color? The answer has been determined in the S&OP meeting. The second question is: What are the probabilities that chair sales will be red, green, blue, or black?

To determine the expected option mix demand, the master scheduler takes the estimate for August chair demand (all color options) and explodes it through the planning bill using the probability percentages to determine the expected demand for each option. Thus, if 1,000 conference center chairs are expected to be needed in August, and if the red option has a 25% probability, then 250 sets of red option items will be required to satisfy the product family's demand plan of 1,000 units. With this information the master scheduler is in a position to put together the master schedule for the common items and the various color options, which is a topic covered in the next chapter.

RESTRUCTURING COMPANY BILLS INTO PLANNING BILLS: A CASE STUDY

Dynoline is a major manufacturer of turbine engines used to drive electrical generators in industry and in smaller public utility plants. The company manufactures a variety of engines, each of which can be ordered with one of three different fuel systems: natural gas, liquid, and dual fuel. Because customer preferences for fuel systems are largely dictated by prevailing market prices for different fuels, Dynoline's marketing department has never been successful in forecasting the fuel options ordered by customers. The result is that the company operates on a strictly make-to-order basis, starting the build process once it has the order with the specifications, including the fuel system specification.

The company maintains three different bills-of-material for the fuel system on each engine. It also has a cumulative lead time of eight months to complete each engine—from start to ship date. Several years ago, faced with a tougher competitive environment, Dynoline sought a competitive edge in time-to-delivery. If it could deliver a complete turbine engine with the specific product features required by the customer in less time than competing producers, Dynoline would win more business. Thus, reducing lead time was a mandated improvement. Further, Dynoline's chief executive officer announced that the goal would be to reduce lead time to the point that the customer could have any of the company's turbine engines within three months of placing an order. The CEO also made it clear that solutions to this time compression challenge would have to be made within four weeks.

Walt Webber was vice president of manufacturing for Dynoline. Over lunch, he and the master scheduler, Virginia Hall, discussed the problem of slicing five months from their lead times. "Marketing and sales would say that the way to handle this would be to build an inventory of engines with each fuel system," Virginia joked.

"Sure," said Walt, "the finance department would love to keep an inventory of a dozen or so $250,000 engines. They could take the carrying costs out of the soft drink machine fund!"

"Or out of your salary, Walt," Virginia quipped. "I suggest that we take a look at our time-phased bills-of-material as a first step. This is probably the best place to start looking for ways to cut lead times. The time-phased bills will show us at a glance the time line for each engine and the cumulative lead times for each component."

Walt agreed, and they went to his office to examine the BOMs. For simplicity, they started with the turbine engine with gas-fuel system, which appears in Figure 8.10.

It was clear from this time-phased bill-of-material that the cumulative lead time—the total elapsed time required to acquire or build the entire gas-fuel engine from start to finish—was eight months. Walt took a pencil and drew a dashed line vertically through the time-phased bill-of-material at month 3. "This is it," he said. "We have to be able to ship product in three months from this point. This shows us what we

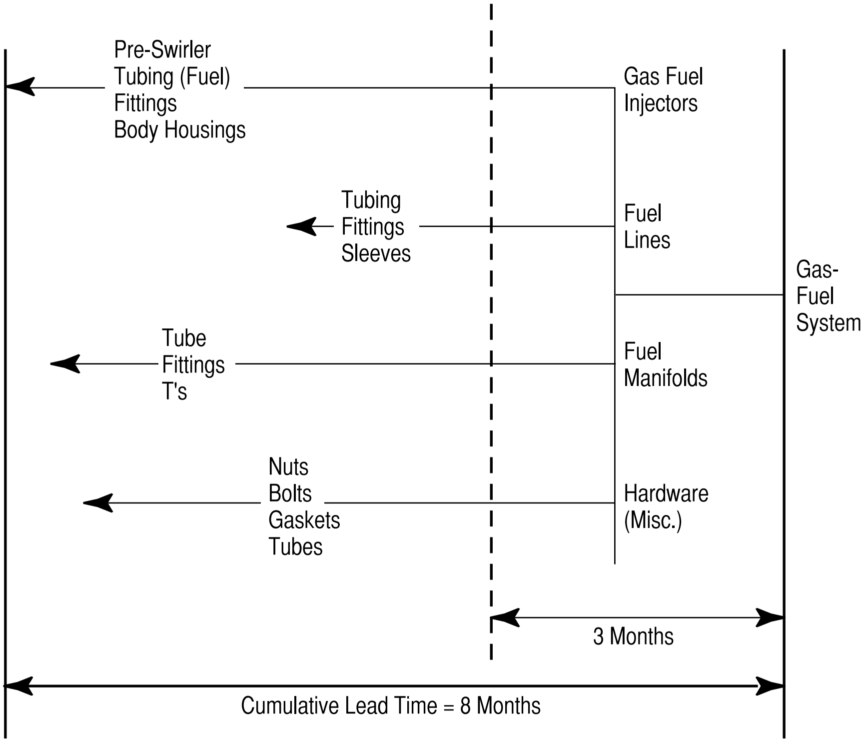

Figure 8.10 Dynoline Gas-Fuel Turbine Engine Time-Phased Bill-of-Material

need in stock in order to compress the lead time by five months. So, how can we restructure our engineering bills into planning bills that will allow us to effectively plan these stocked options?"

Both Virginia and Walt knew that they had various options for reducing the cumulative lead time. The most drastic of these was to redesign Dynoline turbine engines to have fewer parts, simpler assembly procedures, and the like, so that they could be built from start to finish in just three months. This was *design for manufacturability,* a process used by many companies to improve their products and their lead times. In the long run, this was probably the best solution, but not one that could be accomplished within the four weeks mandated by the CEO.

Another option would be to systematically work on process improvements to reduce the build or order times for a variety of operations.

Squeezing these into shorter lead times could reduce the overall lead time for the completed product. But there was another way.

"The most obvious way to reduce our lead time," Walt remarked, "without stocking completely built engines, is to work back through the time-phased bills-of-material from expected ship date to three months before expected ship date. Assuming that we can't compress the lead times for all activities in these three months, we must have everything else in stock and ready to go just as soon as the customer order arrives."

"But will three months give us enough time to handle the fuel-system option?" Virginia asked.

They examined the gas engine BOM carefully and determined that all of the requirements specific to this engine's gas-fuel system were addressed within the final three months of the cumulative lead time. "You see, Virginia, it can be done," Walt responded. "For the gas engine, at least, everything up to three months could be based upon one set of common parts and various stocked options. We could build-to-stock up to that level of uniqueness and commonality, then finish the engine off after the order is received." But would this work for the other engines? The only way to know was to check the BOM for each.

Later that day, Walt assigned the job of examining the BOMs for the liquid-fuel and dual-fuel systems to a staff assistant, who later reported that the requirements for these other systems, like the natural gas–fuel system, could all be handled within the three-month lead time. The assistant also reported that fully 90% of all the fuel-related parts were common.

Sensing that he was near a solution to the CEO's three-month delivery challenge, Walt changed the agenda of that week's upcoming master scheduling meeting from routine items to an initial attempt at restructuring the planning bills for Dynoline's turbine engines. In addition to Virginia and the other production people, Walt invited the sales manager, who understood the typical order patterns for the different fuel-system options.

As the meeting came to order, Walt's assistant rolled in a whiteboard on which a graphic representation of a fuel system, showing its common and unique parts, had already been sketched out (Figure 8.10).

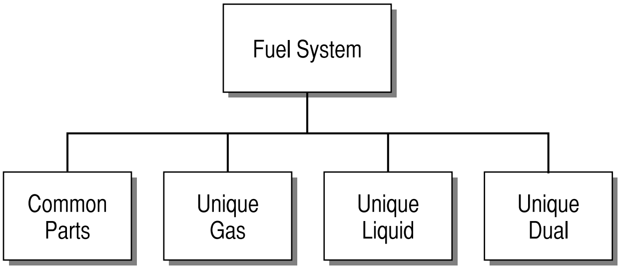

Figure 8.11 Product Family Fuel System

Walt explained to the assembled group that their job that morning would be to attempt to cut the time to delivery by sorting out what was common to each of the three engine fuel systems, what was unique to each, and what had to be stocked if the company had only three months to build the product after receipt of an order.

"Today we are going to examine the bills-of-material for each of our turbine-engine fuel systems," he explained, "and sort out what is common and what is unique up to a point three months prior to the completion time for a turbine engine. We will go through the BOMs for each of the different fuel systems in turn, and Virginia will lead the discussion of the first one."

Virginia Hall walked up to the front of the room and taped five cards to the wall, as shown in Figure 8.11. The words *Fuel System, Common Parts, Unique Gas, Unique Liquid,* and *Unique Dual* were boldly lettered on the cards.

"To get things started, I thought we could *deconstruct* our engine by identifying which of its many parts are common and which are unique. You have the BOMs for the natural gas-, liquid-, and dual-fuel systems in front of you." (Figure 8.12 is a cut-down version of the product.)

"Let me begin by saying that Level 0 is our finished gas-fuel turbine engine. Level 1 represents all of those items that are required to make one Level 0 product, and Level 2 represents all of those items required to make one Level 1 item. Is everyone with me?" All nodded in agreement.

Over the course of the next two hours, Virginia and other attendees of the meeting went through the entire bills-of-material for the fuel

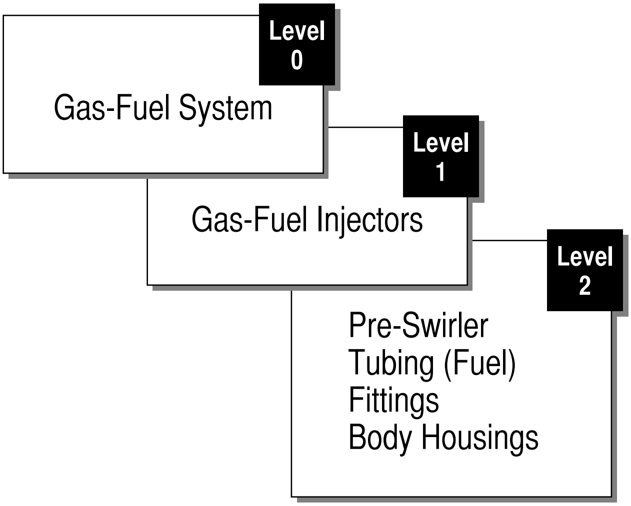

Figure 8.12 Indented Bill for Gas Turbine Engine

systems; each part was identified on a Post-It Note by item number, description, unit of measure, whether it was a make or buy item, and by lead time, and stuck under one of the five cards taped to the wall (Figure 8.11). At the end of the exercise all the required stocked items were identified as common to the fuel system or unique to the gas-, liquid-, or dual-fuel system. As the group sat back to admire its work, the group knew that it had restructured the engineering bills into a planning bill. By using this planning bill to plan materials and resources, a customer requirement could be met in the three-month time frame as long as the execution of the plan took place.

"Okay," Walt said, "is this it? Do we have our new planning bill?" The group nodded its approval. "Virginia, you will be responsible for putting the planning bill into the computer system. In order to do this, you need to know what to put into the quantity field for each component."

Walt looked over at the sales manager. "Here's where you come in, Al. We need to know the probabilities of the gas, liquid, and dual systems to be ordered. We will take your probabilities, convert them to decimals [50% = .5], and enter the results into the quantity field on the planning bill. By doing this we will be able to take the output of the sales and operations planning process and determine the expected option requirements. Of course, the common parts are always required and will carry one hundred percent probability [or a quantity of 1.0]. Can you get us those numbers?"

The sales manager indicated that he had done his homework and knew the probabilities. He told the group that he used a combination of order history and future-order forecasts. The numbers were given to Virginia so that she could create the planning bills as directed.

The last thing the group did was to identify who in the organization was going to be responsible for the planning bill database. It was decided that the master scheduler would be responsible and accountable for the planning bill structure (ensuring compatibility with engineering design and proper maintenance of the planning bill), and sales and marketing would be responsible and accountable for the quantities that contained the probability numbers. At this time, the members of the group patted one another on the back and exchanged compliments on a job well done.

In complex environments that deploy make-to-order strategies, the creation and use of planning bills is an effective way to plan and control materials and capacities. Once the planning bills are in place, the master scheduling system can use the structures and probabilities to generate option forecasts for each master scheduled item called out. This logic, plus the actual creation of the master schedule, is the topic covered in the next chapter.

9

Two-Level MPS and Other Advanced Techniques

Without data, you are just another person with an opinion.

The previous chapter introduced the conference center chair product family of the Soft Seat Corporation, posing a key question: For every chair sold, how many are anticipated to be sold with the black option? Red option? Black-and-red option? The answers to these questions are necessary to complete the forecasting process, which in turn is essential to creating a master schedule. Before continuing our discussion of master scheduling (MPS) and the forecasting process, another component of the master scheduling process must be examined—the *backlog* or *order book curve.*

The Backlog Curve

Backlog is defined as orders booked but not shipped. This definition does not say that the orders are past due, in which case they are referred to as *back orders;* many, and sometimes all, orders in the backlog curve—or *order book*—are *expected* to ship in the future. The backlog curve is a profile of those booked-but-not-shipped orders in the framework of the company's planning forecast. Virtually all make-to-order (MTO) and engineer-to-order (ETO) companies have backlogs, and each must understand the nature and shape of that backlog in scheduling current and future production.

Figure 9.1 is a conceptualized view of the backlog profile. In the earliest periods of the planning horizon (the leftmost extreme) the demand pipeline is filled with booked but unshipped orders. These may be orders where production has yet to begin work, others in some stage of work-in-process, and still others ready to be crated for shipment. The opposite extreme (the rightmost portion of the planning horizon) contains no backlog; the only demand here is forecasted orders. Between these two extremes are a number of planning periods containing both booked and forecasted orders.

Master schedulers segment the backlog curve into zones that define the status of orders in each. These are the "sold-out zone," in which all expected demand is backed by an actual order; a "partially sold-out

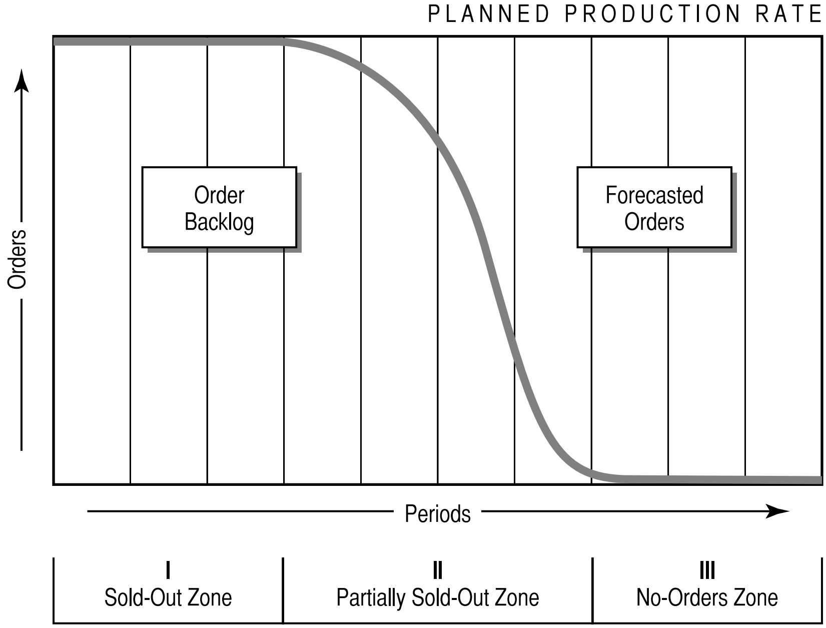

Figure 9.1 The Backlog Curve by Product Family

zone," in which some of the demand is supported by actual orders and the remainder is supported strictly by a forecast; and a "no-orders zone," which extends beyond the backlog, in which all production, material planning, and capacity planning are geared to forecasted sales (whereas in the first two zones some or all production, material planning, and capacity planning are geared toward satisfying real customer or stocked orders).

To understand how the master scheduler deals with the backlog curve, we return to the Soft Seat Corporation where, following the S&OP monthly meeting, executive management has approved product demand or a production rate (assuming a make-to-order product) of 40 (could be 4,000 or 40,000) conference center chairs per month. (Remember that since this is a make-to-order example, deliveries are promised into the future after the order is booked.) Figure 9.2 shows a two-month demand or production rate of 40 units per month (assumes four periods in each month), and these have been broken down into 20 units in every other period.

Thus, product demand and the production rate are set at 20 in periods 2, 4, 6, and 8, for a total of 80 for the two-month or eight-week horizon. The demand rate is the same as the production rate, because Soft Seat operates in a make-to-order environment—that is, the production rate equals the expected shipment rate, which is keyed to the customers' expected product receipt minus transportation time.

It is easy to see from Figure 9.2 that Soft Seat's backlog curve has the three zones just mentioned. In period 2 it has customer orders equaling its current production rate of 20 chairs every two periods. This, then, is a sold-out zone in which there are 0 chairs available-

	Past Due	1	2	3	4	5	6	7	8
Production Rate			20		20		20		20
Actual Demand			20		16		8		0
Available-to-Promise (ATP)		0	0 0	0	4 4	4	12 16	16	20 36

Figure 9.2 Backlog for the Conference Center Chair Product Family

to-sell or available-to-promise (ATP). However, period 4 contains only 16 customer orders that have consumed the 20 units scheduled for production, leaving 4 available-to-promise to any customer who happens to call. Available-to-promise increases to 12 in period 6 and to 20 in period 8 as fewer orders are booked relative to the planned production rate. Notice that in the ATP line the top set of numbers is the number available-to-promise for that particular period (as in period 6 where 20 are expected to be produced less 8 units of actual demand leaving 12 ATP). The bottom set of numbers is *cumulative* ATP—that is, the total number of ATP units , which is the ATP in that period *plus* all the previous ATP quantities, which are units still unsold.

Figure 9.3 shows the current backlog curve for the Soft Seat chair product and the position of its various zones. Periods 1 through 3 are sold out; periods 4 through 7 are partially sold out; and period 8 is in the zone containing no customer orders. The shape of the curve and duration of the zones will differ for each company and industry. In an engineer-to-order company, we would expect the sold-out zone to be

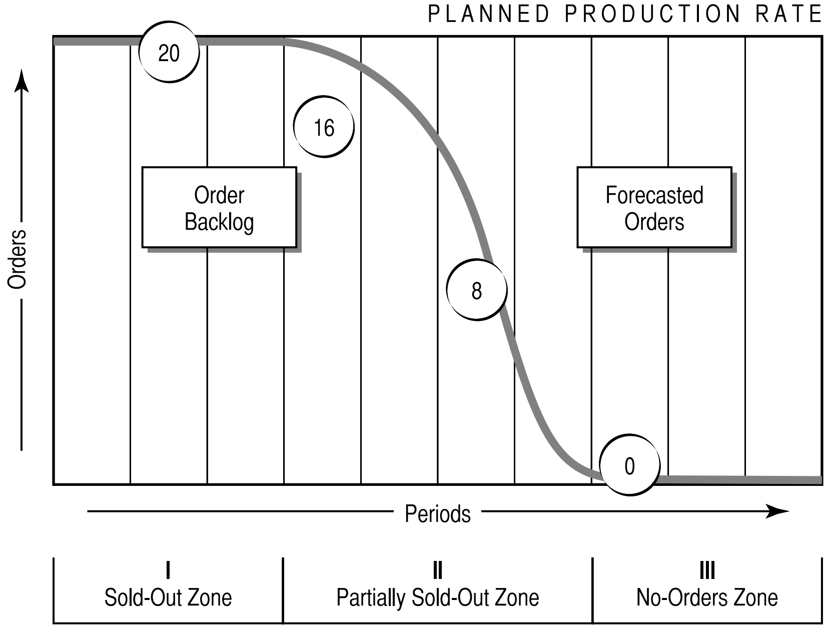

Figure 9.3 Soft Seat Backlog Curve

Scheduling and the Backlog Curve Zones

From the perspective of master scheduling in the finish-to-order, assemble-to-order, and make-to-order environments, the sold-out zone is relatively easy to deal with—the customer requirements and the specifications for each in the form of customer orders are already in hand. Therefore, in the sold out zone, the master schedule (supply) for any pseudo items (see Chapter 8) should be made to equal the customer orders (demand). No forecasting is required. Furthermore, the no-orders zone is likewise easy for the master scheduler to plan out. With no customer orders in hand, sales and marketing plans provide the guidance. And barring products with short lead times, time is on the side of the master scheduler; one would expect the accuracy of the anticipated demand to improve as time passes and forecasted sales are turned into customer orders.

It is generally the middle area—the partially sold-out zone—that can give master schedulers fits. Here, time is slipping away, and there is still forecasted order demand for which neither quantities nor configuration specifications have been established. As discussion of the configure-to-order environment continues, keep this thought in mind.

quite lengthy, stretching far out into the future. For a company that is strictly make-to-stock, the sold-out zone may be very short.

Identifying Demand

Since the demand and production rates for product families over the planning horizon have been determined during the S&OP process, the next step is to determine the demand for each master scheduled item—for example, the demand for every item that goes into the conference center chair family. This is done by taking the S&OP output and converting it into discrete item numbers, quantities, and due dates.

In the previous chapter we created a series of planning bills that identified common items along with the red, blue, green, and black options. In order to simplify the example, this chapter will deal with only two options, red and black, each of which has a 50% probability. For the sake of discussion, sales and marketing have pulled the green, blue, and mixed options from the company's offerings. The focus in this section will be on the red option, which contains a red seat assembly and a red back splat assembly. The red option bill has already been described as a pseudo in that manufacturing cannot create a finished chair from a red seat assembly and back splat assembly; only when these are united with a set of common items does a red chair become a real, shippable product. But remember, even though true pseudos cannot be built, they can be master scheduled.

Figure 9.4 on page 246 presents the MPS matrix for the red option components. Note the forecast line. If the red option was a real item (remember, it's a pseudo or artificial item) and if there was any independent demand, it would show up on this line. But since this item has been identified as a pseudo (which means it can't be built), there is no service demand in our example. If, for some reason, the seat and back are sold as a kit, independent demand could then appear.

The Actual Demand Line

When the planning bill for the conference center chair family in this chapter was set up, the red option was given a probability of 50%—that is, if 20 units were sold and committed, Soft Seat expects 10 to be sold as red chairs. So when the 20 units were sold for delivery in period 2 plus final configuration lead times, the company would have expected 10 to be red. However, in the case of period 2, 12 of the 20 units of *actual* demand for the chair family (Figure 9.4) turn out to be red chairs requiring the red option (example displays when option items are required to be delivered to the finishing or final configura-

	Past Due	1	2	3	4	5	6	7	8
Item Forecast		0	0	0	0	0	0	0	0
Option Forecast			0		2		6		10
Actual Demand			12		7		5		0
Total Demand			12		9		11		10
Projected Available Balance	0	0	0	0	2	2	2	2	2
Available-to-Promise		0	0 0	0	4 4	4	6 10	10	10 20
Master Schedule			12		11		11		10

Figure 9.4 MPS Matrix, Red Option Items (50 percent probability)

tion line). In period 4, a total of 16 chairs were sold. Here, Soft Seat would have expected 8 to be red, but out of the 16 sold, only 7 were red units. While the predicted sales were wrong, they were nevertheless close; many companies, in fact, would be glad to come this close to the product mix forecast. In period 6, 8 conference center chairs were sold, of which 5 were red, as shown in the actual demand line in period 6 of Figure 9.4. Again, the actual demand did not match the expected demand, but the forecaster was not far from the mark. Since no orders are committed for period 8, the actual demand for the red option in period 8 is zero.

The Option Forecast Line

Now that the master scheduler knows the expected service demand (zero has been forecasted in this example) and the actual demand supported by real customer orders, the piece of the total demand picture that remains unknown is the option forecast—how many red chair orders are still anticipated to be received over the eight-period horizon in the example. To answer this question we need to revisit the backlog curve and the conference center chair product family data contained in Figure 9.2 (see p. 242).

The Sold-Out Zone

The data in the matrix tells the master scheduler a good deal. Period 2 is in the sold-out zone. The master scheduler knows that 12 red options are required in this period (see actual demand line, period 2, Figure 9.4). The master scheduler also knows that no red options are required in period 2 to support expected service demand (see item forecast line, period 2, Figure 9.4). So the only open question is: How many additional red options will be required in period 2 to support any additional expected sales? The answer is straightforward: zero! Since period 2 is in the sold-out zone, the master scheduler should not expect sales to book any more orders requiring a period 2 delivery. Now, can you imagine telling sales that they cannot commit any deliveries until period 4 (the first period in which product is available-to-promise)? But that's exactly what must be done—to a point.

This is a very key point in our discussion of two-level master scheduling. When executive management determines a production rate in the make-to-order environment, it is in a sense communicating to the master scheduler how many sets of common items will be required, since there is a one-for-one relationship between a product family and common items. If the production rate for the conference center chair family is 20 in period 2 and all 20 have customer orders attached, there are no more common items available in period 2 to satisfy additional orders. Therefore, any booked order that promises a period 2 delivery may be a bad promise unless something can be done to reschedule the booked demand or to change the master schedule at this late date.

Upon hearing that the company cannot take any more orders for delivery in period 2 over the 20 authorized, sales may suggest that the master scheduler get 22 or 24 sets of common items—a few extra just in case. If sales wants more than 20, however, it must either get the participants in the sales and operations planning (S&OP) process to agree upon a demand rate that translates into a higher production rate, or else have them authorize the extra sets of common items.

The master scheduler will then make preparations to have those extra sets of common items ready to satisfy customer demand as booked by sales. However, if you think about it, there is little value in the master scheduler hedging any bets or second-guessing the need for common items. Common items are not the planning problem in this environment; the planning problem is the unique items (red and black option items).

A company need not put an absolute freeze on orders. It may be good business sense to take and commit to a delivery inside the sold-out zone. However, there are no "free lunches" here, and sales must be asked, and must answer to, which currently booked order or orders scheduled for period 2 delivery are to be shipped later. The answer to this question establishes order priorities and tells the master scheduler how to reschedule delivery dates.

At this point the master scheduler knows that the expected demand for the option in question is the sum of the top three lines in the MPS matrix—the item forecast (independent demand), the option forecast (dependent demand), and actual demand (customer orders). Thus, in period 2, the total demand is 12 red options, since there is no service demand, no option forecast, and 12 committed to customers.

The Partially Sold-Out Zone

In the partially sold-out zone, total expected demand is not so easily identified. Here, some orders are in hand and others are anticipated by the forecast. The item forecast line states that no service demand is expected, while the actual demand is for seven red options in period 4 and five red options in period 6 (obtained through an order-entry process). The remaining question is: How many additional red options should be forecasted to satisfy anticipated demand in period 4 and period 6?

Here the master scheduler is faced with a range of alternatives. Period 4 is analyzed first:

1. *No chairs requiring the red option.* Even though red is a 50% option, the four chairs remaining to be sold in period 4 may not be red.

Perhaps red has simply gone out of fashion. Or a sales representative has just landed an order for four black conference center chairs and committed them to a period 4 delivery. The right answer in this case is zero.

2. *One chair requiring the red option.* Sales of 40 conference center chairs are anticipated for each month (periods 1 through 4 and periods 5 through 8), with a probability of 50% (20) being red. Actual demand for red chairs during the first month (periods 1 through 4) indicates that 19 red chairs have been sold to date and scheduled for delivery (12 in period 2 and 7 in period 4). Therefore, current sales information combined with historical knowledge make it plausible that only 1 more red chair will be sold and scheduled for delivery during the month. This logic assumes that the events that have already occurred in the month will have impact on events yet to occur. In other words, over a month, the predicted sale of chairs will equal the probability chosen (50%).

3. *Two chairs requiring the red option.* A case can also be made that two of the four chairs (50% probability) still left to promise in period 4 will be red. The ATP in period 4 at the conference center chair level is four units. The important point here is that the master scheduler has four sets of common items available-to-promise in that period. To build a chair, the company needs a set of common items as well as the black or red option items. Therefore, we expect a demand for only four more chairs in period 4.

If the red option has a 50% probability, the option forecast for that red option in period 4 is two. This case proceeds from the notion that the probabilities for chair sales in periods 1, 2, and 3 are *independent* of the probabilities for chair sales in subsequent periods—just as the probability of a coin turning up heads is 50%, even though previous coin flips may have been all heads or all tails.

4. *Three chairs requiring the red option.* According to the established demand and production rate for the conference center chair family, 20 chairs are anticipated to be promised for delivery in period 4. Since the red option is a 50% option, we might have expected that

10 promised chairs for the period (50% of the aggregate 20) would require the red option. A review of the actual demand in period 4 for the red option shows that 7 chairs have already been committed, leaving 3 out of the next 4 to require this option. This logic assumes that the previous events in the order placing cycle affect future events.

5. *Four chairs requiring the red option.* Even though red is a 50% option, the 4 chairs remaining to be sold in period 4 may be all red. Perhaps red is a hot color. Or a sales representative just landed an order for 4 red conference center chairs and committed them to a period 4 delivery. The right answer in this case is 4.

Master scheduling systems generally support one, two or three of the types of logic represented above—specifically, option forecasts in examples 2, 3, and 4. In example 2, the master scheduling system takes the aggregate production rate for an MTO product or demand rate for an MTS product for a group of periods and explodes it through the planning bill; it then subtracts the actual demand for those periods to determine the option forecast. In example 3, the master scheduling system takes the available-to-promise value and explodes it through the planning bill, multiplying ATP by the probability associated with the option in question. In example 4, the master scheduling system takes the planned production (MTO) or demand (MTS) rate for the period and explodes it through the planning bill; it then subtracts the actual demand for that period to determine the option forecast.

The ATP approach is probably the most commonly used, and for that reason it is the basis for the examples used in this book. Applying this logic, the forecast in period 4 for the red option is identified as 2. With this information, the master scheduler knows that 9 is the total expected demand for the red option in period 4—2 to support the option forecast and 7 to support actual demand.

Continuing use of the ATP explosion logic, look at period 6, where 12 more conference center chairs are available-to-promise. If that ATP is exploded through the planning bill, a demand for 6 red options are identified in period 6. The same logic can be applied in period

8, where 20 conference center chairs are available-to-promise. Exploding that quantity through the planning bill results in a red option forecast of 10.

Regardless of the method chosen, the reader should check the company's software to determine alternatives. The total demand for each of the master scheduled options must be determined before a master schedule that satisfies demand and stays within production plan constraints can be created.

Creating the Master Schedule in a Make-to-Order Environment

A make-to-order product is one finished *after* receipt of a customer order. Frequently, long lead-time components are planned prior to receipt of an order as a means of reducing delivery time to the customer. In cases in which options or other intermediates are stocked prior to order receipt, the terms *assemble-to-order* and *finish-to-order* are commonly used.

The master scheduler working in this environment needs to understand the shape of the company's backlog curve and which periods are sold out, partially sold out, or void of booked orders. The following sections analyze each of these zones in terms of the conference center chair used in this chapter.

The Sold-Out Zone

The first demand appears in period 2—when 12 red options are expected to be delivered to the finishing process (refer to Figure 9.4 on p. 246). Here emerges the question: How many red options should be currently scheduled to be available in period 2? This question suggests three others:

1. What is the very *least* that should be scheduled?
2. What is the very *most* that should be scheduled?
3. What number will *most likely* satisfy demand?

The answer to the first question (the least) for period 2 is 12 because 12 customer orders are already booked and promised. If less than 12 are scheduled, a risk of missing a customer promise in period 2 is not only possible, but probable.

The answer to the next question—the *most* that should be scheduled—is, again, 12. This is the sold-out zone, and there are no more common items to promise. The reason the ATP at the conference center chair product family level is zero is that all 20 sets of common items are committed—12 to red chairs and the other 8 to black chairs. "Theoretically that's fine," a master scheduler might argue, "but if sales has an opportunity to sell an additional conference center chair and commit it for delivery in period 2, can I really tell them not to take the order? After all, we're not in the business of turning away orders." No one wants to lose orders but consider the risk of committing it for delivery in period 2. Based on the S&OP process, executive management has agreed that 20 conference center chairs should be promised for delivery in period 2. This decision has been made in consideration of capacities, materials, capital, marketplace presence, quality, and competition. Therefore, the master scheduler has planned to have 20 sets of common items. Since every chair needs a set of common items, to sell more chairs than there are common items is to make a bad promise. The sales force could, however, book and commit an additional order in the sold-out zone and shift a set of common items from, say, a customer who ordered a black chair to a customer who ordered a red chair. Or sales could request the shifting of the common items from one order to another, both for the same color option. In either case, the items in the options must be available before the shift can take place. But the fact that such a manipulation is possible is no basis for scheduling more than the anticipated volume of conference center chairs.

Now consider the converse situation—sales books only 18 orders, 2 *less* than the expected demand. Since a complete chair cannot be made from the 2 sets of uncommitted common items, the master scheduler must either reschedule them out into the future, move something up earlier, produce something to stock, or place the individual completed common items into inventory.

Finally, the third question—the number *most likely* to satisfy demand. Answer: the aggregate of the three demands. Figure 9.4 on page 246 indicates an item forecast of zero, an option forecast of zero, and an actual demand of 12; the most likely demand is 12, and we should expect that 12 would be scheduled for receipt in period 2. Thus, an important rule in the make-to-order environment: For a *pseudo item,* the master schedule should equal the actual demand for all periods in the sold-out zone. This rule makes master scheduling in the sold-out zone relatively easy compared to the partially sold-out zone, the next subject for discussion.

The Partially Sold-Out Zone

In the conference center chair example, the partially sold-out zone lies somewhere between periods 3 and 7 (refer to Figure 9.4 on p. 246). Here, four chairs remain available-to-promise in period 4, the first period in the partially sold-out zone. As a first step in determining how many to master schedule, again ask the three questions: What is the *least* that should be scheduled? What is the *most*? What number will *most likely* satisfy demand in the period?

The actual demand line for period 4 indicates that 7 red options are committed to customer orders, so the *very least* that should be scheduled is 7—enough to satisfy real customer demand. That covers the red chairs already sold, but how many more chairs requiring the red option could possibly be promised in this period? The answer is 4 because, even though half of the remaining 4 required conference center chairs are predicted to be red, it is possible that *all* could be sold as red chairs. Therefore, the *most* that should be master scheduled in period 4 is 11 (the 7 already promised to customer orders and the 4 that *could* be so promised).

Finally, what is the *most likely* number of red options that could be scheduled to satisfy expected demand in period 4? Answer: 9. This is determined as follows:

1. There is zero service demand.
2. Four more sets of common items are available-to-promise; half of these are expected to go with the red option. Therefore 2 of the 4 expected demand should be red.
3. Seven orders for red chairs are already in hand and require the red option.
4. The most likely total demand is 9 (0 + 2 + 7).

Moving on to period 6, ask the three questions again. The answers are as follows: The least that should be scheduled would be 5—the actual demand; the most that should be scheduled is the 5 that are committed plus the conference center chair ATP of 12, or 17; and the most likely number to satisfy demand is the sum of the three demand lines, or 11 (0 + 6 + 5). So the range for period 6 is between 5 and 17, with 11 the most likely (refer to Figure 9.4 on p. 246).

The No-Orders Zone

The no-orders, or forecast, zone is by definition one in which (theoretically) no product configurations have been ordered and committed. With no orders in hand, and with the forecast as a sole guide, the master scheduler must nevertheless plan and schedule material and capacity; and again, the three questions offer guidance. The period in question is period 8.

The *least* that could be scheduled is zero, since no actual demand exists. The *most* that should be scheduled is 20 (0 actual demand plus the 20 ATP from the product family). Here, the assumption is that every one of the conference center chair sales forecasted for delivery in period 8 would require the red option.

What about the *most likely* scenario for the red option? Here again, the answer is the sum of the three demand streams: the service demand of zero, the actual demand of zero, and the option forecast of 10. Thus, 10 is the *most likely* value. This scenario assumes 50% of the chairs sold requiring a period 8 delivery will have the red option.

So what should the master schedule for the red option be for periods 2, 4, 6, and 8?

- Period 2. It should have 12 red options scheduled for receipt—no more, no less. For a pseudo item like the red option, the master schedule should equal the actual demand in the sold-out zone.

- Period 4. We have already determined that in period 4 the *least* was 7, the *most* was 11, and the *most likely* was 9. We know the master schedule in period 4 should be somewhere between 7 and 11. Hold that thought for now, as the next section on overplanning will shed more light on what should be scheduled in this period.

- Period 6. This is similar to period 4 in that it is in the partially sold-out zone. For now, let's say the master schedule should have 11 in period 6—the most likely expected demand.

- Period 8. The master scheduler should adopt the *most likely* expected demand and schedule 10 units in this period.

Option Overplanning

As has been stressed so far, the more difficult issue is not coming up with a forecast for common items, but with the forecast for the right mix of unique option-related items. The question always remains: What are the chances that the actual sales will come in right on the forecast? Since the answer is invariably "not very high," it may be necessary to protect the company and its ability to satisfy customer demand from possible forecast error.

One way to protect against forecast error is to provide safety stock for the items required to build a conference center chair. This could be expensive, and if the safety stock carried is forecasted wrong the company may pay for the error at least four times:

- In stocking items not required by actual booked customer orders
- In lost sales because the wrong items were stocked and the company lacked the complete sets of items to build entire products for shipment
- In stocked items being broken, lost, stolen, or otherwise unavailable (i.e., shelf life expires) when needed
- In overstocking items that are common to each product sold and thereby not needing forecast error protection

Alternately, a company could safety stock finished products to cover their bases. But that would be both impractical and expensive in terms of inventory, space, production, obsolescence risk, and so on.[1]

A much better approach to protecting the plan from forecast error is *option overplanning*, a technique that entails increasing the master schedule for unique options in the partially sold-out zone to provide protection against demand variation. To understand option overplanning, ask this question: When a customer places an order, when does he or she usually want delivery? In most cases, the answer is "yesterday," "as soon as possible," or "right now!"

Look again at the backlog curve for Soft Seat shown in Figure 9.3 on page 243. If a new customer order appears now, the earliest that delivery can be promised (if other orders and the master schedule are not manipulated) is the first period of the partially sold-out zone. This makes sense, since all production capacity and material in the sold-out zone are already committed to customer orders.

In the Soft Seat example, the first unsold period is period 4, and that is where protection should be applied (refer to Figure 9.4 on p. 246). But what should be protected? Earlier discussion suggests that no protection for common items is needed since a one-for-one relationship exists within the product family. If four conference center chairs

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[1] One wonders how often manufacturers have disassembled or torn down finished stock to retrieve common items needed for the product configurations the customers actually wanted.

remain available-to-promise, then four sets of common items should be available, since the master schedule for common items is set up to match expected demand. Again, the problem surfaces with respect to the *unique* items, the color options in our example.

From earlier discussion we know that the least number of red chairs that should be scheduled for period 4 is 7, the most is 11, and the most likely is 9. To provide 100% forecast-error protection to the first unsold period (period 4 in the example) we would schedule to match the *most* demand that could be received. In the case of the red option, that is 11. Thus, there would be adequate supply of red options to cover demand even if the forecast were 100% wrong.

Just exactly what does option overplanning buy a company?

- Option overplanning provides protection against demand variation in the first unsold period. It is in this period that the customer usually wants delivery.

- Option overplanning drives the material requirements planning system. Material requirements planning, in turn, tells planners and schedulers what must be done to satisfy the master schedule in *matched* sets of parts, ensuring that master scheduled items can be produced as promised.

- Option overplanning creates inventory *only* for material with a lead time greater than the backlog horizon. The benefit, of course, is the reduction of unneeded inventory (a company does not need safety inventory across the sold-out zone—the customer has told the company what he or she wants).

Although overplanning is a powerful technique, it potentially creates inventory and must be used with caution; it must be managed in terms of quantities and dates. Overplanning also tends to move around, as we will observe in the next chapter. It must be managed and scheduled properly, usually in the first unsold period of the partially sold-out zone. Let's say it again: There is no reason to have any material protection or option overplanning in the sold-out zone.

Likewise, it probably is not a good use of funds to provide material protection in the no-orders zone. A well-informed master scheduler will keep the option of overplanning somewhere in the partially sold-out zone.

Calculating Projected Available Balance

Once the master schedule is created, the computer system will calculate the projected available balance (PAB). As shown in Figure 9.4 on page 246, there is a starting PAB of zero—not surprising, since the red option is a pseudo and, thus, cannot be built. Nor should it be surprising to see that PAB remains zero through period 3 since this is a pseudo item. In creating the master schedule for these periods we said that the master schedule line must balance with the actual demand line. This done, the PAB will be zero.

In period 1 there is no activity, and in period 2 there are 12 units master scheduled against an equal total demand. Period 3 is zero because there is no additional activity. Calculating period 4, zero units are projected to be available at the end of period 3; these are added to the 11 master scheduled (expected receipts) resulting in a total supply of 11 against a total anticipated demand of 9. The difference of 2 represents the option overplanned quantity.

The projected available balance remains 2 in period 5, since there is no activity. In period 6, there are the 2 from period 5's PAB plus the 11 from the MPS line, minus total demand of 11, which again leaves 2. The same logic applies to periods 7 and 8.[2]

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[2] Note: Option overplanning is generally done in the first unsold period, although for various reasons (e.g., budget) the master scheduler may wish to spread the overplanning over the first few periods in the partially sold-out zone for forecast-inaccuracy protection. For example, since period 6 is still in the partially sold-out zone, the master scheduler could overplan and schedule up to a total of 17 units, the most red options that could be required to service customer needs in that period.

Calculating Available-to-Promise

In calculating the available-to-promise (ATP) quantity for the red option, we work backward from period 8 (Figure 9.4). The first step is to take what is master scheduled and subtract the commitments (orders booked but not yet shipped).

The idea of ATP is to protect the company's promises to customers. A forecast is not a commitment, but rather a prediction or request for product; thus, forecasts are generally ignored in the ATP calculation. Working right to left starting in period 8, 10 red options are master scheduled, and 0 are committed (see the actual demand line for period 8), so the ATP is 10—a noncumulative value.

For period 6, 11 red options are master scheduled, and the actual demand is 5, leaving 6 available-to-promise in that period (noncumulative) to any incoming new orders. In period 4, the 11 master scheduled units have commitments against them of 7, resulting in 4 available-to-promise. For period 2, 12 units are master scheduled and 12 are committed, leaving an ATP of zero.

These ATP values are noncumulative. To calculate a cumulative value or carry over the values, simply add the ATP from each period working left to right. Why is this important? What if a customer calls and asks, "How many red chairs can you give us by period 8?" The

As stated earlier, a pseudo cannot be built, but it can be master scheduled. And if a pseudo can be scheduled, it is possible that the projected available balance could be calculated to be a positive number. If this is so, as Figure 9.4 period 4 indicates, the system is telling us how much overplanning the master scheduler is doing. In this instance there are 2 extra sets of the items that make up the red option pseudo.

answer is 20, assuming the 20 sets of common items needed are also available (see ATP, period 8, cumulative value, Figure 9.4).

At this point, you would have a complete master schedule, not only for the red option but for the common items and the other colors as well (see Figure 9.5 on pp. 262–263); for simplicity the only other color option in the discussion is black. The next step in understanding the process is to actually commit an order using ATP.

Using ATP to Commit Customer Orders

In the next example, the customer has requested 10 conference center chairs to be delivered in period 6: Of these, 9 are to be red and 1 black. Can this order be accepted? Use Figure 9.5 on the following pages to answer this question. Period 6 in the ATP line for the common parts indicates that 12 sets of common items are available-to-promise. In fact, a total of 16 sets of common items are available-to-promise, as shown on the cumulative ATP line. The cumulative ATP in period 6 of the red option schedule indicates that 10 sets of red option items are available-to-sell. And 10 sets of black option items are available through period 6, as the master schedule for that option makes clear. Thus, customer order entry, demand management, and the master scheduler know that the order *can* be taken.

Committing to customer orders always requires that two questions be asked. First, can the order be taken? Available-to-promise provides the answer. Second, do we want to take the order and commit to its delivery requirements? In other words, in this example is the company willing to sell 10 conference center chairs here and have only 6 left to sell for the next six periods, of which only 1 can be red? This second question requires a management decision. If both questions are answered in the affirmative, the next step is to book the order.

First, look at period 6, the actual demand line, in the conference center chair family schedule (top of Figure 9.5). Currently it is 8, but with the new order of 10 it will become 18 (see Figure 9.6 on pp. 264–265). The ATP of 12 will be reduced by 10, leaving an ATP of 2 for the same period and 6 cumulative. The same process is true for the common items. Now, dropping down to the red option schedule for this same period, the actual demand of 5 in period 6 will increase by 9, to 14. The black option's actual demand in period 6 will increase by 1, to 4. The master scheduling system then recalculates the option forecast; it takes the ATP for the chair family, 2 in this case, and explodes it through the planning bill, applying the probability of 50%, leaving an option forecast of 1 for both red and black options. What we have just seen is the system automatically consuming the forecast at the option level. It's important to note that not only does the master scheduling system consume the forecast for products and options sold, it also consumes the forecast for products and options not being sold. This is the only logic and consumption logic known to the author that does this—forecast consumption logic generally only consumes what's sold, not what's not sold.

Total demand for the red option increases to 15 in period 6, which is the total of zero service forecast, an option forecast of 1, and 14 actual demand. The black option's total demand in period 6 is 5. To recalculate the red option ATP, we note that 9 additional red options have been booked, resulting in a total committed demand of 14 for that period (5 + 9). Since 11 units are master scheduled in period 6 and 14 have been committed, the resulting ATP is −3. Since an ATP of −3 does not make much sense for the red option, the ATP in period 6 will become zero (the total master schedule in period 6 is consumed). To protect the entire commitment of the 9 additional units, the master scheduler (really the master scheduling software) must cover 3 more units of demand (the negative 3). The MPS line shows an MPS lot of 10 in period 8, but these units will be too late to commit to period 6. Working back in time, the master scheduler finds 4 available-to-promise in period 4. By using 3 of these units for period 6 coverage and taking them out of ATP, 1 red option set would remain available-to-promise in period 4. By working back into time, from period 6 to period 4, a master scheduler can use ATP to protect customer promises without committing current inventory any earlier than necessary. To complete the

Conference Center Chair Product Family

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		4		12		20	36
Option Forecast			0		0		0		0	0
Actual Demand			20		16		8		0	44
Total Demand			20		20		20		20	80
Projected Available Balance	0	0	0	0	0	0	0	0	0	0
Available-to-Promise		0	0 0	0	4 4	4	12 16	16	20 36	36
Master Schedule			20		20		20		20	80

Common Items (100 percent probability)

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		0		0		0	0
Option Forecast			0		4		12		20	36
Actual Demand			20		16		8		0	44
Total Demand			20		20		20		20	80
Projected Available Balance	0	0	0	0	0	0	0	0	0	0
Available-to-Promise		0	0 0	0	4 4	4	12 16	16	20 36	36
Master Schedule			20		20		20		20	80

Figure 9.5 Complete Master Schedule for Chair Family, Common Items, and Options

Red Option (50 percent probability)

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		0		0		0	0
Option Forecast			0		2		6		10	18
Actual Demand			12		7		5		0	24
Total Demand			12		9		11		10	42
Projected Available Balance	0	0	0	0	2	2	2	2	2	2
Available-to-Promise		0	0 0	0	4 4	4	6 10	10	10 20	20
Master Schedule			12		11		11		10	44

Black Option (50 percent probability)

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		0		0		0	0
Option Forecast			0		2		6		10	18
Actual Demand			8		9		3		0	20
Total Demand			8		11		9		10	38
Projected Available Balance	0	0	0	0	1	1	2	2	2	2
Available-to-Promise		0	0 0	0	3 3	3	7 10	10	10 20	20
Master Schedule			8		12		10		10	40

Figure 9.5 ***Continued***

Conference Center Chair Product Family

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		4		2		20	26
Option Forecast			0		0		0		0	0
Actual Demand			20		16		18		0	54
Total Demand			20		20		20		20	80
Projected Available Balance	0	0	0	0	0	0	0	0	0	0
Available-to-Promise		0	0 0	0	4 4	4	2 6	6	20 26	26
Master Schedule			20		20		20		20	80

Common Items (100 percent probability)

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		0		0		0	0
Option Forecast			0		4		2		20	26
Actual Demand			20		16		18		0	54
Total Demand			20		20		20		20	80
Projected Available Balance	0	0	0	0	0	0	0	0	0	0
Available-to-Promise		0	0 0	0	4 4	4	2 6	6	20 26	26
Master Schedule			20		20		20		20	80

Figure 9.6 Complete Master Schedule for Chair Family, Common Items, and Options After Booking Order for 10 Chairs—9 Red and 1 Black

Red Option (50 percent probability)

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		0		0		0	0
Option Forecast			0		2		1		10	13
Actual Demand			12		7		14		0	33
Total Demand			12		9		15		10	46
Projected Available Balance	0	0	0	0	2	2	–2	–2	–2	–2
Available-to-Promise		0	0 0	0	1 1	1	0 1	1	10 11	11
Master Schedule			12		11		11		10	44

Black Option (50 percent probability)

MPS MATRIX	Past Due	1	2	3	4	5	6	7	8	Total
Item Forecast			0		0		0		0	0
Option Forecast			0		2		1		10	13
Actual Demand			8		9		4		0	21
Total Demand			8		11		5		10	34
Projected Available Balance	0	0	0	0	1	1	6	6	6	6
Available-to-Promise		0	0 0	0	3 3	3	6 9	9	10 19	19
Master Schedule			8		12		10		10	40

Figure 9.6 ***Continued***

example for the red option, the cumulative ATP would then drop to 1 through period 7, while period 8 would drop to 11. (Remember, we started with a total ATP of 20 red options and sold 9, leaving 11.) The same process would be done to complete the black option. The good news is that most master scheduling software does these mechanics for us, allowing the master scheduler to manage the information and the business decisions.

Changes in Projected Available Balance

The projected available balance is also affected by the booking process. Periods 1 through 5 remain the same, since no activity occurred to change the total demand; the booking took place in period 6. Two red options were originally projected to be available at the end of period 5, due in part to overplanning. If these 2 are added to the master schedule of 11 in period 6, the result would be a projected available balance of 13 (11 + 2). The new red option total demand is 15 (1 option forecast, 14 actual demand), leaving a potential deficit of 2. Periods 7 and 8 also have a cumulative potential deficit of 2, since the master schedule in period 8 equals the total demand.

Returning to periods 4 and 6, 2 additional units over the current actual demand are expected to be required in period 4 and 1 in period 6 (option forecast line), yielding a total red option forecast of 3 through period 6. Look at the master schedule line in period 4. Remember that we overplanned the red option by 2. If that had not been done, then the ATP would have been 2 instead of 4, which means that we would not have been able to satisfy the customer's request for all the conference center chairs—only 8 red could have been committed. But because of the option overplanning, we could commit to fulfilling the entire request, 9 red and 1 black.

Period 4 was overplanned by 2 units. At this point, 1 of the overplanned red options has been given up. In period 6, you have a projected deficit of 2. Remember the option forecast above of 3. If that 3 does not come in, then the projected available balance will be plus one. That plus one is the remaining overplanned red option. So you can take only 1 more red chair order through period 6, but not 3, unless an adjustment is made to the master schedule.

Another interesting point can be highlighted here. Prior to the booking of the order for 10 conference chairs, we had option overplanning for the red option equal to 2 in period 6 (projected available balance). After the order was booked (9 of the chairs being red), the option overplanning in period 6 for the red option is –2 (projected available balance). That is a shift of 4 units (+2 to –2). The only place these 4 units could have gone is to the black option. Prior to the order booking, the option overplanning for the black option in period 6 was 2 units (projected available balance); after the booking, it is 6 units (projected available balance), which includes the 4 units that shifted.

Option Overplanning in the Make-to-Stock Environment

Working in a make-to-stock (MTS) environment forces the manufacturing company to build to a forecast so that product is available when the customer requests it. We have spent enough time discussing the fact that forecasts usually contain some degree of error. So look at this situation. The sales and operations planning output calls for the company to build and deliver 100 products to the marketplace during a particular month. For discussion purposes, this product family has two items in it. Therefore, marketing must forecast the expected demand—let's say they forecast that 60 will be A units and 40 will be B units. Since this is a forecast, what are the chances of the sales force bringing in orders that will perfectly match this expected demand? We should not be surprised if the answer is not very good!

If this expectation is true, then the chance of the company's meeting the overall volume target is nil. If the company sells 61 units of A and 39 units of B, the total product that can be delivered on time is 99, as-

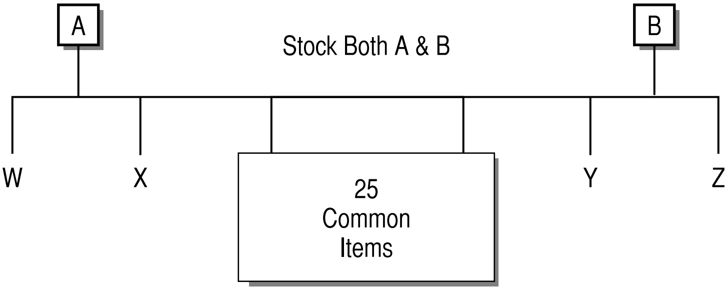

Figure 9.7 Make-to-Stock Product Structures for Stocked Items A and B

suming manufacturing built 60 A and 40 B. To protect itself from this condition, many manufacturing companies carry safety stock on the finished A and B units (say they hold 10 extra A and 8 extra B on individual, lower-level items). While this approach may work sometimes, it can be expensive as well as hard to forecast. Is there another way? Sometimes a company may be able to provide forecast-error protection in the MTS environment by overplanning some of the unique items that make up the finished product.

Figure 9.7 is an example of a make-to-stock strategy being employed on products A and B. As the figure illustrates, product A is made from parts W and X and the 25 common components. Product B is made from parts Y and Z and 25 common components. In this example we will assume that a short finishing cycle exists, there is a variable demand pattern, and unique items W, X, Y, and Z are used in other places. The master scheduler has decided to do some dependent overplanning and use the MRP system to overplan in matched sets of parts.

To do this, two planning bills are created—one for A's unique items and one for B's unique items. Figure 9.8 shows these simple planning bills with their unique items, identified as A-op and B-op. Since the common items are needed to build either A or B, both A-op and B-op are pseudos.

The next step is to create a master schedule for A option and B option equal to the overplanning desired. Since period 1 may be inside the finishing lead time, the overplanning in the example has been done in periods 2 and 3. The master scheduler has placed firm planned orders for A option in period 2 for 20 and in period 3 for 10. The B option

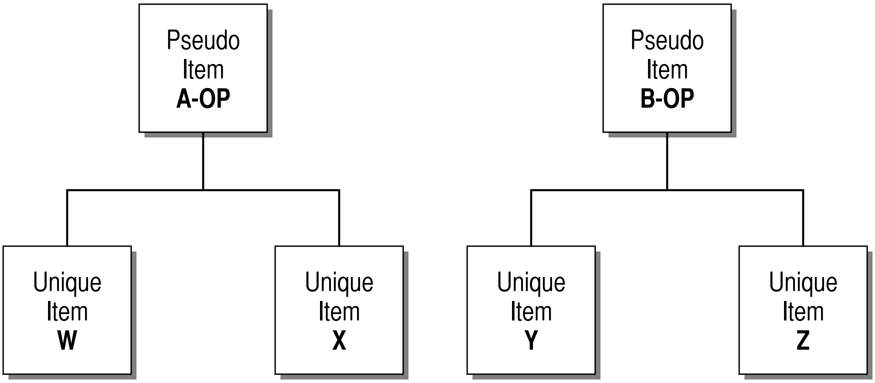

Figure 9.8 Planning Bills for Unique Items in Product Structures A and B (A-op is A Option Bill and B-op is B Option Bill)

has been scheduled for 15 receipts in period 2 and 5 receipts in period 3. The total overplanning is 50 sets for both periods. (Remember: We are overplanning only the unique items, W, X, Y, and Z.)

By creating the unique items planning bills and by master scheduling the A option and B option pseudos, the master scheduler has provided protection for expected forecast error in matched sets of items. This is done by driving the material requirements planning system with the master schedule for A option and B option. Refer to Figure 9.9 to see how it actually works.

Products A and B are forecasted at the 60/40 split. Using these probabilities, 60 A are scheduled to be produced in periods 1, 2, and 3. At the same time, 40 B are scheduled to be produced in each period. Using the A-op schedule, 20 sets of items W and X are planned to be available in period 2, while 10 are scheduled to be available in period 3. Using B-op's master schedule, we expect 15 Ys and Zs to be available in period 2 and 5 more sets to be available in period 3. So, what has this bought the master scheduler? To answer this, let's ask the following questions: What is the maximum number of A that could be committed in period 2? What is the maximum number of B that could be committed in period 2? What is the maximum number of A that could be committed in period 3? What is the maximum number of B that could be committed in period 3?

100 Units/Period

A & B Family	1	2	3
A	60	60	60
B	40	40	40
Total	100	100	100
A-op	0	20	10
B-op	0	15	5
Total	0	35	15
A	60	45 80	55 70
B	40	20 55	30 45
Total	100	135	115

Figure 9.9 Master Schedule for Products A, B, A-op, and B-op

Using Figure 9.9 to answer each question shows us the benefit of this overplanning technique. The maximum number of As that can be committed in period 2 is 80 (60 A and using the 20 A-op overplanning). However, if 80 A are committed in period 2 then only 20 B can be committed (a total of 100). The maximum number of B that can be committed in period 2 is 55 (40 B and using the 15 B-op overplanning). However, if 55 B are committed in period 2, only 45 A can be committed (a total of 100). This is true because we have only 100 sets of common items—no overplanning has been done for those 25 items.

What does this really mean? Imagine going to sales and telling them that they had to create the perfect forecast or the company would not be able to achieve its overall plan. Or telling finance that a safety stock for all stocked items must be carried or the company would not be able to achieve its delivery plans. Finance might ask if inventory goals and targets are more important to the business than safely making money and a profit.

By employing the technique in the example, the master scheduler can respond in a different way. If sales books and commits delivery for A in period 2 somewhere between 45 and 80, and for B somewhere between 20 and 55, the company will be able to reach their goals. But remember, only 100 units (A and B together) can be sold and committed in any period because of the common items constraint. Looking at period 3, if A orders are somewhere between 55 and 70, and B orders are between 30 and 45, the plan can be achieved. By using this overplanning technique, a wide range of possibilities will now satisfy management's plan. And it didn't cost the master scheduler or the company a great amount of time or money.

Master Scheduling in Make-to-Order and Make-to-Stock Environments: A Comparison

Make-to-stock products are generally master scheduled at the end-item level. By contrast, products in the make-to-order environment call for master scheduling below the end-item level, often working with pseudo bills-of-material to manage hundreds of options.

Another difference is that make-to-stock transactions are often simpler—the customer wants a standard electric switch box, and the manufacturer simply pulls one out of finished-goods inventory. Transactions in the make-to-order environment, though, are more complex in that several actions must take place. First, the customer must indicate product specifications and a desired delivery date. Second, the manufacturer must match the desired specifications and delivery date with the requisite common and unique items. Third, the order must be booked identifying the demand date for all the unique items plus the common items. Finally, the timing of production and meeting promised deliveries must be coordinated through the master scheduling and finishing functions.

To ensure customer satisfaction in the MTS environment (where immediate or near immediate delivery is required), conventional statistical techniques are often used to analyze desired customer service levels and compute how much safety stock should be carried for each end item being master scheduled. But in a make-to-order environment, it doesn't make sense to stock completed items, since the final configurations required by customers will be unknown until the order appears. Trying to safety stock individual items is also impractical. How do you decide which items need safety stock, in what quantities, and so on, when literally thousands of unique products are made by a single company? Therefore, techniques such as option overplanning in the first unsold time period should be used.

Yet another difference concerns finishing schedules (to be discussed in depth in Chapter 12). In the MTS world, finished products are usually built to a forecast using available capacity. In an MTO environment the customer order must precede the finishing or final assembly process. Moreover, information in the customer order must be communicated to the manufacturing facility; all the required items listed on the pseudo bills-of-material must be sent to the right operation on the finishing line at the right time. In addition, process instructions detailing the configured customer order must be developed. In short, planning and scheduling in the MTO environment is a lot tougher than simply planning to build a red conference center chair and placing it on the shelf.

In regard to the bills-of-material being used, companies that have products that are make-to-stock use standard engineering BOMs for the entire planning, scheduling, and building phases. Products in a make-to-order environment, though, do not universally use standard BOMs, at least at the upper levels. Instead, planning and pseudo bills are common. Many times in an MTO environment, a conventional bill is restructured into a planning bill, possibly several levels down, based on the competition's lead time, the company's cumulative lead time, the company's willingness to invest in inventory, and the capacity needed to finish the order to a customer specification. This restructuring is done for three reasons: first, to allow a company to master schedule the fewest number of items; second, to give marketing and sales a better chance at creating an accurate forecast (the accuracy of the forecast will always be better at the aggregate level than at the detail level); third, by separating the common items from the unique items, option overplanning can be applied to just the unique items, thus reducing the inventory carried as protection against demand variability.

Most of the discussion in this chapter concerns itself with the mechanics of two-level master scheduling and how the planning bill is used to assist the master scheduler in forecasting demand at the MPS second level. It also has dealt with the logic used to create the master schedule and how, when, and where to use option overplanning. With the knowledge of two-level master scheduling, we are now ready to return to the job of the master scheduler and scheduling in make-to-order environments.

The next chapter follows the same format as Chapter 5, which presented situations for the master scheduler to analyze along with information screens to use in drawing conclusions. The goal of the chapter is not to provide a set of “right” answers, but rather to promote an understanding of the job of master scheduling in the make-to-order and option-planning environments.

10

Using MPS Output in a Make-to-Order Environment

In the absence of facts, arguments will persist.

This chapter considers how the master scheduler working in a make-to-order (MTO) environment uses the information presented by the master scheduling (MPS) system. Special attention is given to the following:

- Differences in the information used in make-to-stock (MTS) and make-to-order (MTO) environments
- Using the planning bill to generate forecasts for master scheduled items
- Balancing the master schedule to the actual and anticipated demand for pseudo items
- How available-to-promise (ATP) information and forecast consumption are handled
- Overplanning at the option level in the partially sold-out zone
- Action messages supplied by the computer system and how the master scheduler may respond to them

To maintain continuity, this chapter uses the winch example introduced in Chapter 5. Figure 10.1 describes the three winch models WA01, WA04, and WA06, listing all major components. The matrix used here is a helpful way of identifying what is common and what is unique in the product family. Notice that the A100 carriage assembly and the P100 pendant assembly are common to all three winches.

		WAO1	WAO4	WAO6	Characteristic
A100	Carriage Assm.	1	1	1	Common
C100	2000# Cable Assm.	1			
C101	4000# Cable Assm.		1		
C102	6000# Cable Assm.			1	Unique
D100	Drum - 50', 1/4" Cable, 1"	1			
D102	Drum - 50', 3/8" Cable, 1.5"		1		
D103	Drum - 50', 1/2" Cable, 1.5"			1	Unique
G102	Gearbox 4 FPM, 1" Shaft	1	1	1	Common
M100	5 HP Motor	1			
M103	8 HP Motor		1		
M105	10 HP Motor			1	Unique
P100	Pendant Assm.	1	1	1	Common
S100	Shaft, 1" x 24"	1			
S101	Shaft, 1.5" x 24"		1	1	Unique
	Lift Speed (feet per minute)	4	4	4	
	Capacity (in thousand pounds)	1	4	6	

Figure 10.1 Winch Product Comparison

These winches have the same lift speed—4 feet per minute (fpm)—but vary as to lift capacity (1,000, 4,000, and 6,000 pounds). The G102 gearbox is a common item as long as the lift speeds remain at 4 fpm. However, this has changed, as described in the next paragraph.

Using Planning Bills to Simplify Option Scheduling

Assume for a moment that management of the company producing the winch wants to expand its offerings. Instead of offering just three winches with the same lift speed, the company will offer winches that operate at 4, 6, and 10 feet per minute. In addition, winches with 2,000, 3,000, and 5,000 pound (#) capacities will be added to the product line. Thus, the company will make available winches with three different lift speeds and six different capacities—18 different configurations instead of the previous 3.[1]

The company's decision to expand its winch product family means that master scheduling at the end-item level will be significantly expanded and made more complex. To simplify matters, the company has decided to create a planning bill-of-material for the winch family (WXYY) that contains both a common-items bill (A100 and P100) and various-option bills for the different capacities and lift speeds (1,000#, 2,000#, 3,000#, 4,000#, 5,000#, 6,000#, 4 fpm, 6 fpm, and 10 fpm). With the planning bill structure in place, marketing and sales provided the probability of sales for each of the various options. This winch family planning BOM with the best estimate for each of the various options is shown in Figure 10.2.

The planning bill thus reflects all options as well as common parts. This bill makes it possible to cut out nearly 50% of the otherwise mas-

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[1] Here we make the assumption that all of the gearboxes work with any of the capacity options.

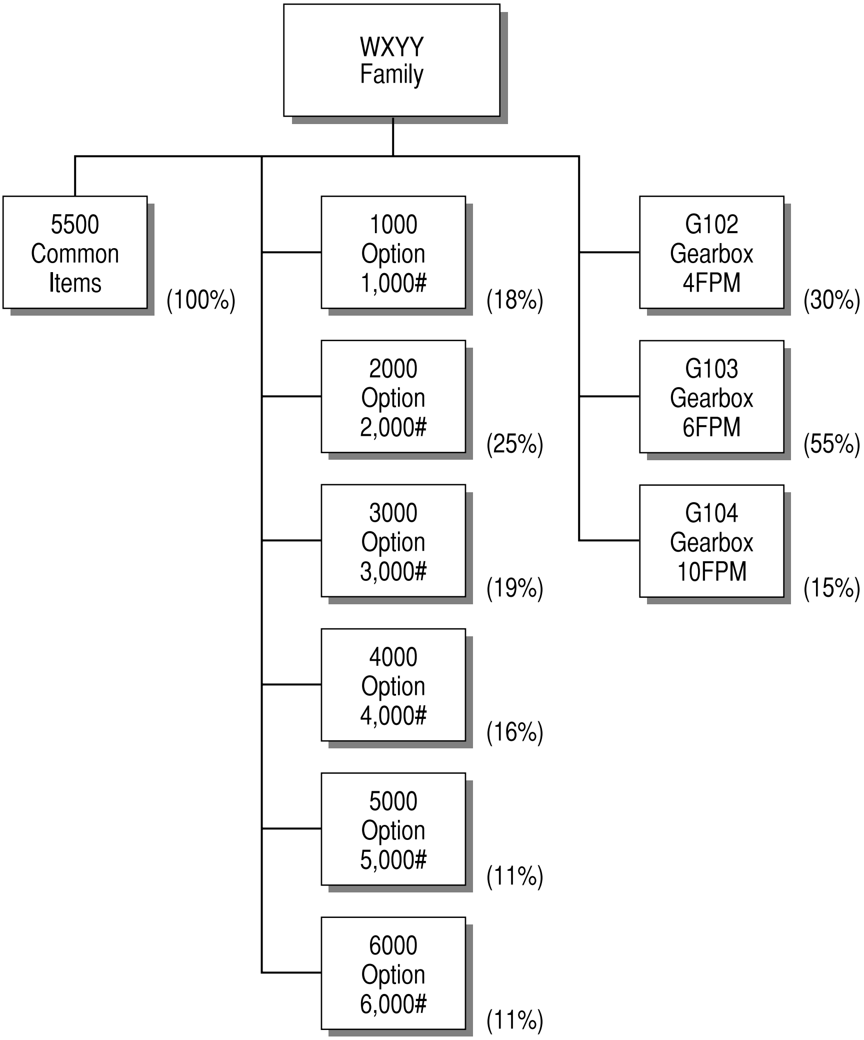

Figure 10.2 Winch Product Family Planning Bill-of-Materials

ter scheduled items, reducing their numbers from 18 to 10. The 10 remaining items are the common group (1), capacity options (6), and various gearboxes (3).

The chapters on planning bills and master scheduling in the make-to-order environment show that master scheduling is done at the option or feature level and not at the level of the end item. Applying this logic, the master scheduler for the winch product family does the same, dropping down one level to gain better control, ease the job of forecasting, add flexibility in manufacturing, and better serve the customer.

The Scheduling Process

In the example, the winch family's common items and various capacity option bills are all pseudos—that is, artificial groupings of items that can be scheduled but not built. The gearboxes are purchased items and therefore *not* pseudos. Since the gearboxes are purchased complete, the common-items bill contains only common items from the capacity options (no common items between the various gearboxes are included). If the gearboxes were manufactured in-house, an opportunity to add the common items in the gearboxes to the common-items bill would exist, and the company should seize the opportunity.

Time-Phased Bills-of-Material

Once structured, the planning bill for the common items as well as each of the capacity options can be time phased. Time phasing the master scheduled items simply means that each item is exploded into its underlying raw materials, components, subassemblies, and assemblies, and the length of time required for material procurement, manufacturing, and assembly is noted. Time-phased bills-of-material (BOMs) for the common items and for one of the capacity options (3,000#) are shown in Figures 10.3 and 10.4, respectively. (Refer to Chapter 5 for details on creating time-phased bills.)

The figures indicate a cumulative lead time for the common items and options of 16 weeks, with the greatest lead time component being the housing casting (1200C) in the common items and the drum casting (D101C) in the 3,000# option bill. Figure 10.3 indicates that

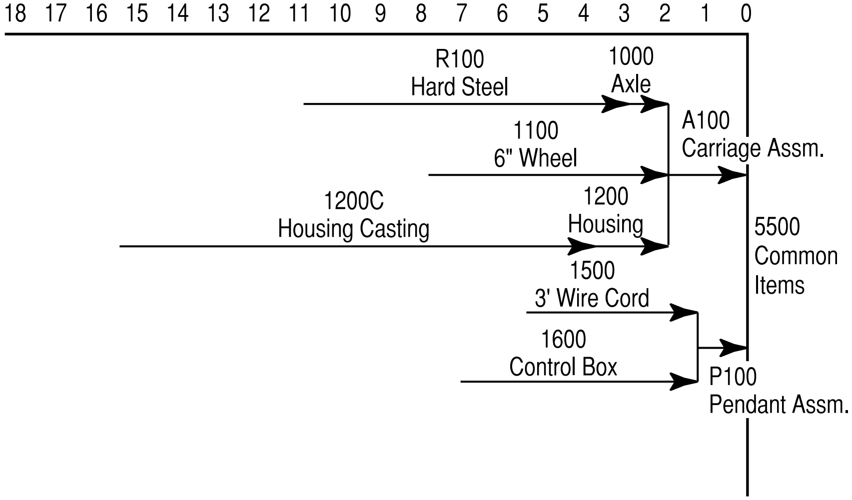

Figure 10.3 Time-Phased Common Items Planning Bill-of-Material

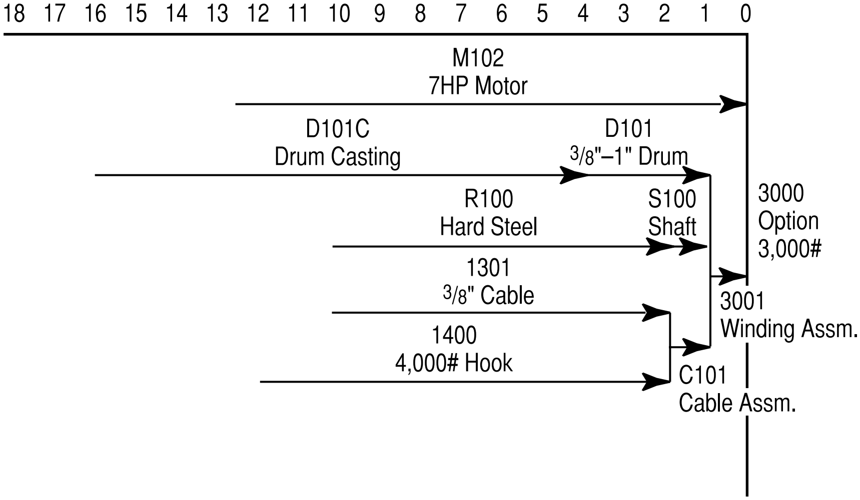

Figure 10.4 Time-Phased 3,000# Option Planning Bill-of-Material

two major assemblies make up the common items: the A100 carriage assembly and the P100 pendant assembly. The A100 is itself made from item 1000 (an axle), item 1100 (a 6-inch wheel), and item 1200 (a housing). Figure 10.4 shows that the capacity option is also made up of two major assemblies, a 7 horsepower motor (M102) and a winding assembly (3001).

For purposes of illustration, assume that manufacturing has added the winding assembly (3001) to increase efficiency in production. This winding assembly includes a 3⁄8–1″ drum, a shaft, and a cable assembly. Grouping and assembling materials into intermediates is often done for purposes of efficiency, control, and manufacturing flexibility. These intermediates can either be built and placed in stock or remain on the manufacturing floor for immediate consumption by a parent item. In the later case, the intermediate is commonly referred to as a "phantom" item—that is, an item that is real but not planned to be stocked.

In the example, the 3001 winding assembly is actually a produced item. This not only creates greater efficiencies but allows for the creation of a modular subassembly. The same logic can be used in the other capacity option bills. Such time-phased bills can help the master scheduler determine which items will be affected by a process change. For example, if a change were to be made nine weeks prior to shipment, the time-phased planning bill would make it possible for the master scheduler to quickly identify the several affected items. Thus, among the common items in Figure 10.3, the hard steel and housing casting would be affected. In the 3,000# option in Figure 10.4 the motor, drum casting, hard steel, 3⁄8″ cable, and hook are affected.

Item Numbering System

To continue with the example, assume that a significant item numbering system is being used at the end-item level.[2] Now consider the

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[2] This is not a recommendation; it is simply used here for illustration purposes. Some companies use product configurations driven by a significant item numbering scheme for entering customer order requirements.

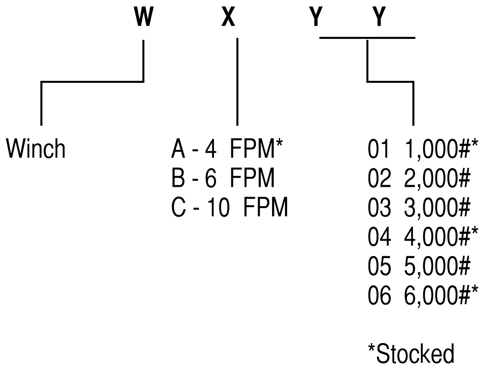


Figure 10.5 Significant Item Numbering System (WXYY)

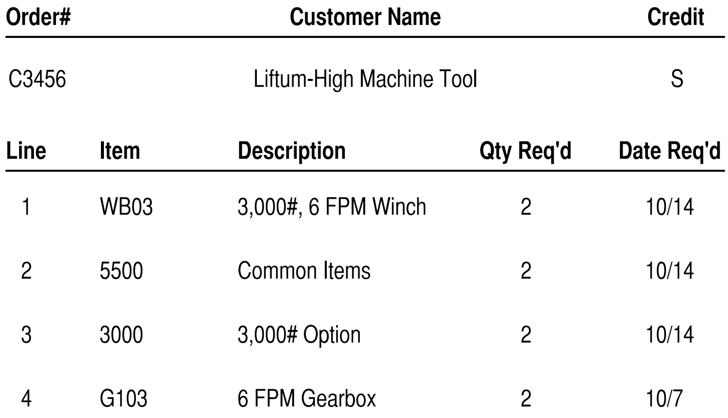
WXYY family in terms of its significant item number system, as described in Figure 10.5.

The first character defines the product family (W = winches), the second character defines the lift speed, and the last two define capacity. With 18 possible configurations to deal with, this significant item number approach is useful in sales planning and for order-entry purposes. In such a case, the sale of a WC05 would mean a winch that operates at 10 fpm and lifts up to 5,000 pounds.

When orders are received in this environment, the customer defines the configuration required, the number of units needed, and product delivery date. For example, the customer order entry screen reproduced in Figure 10.6 on page 282 indicates that the customer has ordered two 6 fpm winches, each with 3,000-pound lift capacity, for delivery on October 14.

To satisfy this particular customer order, the master scheduler needs the following:

- Two sets of common items
- Two sets of 3,000# option items
- Two 6 fpm gearboxes



Order#	Customer Name	Credit
C3456	Liftum-High Machine Tool	S

Line	Item	Description	Qty Req'd	Date Req'd
1	WB03	3,000#, 6 FPM Winch	2	10/14
2	5500	Common Items	2	10/14
3	3000	3,000# Option	2	10/14
4	G103	6 FPM Gearbox	2	10/7

Figure 10.6 Customer Order Entry Screen

With this background for the winch example, attention can be turned to using the MPS information to make decisions in the make-, assemble-, and finish-to-order environments, starting with the common items.

The Common-Items Master Schedule

Figure 10.7 on pages 284–285 is the master schedule for the common items (5500) used in the winch. This is typical of the MPS screen formats produced by contemporary software programs.

The screen format is divided into several major sections: item information; planning horizon summaries of supply and demand; and detail data sections containing information on requirements and replenishment order status, action messages, and various reference data. The MPS screen summarizes critical details used by the master scheduler in managing and timing supply and demand. These screen formats are the same as those used in Chapter 5. Here it would be useful to highlight some of data that makes this particular screen unique to a make-to-order scenario.

Item Information Section

This section of the MPS screen contains background information about the item being scheduled: item number, item description, product family, and the like. It also contains information specific to the item that helps the master scheduler to properly manage the item's progress through production: lot size, lead time, the position of planning time fences (PTFs), and so forth.

In Chapter 5, the *Item Status* on the winches was "STK" (stock). In this case the common-items bill is a pseudo; thus its item status is "PSDO." Under *Forecast Source* and *Forecast Consumption,* the screen notes "PLANBL" for planning bill. This means that the forecast source (identified as "judgment" in Chapter 5) is the planning bill, and the items in the planning bill are forecasted automatically. Also, the forecast is automatically consumed using the planning bill. The technique used to consume the forecast is to explode the available-to-promise quantities through the percentages that reside in the planning bill, as explained in the previous chapter.

On the next information line, the *Balance on Hand* is zero, which is not surprising since a pseudo cannot be built or stocked. As for *Lot Size,* discrete lot sizing rules are applied to pseudos; therefore, lot-for-lot ("LFL") is used in the example. Also, since a pseudo cannot be stocked, it should have no *Safety Stock* indicated.

The *Lead Time* one level down is set to 1 (week in the example), while the *Cumulative Lead Time* is 16 (the time required to pull together all the common items from scratch). To shorten that lead time the master scheduler has chosen to safety stock the housing casting, which in the time-phased BOM was shown to be the long lead time item. He or she is reminded of this decision by the text under *Special Instructions.* By safety stocking the housing, its contribution to cumulative lead time is effectively reduced and the manufacturer is able to deliver the common items 4 periods sooner. This explains why the *Planning Time Fence* may be set at 13 periods, which is inside the

Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source
5500	COMMON ITEMS	PSDO	WXYY	PROUD	PLANBL

Balance on Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cumul. Lead Time	Standard Cost
	1	2	Policy	Factor	1	2	3			
0	LFL	1	NO	0	P-13	C-12		1	16	565

Period	Past Due	10/13	10/20	10/27	11/03	11/10	11/17
Item Forecast							
Option Forecast		10	0	265	370	400	400
Actual Demand		385	405	135	30		
Proj. Available Balance	0	5	0	0	0	0	0
Available-to-Promise		10	0	265	370	400	400
Master Schedule		400	400	400	400	400	400

Period	1/12	1/19	1/26	2/02	2/09	2/16	2/23
Item Forecast	P						
Option Forecast	440 P	440	440	440	440	440	440
Actual Demand	P						
Proj. Available Balance	0 P	0	0	0	0	0	0
Available-to-Promise	430 P	440	440	440	440	440	440
Master Schedule	430 P	440	440	440	440	440	440

Master Schedule Detail

Req'd Date	Order Number	Lot Number	Order			Recomm. Action
			Qty.	Type	Status	
10/13	5500	413	400	MPS	FIRM	
10/20	5500	414	400	MPS	FIRM	
10/27	5500	415	400	MPS	FIRM	
11/03	5500	416	400	MPS	FIRM	
11/10	5500	417	400	MPS	FIRM	
11/17	5500	418	400	MPS	FIRM	
11/24	5500	419	400	MPS	FIRM	
12/01	5500	420	400	MPS	FIRM	
12/08	5500	421	420	MPS	FIRM	
12/15	5500	422	420	MPS	FIRM	
12/22	5500	423	420	MPS	FIRM	
1/05	5500	424	430	MPS	FIRM	
1/12	5500	425	430	MPS	FIRM	
1/19	5500		440			PLAN

Req'd Date	Order Quantity
10/13	35
10/13	60
10/13	45
10/13	25
10/13	15
10/13	40
10/13	14
10/13	70
10/13	20
10/13	36
10/13	25
10/20	40
10/20	50
10/20	10
10/20	60

Figure 10.7 Master Schedule Screen, Common Items

Forecast Consumption	Resource Profile	Critical Resources							
		Res.	Qty.	Res.	Qty.	Res.	Qty.	Res.	Qty.
PLANBL	WXYY	MCH	6.0	SUB	3.5	ASSM	10.0	KIT	1.0

Selling Price	Special Instructions	Date Run	Action Recommended		
1,010	SAFETY-HSING CAST	XX-XX-XX	PLAN		

11/24	12/01	12/08	12/15	12/22	1/05	Period
					C	Item Forecast
400	400	400	400	400	400 C	Option Forecast
					80 C	Actual Demand
0	0	20	40	60	10 C	Proj. Available Balance
400	400	420	420	420	350 C	Available-to-Promise
400	400	420	420	420	430 C	Master Schedule

3/02	3/09	3/16	3/23	3/30	4/06	Period
						Item Forecast
440	440	440	440	440	440	Option Forecast
						Actual Demand
0	0	0	0	0	0	Proj. Available Balance
440	440	440	440	440	440	Available-to-Promise
440	440	440	440	440	440	Master Schedule

Actual Demand Detail

Refer. Number	Order Number	T	S	C	Req'd Date	Order Quantity	Refer. Number	Order Number	T	S	C
Main Mfg	C1759	A	R		10/20	30	Everglass	C1819	A	F	
WA0I	M0814	F	R		10/20	15	Phillips	C1825	A	F	
WA04	M0815	F	R		10/20	5	Pacific Inc	C1831	A	F	
WA06	M0816	F	R		10/20	10	Moore Mfg	C1832	A	F	
Allen Mfg	C1802	A	R		10/20	50	Eagle Betts	C1829	A	F	
WC02	M0817	F	R		10/20	35	Riverbend	C1830	A	F	
Captain Mtrs	C1746	A	R		10/20	100	West Coast	C1849	A	F	
Desert Co	C1811	A	R		10/27	60	WA0I	M0820	F	F	
Deer Cross	C1814	A	R		10/27	40	Excor	C1835	A	F	
G Gregory	C1815	A	R		10/27	10	Smith Co	C1837	A	F	
Int'l Energy	C1821	A	R		10/27	25	Ames Mfg	C1841	A	F	
Chuck Mfg	C1823	A	R		11/03	30	MPRS	C1856	A	F	
WC04	M0818	F	R		1/05	80	Daly & Sons	C1801	A	F	A
Roadman	C1824	A	F								
WA06	M0819	F	F								

Figure 10.7 ***Continued***

cumulative lead time of 16 periods but outside the cumulative material ordering time (16 – 4 = 12). Of course, there is no reason why the master scheduler could not set the planning time fence at 12 periods. It also could be set at 14 periods. The setting of the planning time fence does not need to line up exactly with the cumulative lead time or any other lead time.

Planning Horizons Section

This section of the screen contains the supply-and-demand information needed to manage the master schedule. In contrast to the screens in Chapter 5, this screen summarizes booked orders on the actual demand line by period. In addition to showing actual demand, the screen provides the available-to-promise quantity described in Chapter 8. Thus, for period 10/13, there are booked orders needing 385 sets of common items.

The master scheduler has placed two time fences in this example: a capacity fence set at the end of week 1/05 and a planning time fence at the end of the following period. The capacity time fence is a memo-type time fence indicating that it is difficult to make capacity adjustments within the fence. The planning time fence is used to control computer behavior; all master scheduled orders within the planning time fence are controlled by the master scheduler, while those outside the fence are generally controlled by the computer software.

Detail Data Section

The bottom portion of this screen contains two separate categories of information, both generated by the MPS software system using data from various order files—that is, manufacturing and supplier orders on the supply side, and customer and stocked orders on the demand side.

The first category of information is *Master Schedule Detail,* which identifies the released orders as well as the firm planned orders already placed, along with their respective identification numbers (lot) and required dates. The MPS detail section also includes a *Recommended*

Action column. In the case of the last supply order (required date 1/19), the recommended action is “PLAN,” or “it is time to convert the computer planned order in question into a firm planned order.”

The section labeled *Actual Demand Detail* indicates the source of demand on the line of that name in the planning horizon summaries. This section calls out required date, quantity ordered, order reference number, and order number.

Analyzing the Detail Data

With the general sections of the master scheduling screen understood, we consider the finer details. Begin with the planning horizon in the 10/13 column. In the MPS line of that period, the master schedule shows a firm planned order for 400 sets of common items ready to be applied to customer orders. That was the plan, but a review of the plan for this period indicates actual demand is for only 385 sets of common items.

Eleven separate customer orders, each listed individually in the actual demand detail section of the screen, are the source of this demand. For example, on 10/13 there is an order for 35 units for “Main Mfg” (customer order C1759). The “A” in the *T* column indicates that the unit is assemble-to-order. The order beneath this indicates a quantity of 60 units required on 10/13. This requirement has a reference number—WA01—which is not the name of a customer but one of the company’s own product numbers. In this case the master scheduler has committed 60 sets of common items to a finished-goods order. (In addition to building and configuring to customer orders, the master scheduler may at times choose to build popular configurations to stock.)

“M0814” indicates that the order is a manufacturing order rather than a customer order. The “F” next to it indicates that the product is being built for finished goods. Thus, the master scheduler is building to order as well as to stock.

Determining ATP. Since the 11 lines of detail demand summarize to the 385 shown in the 10/13 period's actual demand, the available-to-promise quantity for this period can be calculated by subtracting actual demand for the period from the 400 sets of common items scheduled to be due in 10/13, yielding an ATP of 15 units.

Oddly, the screen shows an ATP in period 10/13 of only 10, which is explained as follows. Looking ahead to period 10/20, we can see that the master scheduler has planned for another 400 sets of common items to be available. Since actual demand for that period is 405 (5 over the amount master scheduled), the need for common items in that period is overbooked by 5 units. To ensure the company's ability to satisfy each customer promise, the master scheduler plans to use 5 sets of the 10/13 period's common-item surplus to cover the 10/20 overbooking. As a result, the ATP in 10/13 is reduced by 5, resulting in the indicated ATP of 10.

ATP and the Sold-Out Zone. Periods 10/13 and 10/20 are in the sold-out zone, meaning that no more customer orders are expected. This zone is sold out even though 10 units are still available-to-promise. To understand this, ask the question: Will sales be bringing in a last-minute order? If the answer is yes, it's time for sales to define the configuration needed. Remember, we're talking about the current period. If sales does not have an order, the master scheduler must take other action.

What is to be done with the 10 sets of common items that are available-to-promise in period 10/13? If no action is taken by the master scheduler, and if no customer orders appear at the beginning of the period, then there will be 10 sets of common items for which there is no home.

Balancing the Sold-Out Zone for Common Items

As period 10/13 begins, the master scheduler must ask: What are the chances of an order coming in the door with a delivery time of one period or less? To make good on such an order, the order must appear right away, and the winch configuration must be known. If an order for 10 winches magically appeared, the problem of excess common items would go away, as the order would consume the option forecast and planned production (ATP would become zero). More likely than not, an order will not appear just in time to solve the master scheduler's common-items problem, and the company will face two undesirable realities: (1) having the capacity to assemble 10 winches that will remain idle, and (2) carrying inventory of all material in the common-items bill. Neither of these is satisfactory from the company's point of view, but what alternatives are available?

The master scheduler has several alternatives (four will be discussed here) for meeting the challenge presented in the example's sold-out zone. The first alternative is to look into the future and see if any customer order can be moved up. For instance, the actual demand detail section in Figure 10.7 (see pp. 284–285) indicates a customer order of exactly 10 units (Moore Mfg. order number C1832) required for delivery in period 10/20. Perhaps this customer would be agreeable to taking early delivery, making it possible to pull that 10-unit order into period 10/13. But first the master scheduler must determine which capacity options and gearboxes that customer has requested, and examine the various option screens to make sure that those options are also available in 10/13.

This alternative would solve only the current-period issue—not the sold-out zone problem. Available capacity would be shifted out to period 10/20. So the master scheduler should look beyond the sold-out zone for other possible orders to move up. In this case, the entry for Smith Co. in period 10/27 is a possible candidate. The Smith Co. order of 10 units is scheduled for the first period of the partially sold-out zone. If this order can be pulled into either the 10/13 or 10/20 period (the sold-out zone), the problem of losing the capacity in that zone can be solved. But first the master scheduler must look up Smith Co. customer order (C1837) and find out which capacity options and gearboxes go with it, then check the master schedule for those options to be sure that the needed materials are or will be available.

The second alternative is to split a customer order into multiple deliveries. There are some large orders in period 10/27 and further out that might be split up—some to be produced with the capacity available in the sold-out zone and the remainder to be produced in the originally scheduled period. The order of 40 units for Excor, for example, might be broken into 10 and 30, with 10 units moved into period 10/13 and the remaining 30 staying where they are. It might be better from a business standpoint to produce the 10 early and hold them as inventory than to lose the capacity. Of course, the customer should be given the opportunity to accept an earlier delivery; the earlier delivery would be the best of both worlds for the company, allowing it to build earlier yet not carry the inventory.

Instead of getting the demand to match the master schedule, a third alternative is to decrease the master schedule so that it equals the actual demand. In this example, the total of the master schedule for the sold-out zone must be 790 (385 for the demand in period 10/13 and 405 for the demand in period 10/20). The perfectly balanced schedule would require reducing the lot of 400 in period 10/13 to 385 and increasing the master schedule in period 10/20 to 405. This would mean that 5 sets of common items would be rescheduled into 10/20 and 10 sets would be rescheduled into some period beyond 10/20.

The fourth alternative is to build a popular configuration to stock. As already discussed, the winch company seems to do this. Look at the actual demand detail: You see WA01, WA04, and WA06 winches being built on manufacturing orders for finished goods. The master scheduler should analyze the options to determine what material is available. That information, in addition to consultation with sales, marketing, demand management, manufacturing, and finance, should lead to a decision and possibly production authorization with respect to the inventoried configuration.

Handling Abnormal Demand

With the immediate problem of cleaning up the sold-out zone (reducing the ATP to zero) taken care of, the master scheduler must look further into the future to determine what else needs to be done. For the company represented in the Figure 10.7 screen, the future planning zone for common items 5500 begins 11/10 and continues to the end of the horizon. Normally, this zone contains no orders. But in this case an order for 80 sets of common items exists in period 1/05 of the planning horizon. This order is from a customer with whom the company normally does no business, which means that it represents abnormal demand. Abnormal demands are composed of orders not anticipated by the regular sales forecast. In this case, sales/customer service has indicated that the order for 80 units represents abnormal demand (code "A") in the detail section.

Period 1/05 contains an option forecast of 400 units and actual demand (known to be abnormal) of 80. Since we know that abnormal demand is not part of the forecast, some adjustment to the master schedule must be made to ensure that an extra 80 sets of common items are available to satisfy that abnormal demand. The master scheduler has, in this example, already made that adjustment. The Figure 10.7 screen indicates that by period 1/05, 90 more units are scheduled than are forecasted. This was done by increasing the master schedule by 20 units in periods 12/08, 12/15, and 12/22 and again by 30 in period 1/05. The master scheduler has decided to get the common items ready early, thus ensuring that sufficient common items are available to handle the abnormal demand.

But the abnormal demand is only 80; why the 10 extra units? The answer is that the forecast for period 1/12 jumps abruptly from the typical 400 to 440. By increasing the MPS schedule in period 1/05 to 430 and holding it through 1/12 (stabilizing the MPS and using small, incremental adjustments), the expected demand orders can be satisfied.

The buildup thus helps solve the abnormal demand issue and in addition helps to solve the expected increased demand in the forecast. In planning the buildup over the six periods in question, the master scheduler would have returned to the time-phased BOM for the common items (Figure 10.3, p. 279) to make sure of the availability of materials. So, starting with period 12/08, when the MPS amount increases to 420, the master scheduler would have to check the R100 hard steel and the 1200C housing casting. The beauty of the time-phased

BOM is that the master scheduler can instantly determine the items that are impacted by the change in the schedule.

To review how the master scheduling system handles abnormal demand, look at period 12/22, where there is a projected available balance of 60. The master scheduler has arranged for an additional 430 sets of common items to be available in period 1/05, making a total of 490 sets of common items available (60 + 430 master scheduled = 490). With a forecast demand of 400, 90 will be left over. Since the 80 is abnormal demand—and not considered part of the forecast—it is also subtracted from the remaining 90, leaving a projected available balance of 10.

Action Messages

As the master scheduler looks further into the horizon, he or she observes in period 1/19 a computer planned order of 440 and in the master schedule detail section a recommendation to convert that computer planned order to a firm planned order. The reason for the recommendation stems from the fact that 1/19 is the first period outside the planning time fence. Therefore, the master scheduler should convert this CPO to an FPO so that the 440 shows up inside the planning time fence the next time the calendar rolls and master scheduling system is run.

At the end of the current period, 10/13, we would expect the 385 units to be shipped and all subsequent periods to shift to the left. But at this point the 440 is still a computer planned order, and the master scheduler needs to convert it to a firm planned order. If no action is taken, the planning time fence would move to the end of period 1/19, and the 440 in that period would be moved with it to the right—outside the time fence, since computer planned orders cannot exist inside the planning time fence. In that case, the master scheduled lot of 440 in period 1/26 (the *new* first period outside the planning time fence after the system shifts all periods to the left) would be doubled, from

440 to 880. An accompanying message would also inform the master scheduler of a negative available balance inside the planning time fence. The ATP would drop to zero in period 1/19 because the master scheduled lot is moved out of the period.

Working the Pseudo Options

With the current situation for the common items in the continuing example now understood, and some actions in future periods taken, the next step is to analyze the remainder of the options to determine what further actions might be necessary to ensure a complete and valid master schedule. Here, the option issues are illustrated through analysis of the 1,000# and 3,000# lift capacity options and the G102 gearbox.

The 1,000# Option

ITEM INFORMATION SECTION. The data contained in this section of the screen (Figure 10.8 on pp. 294–295) for the 1,000# option is basically the same as the item information in the common items screen; however, there are a few differences. Under *Special Instructions,* for example, the option is listed as being part of the winch product family, 18% of whose sales are expected to require this option configuration (note that the 18% is taken directly from the planning bill).

MASTER SCHEDULE DETAIL SECTION. This section shows a series of action messages for the master scheduled item. Here, the software logic recommends a number of reschedule-ins and the conversion of a computer planned order to a firm planned order. The master scheduler would quickly see that 12 of the 13 MPS lots are currently scheduled incorrectly, as evidenced by the R/I-01 ("reschedule-in") messages. At first blush there appears to be a serious timing problem.

Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source
1000	1000# OPTION	PSDO	WXYY	PROUD	PLANBL

Balance on Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cumul. Lead Time	Standard Cost
	1	2	Policy	Factor	1	2	3			
0	LFL	1	NO	0	P-13	M12		1	16	1,305

Period	Past Due	10/13	10/20	10/27	11/03	11/10	11/17
Item Forecast							
Option Forecast		2	0	48	67	72	72
Actual Demand		74	75	60			
Proj. Available Balance	0	–4	–7	–30	–25	–25	–25
Available-to-Promise		–2	–3	20	72	72	72
Master Schedule		72	72	85	72	72	72

Period	1/12	1/19	1/26	2/02	2/09	2/16	2/23
Item Forecast	P						
Option Forecast	80 P	79	79	79	79	80	79
Actual Demand	P						
Proj. Available Balance	–26 P	0	0	0	0	0	0
Available-to-Promise	80 P	105	79	79	79	80	79
Master Schedule	80 P	105	79	79	79	80	79

Master Schedule Detail

Req'd Date	Order Number	Lot Number	Order Qty.	Order Type	Order Status	Recomm. Action
10/13	1000	226	72	MPS	FIRM	
10/20	1000	227	72	MPS	FIRM	R/I - 01
10/27	1000	228	85	MPS	FIRM	R/I - 01
11/03	1000	229	72	MPS	FIRM	R/I - 01
11/10	1000	230	72	MPS	FIRM	R/I - 01
11/17	1000	231	72	MPS	FIRM	R/I - 01
11/24	1000	232	72	MPS	FIRM	R/I - 01
12/01	1000	233	72	MPS	FIRM	R/I - 01
12/08	1000	234	72	MPS	FIRM	R/I - 01
12/15	1000	235	72	MPS	FIRM	R/I - 01
12/22	1000	236	72	MPS	FIRM	R/I - 01
1/05	1000	237	72	MPS	FIRM	R/I - 01
1/12	1000	238	80	MPS	FIRM	R/I - 01
1/19	1000		105			PLAN

Req'd Date	Order Quantity
10/13	60
10/13	14
10/20	40
10/20	35
10/27	60

Figure 10.8 Master Schedule Screen, 1,000# Option

Forecast Consumption	Resource Profile	Critical Resources							
		Res.	Qty.	Res.	Qty.	Res.	Qty.	Res.	Qty.
PLANBL	WXYY	MCH	7.0	SUB	3.5	ASSM	10.0	KIT	1.0

Selling Price	Special Instructions	Date Run	Action Recommended		
1,650	WXYY-18% OPTION	XX-XX-XX	NEGATP	R/I	PLAN

11/24	12/01	12/08	12/15	12/22	1/05		Period
						M	Item Forecast
72	72	75	75	75	63	M	Option Forecast
						M	Actual Demand
–25	–25	–28	–32	–35	–26	M	Proj. Available Balance
72	72	72	72	72	72	M	Available-to-Promise
72	72	72	72	72	72	M	Master Schedule

3/02	3/09	3/16	3/23	3/30	4/06	Period
						Item Forecast
79	79	79	80	79	79	Option Forecast
						Actual Demand
0	0	0	0	0	0	Proj. Available Balance
79	79	79	80	79	79	Available-to-Promise
79	79	79	80	79	79	Master Schedule

Actual Demand Detail

Refer. Number	Order Number	T	S	C	Req'd Date	Order Quantity	Refer. Number	Order Number	T	S	C
WA01	M0814	F	R								
Captain Mtrs	C1746	A	R								
Chuck Mfg	C1823	A	R								
Riverbend	C1830	A	F								
WA01	M0820	F	F								

Figure 10.8 ***Continued***

But a complete analysis should take place before any knee-jerk action is taken.

PLANNING HORIZONS SECTION. The first step toward determining the source of the problem is to examine the sold-out zone, periods 10/13 and 10/20. Period 10/13 has 72 sets of the 1,000# option scheduled to be received. In-house customer orders, however, total 74 units for this period, and there are still 2 more units forecasted. Therefore, the total demand shown is 76 (74 + 2). Since only 72 units are scheduled to be available, the projected demand exceeds supply by 4 option sets.

Now review the next period, 10/20. Again, 72 sets of the 1,000# option are scheduled against a total projected demand (all in-hand customer orders) of 75, resulting in demand exceeding supply by 3 option sets. The projected available balance in that period has gone from −4 to –7, because of the 3 overbooked options. The difference between the –7 projected available balance, which is a cumulative figure, and the cumulative ATP for the two periods (–5) is the option forecast for period 10/13 (remember, ATP does not take forecast into account, whereas projected available balance accounts for *all* demand).

At this point, the master scheduler must ask: Is current scheduling in the sold-out zone a problem? Here it must be remembered that in the current period of the sold-out zone, the chance of bringing in an order to use the common items was slim. So when analyzing the common items earlier in this chapter, the master scheduler decided to either pull in an order that had been scheduled already and possibly ship it early, split a customer order and move some forward, decrease the master schedule to equal the actual demand, or build a popular configuration to stock. In each case, the ATP at the common parts and product family levels would go to zero. Remember, that is a responsibility of the master scheduler to make the master schedule line equal to the actual demand line in the sold-out zone for all *pseudo* items. If the ATP of 10 goes to zero at the product family level, that zero will be exploded through the planning bill (which obviously yields zero) to generate a forecast for all options and common items. When this is done, the option forecast for the 1,000# option will become zero in period 10/13. The additional forecast of two 1,000# options then vanishes. If the option forecast of 2 in period 10/13 disappears, the projected available balance increases from –4 to –2. In period 10/20, it increases from –7 to –5.

Solving the Problem. The solution to bringing the MPS into balance begins by examining the actual demand detail section of Figure 10.8 on pages 294–295. In periods 10/13 and 10/20, 74 and 75 units of actual demand appear, respectively. The actual demand detail section indicates the sources of those numbers.

With respect to the 74 units of demand, the detail section indicates two sources. The first is an order for 60 for WA01, under manufacturing order M0814. The second is for 14 units for Captain Motors, customer order C1746. The customer order for Captain Motors is a regular assemble-to-order; we know this because of the code "A" in order type. But the order for 60 is being built for stock on a manufacturing order; again, the code "F" (for finished goods) makes this clear. In other words, 60 of those 74 are for the company's own stock inventory! In attempting to bring actual demand and the master scheduled quantities into equality, which of these two demand sources might be easier to manipulate? The Captain Motors order may be untouchable for customer service purposes, but perhaps the order to add to the company's inventory could be reduced from 60 to 58 or even something less. If that is possible, the problem in 10/13 will be solved.

Period 10/20 is also oversold, as evidenced by the negative ATP, this time by 3 units. Again, the solution begins with determining the source(s) of actual demand. Here, there are two orders, one of 40 units for Chuck Mfg., and one of 35 units for Riverbend. These are real customer orders for which promises have been made. The question must be asked: Can we reduce the finished-goods order in the first period from 60 to 55 or less? If we can, the problem is solved. This would, in fact, result in 3 units being on hand as period 10/13 ends, enough to cover the deficit in period 10/20 and provide a perfect balance through the sold-out zone.

Thus, what appears to be a complicated and messy situation can be resolved simply by the demand side of the house reducing one stock order. The moral of this example? Know the customers, including the needs of internal customers; don't panic and jump to immediate conclusions; analyze the horizon as a whole; and use people's product and process knowledge to do what's best for the company.

When examining master scheduling screens it is easy to believe that the numbers represented in them are scientifically derived and absolutely valid. This is rarely the case. In searching for ways to rebalance the schedule, it is legitimate to continually challenge these numbers.

- Are items being made for inventory really critical?
- Is the lot size optimal, or has it been arbitrarily set?
- Is there a bias in the forecast to ensure abundant supply?
- Is the ship date for a big order being dictated by the customer's needs or by a salesperson's commission calendar?
- Has the lead time requested been padded by safety time, just in case?

These are all legitimate questions for the master scheduler to ask as he or she attempts to balance supply and demand within a time frame that meets market needs.

Returning to period 10/13 for the 1,000# option (Figure 10.8 on pp. 294–295), we see that by dropping the WA01 demand order to 55 (this should only be done by the person or function creating the demand, not the master scheduler) the first two reschedule-in messages would vanish—there would be no need to reschedule the MPS lot in 10/20 into 10/13, or the 85 in 10/27 into 10/20, as the projected available balance at the end of 10/20 would be zero, not negative.

In 10/27, another demand order for 60 is on tap. Above that is demand for 48 additional sets of the 1,000# option, which was generated by the WXYY family of common items above, exploding its ATP through the planning bill (18% probability). To see how that happens, return to the common items (Figure 10.7 on pp. 284–285). There, the ATP in 10/27 is 265 units for the common-items set (same as the product family). By exploding that 265 through the planning bill at the designated 18% probability for the 1,000# option, the result is 48 units, which appear in the option forecast line of that option's master schedule screen. Adding the 48 forecasted to the 60 already booked yields a total demand of 108 units against a master schedule of 85. Therefore, since the 60 units booked are for inventory (as indicated in the actual demand detail), the source of the problem is once again internal demand.

Demand is managed by marketing; the master schedule is managed by manufacturing. The problem revealed in our example is that the company has overbooked the master schedule—in this case with demand from a finished-goods item.

Another of the master scheduler's challenges is to understand what constitutes *real* demand and to how to satisfy it. As the example implies, not all demand is real and necessary. The master scheduler works closely with the demand manager and with sales and marketing when determining who gets what and which orders receive priority.

The last item for discussion on the 1,000# option is the ATP in period 10/27. We see that 85 options sets are scheduled for receipt.[3] Actual demand is 60, which is subtracted from the MPS receipt of 85, leaving 25, not 20. The ATP of 20 is a result of the system's using 5 available options to cover the oversold 5 units in periods 10/13 and 10/20. In other words, the master scheduler should not commit more than 20 of the 1,000# options through 10/27.

HANDLING THE ACTION MESSAGES. Getting the 60-unit inventory orders reduced makes all the reschedule action messages in this example disappear. The last task of the 1,000# option master scheduler is to convert the CPO for 105 units in 1/19 (just beyond the planning fence) to an FPO. As time passes and period 10/13 disappears, all remaining periods shift to the left, but no computer planned orders in the MPS line can shift inside the planning time fence without their conversion to FPOs by the master scheduler. Failure to do so would result in the CPO being moved out into period 1/26. The master

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[3] This is a good example of overplanning, since the other master schedule receipts are for 72; this 85 is also scheduled in the first unsold period.

scheduler should follow the system's recommendation and convert the CPO into an FPO, with the quantity being dependent upon the action taken when balancing the supply and demand in the sold-out zone.

The 3,000# Option

The 3,000# option is another pseudo option, just like the 1,000# option. The difference is simply the lift capacity. The item information indicates nothing unusual (refer to Figure 10.9 on pp. 302–303). The planning time fence is the same for both options, as are the lot sizes. One difference is that the 3,000# option is planned as a 19% option, instead of an 18% option.

Next, the master scheduler should look at the planning horizons data. In period 10/13, notice the option forecast of 2 units. This will automatically vanish when the common items and winch product family's sold-out zone is cleaned up. Also in period 10/13, there is an actual demand of 71 and an MPS lot of 76. The projected available balance in that period will now be 5 (adding 2 to the PAB of 3 to take into account the option forecast dropping to zero), indicating that 5 more sets of the 3,000# option are scheduled than exist as in-house orders. Since the chances of bringing in an order of 5 for this period are slim, the master scheduler needs to clean up the sold-out zone for the 3,000# option.

Cleanup first requires a look ahead to period 10/20, where the actual demand is 75 and the option forecast is zero—the company is not expecting to sell any more winches during the first two periods. In the example the master scheduler needs to cover the actual demand of 146 (71 + 75) for the sold-out zone, for which 166 of the 3,000# option sets are scheduled, leaving a surplus of 20 of the 3,000# options.

Also notice in period 10/20 that the projected available balance is 18 and the ATP is 15. This PAB will increase to 20 once the option forecast in period 10/13 is reduced to zero. A majority of this surplus is caused by the master schedule receipt of 90. A significant portion (14) of this MPS lot probably represents option overplanning done to compensate for expected forecast error. Here, the overplanning has moved into the sold-out zone. Since no additional winch orders are planned to be received for immediate delivery in the sold-out zone, it makes no sense to schedule more 3,000# options than are required by customer orders. Therefore, the master scheduler should reschedule the overplanning (set at 14 options in the example) to the first unsold period in the partially sold-out zone, which is period 10/27, or make preparation to use them. Most master scheduling software systems will not make this suggestion; thus, the master scheduler may have to personally and carefully manage the overplanning dates and quantities.

Here the same alternatives confront the master scheduler as those presented earlier with respect to common items. The availability of the 3,000# option suggests the pulling up of a customer order. Looking at the actual demand detail we see that the company has an order for Ames Mfg. (C1841) requiring 25 of the 3,000# option winches in 10/27. This being the case, the master scheduler could elect to build some of these configurations ahead of time and either ship early (with customer approval) or store the completed products for a period or two.

The master scheduler could also choose to build a *popular* configuration early, using the common items available and overplanned gearboxes, whatever they may be. (An examination of the gearbox master schedule's ATP would determine the feasibility of this alternative.) The point here is that demand, as well as supply, can be managed in an effort to balance the master schedule in the sold-out zone.

If demand cannot be altered, then the supply must be changed. If the master scheduler decides to reduce supply, the purist's approach would entail moving the 14 overplanned options to period 10/27 from 10/20. The purist would again lower the 76 in period 10/13 to 71, and in 10/20 the MPS would read 75. The master scheduler should also pay attention to the fact that the projected available balances in the future are too high, indicating an inventory buildup. The overplanning quantity is 14. Is this too much? Since the projected available balance continues to be positive, overplanning may need to be reduced.

Consider the master schedule detail in Figure 10.9 for period 1/19. The system is recommending the conversion of the CPO for 60 to an FPO. The planning-horizons data for this same period indicates that it is time to make this conversion. But why the quantity of 60? The lot

Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source
3000	3000# OPTION	PSDO	WXYY	PROUD	PLANBL

Balance on Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cumul. Lead Time	Standard Cost
	1	2	Policy	Factor	1	2	3			
0	LFL	1	NO	0	P-13	M12		1	16	1,540

Period	Past Due	10/13	10/20	10/27	11/03	11/10	11/17
Item Forecast							
Option Forecast		2	0	50	70	76	76
Actual Demand		71	75	25			
Proj. Available Balance	0	3	18	19	25	25	25
Available-to-Promise		5	15	51	76	76	76
Master Schedule		76	90	76	76	76	76

Period	1/12	1/19	1/26	2/02	2/09	2/16	2/23
Item Forecast	P						
Option Forecast	84 P	83	84	84	83	84	83
Actual Demand	P						
Proj. Available Balance	23 P	0	0	0	0	0	0
Available-to-Promise	84 P	60	84	84	83	84	83
Master Schedule	84 P	60	84	84	83	84	83

Master Schedule Detail

Req'd Date	Order Number	Lot Number	Order			Recomm. Action
			Qty.	Type	Status	
10/13	3000	216	76	MPS	FIRM	
10/20	3000	217	90	MPS	FIRM	
10/27	3000	218	76	MPS	FIRM	
11/03	3000	219	76	MPS	FIRM	
11/10	3000	220	76	MPS	FIRM	
11/17	3000	221	76	MPS	FIRM	
11/24	3000	222	76	MPS	FIRM	
12/01	3000	223	76	MPS	FIRM	
12/08	3000	224	76	MPS	FIRM	
12/15	3000	225	76	MPS	FIRM	
12/22	3000	226	76	MPS	FIRM	
1/05	3000	227	76	MPS	FIRM	
1/12	3000	228	84	MPS	FIRM	
1/19	3000		60			PLAN

Req'd Date	Order Quantity
10/13	35
10/13	36
10/20	15
10/20	10
10/20	50
10/27	25

Figure 10.9 Master Schedule Screen, 3,000# Option

Forecast Consumption	Resource Profile	Critical Resources							
		Res.	Qty.	Res.	Qty.	Res.	Qty.	Res.	Qty.
PLANBL	WXYY	MCH	7.5	SUB	4.5	ASSM	10.0	KIT	1.0

Selling Price	Special Instructions	Date Run	Action Recommended		
1,980	WXYY-19% OPTION	XX-XX-XX	PLAN		

11/24	12/01	12/08	12/15	12/22	1/05		Period
						M	Item Forecast
76	76	80	80	79	67	M	Option Forecast
						M	Actual Demand
25	25	21	17	14	23	M	Proj. Available Balance
76	76	76	76	76	76	M	Available-to-Promise
76	76	76	76	76	76	M	Master Schedule

3/02	3/09	3/16	3/23	3/30	4/06	Period
						Item Forecast
84	84	83	84	83	84	Option Forecast
						Actual Demand
0	0	0	0	0	0	Proj. Available Balance
84	84	83	84	83	84	Available-to-Promise
84	84	83	84	83	84	Master Schedule

Actual Demand Detail

Refer. Number	Order Number	T	S	C	Req'd Date	Order Quantity	Refer. Number	Order Number	T	S	C
Main Mfg	C1759	A	R								
G Gregory	C1815	A	R								
Phillips	C1825	A	F								
Moore Mfg	C1832	A	F								
Eagle Betts	C1829	A	F								
Ames Mfg	C1841	A	F								

Figure 10.9 ***Continued***

size for a pseudo is generally lot-for-lot (LFL). Using this logic, the computer software asks what should be released to put supply and demand in balance. In period 1/12, the projected available balance is 23, indicating that there is expected to be 23 option sets available at the end of this period. Since demand for the 3,000# option in 1/19 is 83, and 23 are projected to be available at the end of the previous period, a computer planned order for 60 is created. As the example highlights, the computer software adjusts the supply to equal the demand in the first period outside the planning time fence, the first period when CPOs can be placed.

Master Scheduling a Purchased Item in the Planning Bill

Now we turn to the MPS screen for the 4 fpm gearbox, a purchased item (Figure 10.10 on pp. 306–307). Master scheduling a purchased item in the MTO environment is a combination of the logic discussed in Chapter 5 (on using the MPS in an MTS environment) and this chapter's logic on using MPS in an MTO environment supported by planning bills.

ITEM INFORMATION SECTION. The item information section contains the part number (G102) and other key information used by the master scheduler.

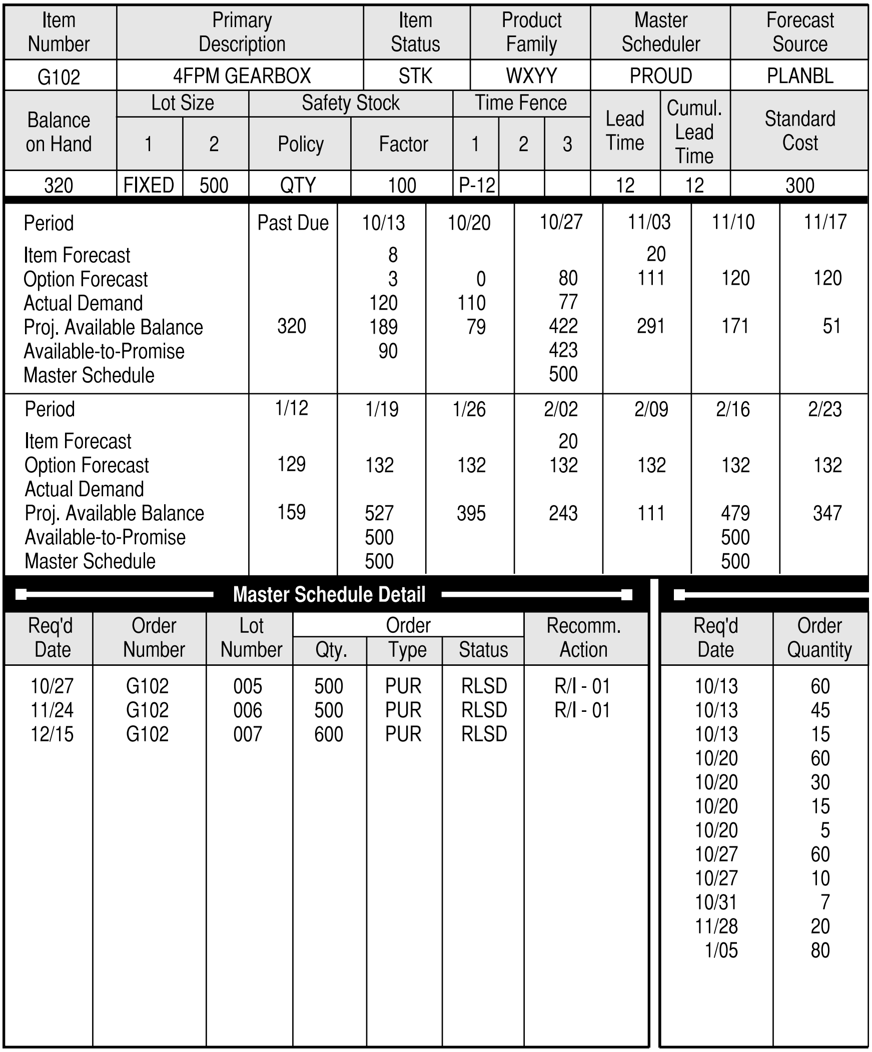
- On-hand balance equals 320 (this is a *real* item).
- Lot sizes are fixed at 500 units per order (minimum order quantity).
- The company intends to maintain a safety stock of 100 units.
- The gearbox is a stocked (STK) item, not a pseudo.

- The lead time is 12 periods—it takes 12 weeks to receive a gearbox from the supplier after an order is placed. The planning time fence is set at 12.
- Thirty percent of winch family sales are forecasted to include this 4 fpm gearbox feature.
- Reschedule-in action is recommended.

Planning Horizons Section. Beginning in period 10/13, there is a service forecast demand of 8 units, indicating that not only is the gearbox part of the winch's final assembly but it is sold as a spare or service item. This means that the gearbox option has a dual demand stream. A forecast of 20 units for expected service demand is found in the first period of each month, rather than being spread evenly at 5 per period.

Returning to period 10/13, where the remaining service forecast is 8, one might speculate that the original quantity for the month of October was 20. In this case the 8 tells us that orders have been taken for 12, leaving the 8 of the original 20 unconsumed. How have those 12 been consumed? The actual demand detail section for 10/31 provides part of the answer: A customer order for seven 4 fpm gearboxes has been promised to customer Liftem-Hi (C1834), with a promised delivery of 10/31. This order has consumed the forecast that precedes it by date. In period 10/27, there is actual demand of 77—and 7 of those are the service order (S) from Liftem-Hi. Since no more service orders are listed in the demand detail section, we would have to assume that the missing 5 service orders have already been shipped or the original forecast for October was 15, not 20.

The option forecast line for the 4 fpm gearbox is simply derived by exploding the ATP of the product family or common items through the 30% in the planning bill. Thus, if 400 winches (of all descriptions) were forecasted for period 11/10, then 120 of the 4 fpm gearboxes would be forecasted (400 × 30% = 120). This gearbox option forecast is automatically consumed every time an order for a winch is booked (this is so because the gearbox is part of the winch's planning bill). In this gearbox's MPS screen (Figure 10.10), forecast consumption is



Item Number	Primary Description	Item Status	Product Family	Master Scheduler	Forecast Source
G102	4FPM GEARBOX	STK	WXYY	PROUD	PLANBL

Balance on Hand	Lot Size		Safety Stock		Time Fence			Lead Time	Cumul. Lead Time	Standard Cost
	1	2	Policy	Factor	1	2	3			
320	FIXED	500	QTY	100	P-12			12	12	300

Period	Past Due	10/13	10/20	10/27	11/03	11/10	11/17
Item Forecast		8			20		
Option Forecast		3	0	80	111	120	120
Actual Demand		120	110	77			
Proj. Available Balance	320	189	79	422	291	171	51
Available-to-Promise		90		423			
Master Schedule				500			

Period	1/12	1/19	1/26	2/02	2/09	2/16	2/23
Item Forecast				20			
Option Forecast	129	132	132	132	132	132	132
Actual Demand							
Proj. Available Balance	159	527	395	243	111	479	347
Available-to-Promise		500				500	
Master Schedule		500				500	

Master Schedule Detail

Req'd Date	Order Number	Lot Number	Order Qty.	Order Type	Order Status	Recomm. Action
10/27	G102	005	500	PUR	RLSD	R/I - 01
11/24	G102	006	500	PUR	RLSD	R/I - 01
12/15	G102	007	600	PUR	RLSD	

Req'd Date	Order Quantity
10/13	60
10/13	45
10/13	15
10/20	60
10/20	30
10/20	15
10/20	5
10/27	60
10/27	10
10/31	7
11/28	20
1/05	80

Figure 10.10 Master Schedule Screen, 4fpm Gearbox

Forecast Consumption	Resource Profile	Critical Resources							
		Res.	Qty.	Res.	Qty.	Res.	Qty.	Res.	Qty.
PLANBL	NONE								

Selling Price	Special Instructions	Date Run	Action Recommended		
440	WXYY-30% OPTION	XX-XX-XX	R/I		

11/24	12/01	12/08	12/15	12/22	1/05		Period
	20				20	P	Item Forecast
120	120	126	126	126	105	P	Option Forecast
20					80	P	Actual Demand
411	271	145	619	493	288	P	Proj. Available Balance
480			520			P	Available-to-Promise
500			600			P	Master Schedule

3/02	3/09	3/16	3/23	3/30	4/06	Period
20					20	Item Forecast
132	132	132	132	132	132	Option Forecast
						Actual Demand
195	563	431	299	167	515	Proj. Available Balance
	500				500	Available-to-Promise
	500				500	Master Schedule

Actual Demand Detail

Refer. Number	Order Number	T	S	C	Req'd Date	Order Quantity	Refer. Number	Order Number	T	S	C
WA01	M0814	F	R								
WA04	M0815	F	R								
Allen Mfg	C1802	A	R								
WA06	MO819	F	F								
Everglass	C1819	A	F								
Phillips	C1825	A	F								
Pacific Inc	C1831	A	F								
WA01	M0820	F	F								
Smith Co	C1837	A	F								
Liftem Hi	C1834	S	S								
SGA	C1813	S	F	A							
Daly & Sons	C1801	A	F	A							

Figure 10.10 ***Continued***

taking place two different ways: one by the planning bill (affects the option forecast) and one by the forecasting logic in the system (service forecast).

TROUBLESHOOTING THE PLANNING HORIZON. The fact that the example company has a safety stock policy of maintaining a 100-unit inventory of gearbox G102 should send a signal to the master scheduler to scan the planning horizon for any violation of that requirement. The projected available balance line tells the tale. There are two violations—in period 10/20 (79 projected to be available) and in period 11/17 (51 projected to be available).

These safety stock policy violations are the source of the action messages in the master schedule detail section and the reason for the recommendations to move 500 gearboxes into the 10/20 and 11/17 periods. If left to its own devices, the master scheduling software system would follow these recommendations. However, before the master scheduler does any rescheduling, he or she should give some thought to the company's unwritten policy of stable master schedules, avoiding mountains of stock, and having enough inventory to satisfy customer demand. Before moving in an order of 500 gearboxes to satisfy a 21-unit safety stock problem (100 – 79 = 21), the master scheduler should make an attempt to finesse the situation.

The search for a solution to this problem begins at the sources of demand for the 4 fpm gearboxes: the various finished-goods winch configurations for which this gearbox is a BOM item, service or spares demand, and safety stock.

We have already seen how the master scheduler got demand reduced for the 1,000# option. One part of that reduction was the product family's ATP of 10 being reduced to zero. That reduction would also explode down to the 4 fpm gearbox in question, reducing demand for it by 3. Suppose, as discussed earlier in this chapter, that the master scheduler got the finished-goods order for the WA01 (1,000# options, 4 fpm gearboxes) reduced from 60 to 55 in 10/13 and from 60 to 30 in 10/27. These reductions of 35 units would flow down to the 4 fpm gearbox level, reducing demand for it—more than enough to eliminate the first reschedule-in recommendation. Of course, the reason for this reduction is that the stocking orders in question use the 4 fpm gearbox.

Another point to consider before blindly following the computer software's rescheduling recommendations is the safety stock policy itself. Safety stock is not sacred; it is there to be used when it suits the best interests of the company and its customers—when unexpected orders need to be satisfied, when production shortfalls occur, and to save the company from ordering 500 gearboxes (may be the supplier's required order quantity) when only a handful are needed!

Period 11/17 shows a projected available balance of 51—49 units fewer than the 100 required by the safety stock policy. The demand reductions for WA01 winches just mentioned would reduce that shortfall, leaving what many experienced master schedulers would view as a somewhat comfortable level of safety stock. A novice might jump in and act quickly on the second reschedule-in message (which is why so many are nicknamed "Pogo"), while the veteran master scheduler may ignore it and move on.

ABNORMAL DEMAND. Finally, looking at period 1/05, the 80 units in the actual demand line of Figure 10.10 represent abnormal demand (the order for Daly & Sons we saw listed on the common-items screen). On 11/28 there is another abnormal demand—20 for SGA (see actual demand detail). Since this SGA order is a service requirement (indicated with an "S") and is abnormal, the booking of these 20 units did not consume the spares forecast. Remember, abnormal demand is incremental demand, and a system with an automated forecast consumption mechanism should not consume the forecast with any demand indicated as abnormal. The handling of the 80 units of abnormal demand in period 1/05 has already been discussed under common items. The difference between master scheduling this gearbox and the pseudo common items above basically centers around the fact that gearboxes can be inventoried, while pseudo items cannot.

Linking Master Schedule and Material Plan

To understand the connection between the master schedule and material requirements planning for pseudo items, refer back to the 3,000# option (see Figure 10.9 on pp. 302–303). Recall that a winding assembly (item 3001) had been structured in as part of this option, and therefore demand for the 3,000# option triggers a one-for-one demand for the winding assembly through the MRP system. The MRP screen for the 3001 winding assembly is seen in Figure 10.11 on pages 312–313.

The MRP screen format is the same as the one introduced in Chapter 5 and similar to the MRP screens worked through earlier in this book. However, there are a few differences. Generally, the MRP system is driven by the MPS line of the master schedule. Thus, if the MPS for the 3,000# option calls for 90 units in period 10/20, that triggers a projected gross requirement of 90 winding assemblies in period 10/13—one lead-time period earlier. However, the 3,000# option is a pseudo and requires a slight modification to that logic.

The MRP System

The *past due* period in Figure 10.11 on pages 312–313 indicates projected gross requirements of 41 units of part 3001 and a scheduled receipt of 8 units. Therefore, the starting projected available balance can be calculated as follows:

	249	On hand
–	41	The number needed to satisfy the past-due requirement (The master scheduler should challenge why these items have not been issued if they are on hand.)
+	8	Past due, but expected to be received instantly since they have not been rescheduled
	216	Starting projected available balance

Requirements Detail Section. The requirements detail in Figure 10.11 is analogous to the actual demand detail of the MPS screen and explains the origins of demand for the item being analyzed. In this case, notice the first two lines of the requirements detail. The first line is for 36 units for customer G. Gregory; the second is for 5 units for the 3,000# option. The 36 units for G. Gregory are a customer requirement. The second is to fill an expected requirement for the 3,000# option. Looking back to the actual demand detail in the MPS screen for the 3,000# option (Figure 10.9 on pp. 302–303), that requirement—36 units for customer G. Gregory—is for 10/13. That is the required date to the finishing line. But to meet this date, the one-period lead time for option 3,000# requires work to start on the item in period 10/07. This can be observed both in the planning horizon for that date and in the requirements detail section.

The 5 units from the second line of the requirements detail (Figure 10.11) represent the winding assemblies expected to be required by the 3,000# option in period 10/13 and are a direct result of the available-to-promise quantity at the MPS option level, the quantity still not committed. Therefore, what is passed to material requirements planning from the master schedule for a pseudo item is a combination of the actual demand and the available-to-promise.

Now look at the 3,000# option in period 10/13 of Figure 10.9, where the actual demand is 71 units. Two orders are found in the details section of that screen: one for 35 and one for 36 (refer to Figure 10.11). Since only the order for 36 appears in the material requirements planning screen, the master scheduler knows that the requirements for 35 units of the 3001 winding assembly have already been satisfied. The remainder of this MRP screen example is provided as reference material for the reader who wants to dig a little deeper into the MPS and MRP integration program.

In working through the several make-to-order examples in this chapter, the reader should get a sense of the difficulty of master scheduling in the MTO environment—the use of pseudo planning bills having contributed an added level of complexity. Difficult though it may be, it is a job that must be done if companies hope to be successful in satisfying customer orders within the lead time demanded by the marketplace.

Item Number	Item Status	U/M	Primary Description	Item Type	Comm. Code	MRP Planner	Value Class
3001	STK	EA.	WINDING ASSM	SUB	NONE	ALLEN	A

Balance on Hand	Safety Stock		Scrap Factor	Annual Gross Requirements	Total Released Requirements
	Policy	Factor			
249	NO	0	0%	4,180	136

Period	Past Due	10/13	10/20	10/27	11/03	11/10	11/17
Service Requirements							
Production Requirements	41	90	76	76	76	76	76
Scheduled Receipts	8						
Proj. Available Balance	216	126	50	–26	–102	–178	–254
Planned Order Release			178			228	

Period	1/12	1/19	1/26	2/02	2/09	2/16	2/23
Service Requirements							
Production Requirements	69	84	84	83	84	83	84
Scheduled Receipts							
Proj. Available Balance	787	–871	–955	–1038	–1122	–1205	–1289
Planned Order Release		251			251		

Master Schedule Detail

Req'd Date	Promised Date	Order Number	Lot No.	Rem. Qty.	Received	Type	Status	Recomm. Action
10/06	10/06	3001	86	8	220	MFG	RLSD	R/O - 03
10/27	10/27	3001	87	178				Order

Req'd Date	Req'd Quantity
10/07	36
10/07	5
10/13	15
10/13	15
10/13	10
10/13	50
10/20	25
10/20	51
10/27	76
11/03	76
11/10	76
11/17	76
11/24	76
12/01	76
12/08	76

Figure 10.11 Material Requirements Planning Screen, 3001 Winding Assembly

Lead Time	Cumul. Lead Time	Order		Minimum Order Qty.	Maximum Order Qty.	Multiple Release Requirements
		Policy	Qty./Time			
1	16	POQ	3	100	NONE	NONE

Total Sceduled Receipts	Special Instructions	Date Run	Action Recommended		
8	NONE	XX-XX-XX	R/O	ORDER	

11/24	12/01	12/08	12/15	12/22	1/05	Period
						Service Requirements
76	76	76	76	76	76	Production Requirements
						Scheduled Receipts
–330	–406	–482	–558	–634	–718	Proj. Available Balance
	228			237		Planned Order Release

3/02	3/09	3/16	3/23	3/30	4/06	Period
						Service Requirements
84	83	84	83	84	83	Production Requirements
						Scheduled Receipts
–1373	–1456	–1540	–1623	–1707	–1790	Proj. Available Balance
250			84			Planned Order Release

Actual Demand Detail

Refer. Number	Order Number	Lot	T	S	Req'd Date	Req'd Quantity	Refer. Number	Order Number	Lot	T	S
G Gregory	C1815		A	R	12/15	76	3000		226	P	F
3000		216	P	F	12/22	76	3000		227	P	F
3000		217	P	F	1/05	84	3000		228	P	F
Phillips	C1825		A	F	1/12	69	3000			P	P
Moore Mfg	C1832		A	F	1/19	84	3000			P	P
Eagle Betts	C1829		A	F	1/26	84	3000			P	P
Ames Mfg	C1841		A	F	2/02	83	3000			P	P
3000		218	P	F	2/09	84	3000			P	P
3000		219	P	F	2/16	83	3000			P	P
3000		220	P	F	2/23	84	3000			P	P
3000		221	P	F	3/02	84	3000			P	P
3000		222	P	F	3/09	83	3000			P	P
3000		223	P	F	3/16	84	3000			P	P
3000		224	P	F	3/23	83	3000			P	P
3000		225	P	F	3/30	84	3000			P	P

Figure 10.11 ***Continued***

The next chapter considers another environment: custom products and design-to-order (DTO) or engineer-to-order (ETO). Here the master scheduler must make decisions in an environment in which bills-of-material, routings, lead times, and completion dates are not predetermined. In addition to addressing the DTO and ETO world, we shall take a look at the make-to-contract environment, which has some similarities to the make-to-order as well as the design-to-order or engineer-to-order environments.

11

Master Scheduling in Custom-Product Environments

Failure to plan on your part does not
constitute an emergency on my part.

Back in Chapter 6, several manufacturing strategies—make-to-stock, finish-to-order, assemble-to-order, make-to-order, engineer-to-order, and design-to-order—were introduced and discussed. Each strategy was partially dictated by the competitive environment faced by the company and the need to meet the customer at some point in time earlier or later in the production process. In this chapter our focus will be on the design-to-order or engineer-to-order (ETO) strategy and on the particulars of scheduling in these environments. The process of developing and introducing a new product for which no actual demand yet exists, whether it be in a make-to-stock or make-to-order company, is a unique application of the design-to-order or engineer-to-order strategy.

As a brief review, recall that ETO companies generally do not begin the design and/or production process until an order, contract, or letter of intent is actually in hand. Producers of specialized industrial equipment, large passenger aircraft, high-tech military equipment, commuter subway cars, and shopping malls are typical of ETO companies. Because these products are expensive and suited for a limited number of customers and applications, their manufacturers cannot afford to design, build, and hold them in inventory in the expectation of future orders. Unlike make-to-stock companies (environments or companies that make their products to stock) that meet their customers at or near the time of delivery, ETO companies (companies or environments that design their products to order) and their customers may meet months and even years before completion and delivery of the final product.

This is not to say that companies that design to order do not, or need not, forecast future business activity or practice the disciplines of sales and operations planning, supply management, and demand management. The mere fact that these companies have engineers, designers, and manufacturing personnel on the payroll is clear evidence that future design and manufacturing activities are anticipated and that some forecasting is, in fact, taking place. Only the time horizons are different.

The Unique Challenges of the ETO Environment

To appreciate the challenges facing master schedulers in companies that design to order and engineer to order, consider Figure 11.1,

Figure 11.1 Tasks of Manufacturing Strategies Compared

which roughly describes the cost/value-adding activities that must go on within the company between its contract with the customer and actual delivery of the finished product. For perspective, companies that make to stock and make to order are added to the figure. The bottom axis of the figure is a time line along which these activities are listed. As the figure makes clear, the company that engineers to order faces the demand management and supply management chores of other companies, but these are just the tip of the iceberg, so to speak—other major planning and scheduling tasks lie beneath the surface:

- Product specifications must be worked out, usually in collaboration with the customer.
- A prototype or sample must be produced and tested.
- Feedback from prototype testing must be reflected in engineering and design changes.
- Bills-of-material or recipes and process routings must be created.
- Ramp-up to the final manufacturing level must begin.

Many of these activities precede the traditional master scheduling and material requirements planning activities so far discussed. This does not mean, however, that the master scheduler and the tools for balancing supply and demand cannot be useful in these earlier activities. Quite the contrary: The master scheduler, being one of the persons responsible for getting the final product to the customer, is the logical coordinator of ETO activities, and master scheduling techniques are eminently suited to ETO activities from design/engineering through final manufacturing. The main difference between master scheduling manufacturing activities and engineering activities is that instead of bringing materials and manufacturing capabilities together within certain build times, the ETO master scheduler must provide for human resources and elapsed times for products thought of in a much broader sense: research specifications, engineering drawings, tooling configurations, testing activities, and so forth.

The Case of New-Product Introductions

Engineer-to-order scheduling issues are equally relevant to companies that make to stock and make to order when they plan and introduce new products. In these instances, a product is being designed or engineered to order at the behest of executive management and the marketing function, who have determined the feasibility and sales potential of the item. New products for these companies must pass through the same research and development activities—research, design, prototype, trials testing, acceptance, ramp-up, training, and full purchasing and manufacturing phases—as ETO products. The same challenges apply. Demand must be forecasted; product specifications or formulations must be developed; design changes based on prototype or clinical testing must be made; agency approvals need to be granted (not in all cases); and processes for manufacturing the final new product must be arranged. In fact, new products create two extra levels of scheduling difficulties regardless of the manufacturing strategy chosen: (1) timing the introduction, and (2) planning for the impact of the new product on current lines of business. These two difficulties are not unrelated.

Timing New-Product Introductions

New-product introductions are always risky. Product development requires high expenses for research and development, design, engineering, and the tooling to bring the product to market. These costs are incurred before even one dollar of revenue is generated and must be paid, even if the product is a failure. And there is no assurance that the new product will succeed. No matter how much thought goes into market research, no matter how much money is spent on promotion designed to introduce the new product to the market, high failure rates for new products are the rule.

Minimizing the risks associated with new-product introductions requires careful forecasting and coordination of production with sales and marketing. From the master scheduler's perspective, this means working closely with marketing and new product technology to hit rollout dates planned in the company's promotional strategy. The confusion and damage caused by poor coordination between production and promotion can be great and are well illustrated in these two cases:

- In the late 1980s, Lotus Development Corporation spent months and millions preparing its large base of Lotus 1-2-3 users to switch over to a forthcoming upgrade of its popular spreadsheet program. The customers were ready, but the product was not. Month after month of production delays caused confusion and frustration for both the company and the market.
- In late 1991, Apple Computer Company introduced its low-priced Classic model of the Macintosh. The product rolled off Apple's new, state-of-the-art plant built especially for this machine; they were right on time for the Christmas buying season. The Classic was an immediate success in all but one respect: Demand was more than twice what had been forecast. The result: angry dealers who were allocated a few machines at a time, demoralized salespeople, and many customers who simply gave up waiting for their promised Classics and bought competing machines to put under the Christmas tree.

Planning for the Impact on Existing Products

The introduction of a new product generally has some impact on a company's existing products. In some cases the new product is an intended *replacement* and, except for spare parts, production of the existing product is discontinued; the annual model changes of automobiles are a good example. In other cases, it is assumed that the new product will cannibalize some sales from the company's existing products; one might assume Apple's introduction of the Powerbook surely had that effect on its basic, monochrome-screen models. When over-the-counter drug manufacturers promote a new, improved aspirin on television, they cause significant impact on demand. In some cases, as with the introduction of new products in separate product markets, no impact on existing products would be expected; Sony's introduction of a new video camera, for example, would have no measurable impact on sales of its popular Walkman.

Consider a company preparing for the introduction of a new product that it hopes to eventually replace demand for an existing product. In planning its initial periods of production, the company needs to do several things: It must continue satisfying demand for the old product until the new product catches on in the marketplace; it must plan on the elimination of inventory for the old product; and it must phase in production of the new product as demand and production for the old one taper off (Figure 11.2).

In this case, the company planned the new-product introduction for period 3, and planned for the gradual displacement of the old product by the new product over periods 3 through 6. This is a simple case without lead time or inventory complications. Nor does it recognize the possibility that the production line may have to be shut down for production training and product changeover. But this case should make the point about the issues the master scheduler must consider in planning new-product introductions. Let's take a look at the process for getting a new product to the marketplace.

Master Scheduling Activities and Events

Virtually any set of items, activities, or events can be master scheduled. In the traditional sense, master scheduling typically means

	1	2	3	4	5	6
Old Product	20	20	15	10	5	0
New Product	0	0	5	10	15	20
Total Production	20	20	20	20	20	20

Figure 11.2 Introduction of a New Product (in Period 3)

Launching a New Product

The job of putting a new product into the marketplace in a respectable time frame has proven to be a frustrating experience for many organizations. To improve the process, a number of companies have adopted a four-step approach to new-product introductions.[1]

1. Use a task force to plan and create data structures, and maintain control of these structures. The task force usually consists of four to seven people representing research, design, marketing, process engineering, master scheduling, planning, operations, purchasing, and possibly regulations.

2. Make all new products and their market introductions part of the sales and operations planning process. Each new product is added to the monthly agenda, with discussions revolving around design, manufacturing, marketing promotion, pricing, and strategy issues.

3. Create a bill-of-activities that includes all the activities and events that must take place between product idea approval and actual product launch. Couple this bill-of-activities with resource templates to generate priorities and resource requirements. Eventually, these bills-of-activities will be replaced with actual bills-of-material, recipes, formulations, and process routings.

4. Use planning and control concepts of master scheduling and Enterprise Resource Planning to execute materials and activities requirements. This makes it possible for the company to plan, schedule, and report progress and to know at all times what needs to be done, the nature of resource requirements, and when each activity is to be completed.

[1] For a complete discussion of new-product launches, see Jerry Clement, Andy Coldrick, and John Sari, *Manufacturing Data Structures* (New York: John Wiley & Sons, 1992).

scheduling production of tangible materials: putting together the items or ingredients to produce a ballpoint pen, a bottle of shampoo, an automobile, a can of paint, or the like. In the ETO and new-product environment as seen in Figure 11.3, many of those activities and events take place at CAD-CAM screens, in testing laboratories, in sales brochures, and around conference tables. *These can, nevertheless, be scheduled.* This goes back to the earlier discussion of *what* do we master schedule? End items? Options? Raw materials? Here we schedule activities and events, and instead of recipes or bills-of-materials, bills-of-activities or bills-of-events are among the tools of the master scheduler's trade.

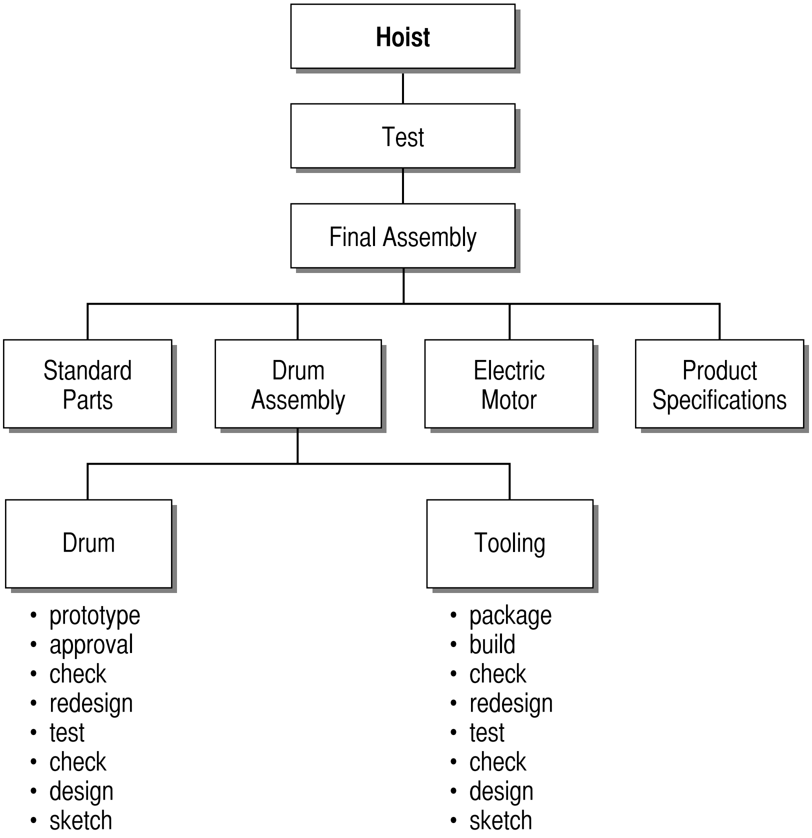


Figure 11.3 Bill-of-Activities for Special Hoist

Consider Levitation Lift Corporation (LLC), which is in the heavy-duty hoist and crane business. Working with executive management and marketing, LLC's research and development center has proven a new hoist technology that it is ready to give to manufacturing. A small-scale model based on off-the-shelf materials has been tested in the lab and in the field, and it is time to bring it up to full scale through design and engineering and ready it for production.

No design specifications and no bills-of-material currently exist for this new product, but the master scheduler can still apply his art and tools to this project following these steps:

1. *Classify the scope of the change.* Is the hoist a major or minor product change, or does it represent a new-product concept? Does it fit into any existing product family? This information imparts a feel for the complexity and difficulty associated with the upcoming change.

2. *Create a dummy item number for the finished hoist.* Ask engineering to release a number that will be used for planning purposes. At some future point the new product will either carry this number or be assigned a new one.

3. *Identify significant activities.* Here the scheduler or task force would list the set of important tasks necessary for designing and producing the hoist—ideally, in the sequence in which they must take place. In this case, design, detail engineering, perhaps a customer approval of the detailed design, drafting, checking the drawings, creating of a prototype, and so forth, all the way through the assembly and shipping activities, might make up this list. Even significant marketing activities should be identified.

Naturally, the master scheduler cannot know in detail all significant activities and events associated with the creation of this hoist: They do not yet exist. But knowledge of the products of his or her business, and close consultation with relevant parties within the company, make a close approximation possible. And at this stage, a close approximation is all that is required.

4. *Create a bill-of-activities.* At this point a bill-of-activities like the one in Figure 11.3 can be constructed. The product will be built from the bottom up, but anyone looking at the bill will know that to get the special hoist onto the shipping dock, a test will have to be made. Four significant events must take place before that test can be made: Product specifications must be developed and produced; an off-the-shelf motor must be obtained; a drum assembly must be designed and built; some standard parts must be procured as their significance to the hoist is spelled out. Each of these four significant events has its own bill-of-activities or defined bill-of-materials. As unknown events are entered into the bills-of-activities, use dummy numbers.

5. *Estimate total resources and lead time for each activity or event.* In the example, we would consider the resources required to complete each of the four significant activities (and their subactivities) and the test involved in making the special hoist (Figure 11.4). The lead times for performing each of these activities can be estimated from past projects and programs as well as conversations with the relevant company functions, and these can be used to create the planning lead times and a cumulative time frame for the entire ETO project or program.

To take just one activity as an example, LLC might schedule the tooling for the drums as follows:

The schedule for the drum tooling is combined with similar schedules for each of the other significant activities to construct an overall project lead-time schedule. This is then available for the next step.

6. *Rough cutting the project or program lead-time schedule.* The methodology for rough cut capacity planning (Chapter 14) is here brought to bear on the hoist's schedule of the project to determine if the plan is feasible, given the company's resources and other commitments.

7. *Replace dummy item numbers with real numbers.* As the bill-of-activities becomes more fully articulated with design specifications

Activity	Elapsed Time (weeks)	Hours Required	Competition/ end of week #
Sketch	3	120	3
Design	4	165	7
Check	1	15	8
Test	1	10	9
Redesign	2	80	11
Check	1	15	12
Build	3	120	15
Package	1	20	16
Total	16	545	16

Figure 11.4 Loading and Scheduling the Activities

and actual materials or ingredients required, obtain real numbers from design for those items and substitute them for the "dummy" numbers in the original plan.

8. *Validate/adjust lead times and resources as required.* Over time, as more information becomes available, the original estimates for lead times and resource requirements will need to be validated and, where appropriate, adjusted. The Enterprise Resource Planning software system (maybe in conjunction with a project management system) can then be used to recalibrate the entire project or program.

9. *Reprioritize all materials and activities.* This is where a scheduling and network system can be of the greatest use. If all marketing, engineering, and manufacturing activities are driven by a common master schedule, each event will be in line with the others to ensure continuity with the entire schedule.

Prices and Promises to Keep

The schedule developed through the steps just listed has three uses in ETO and new-product introduction situations:

1. To determine a delivery date for the marketplace, sales force and the customer. In new-product introductions, as in the Lotus Development anecdote cited earlier in this chapter, it was important to be able to tell dealers, sales representatives, and end users when the product would be available. They needed this information for their planning purposes, and woe unto the manufacturer that fails to deliver on its promises. Delivery dates are also critical to the negotiating process between company and customer on engineer-to-order products.

2. In cases for which a delivery date requirement has already been determined, the bill-of-activities product schedule allows the company to backward schedule to obtain all the event start and required completion dates that will make the delivery date feasible. These become the start and due dates for all individual tasks.

3. In the absence of bills-of-material or recipes, the schedule and bills-of-activities just described form a basis upon which the company can estimate its costs in time and materials on an ETO product or new-product introduction. These costs are an important element in pricing the forthcoming product, which is generally required in competitive bidding situations for ETO products.[2]

[2] American and European firms have tended to determine product price on the basis of their manufacturing and development costs. Japanese firms generally have adopted a target-price approach, first determining a price that will allow their new products to penetrate or create a market, and then working back through manufacturing and materials to design and engineer the product with a cost structure that allows them to meet that price objective profitably.

What Can Go Wrong

The ETO and new-product schedule can be upset by a number of unforeseen problems. In fact, the longer the planning horizon, the greater the potential for these problems to manifest themselves. Among the sources of scheduling problems are the following:

- *New or unknown processes and technologies.* Since the company is dealing with a new product, it is possible that the processes necessary to produce it may also be new. Of course, the same can be said for the technology needed to bring the product to the marketplace.

- *Lack of product specifications, at least initially.* It is not unusual in this environment for design to release to manufacturing an incomplete set of specifications.

- *Frequent design and engineering changes.* For example, in scheduling the introduction of a complex new product, a period of many months may elapse between the point at which certain materials are specified within the design and the date at which materials are actually scheduled for purchase. During this time, and unknown to the manufacturer, the supplier of that material may have gone out of business or switched to a different material, which may not be compatible with the design. This adversely affects the schedule.[3] This would not happen if the supplier was part of the team.

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[3] For a very complete description of the problems of product development management, with emphasis on the worldwide auto industry, see Kim B. Clark and Takahiro Fujimoto, *Product Development Performance* (Boston: Harvard Business School Press, 1991). Other research performed by the Ford Motor Company in 1986 indicated that the typical U.S. automaker accelerated the frequency of its engineering changes up to the time of the first production run, and even continued those engineering changes at a high pace several months into the production phase of the new-model introduction. The result was surely much confusion, delays, and poor-quality automobiles until such time as

What typically happens in many development projects is shown in Figure 11.5. This shows planned activities and their schedule along a time line from project inception in January to manufacturing and shipping in late August. The first part of the figure is what was planned; the second part shows what can happen: Here design has consumed more time than planned, and since the activities are sequential, all the remaining activities must be squeezed into a shortened time frame if commitments to the marketplace and customers are to be met. Product quality usually suffers and people's frustrations mount as a result.

Integrating Design and Operation Activities

Engineering and manufacturing schedules must be integrated so that all energy in the company is focused on a common goal: satisfying customer needs while safely making a profit. In companies that produce highly engineered products, and in companies for which new-product development is a major strategic thrust, engineering and related functions make up a significant portion of schedule time and costs. These engineering activities precede manufacturing activities, and they do not stop with new-product design and release, but continue in the form of ongoing engineering support.

Even though it is easy to see why engineering and manufacturing activities should be integrated, they are not always integrated in practice. This is because engineering and product development schedules typically are not derived from manufacturing and procurement schedules that trace their origins back through the master schedule to sales plans and customer commitments.

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the level of changes stabilized. The same Ford study indicated that engineering changes for Japanese auto firms peaked 16 to 20 months *before* the first production run; very few changes were made in the months just prior to initial production, and virtually none once production was in full swing.

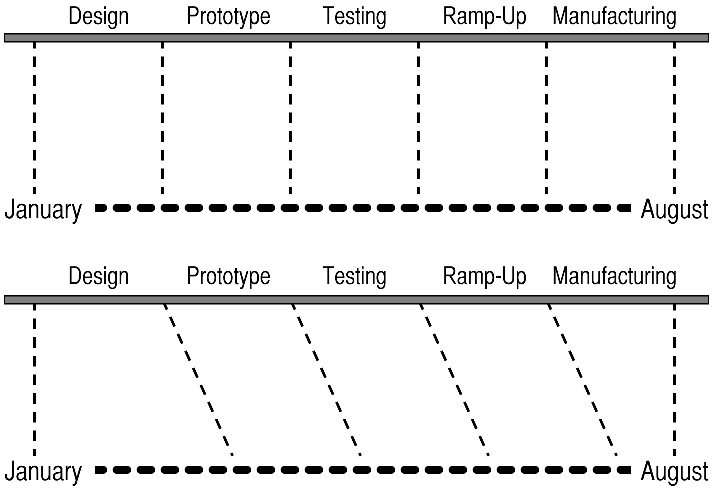

Figure 11.5 Effects of Schedule Delays

Figure 11.6 on page 330 illustrates the relationship between engineering/design and manufacturing activities in moving from the early stages of a project to a delivered project. This relationship goes beyond product engineering to tool and process flow design.

Many companies fail to integrate engineering activities with manufacturing activities or drive them with a common master schedule. This is a typical source of trouble. It does very little good to be ready to perform a manufacturing operation on time when the product design is not yet complete; nor does it help company efficiency and effectiveness when different design projects converge on a design resource bottleneck at the same time.

The solution to the problem of engineering-manufacturing integration is to drive all requirements—whether engineering, sales, marketing, manufacturing, or finance—with a common master schedule (Figure 11.7, p. 331).

A common master schedule ensures that a company's total resource requirements are aligned with the goal of satisfying customer needs. It is tied directly to the output of the sales and operations planning process. By generating need dates through Enterprise Resource Plan-

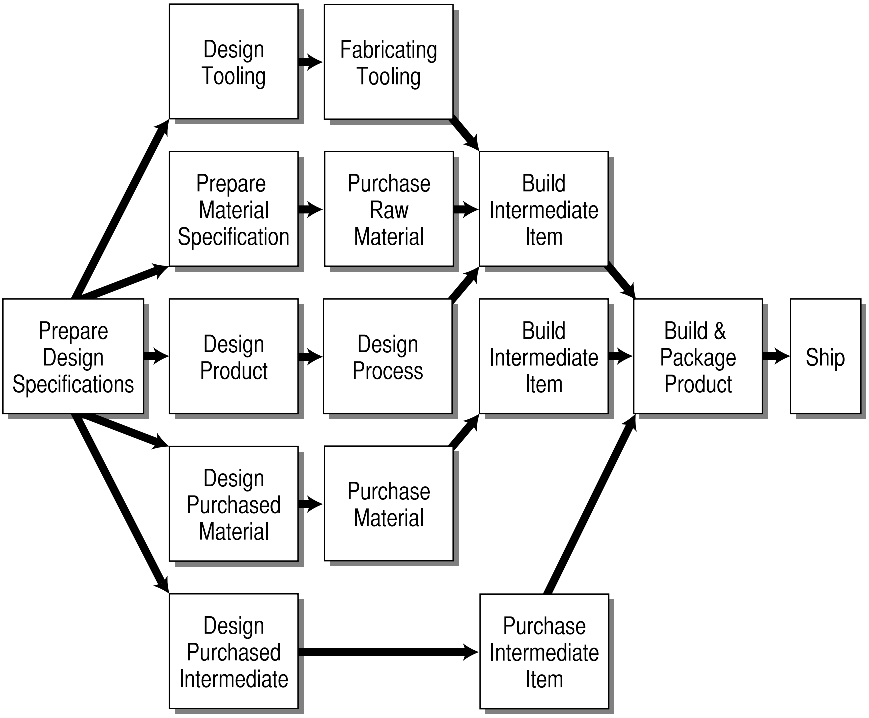

Figure 11.6 Engineering and Manufacturing Dependent Relationships

ning, design personnel are informed of required dates for its products (drawings, specifications, process instructions, etc.). These required dates can be passed upstream until all activities and priorities are scheduled.

For years, manufacturing companies have used a combination of the master schedule, process routings, and work center resource data to plan and control capacities. To do the same for design resources, process templates that define tasks for each engineering job need to be created. These templates identify the sequence of tasks, where work will be done (e.g., in the laboratory), and the time estimated to complete each task. With the templates in hand, a resource capacity plan can be generated for design and manufacturing work. Tasks that require common resources (e.g., drawing, checking) are highlighted

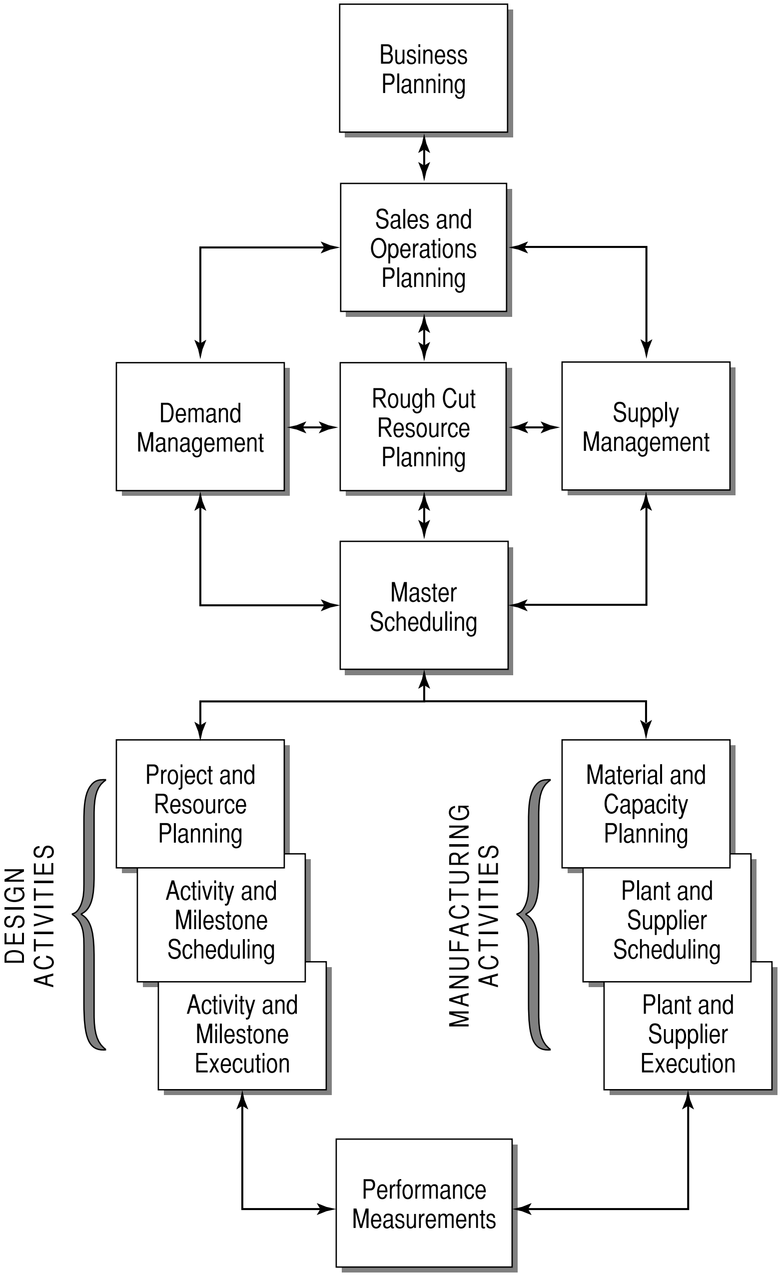

Figure 11.7 Design and Manufacturing Resource Planning Using a Common Master Schedule

as potential impediments to the scheduled completion of design requirements.

This process is known as design or engineering resource planning. It is a methodology that integrates design and manufacturing requirements by means of a common master schedule.

Plan Down, Replan Up

Design engineering has products just like manufacturing. Some of these products consist of drawings, bills-of-material, routings, recipes, formulations, process sheets, and specifications. In order to produce these products, a series of activities or events like designing, drafting, checking, and documenting must take place. Therefore, if a company can tie together these design activities, identify the amount of lead time necessary to complete each activity, and determine the due date for the product or project, a detailed activity plan can be created. Figure 11.8 on page 333 is an example of a customized product that requires standard manufacturing items and operations plus yet-to-be-designed materials and tooling.

In a demand-driven business, the initial plan is created by starting with the demand due date and planning down through all of the activities needed to satisfy this demand due date. The due date for the product in this example is workday 145 (the planning start is shown on the left side of the boxes in the figure). The final configuration of the product is estimated to take five days of work once the two standard times and one new time are available. Taking this into account, the start date for the final configuration process is workday 140. This start date creates the due dates for the standard and new items.

All initial planning numbers are shown on the left side of each activity box while the replanning numbers are shown on the right side of the activity box. The start dates are shown at the bottom of the

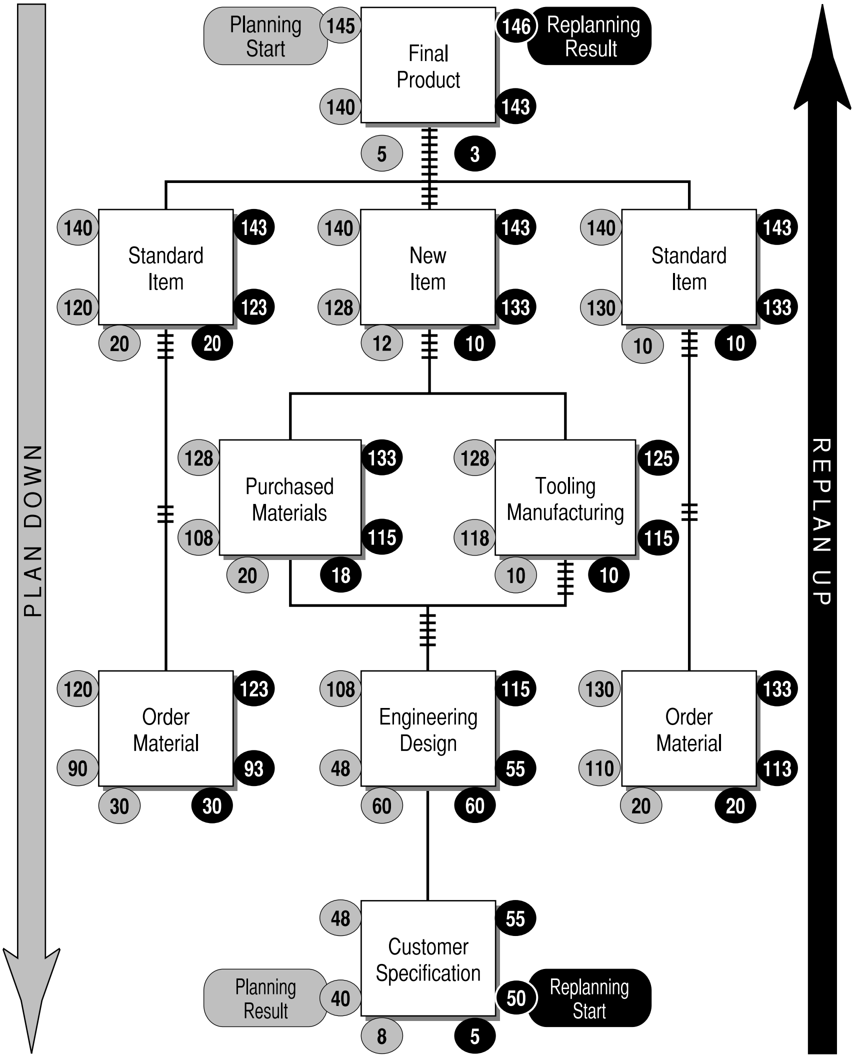

Figure 11.8 Plan and Replan Example

activity boxes while the due dates appear at the top of the boxes. The logic used here is standard master scheduling and event requirements planning for the standard items. The process continues as shown in Figure 11.8. However, there is more to this product build than just the standard item. What about the new item?

The due date of the new item is workday 140. Once the new materials and tooling are available, it is estimated that it will take 12 days to manufacture this new item. Therefore, the planned start date for the new item is workday 128. This means the materials and tooling must be available on workday 128. The lead time for the purchased materials is 20 days, creating a start date or purchase date of workday 108. The tooling, which will be built parallel to the purchase material lead time, has a start date of workday 115 due to its 10 days of lead time.

The example indicates an engineering design group that is responsible for both the material and tooling designs. With this in mind, the earliest start date (workday 108 for the purchasing of the new materials and workday 118 for the tooling manufacturing) is used as a due date for the completed designs (workday 108). The designs are anticipated to take 60 more days, and therefore must be started on workday 48. This means the customer's completed order and company's (i.e., engineering's) understanding of the design specification must be available on workday 48. The company in this example has planned 8 workdays to study and analyze the customer's specification. This means the customer must deliver its order specification on or before workday 40. What the company has now is a detailed activity plan. Once this plan is done, it is time for execution.

The customer in this example missed the order specification delivery date by 10 days, delivering the specification on workday 50. Since the plan was for the company to have this specification on workday 40, a potential problem exists in meeting the final product delivery date. The good news is that this potential problem has surfaced on workday 50, not workday 145, the product delivery date. The process now moves from a downward planning effort to an upward replanning effort.

Going back to the figure and starting at the bottom (replanning start), the company determines if the specification can be studied and understood in less than 8 days, perhaps even 5 days. If this can be done, the specifications will be available in engineering design on workday 55. The next question is if engineering design can cut their lead time to delivery. In the example, the answer is no. Therefore, the materials and tooling design will be available on workday 115. This tooling design delivery date does not present any problems to tooling manufacturing since the initial plan calls for a delivery of the tooling on workday 128. (Tooling will be ready on workday 125, assuming a 10-day lead time.) The problem is purchased material.

Can the supplier shorten its lead time of 20 days? The answer in the example is a little—maybe by 2 days. With the design arriving in purchasing on workday 115 and a purchasing lead time of 18 days, the materials can be expected on workday 133. This means the manufacturing of the new item can start on workday 133. Can the 12-day manufacturing lead time be compressed? Yes, by another 2 days. Adding the 10-day manufacturing lead time to the start date of 133 gives us an expected completion date of 143. This means that the final configuration process can start on workday 143.

The final product configuration is planned to take 5 days, but this also can be reduced to 3 days. (Final assembly has committed to doing this because of the notification time it received. Remember, this replanning effort is taking place around workday 50 and we're discussing schedule changes for workday 143.) Reducing the lead time of the final configuration process means the new due date for the final product is projected to be workday 146, one day late. Chances are the company can find another day to pull out of the schedule somewhere if the replanning is continued.

The message here is that bad news early is better than bad news late. The earlier the problem is identified, the better chance a company has to positively respond. This example shows real customer service. The customer shows up 10 days late with the specification and the example company expects to deliver on time or, at worst, 1 day later than the original due date.

CAPACITY-DRIVEN ENVIRONMENTS

Just a few weeks on the job was enough to convince Bill Childs that he was dealing with a different set of scheduling challenges. As a master scheduler with 10 years of experience in the automotive-parts industry, Childs was used to situations in which scheduling the flow and assembly of materials and parts was the foremost concern. Indeed, ensuring the smooth movement of materials into the finishing stage of production for alternators, starter motors, and other auto parts had defined his previous work. But at Testing Systems, Inc., his new company, Childs was up against something quite different.

Testing Systems was a high-technology company that engineered hardware and software for diagnostic testing of both electromechanical and microprocessor-based equipment. This was an environment in which engineers and software programmers were many and assemblers were few, where output was measured more in circuitry designs and lines of programming code than in products shipped, and it required a different approach to master scheduling.

Childs found that he needed to change his thinking about many of the basics of scheduling that had served him well in the auto-parts industry. Instead of working back from end-product demand through traditional bills-of-material, this environment required a focus on getting the most out of the company's cadre of highly paid, highly educated "knowledge workers." It was, after all, their capacity to design and program exotic electronic equipment that was Testing System's product; manufacturing and assembly were not where value was added and were, in fact, generally subcontracted to other firms.

Bill Childs's situation is no longer unique in modern industry and actually represents a growing segment of the master schedul-

Material-Driven	Capacity-Driven
• Schedule to meet demand • Schedule fewest number of items • Back schedule from end item or option • Schedule materials, then balance capacity • Customer demand is the controlling variable	• Schedule to utilize resources • Schedule bottlenecks • Forward schedule after bottleneck; back schedule before bottleneck • Schedule capacity, then balance materials • Capacity resources are the controlling variables

Figure 11.9 Two Different Scheduling Environments

ing craft. The real growth industries of the past quarter century—software, microprocessors, medical technology, biotechnology, and aerospace—present situations in which traditional manufacturing and assembly are often the tail of the cost- and value-adding process, and science, design, engineering, and development are the dog that wags that tail. Thus, schedulers have had to learn to measure and manage capacities similar to those presented above, and this learning will undoubtedly continue into the foreseeable future. These are capacity-driven environments, and they represent a departure from the material-driven environment typical of those represented elsewhere in this book.

To understand the difference between the material-driven and the capacity-driven environments, consider Figure 11.9, where the unique concerns of the two are contrasted.

This figure makes it clear that the focus of the master scheduler's attention in the capacity-driven environment is on the key resources of the company, and every opportunity is sought for getting the most from those resources. In a job shop, the internal resources might be metal machining equipment; in a law firm they might be billable hours; in a software development company, they might be the capacity to create lines of programming code; in a plate glass–making facility that utilizes multimillion-dollar continuous-process equipment, they might be machine hours.

What to Master Schedule

Unlike material-driven companies, such as computer producers, capacity-driven companies focus their scheduling not on the final product but on the capacity that produces it. When the question "What should we master schedule?" is asked, the computer company invariably answers, "Finished computers." The capacity-driven company, such as a machine-tooling company, might focus on machine-hour capacity. Consider just such a machine-tooling company and the situation described in Figure 11.10. This company has three items on its schedule, Items 121, 122, and 123. The master scheduler has learned through experience the amount of drilling-machine time required for each of these items. By multiplying the machine hours per hundred items by the quantity of expected demand (in hundreds), the total capacity requirements for each item can be determined.

Like all demand, machine time has both a quantity and time dimension (i.e., the customer wants an item in a certain quantity and by, or at, a certain time). Figure 11.11 is the master scheduling matrix that matches demand and supply for the drilling operation. Here the master schedule lists demand not in terms of the number of items sold, but by the machine hours required for sold items. Available-to-promise (ATP) and the master schedule lines are likewise expressed in machine-hour terms. Reviewing the master scheduling matrix for the drilling operation, the master scheduler sees that he or she is sold out through period 2. In fact, period 2 shows that the company is oversold by 14 hours. As with scheduling in other environments, the shortfall

Item	Machine Hours Required per 100
121	1.00
122	1.25
123	1.40

Figure 11.10 Capacity Matrix

	1	2	3	4	5	6
Actual Demand	240	254	182	140	70	0
Available-to-Promise	0	–14	58	140	210	280
MPS (Capacity)	240	240	240	280	280	280

Figure 11.11 Master Schedule Matrix for Drilling

could be eliminated through the simple expedients of either 14 hours of overtime, off-loading some of the demand to another drilling work center, or subcontracting the work to an outside source. As in the materials-driven environment, the ATP line is a handy guide to determining whether new demand can be accepted and when. Beginning with period 3, for example, the master scheduler notices a positive ATP, signifying that drilling capacity is available to commit and sell.

The master scheduling matrix can help a capacity-driven company commit to customer deliveries without overselling its capacity. Figure 11.12 on page 340 shows four customer orders in which the required capacity has been calculated.

If these orders are to be sequenced in the order shown, when can the master scheduler commit each without further planning overtime, and so forth? (This example assumes that the master scheduler has decided to work overtime to satisfy the 14 hours oversold in period 2. However, no more overtime will be planned.) The first order for item 121 requires 50 hours; it can be committed for a period 3 delivery, which leaves 8 hours in period 3's ATP (58–50). The next order (122) will use the remaining 8 hours of ATP in period 3 plus 4.5 hours of period 4's ATP, leaving 135.5 hours available-to-promise in period 4.

The next order, for item 123, requires 16.8 hours. It, too, can be promised in period 4, leaving an ATP of 118.7 hours of capacity. The last order in the example is again for item 121, which requires 1.00 hour of capacity per 100 units. The request is for 12,000 units, which will require 120 hours of capacity. The numbers tell us that period 5

Item	Machine Hours Required per 100	Order Quantity (100s)	Total Required Machine Hours
121	1.00	50	50.0
122	1.25	10	12.5
123	1.40	12	16.8
121	1.00	120	120.0

Figure 11.12 Matrix Showing Required Capacities

should be the promise date (only 118.7 hours of capacity in period 4 being available-to-promise), but the experienced master scheduler, hoping to satisfy the customer and use company resources most effectively, may commit a period 4 delivery. Even though the rules are not to plan any extra capacity, the person working with capacity numbers must remember that capacity is aggregated planning and not an exact science. Of course, the specified work may also take longer than estimated! Knowing what to do in this instance is part of the art of master scheduling.

Capacity Master Schedules

In the capacity-driven environment, the focus tends to be on bottlenecks in the operation. Many capacity-driven companies have pinch points in their operations, like the hourglass-shaped situations faced by many assemble-to-order manufacturers of option-laden products, and these are the critical scheduling points. By developing routings or bills-of-events, such as those shown in this chapter, master schedulers can work backward to determine the latest possible start date required for each operation that precedes the bottleneck. Likewise, they can determine the earliest expected finish date by doing the same for all events and processes that occur beyond the bottleneck.

Make-to-Contract Environments

In the custom-products environments, many companies do little or nothing until they have a contract in hand for a particular product program or project. At that point, development work begins, as do the other tasks that lead to the completed work. This was not the case at Hyster Company when Larry Wilson, an Oliver Wight Principal, was the master scheduler. Hyster had an engineer-to-order product that was master scheduled with pseudos that contained total hours required on their major shops, an estimate of capacity for key suppliers and typical people-weeks required in engineering, and so on. The pseudo was used to master schedule 18 months into the future and was replaced with the actual bill-of-material upon receiving a customer's letter of intent. The process was then managed as described in this chapter.

The make-to-contract world is very similar to the engineer-to-order world; however, in the make-to-contract environment, the company may very well have completed the design work, and there may already be a working prototype. This is very much the situation in the aerospace industry, in which an aircraft producer may have to approach the U.S. Department of Defense with an operating prototype of the new fighter plane it hopes to sell. At this point, the company has no orders, but it has already invested millions or even billions in design, new-materials development, tooling, and flight testing. This is often the price of admission to the formal competition for the megabillion-dollar-contract award for the next generation of fighter aircraft.

In other cases, the producer may already have an established product that it is selling to a new customer. In winning a contract, it is only building the same product to the quantity and time specification of that customer—perhaps with some minor design changes.

Make-to-contract jobs, especially with the government, very often have strong inducements for on-time delivery—namely, late penalties. Thus, the master scheduler has a critical role to play not only in the successful planning and control of the program or project but in its profitability to the company. These contracts sometimes feature partial-completion payouts to the contractor, in which the company is paid for materials and other expenses *as incurred;* this is quite different from being paid for the work on delivery dates and has an effect on the scheduling policy of the producer.

The Need for Standards

"The Aerospace/Defense Industry is characterized by change in high volume often at rates that seem beyond human responsiveness," according to Paul Hemmen, a former Oliver Wight Principal and longtime friend.[4]

> The application of the computer to the manufacturing environment, in which precise processes are used to produce exacting designs subject to change, offered a solution for maintaining control and responsiveness to change. Using the computer to crunch the numbers as often as necessary to keep essential data current is also required.
>
> Manufacturing resource planning system components—the computer, planning software, and knowledgeable people—have provided the so often sought-after control potential for the commercial industry for two (to three) decades. MRP systems are ideally suited for the Aerospace/Defense [A&D] Industry as well. In fact, the basic logic of how MRP works was born in the industry during the 1950s on submarine programs.

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[4] Paul G. Hemmen, "The Standard for Master Production Schedules," *APICS A&D SIG Digest,* Edition II, April 1991.

So much progress has been made since then, especially adapted by commercial users, that it may seem as though the A&D Industry stood still in updating their management systems. It is probably more correct to say that A&D systems have become nearly as sophisticated as the weapons systems being produced. Commercial users, having found the secret to controls in manufacturing, have on the other hand simplified their systems in applying Just-in-Time/Total Quality Control (JIT/TQC) concepts in the factories that are driven by excellent planning and control processes, such as MRPII. Hence the need for standards that provide a coherent, simple means for applying MRP/MRPII systems in the A&D Industry.

The Standards

Early in 1987, the fate of MRP systems for the A&D Industry was essentially on hold awaiting application criteria and guidance. Government and industry worked as a team and reached agreement, which provided the ten Key Elements subsequently promulgated as Standards in application DFAR sections Subpart 242.72. The ad hoc committee selected the widely known and proven quality standards for successful use of MRP systems as they would be applied for materials management and accounting systems.

Standard Number 2 states in part: “Assure that costs of purchased and fabricated material charged or allocated to a contract are based on valid time-phased requirements as impacted by minimum/economic order quantity restrictions. A 98% bill of material accuracy and 95% master production schedule accuracy are desirable as a goal in order to assure that requirements are both valid and appropriately time-phased.”

When these accuracy levels are not evident, the contractor is burdened with proving the relevant cost significance to the government. Of the Standards, this one is the meat-and-potatoes issue!

Some divergence of views and debate remains, however, about this key element, as to whether it means 95 percent accuracy or performance. MRPII users have established by overwhelming precedent of proof testing and pain in the manufacturing environment the realities and benefits of this goal.

As early users discovered, MRPII without an initial MPS step in the process produced no more than computerized order launching. The essence of the MPS is to inject a clearly distinguishable management step in the process to achieve balance, stability, and validity for requirements and schedules.

The master schedule is management's "anticipated build schedule" and as such must pass the test of doability regarding capacity resources and materials availability on a continuing basis. It is not a static parameter containing a snapshot of the contract requirements. Rather, the MPS is dynamic data representing product configuration and flow, forward-looking supply planning, and performance feedback, within the constraints of reasonable capability and expectation for the company.

The master schedule is management's steering control over all planned activity as it portrays supply versus demand. Continuous feedback (closed-loop in the MRP process) and performance reporting are essential to progress toward the goal of 95 percent MPS. What makes the MPS and BOM the meat and potatoes of MRPII is that they answer three of the four fundamental questions in the manufacturing equation:

What are we going to make? MPS

What does it take to make it? BOM

What do we need and when? MRP

Coupled with Standard Number 5, which sets the quality level for inventory record accuracy (IRA) at 95 percent, and the activity in manufacturing can be bracketed. The equation is solved.

What do we already have? IRA

The essence of the master schedule is to inject a clearly distinguishable management step in the process to achieve balance, stability, and validity for requirements and schedules.

Satisfying the Customer and the Standard

Figure 11.13 is the master schedule for an aerospace company that holds a contract to make and deliver air-to-ground missiles. *The contract is the demand* in this make-to-contract situation, and here the actual demand line indicates the contract delivery dates (20 missiles in

	Past Due	1	2	3	4	5	6	7	8
Actual Demand					20				20
Projected Available Balance	0	5	10	15	0	5	10	15	0
Master Schedule		5	5	5	5	5	5	5	5

Figure 11.13 MTC Master Schedule, Missiles, Level-Loaded

period 4 followed by 20 missiles in period 8). *The master schedule line is the supply.* Late penalties are part of this particular contract.

The level-loaded master schedule in Figure 11.13 works out just fine in terms of the dates and quantities required by the contract, but in its fear of encountering an unanticipated delay that might cause it to miss the delivery dates—and thus incur a financial penalty—the missile producer may sometimes decide to build ahead of the contract, as shown in Figure 11.14. Here the producer is leaving some slack in certain periods—slack that could be used to catch up if any delays occur.

In building slack or buffer into the schedule, the missile producer knows that if there is a delay in periods 1 through 3 or periods 5 through 7, time can be made up in periods 4 and 8. If that time is not needed, the production lines might be scheduled for some other work or for maintenance.

Building unnecessary inventory is generally avoided by make-to-contract companies, but here the extra inventory might be viewed as a prudent safety stock against a possible financial penalty, and it may be that the government is paying the missile company for materials and other expenses as work is completed, not on delivery, in which case inventory has minimal carrying cost to the company. However, someone pays for early inventory; it's not free!

This same missile producer may have a design change to phase in or have another contract for a different missile design that requires that work begin in period 9. In this situation, the company determines that it must close down its line for all of period 8 to make the changeover to begin building the new missile. Since the contract terms for the first missile remain unchanged, the company will have to schedule periods

	Past Due	1	2	3	4	5	6	7	8
Actual Demand					20				20
Projected Available Balance	0	6	12	18	2	7	12	17	0
Master Schedule		6	6	6	4	5	5	5	3

Figure 11.14 MTC Master Schedule, Missiles, Build Ahead

	Past Due	1	2	3	4	5	6	7	8
Actual Demand					20				20
Projected Available Balance	0	6	12	18	4	10	16	20	0
Master Schedule		6	6	6	6	6	6	4	0

Figure 11.15 MTC Master Schedule, Missiles, Line Closing (Period 8)

1 through 7 differently. Figure 11.15 shows just one of the many possibilities.

Variations of these scheduling approaches are applicable to accommodate short weeks due to holidays, slow ramp-up to full production of a new product, slow ramp-down to phase out one product and introduce another, and so on. The possibilities are many. The only constant is that the contract defines the obligation to deliver in terms of product, specifications, quantities, and dates. The supply schedule need not be the same as the contract delivery.

When Supply Can't Satisfy Demand

Despite many defense contractors' belief that "the customer won't let us change the master schedule," the company can and should do what it believes is valid and necessary with the master schedule as long as customer specifications, quality, costs, delivery dates, and quantities are satisfied. The misguided notion that the contract controls the supply schedule leads to all manner of dysfunctional behavior among companies. It is not atypical, for example, for a defense contractor to fall behind schedule to the point that delivery dates cannot *possibly* be met and yet refuse to do the rescheduling of material and capacity that will bring the process back under rational control. The excuse for not rescheduling is that "the customer won't let us change the master schedule." Perhaps the customer will not let the company change the committed *delivery date,* but changing the supply schedule generally is under the company's control.

Producers must control the master schedule, and when the facts dictate that delivery dates cannot be met, the schedule must be adjusted to the new reality. A *past-due* master schedule *cannot* be made as scheduled no matter how hard the company may try. If today is February 15, the product scheduled for completion on February 1 will not be completed on time. Leaving the schedule completion date as the first of February sends invalid information throughout the system. So why not work to *valid* schedules, ones that can be made for which people can be held accountable?

Up to this point, we have concentrated our efforts on master scheduling and the planning of materials and capacities to build products and satisfy customer needs. The next challenge is to schedule production by communicating these real customer needs to manufacturing. The formal communication lines are supported by various techniques, some of which the next chapter on finishing addresses.

12

Finishing Schedules

Rolling delivery promises gather no reorders.

Up to this point, the focus has been on bringing together the material and the capacities to build products that customers will eventually order. At some point the manufacturing floor must be told what to produce, in what quantities, and in what configurations. This communication is accomplished through the finishing (or final assembly) process. The finishing process converts the master schedule from a plan into manufacturing action.

The finishing schedule establishes work authorization—that is, approval to perform work on defined products, using specified capacity and materials—according to a schedule that identifies the sequence in which the work is to be performed. The finishing schedule sets priorities for finishing, assembly, filling, testing, packaging, and so forth. This communication has a variety of labels: work orders, production orders, shop orders, factory orders, job orders, campaigns, batches, production or line schedules, scheduling boards, run rates, and kanbans.

Manufacturing Strategy and Finishing Schedules

The manufacturing strategy of the company has an impact on how and when work authorization should be released to the finishing process. Is the company pursuing a make-to-stock or engineer-to-order strategy? Or is it something in between, like make-to-order? To understand why strategy matters, look at Figure 12.1. On the left, the make-to-stock company has a typically short backlog of customer orders because the product is delivered off the shelf. Over the remainder of the time periods, it must plan demand using a forecast. In a make-to-order environment—on the right side of the figure—the backlog is much longer and the company does not need to plan demand using a forecast to nearly the same extent. This is because in the make-to-order environment, the customer places the order and typically expects to wait for delivery. The important point here is that the time allotted to the finishing process may be less than the sum of the backlog. In a make-to-stock company, the time allotted to finish the product is often greater than the sum of the customer backlog.

Satisfying these two different demand patterns requires different scheduling patterns. In a make-to-stock environment, the product

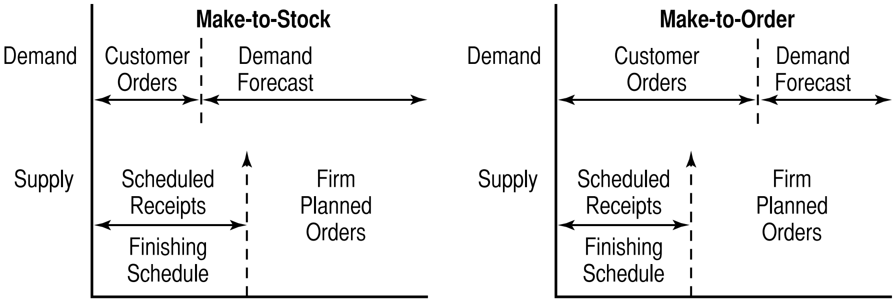

Figure 12.1 Finishing Schedules in Make-to-Stock and Make-to-Order Environments

must be on the shelf prior to receipt of the customer order. Therefore, released schedules must be created prior to receiving the customer orders, and the scheduler must key the finishing schedule to the demand forecast. In contrast, the make-to-order environment is one in which the final product is not built until the customer order is in hand, with all option requirements specified. Here, the customer expects to wait while the company's manufacturing unit releases and executes the finishing schedule.

Although the company's selected manufacturing strategy impacts how and when to release work authorization into the finishing process, other variables also need to be addressed. These questions should be asked:

- Is manufacturing set up in a job shop environment, or does it operate in a continuous-flow environment?
- What is the volume of product moving down the line?
- How about the product mix? Many choices? Few choices?
- Are the manufacturing lead times short or long?

The answers to these questions can affect how best to schedule, sequence, and communicate what needs to be done.[1] For instance, a continuous-flow production line that builds a few types of products with short manufacturing lead times may choose to use production schedules to authorize work; no work order may be necessary.

Manufacturing Approaches

Having a manufacturing strategy is just part of what a company needs; beneath the level of strategy must be some chosen tactic or approach

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[1] See John Dougherty and John Proud, "From Master Schedules to Finishing Schedules in the 1990s" (*APICS 33rd International Conference Proceedings,* 1990), 368.

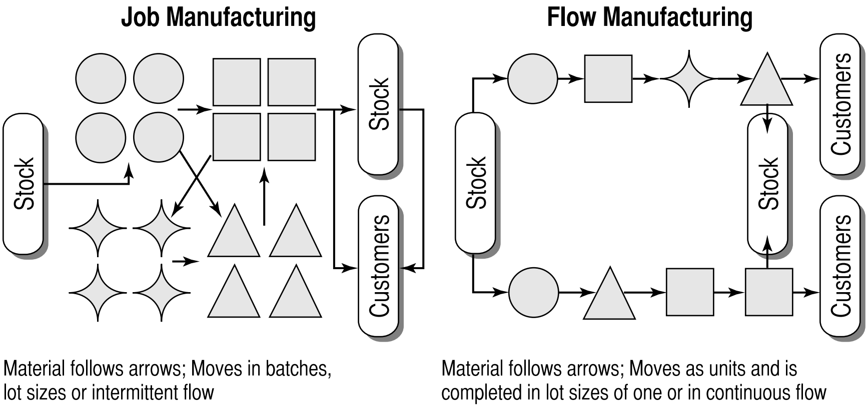

Figure 12.2 Job and Flow Manufacturing

to fulfilling the strategy. For most companies, the approach will be either job or flow manufacturing. Both are represented graphically in Figure 12.2.

Job Type Manufacturing Environments

The left side of Figure 12.2 represents a job type environment. In the job shop work centers and resources are grouped by like functions (saws together, presses together, etc.), so work flows to the various work centers in the sequence of steps needed to be performed. Here, the manufacturing process begins with material in a stock location. Material leaves this location to enter a queue at work center 1, where it awaits processing. When that job becomes the priority, work commences. From work center 1, the partially processed material is moved to either an intermediate stock location or into the queue for work center 2. And so it goes until each step of the manufacturing process has been completed and the transformed material enters the finished-goods inventory or is shipped to a customer. Assembled products built in various lot sizes, engineer-to-order products, low-volume make-to-order products, and others characterized by high product variation are generally manufactured in this way.

Flow Type Manufacturing Environment

The right side of Figure 12.2 represents the flow type environment. In the continuous flow environment work centers or cells and resources are grouped in the normal sequence that work is performed. Here, material starts at the beginning of the line and is subject to processing operations and/or added materials as it literally flows down the line. Other materials flow into the line as required. A good example of a flow environment is found in plate-glass manufacturing, a continuous process in which raw materials are added to one end of a furnace tank, and molten glass pours out of the other, forming a continuous ribbon of glass. This ribbon is subjected to continuous forming, annealing, and cutting operations at various points on the production line. Make-to-stock, quick-speed, and high-volume make-to-order products with minimal product variation—particularly nonassembled products like glass, nylon, chemicals, engineered lumber, and so forth—are most frequently manufactured using this approach.

Mixed Approaches

Job and flow manufacturing approaches to production are not mutually exclusive. It is quite common to have a job shop feeding a flow line, a flow line feeding a job shop, a flow line feeding another flow line, or one job shop feeding another job shop. The combination of approaches used, and their order, is determined by the requirements of the business and by the state of its process technology.[2]

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[2] These issues are addressed in James M. Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1994). Utterback points out how the interaction of product and process innovation has often transformed traditional job shop operations, first into traditional job shop routines interspersed by "islands of automation," and eventually into continuous-flow manufacturing.

Other Manufacturing Issues

Finishing schedules need to consider issues other than the manner in which manufacturing will take place. These are volume, the level of product variability in the product mix, and required completion lead times.

Volume

The finishing schedule for inexpensive ballpoint pens, a high-volume operation with quick speeds, is much different than that of a commercial aircraft manufacturer or other producers of high-cost, low-volume products with slow speeds. In the high-volume, quick speed operation, completed products may come off the line at hundreds per minute—for example, 50,000 pens per shift. To ask manufacturing to report unit completions to a work order would be overwhelming and counterproductive. In the low-volume environment, however, using a work order to collect data and information about each operation is not overwhelming.

Variability in the Product Mix

The amount of variability in the product mix not only influences the choice of job versus continuous flow manufacturing, it also impacts the finishing schedule. High product variability often causes a company to utilize the planning bill concept and pseudo items, which need to be pulled together in the finishing process to correctly communicate what the customer has ordered. Take, for example, a company that manufactures cosmetics. A continuous-flow production line may be used to produce bulk or semifinished product. Once the customer order is received, the bulk may be used in a filling and/or packaging operation.

Completion Lead Time

Does it take a long time to actually produce the product, or is the manufacturing cycle short? The answer to this question may impact how the finishing schedule is communicated to manufacturing. If a long completion lead time is required, the master scheduler might lean toward the use of a work order. But if the company's business is producing sewing needles by the hundreds of thousands, or if its product takes just a few seconds to manufacture, then a work order may not make as much sense, and some form of line schedule may be appropriate. A line schedule (sometimes supported by a schedule board) announces what will be run: by type, quantity, item number, batch, sequence, and so forth.

Sequencing

During the creation of the master schedule, individual manufacturing sequences of products are generally not considered in many environments, specifically job or intermittent production facilities. What mattered then was what needed to be produced in what period (days or weeks) to satisfy anticipated or firm demand. Specific sequencing takes on critical importance in the finishing process, for several different reasons.

A printer, for example, may need to run the light colors first, then run the sheets again, this time with the darker colors (assuming a single-color machine). A textile producer of athletic socks may choose to run the socks requiring light dyes before the dark dyes are used. An engineered lumber producer may want to run the narrow widths before the wider widths due to machine adjustments, and gradually run wider and wider widths to minimize setup times.

However, there are manufacturing environments where the sequencing and grouping of batches may take place earlier in the process—that is, during the master schedule preparation. This may be desired due to the use of common materials (once the bag of powder is open, we want to use it all) and processes (set up adjustment, on a constant, rate-based production line). Chemical, food, and cosmetic producers are examples of companies that plan sequencing early in the game.

Traditional Means of Communicating the Schedule

One traditional way master schedulers communicate to the manufacturing floor is by means of the production order (also commonly called a *shop order* or *work order*). Generally, computer software systems support this form of schedule communications fairly well. A production order is a document or group of documents, conveying authority for the manufacture of specified items or products in specified quantities. It generally includes a bill-of-material for manufacturing the product, a list of operations or steps required by work center, and various other documents specifying tooling, equipment settings, inspection, and testing requirements. It may include documents to be used as turnaround forms to report material consumption, manufacturing activity, or completion of particular steps in the process.

Data contained on separate bills-of-material and routing documents can be combined into a single document with additional information. To do this, each component within the bill-of-material must be identified to the operation or manufacturing step where it is needed. Additionally, the manufacturing location where material is to be delivered must be identified. With this information, a finishing document can be created.

Another way to communicate finishing schedules is by means of work center schedules. Many job shops use these as final authorizations and to set priorities.

Do We Really Need These Computers?

One of the most interesting scheduling boards seen by the author was located in the plant of a Japanese rubber belt manufacturer (Figure 12.3). It was not merely a scheduling board, but an inventory-control system as well. Each item was represented by a vertical tube into which wooden blocks of varying thickness (lot size) could be placed, representing the current inventory level (height of the blocks in each tube) and the required level for the current time frame (pieces of string attached by pins *across* each tube that could be moved up and down as demand for the item changed).

As work was completed, the block of wood representing the inventory was placed in the tube and the physical material was placed in an outbound stocking location. The operator would then remove the next-in-line block of wood from the "out" tube. This block was his or her authorization to begin work on the next item (identified by the block of wood). This simple board served as inventory control, demand driver, work authorization, and priority system. It was simple, and it seemed to work without benefit of electricity, computer chips, or megadollar software.

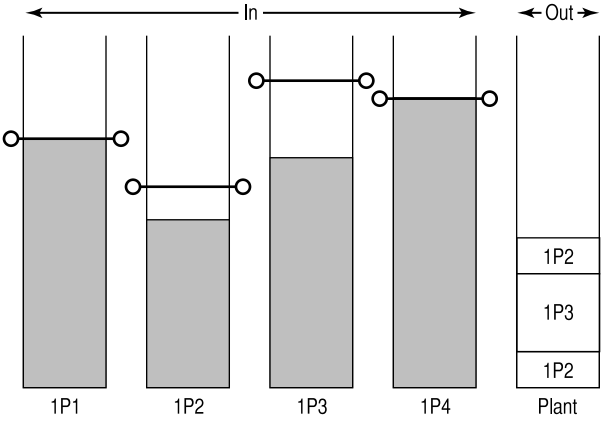

Figure 12.3 Manual Scheduling Board

Yet another means of finishing-schedule communication is by means of a production line schedule, which is most applicable in a continuous flow environment. When it comes to process, repetitive, or lean manufacturing environments, companies may find it beneficial to simply use line or batch schedules without work orders. A line or batch schedule can be a very simple directive, as in "run four lines and two shifts to make this product." Or it can be more definitive, as in "run product 123 on line 1 at 2,000 per shift" or "run product 345 on line 2 at 6,000 per day for three days." Line schedules can be displayed on manually maintained schedule boards or electronic computer scoreboards. These boards notify personnel which job to run next, along with date and quantity specification requirements.

The Kanban System

The kanban, the Japanese term for *signal,* is another popular method of communicating to manufacturing. The signal itself can be a card attached to a bin, a square painted on the floor, or a simple container holding assembled components or raw materials. Japanese manufacturers originally created kanbans as a means for indicating when some action was to take place.

The entire kanban process is set in motion by a demand pull originating with a customer or stocked order. An order creates requirements for products, which in turn pull materials through the entire system of suppliers and production. In the ideal kanban system, nothing moves until an order is taken, but when the order does appear every level of the production system becomes the customer of the next-lower level of production. As manufacturing depletes materials from a kanban container, the empty container becomes an order to refill—a source of demand pulling more of the same materials through the production process. When the container is full, that sector of the production system stops.

The kanban system was designed as a simple but elegant way to tightly link production with demand, thereby eliminating the need for costly inventory and finished goods for which there might be no demand.[3] Raw materials and components are delivered by suppliers only as they are needed—that is, Just-in-Time—and are brought to manufacturing only as needed. The manufacturing floor builds products only to fill orders. When demand is slack, workers perform maintenance, discuss improvements, and so forth. This system, which operates more on the basis of actual demand than on forecasted demand, has many obvious merits but also some serious weaknesses, especially insofar as products with long lead times and fluctuating demand are concerned. In a sense, kanban companies have adopted a make-to-order strategy in competitive environments where others would use make-to-stock. At the same time, they have corrected some of the lead-time problems normally associated with this strategy by pioneering new methods of rapid line changeover, shorter cycle times, lean manufacturing, and Just-in-Time delivery of materials from suppliers.

Product-Dependent Kanbans

There are two types of demand pull systems: product dependent and product independent. With product-dependent kanbans, the kanban itself is identified to a material. The product-dependent kanban is labeled with the item number, description, and kanban quantity. These kanbans are the visible records needed to set the system in motion. Think of the manufacturing floor and refer to Figure 12.4 on page 359. Imagine that each work cell has an outbound stocking location. These outbound stocking locations are identified to a product. In the example, work cell B has three locations for 1S1, two for 1S2, and one for 1S3.

For work cell A, there are five outbound stocking locations. The inbound stocking location for work cell A might be the warehouse.

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[3] The kanban method is based upon the waste-reduction methodology that motivated Japan's postwar industrialists. Devastated by the war, and short on capital and materials, they viewed American production methods of the 1950s and 1960s as creating profligate levels of inventory for which orders might or might not appear. Far better, they thought, to only order materials and build things for which there were orders.

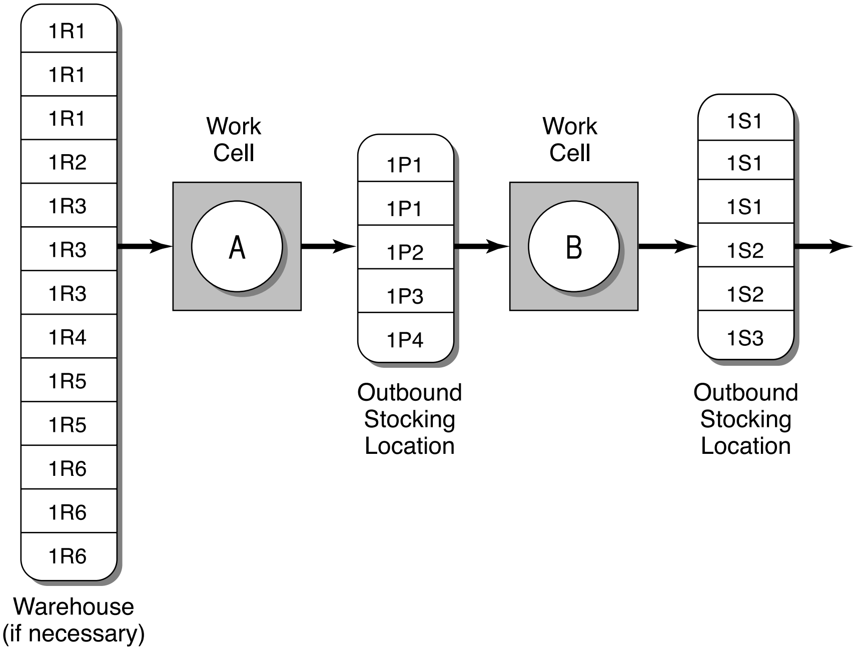

Figure 12.4 Product-Dependent Kanban Example

The way product-dependent kanban works is as follows: If the kanban is empty, fill it. If the kanban is full, stop production. If all kanbans are full, the line is shut down. Now let's assume all kanbans are full, the line is full, and a customer needs a 1S1. That customer can be a customer from outside the plant or the next operation (each work cell has customers and suppliers). Referring to Figure 12.5 on page 360, we see that satisfying this demand leaves an empty kanban square formerly occupied by 1S1—which authorizes work cell B to produce a 1S1.

Assume that it takes a 1P1 and 1P3 to manufacture the 1S1. Work cell B would get or request a 1P1 and 1P3 from work cell A's outbound stocking location, move those two items to work cell B, and commence the operations necessary to produce the 1S1. What this action does is free up two more kanbans—the 1P1 and 1P3. That now authorizes work cell A to fill those two kanbans. Assume that it takes a 1R5 to make a 1P1. Work cell A would get or request a 1R5 from the warehouse and commence working on the 1P1. When finished, work cell A would place the 1P1 in its outbound stocking location designated for

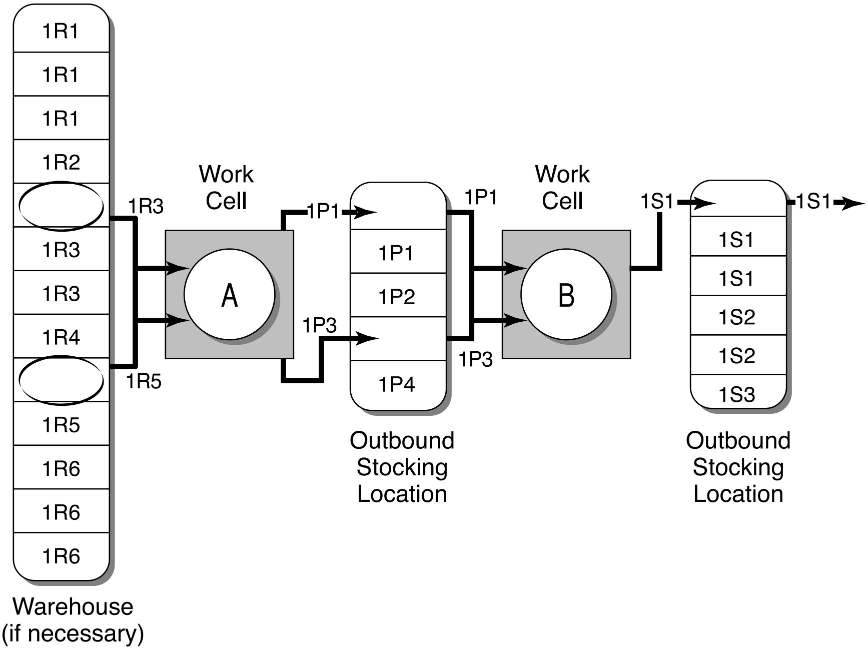

Figure 12.5 Product-Independent Kanban System

1P1, and would still know that it has a 1P3 to build, which takes a 1R3. Work cell A would get or request a 1R3 from the warehouse, build the 1P3, and place it in the outbound stocking location labeled 1P3. This action would free up the warehouse space for 1R5 followed by 1R3, which are replenished in the same manner as the work cell's outbound stocking locations.

Product-Independent Kanbans

This system uses unlabeled outbound stocking locations (Figure 12.6, p. 361). Assume that the production line is full. A demand pull for the 1S1 sets the line in motion. The outbound stocking location for work cell B is now empty, which authorizes work cell B to produce another product.

The work cell B operator looks back and pulls the 1S2 forward into his or her work space (the worker may use additional materials from other feeder lines) and commences work cell B's operations by taking

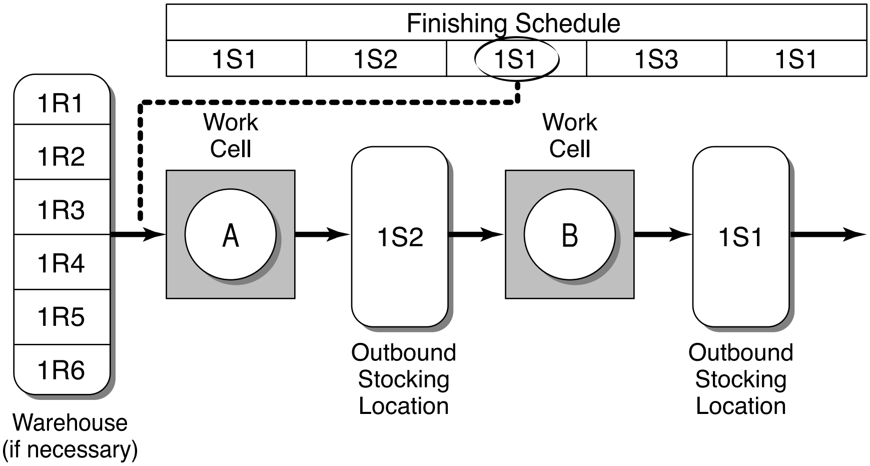

Figure 12.6 Time-Phased BOM Example
Meeting the Customer Before Chair Seat Assembly Work Is Commenced

the 1S2 (semicompleted item) and doing what is necessary to complete the product. When finished, work cell B would move the 1S2 to its outbound stocking location. The initial pull action also puts work cell A into action since its outbound stocking location has been freed up. The next question is, what does work cell A start to work on? The decision is made by using the master schedule or finishing schedule. In the example the finishing schedule states that a 1S1 is the next desired item. Therefore, the gateway operation will commence building a 1S1, which is then passed down the production line as kanbans are freed up by satisfying customers.

Tying It All Together

The Soft Seat example used in Chapters 8 and 9 dealt with a conference center chair product family. In Chapter 8 we discussed the process of restructuring the conference center chair's bill-of-material into a series of pseudo or planning bills. This was done to facilitate forecasting, bill-of-material database maintenance, master scheduling, and option overplanning. Let's return to the Soft Seat chair example and see how these pseudos and the overall planning bill concept is used during the finishing or final assembly process.

When the conference center chair planning bill was structured (refer to Figures 8.6 and 8.7, pp. 228 and 229, for a review), five options were identified: seat assembly, chair back splat assembly (albeit a purchased assembly in the example), left leg assembly, hardware kit, and right leg assembly. The seat and back splat assemblies were color sensitive, so we took the seat and back splat assemblies and put them into a color-sensitive option bill. This meant that a selection of the red option required the red seat assembly and the red back splat assembly. The other three items (right leg assembly, left leg assembly, and hardware kit) were common to all conference center chairs. Therefore, these items were structured into a common-items bill. This structuring was done assuming that the marketplace was permitting a two-period (or two-week) delivery time. The use of the time-phased bill-of-material and knowledge of where the company desires or needs to meet the customer are very important when determining the best way to structure the planning bills. How would the following scenarios impact the planning bill structure? What if, by compressing the manufacturing and procurement lead times, we could remain competitive and not stock completed colored chair seat assemblies? Alternatively, what if the competition began quoting longer lead times so that we didn't have to stock completed colored chair seat assemblies? If we didn't have to stock completed chair seat assemblies, then the color-sensitive items would become the colored all-weather cloth and the colored chair back splat assembly—the seat inners and the label contained in the chair seat assembly become common parts (Figures 12.7 and 12.8).

The new or restructured planning bill looks like Figure 12.8 on page 364. As you can see, the common-items bill now contains the label, seat inners, hardware kit, right leg assembly, and left leg assembly. The red option bill contains the red all-weather cloth and the red back splat assembly. Besides the planning bill structure, the master scheduler may desire to put other useful and meaningful data on each

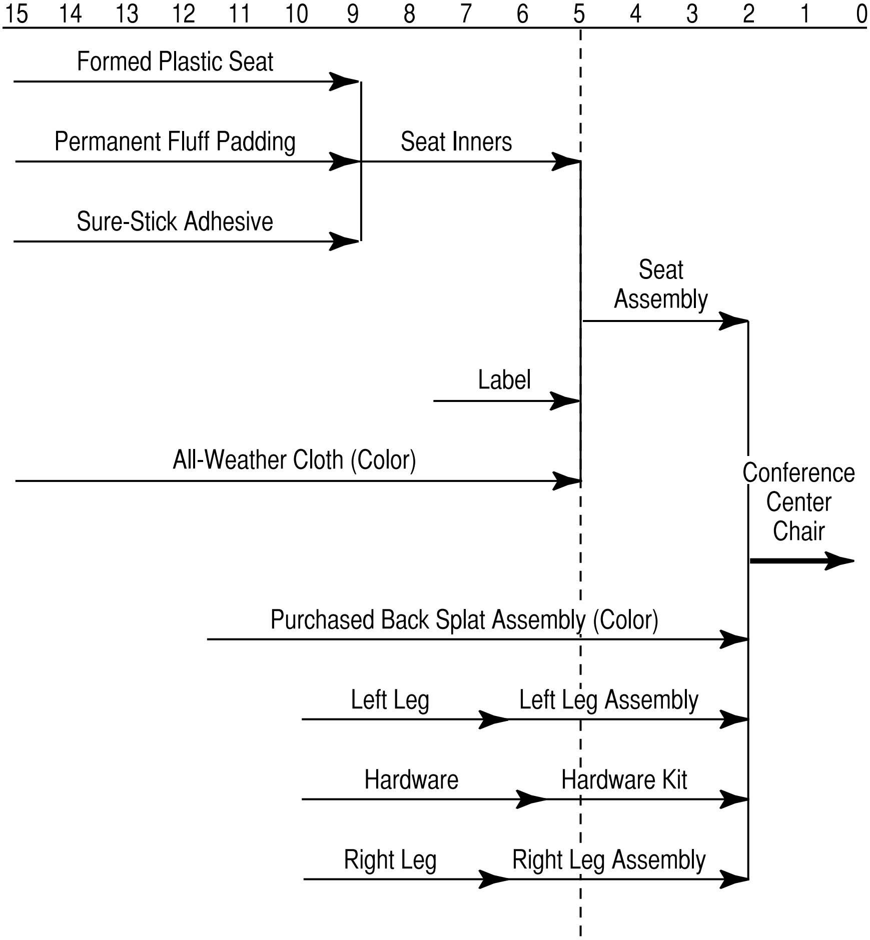

Figure 12.7 Planning Bills When Colored Chair Seats Are Not Stocked

item in the pseudo bill. This data may include delivery point of usage, parent operation number, and lead-time offset.

Review the red option pseudo bill at the bottom of Figure 12.8. The all-weather seat cloth and chair back splat assembly are the items in this bill. Notice that the cloth is required for operation 07, which is done in work center "SA." This tells us that the all-weather seat cloth will need to be delivered to location SA when operation 07 is started. The all-weather seat cloth item (as Figure 12.8 states) has a lead-time

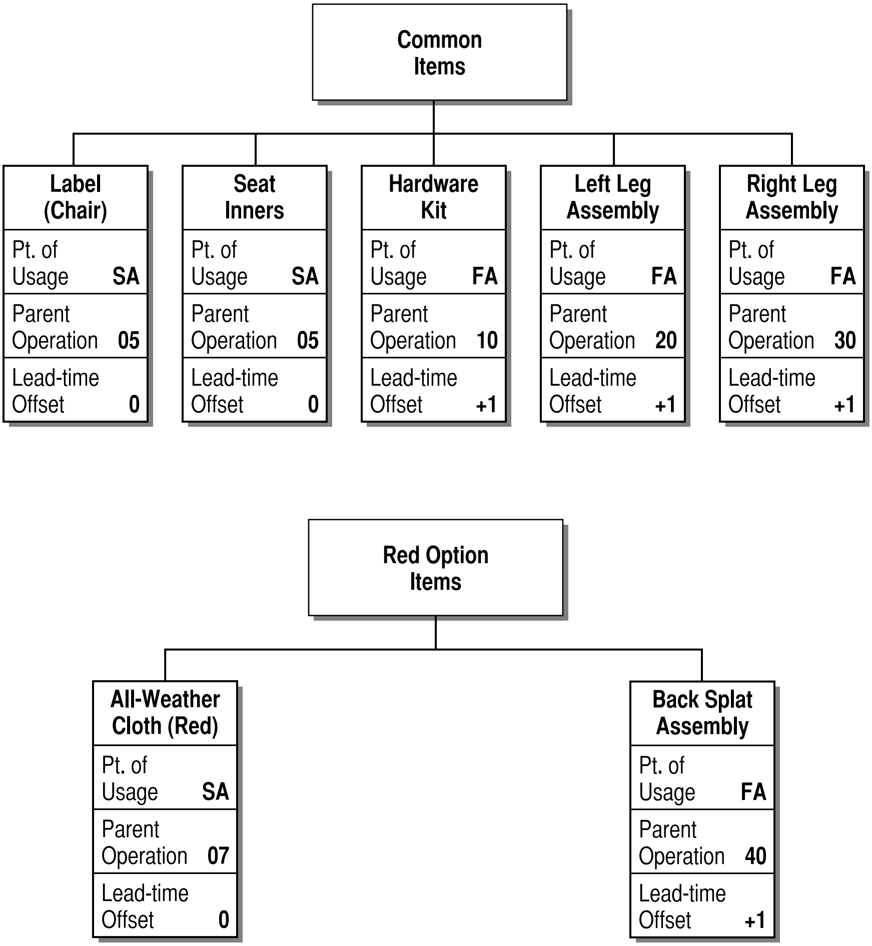

Figure 12.8 Final Assembly and Subassembly Routings for Conference Center Chair

offset equal to zero. In other words, the cloth is needed when the manufacturing work for the conference center chair commences.

If we review the chair back splat assembly, it can be seen that the back splat assembly is needed for operation 40 and is to be delivered to location “FA,” its point of usage. The lead-time offset for the chair back is +1, which means that the chair back splat assembly is required to be on the line one period after the assembly of the chair commences.

The conference center chair's planning lead time is used to offset all items in the option as well as all items in the common-items bills. Next, the lead-time offset serves to adjust or add back in time the identified lead-time offset. With this technique, all items in the conference center chair can be time phased to the time required on the production line. In addition, these materials can be delivered directly to their usage points. This technique and capability are very important when a company commences flattening its bills-of-material, expanding the use of common-items bills, and moving toward the flow-line concept.

Final Assembly or Process Routings

Prior to the flattening of the planning bills for the conference center chair product family (Chapter 8), the red seat assembly was built and put into stock. During this chapter's discussion of the chair's planning bill, we have flattened the chair's bill and no longer plan to stock red seat assemblies. This means that we also need to flatten the associated routings or process instructions.

A routing is defined as the sequence of events necessary to build or produce a product. Figure 12.9 identifies two routings: one for the final assembly of the conference center chair (top half of the figure) and one for the subassembly of the seat assembly (bottom half of the figure).

However, we no longer plan to build and stock the seat assembly—it has been removed from the planning bill structure (see Figure 12.8 on p. 364). But we know the manufacturer still needs to build the chair seat if we are to produce a conference center chair. The red chair seat is composed of seat inners, a label, and red all-weather cloth (see Figures 12.7 and 12.9, subassembly routing section). Since we no longer have a seat assembly in the planning bill to attach the required operations documentation, we have resequenced the operations of the subassembly work (operation 10, which states to attach the label

Operation	Final Assembly Routing	Point of Usage
10	Lay out hardware kit per instructions	FA
20	Assemble left leg assembly to seat assembly using provided hardware	FA
30	Assemble right leg assembly to seat assembly using provided hardware	FA
40	Attach back splat assembly	FA
	Subassembly Routing	
10 → 05	Attach *label* to *seat inners*	SA
20 → 07	Attach *all-weather cloth* to *seat inners*	SA

Figure 12.9 Generic Assembly Routing Attached to Common Items

to the seat inners, has become operation 05, and operation 20, which states to attach the colored all-weather cloth, has become operation 07). These two operations are now the first two operations in the conference center chair's build sequence. The six-step process (two for the seat work and four for the final chair work) is now one complete routing for the final chair assembly (Figure 12.10). This complete routing is attached to the common items' parent item, as it will be required for all conference center chairs that need to be built, the same requirement that is placed on the common items.

The routing for the conference center chair has also taken on the characteristics of a generic or common chair. Look at operation 07 in Figure 12.10. It states that the all-weather cloth will be the color stated on the customer order. The same is true for operation 40. With the addition of these instructions, this assembly routing can be used to communicate to the manufacturing floor the events that must take place in order to produce a customer's desired colored chair, be it red, black, or a combination.

Continuing to look at Figure 12.10, we see the operation number and point of usage that were attached to the planning bill. Look at

Operation	Final Assembly Routing	Point of Usage
05	Attach label to seat inners	SA
07	Attach all-weather cloth to seat inners *(color per customer order)*	SA
10	Lay out hardware kit per instructions	FA
20	Assemble left leg assembly using provided hardware	FA
30	Assemble right leg assembly using provided hardware	FA
40	Attach back splat assembly *(color per customer order)*	FA

Figure 12.10 Red Conference Center Chair Bill-of-Material

operation 05 again. It states that the label needs to be attached to the seat inners. This tells the master scheduler that the label and seat inners are needed to support operation 05. Since operation 05 is done in location SA, that's where the label and seat inners need to be delivered (the point of usage). If we look at operation 10, we see that the hardware kit is required in location FA. The routing states that operations 05 and 07 will be started in location SA one period prior to operations 10 through 40, which are done in location FA. This is the reason behind the lead-time offset of +1 for all items required in work center FA versus work center SA.

Configuring and Building to a Customer Order

We now have in place the database necessary to respond to a customer request and order. If the demand management, supply management, master scheduling, material management, and manufacturing

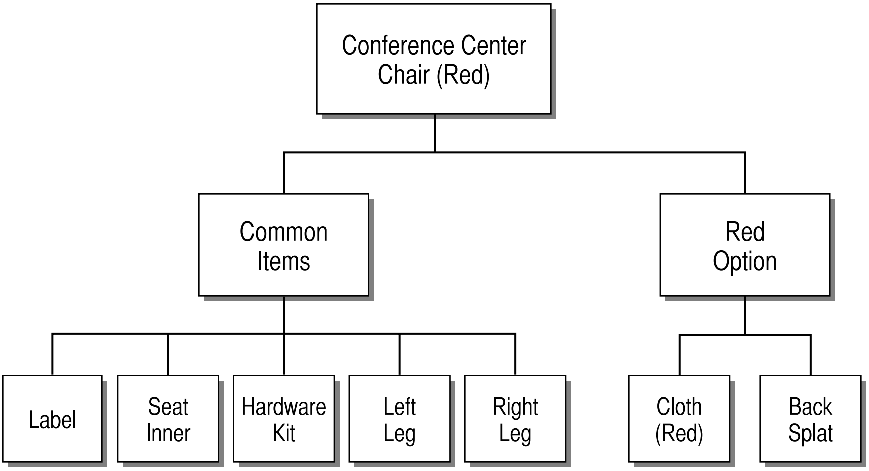

Figure 12.11 Finishing Materials for Red Conference Center Chair

processes work, the materials required to support a customer request for delivery in two to five periods (which equates to where the company has decided to meet the customer) and the resources necessary to produce the final configuration should be in place. The next step is to book an order, commit to a delivery date (assuming the materials and capacity are available), and produce the desired product.

Figure 12.11 identifies what's needed to produce a red conference center chair. This figure shows that in order to produce a red chair, one set of common items (a label, seat inners assembly, hardware kit, left leg assembly, right leg assembly) and one set of red option items (the red cloth and the red back splat) are needed. From this data, a material list for the real material items such as the label, left leg assembly, right leg assembly, back splat, and so forth can be generated. So, if a customer should order a red conference center chair, we can use the planning bills and specific configuration desired to identify all the engineered items required (see Figure 12.12).

Reviewing the figure, you can see the item, description, quantity needed (dependent upon the customer order—the example shows that five red conference center chairs have been ordered), point of usage (location to deliver the items), and date required. The date re-

Materials List **Finish Order F1234**

Item	Description	Qty	Pt. of Usage	Date
125	Chair Label	5	SA	6/9/XX
666	Seat Inners	5	SA	6/9/XX
780	All-weather Cloth	5	SA	6/9/XX
861	Hardware Kit	5	FA	6/16/XX
122	Left Leg Assembly	5	FA	6/16/XX
128	Right Leg Assembly	5	FA	6/16/XX
880	Back Splat Assembly	5	FA	6/16/XX

Figure 12.12 Finishing Routing for Conference Center Chair

quired for each component is calculated by the master scheduling system using the customer's due date and conference center chair's planned lead time plus each item's lead-time offset. (Say the chair has a planned lead time of two periods and the left leg assembly has a lead time offset of +1. The left leg assembly would be required on the production line in location FA one period after the build start date of the conference center chair; the example needs the left leg assembly on June 16 versus a build start of June 9.) Using the lead-time offset capability means that material can be scheduled to arrive on the production line the day it is actually needed. Lead time is offset by day.

Along with the material list shown in Figure 12.12, a set of process instructions (Figure 12.13, p. 370) also can be generated by the master scheduling system. Remember, a generic routing was attached to the common items, which is also needed to build conference center chairs. When the customer order is taken and a due date is committed, this generic routing can be used to determine when each operation needs to be done. This is done either by backward scheduling from the due date to identify the latest possible start date, forward scheduling from the first operation to identify the earliest expected completion date, or midpoint (bottleneck) scheduling, which uses a combination of

Operations List **Finish Order F1234**

Sequence	Description	Work Center	Date
05	Attach label to seat inners	SA	10 Jun
07	Attach all-weather cloth to seat inners *(color per customer order)*	SA	16 Jun
10	Lay out hardware kit per instructions	FA	17 Jun
20	Assemble left leg assembly to seat assembly using provided hardware	FA	19 Jun
30	Assemble right leg assembly to seat assembly using provided hardware	FA	21 Jun
40	Attach back splat assembly *(color per customer order)*	FA	23 Jun

Figure 12.13 Final Assembly Combined Materials and Operations List

backward and forward scheduling. In most cases the choice should be to backward schedule from the customer's need and promise date.

Finishing or Final Assembly Combined Materials and Operations List

At this point we have successfully used the planning bill and the generic routing to create a materials list and to identify all the operations that must be performed in order to produce the customer's requested product—five red conference center chairs. Since we know the operation and when the material is needed, a combined

Operation	Material	Description	Date	Wk. Ctr.	Date
05		Attach label to seat inners	5	SA	10 Jun
	125	Chair label	5		9 Jun
	666	*Seat inners*	5		9 Jun
07		Attach all-weather cloth to seat inners*(color per customer order)*	5	SA	16 Jun
	780	*All-weather cloth*	5		9 Jun
10		Lay out hardware kit per instructions	5	FA	17 Jun
	861	*Hardware kit*	5		16 Jun
20		Assemble left leg assembly to seat assembly using provided hardware	5	FA	19 Jun
	122	*Left leg assembly*	5		16 Jun
30		Assemble right leg assembly to seat assembly using provided hardware	5	FA	21 Jun
	128	*Right leg assembly*	5		16 Jun
40		Attach back splat assembly *(color per customer order)*	5	FA	23 Jun
	880	*Back splat assembly*	5		16 Jun

Figure 12.14 Final Assembly Combined Materials and Operations List

materials and operations list can be created on one screen, as shown in Figure 12.14.

This screen shows that the first event is operation 05. In this operation the manufacturing floor is being instructed to attach the label to the seat inners. In order to do this, labels and seat inners are needed on June 9 in location SA. The attaching of the labels to the seat inners will be done five times, and all the work is to be completed by June 10. The next event in the sequence is operation 07, where the all-weather seat cloth (color per customer order) is attached to the seat inner assembly. In order to complete this operation, five pieces of cloth (color identified) must be delivered to SA by June 9. When this work is done we will have an all-weather colored seat. This seat then flows to location FA, where the next operation (10) will be done.

During operation 10, the hardware kit is made ready for use in final assembly. This means that the hardware kit is needed to be delivered to FA by June 16. Operation 10 is scheduled to be completed by June 17, which was determined by backward scheduling from the customer order commit date.

This process continues until all the operations have been completed and the total customer order is finished. During the process, the manufacturing floor can report progress by each operation, defined milestones, checkpoint operations, or completed chair or group of chairs. This choice is dependent upon the environment, manufacturing strategy chosen, product lead time, product volume, and desired or needed information.

Choosing the Most Effective Approach

There is no one *right* approach to communicating the schedule to manufacturing. The key to making the *best* choice is keeping the ultimate purpose of the finishing or final assembly schedule in mind: the simple and clear communication of work authorization, specifications, and priority.

The best choice is also a function of previously discussed environmental issues. While no ironclad rules are possible, some approaches to finishing and final assembly schedules are used more often in certain environments. In a business with a job shop organization, low volumes, high potential product mix, long lead times, and high need for proper sequencing, it is normal to see individual work orders and bills-of-material traveling with the work to communicate work authorization and specifications.

Conversely, in environments with a flow-line organization, high volumes, few product variations, and short lead times, manual or electronic-generated line schedules, such as schedule boards, communicate end-product priorities. Kanbans may be used to trigger work authorization and signal priorities for all feeder lines and departments that supply the production line.

Most manufacturing environments are somewhere between these two ends of the spectrum. The influence of continuous-improvement programs is pushing more job type environments toward the flow-line scenario. It is also pushing high-volume flow lines toward shorter, quicker runs that can be better supported by the vigorous use of kanbans in all upstream-process steps. Thus, there is something of a convergence of the two extreme models of manufacturing.

Finishing Schedules versus Master Schedules

Master scheduling is a process to schedule and prioritize material and capacity in anticipation of delivering final products to customers. It is typically organized into daily or weekly periods. In the finishing or final assembly process, however, the manufacturing schedule may be stated in days, hours, or even minutes (one Motorola plant the author is familiar with schedules to the minute). This difference in the required precision of planning periods is not the only difference between finishing and master schedules. The master schedule is driven by the sales and operations planning process through the demand (sales) and supply (production) plans, while the finishing or final assembly process is driven by stock replenishment, customer orders, and process requirements (i.e., process industry plants). This naturally results in quite different time horizons—the cumulative lead time being the minimum planning horizon for the master schedule, and the finishing or final assembly lead time for the finishing schedule.

When the master schedule is put together, the actual build sequence is generally not considered in many environments; only the date when the product is expected to be needed is identified. This is not true when looking at the finishing or final assembly schedule. It is very important to analyze the situation and define the best sequence to produce the various products scheduled. Take the athletic sock manufacturer—it would not be smart to dye the blue socks before the yellow socks. If this is done, a complete clean-out or wash-down would be needed before the lighter dye could be used. Additionally, the changeover and setup times required to modify the production line for the next product need to be minimized.

The master schedule's function is to ensure that the material and capacity will be available when it is needed to produce the product. The finishing or final assembly schedule's function is to drive the finishing process using the materials and capacities the master scheduler has preplanned. In other words, the finishing or final assembly schedule relieves the master schedule. Once the finishing or final assembly process commences, the job of the master scheduling function may come to an end and the completion process might be managed under the eyes of the finishing or final assembly process (this depends on the company environment).

Master scheduling and finishing are keys to a successful Enterprise Resource Planning implementation. If a company's master scheduling effort fails, it is going to be very difficult for that company to reach Class A standards. The same can be said for the finishing or final assembly process. To ensure an orderly and smooth master scheduling and finishing implementation, a defined process has been developed. This defined process and the various elements necessary to effectively implement master scheduling into a company is the subject of the next five chapters, which cover integration and implementation.

13

Sales and Operations Planning

There are three types of people: those who make things happen, those who watch things happen, and those who wonder what happened.

In business, as in war, failures often stem from lack of coordination between essential functions. On the battlefield, armies that fail to coordinate the movement of infantry with support from artillery, air, and armor typically are defeated by opponents whose main force and support functions operate as one. In business, the company whose sales force is out booking orders and promising delivery dates without the concurrence of finance, engineering, and manufacturing are likewise imperiled.

While coordination among business functions is obviously essential, it does not just happen, but needs a formal mechanism to ensure that it occurs. For most companies, that mechanism is sales and operations planning. Sales and operations planning (S&OP) is a formal process for managing change related to product demand. As described by George Palmatier and Joseph Shull,

> S&OP is the process whereby the management of the company provides direction, resolves conflicts, and manages the operations of the

INPUTS

- Statement of anticipated demand (from Marketing and Sales)
- Conformation of new-product design availability (from Engineering)
- Indication of capabilities and capacities (from Manufacturing)
- Estimate of financial resources required (from Finance)

OUTPUTS

- Sales plan (accountability—Marketing and Sales)
- Engineering/new-product development plan (accountability—Engineering)
- Supply plan (accountability—Manufacturing)
- Financial plan (accountability—Finance)
- Backlog projection (accountability—General Manager)
- Inventory projection (accountability—General Manager)

Figure 13.1 Sales and Operations Planning Inputs and Outputs

> business. It is the tool [process] that links the business plan to the more specific objectives of the organization . . . [ensuring] that all the divisions, departments, and other organizations within the company are pulling in the same direction at the same time toward the same goals.[1]

Sales and operations planning is an ongoing process, characterized by a monthly review and continually adjusted to match company plans in light of fluctuating customer demand and the company's available resources. The process generates a number of other high-level plans. Figure 13.1 enumerates the inputs and the outputs of this planning process.

The key functions of the organization are all involved in the S&OP process. Each provides input and develops its respective plans based

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[1] George E. Palmatier and Joseph S. Shull, *The Marketing Edge* (New York: John Wiley & Sons, 1989), 26.

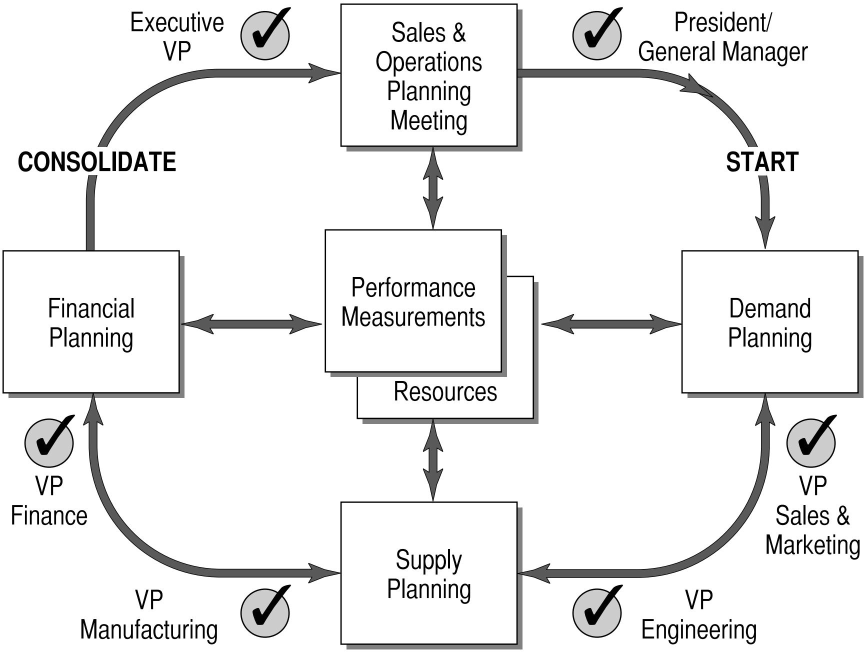

Figure 13.2 Sales and Operations Planning Monthly Process

on understandings reached in the process. The S&OP process ensures that individual plans are in sync with each other (Figure 13.2). Thus, the supply plan is coordinated with the new product plan and demand plan; the financial plan is reconciled with the new product, demand, supply, and business plans; and so forth.

Besides ensuring that each individual plan is in balance with the other individual plans, the sales and operations planning process analyzes the company's vital resources (current plus planned) to make certain no unexpected problems surface in the future. Additionally, new-product, demand, and supply performances over the last several months are evaluated to see if and what adjustments need to be made to these plans. Another important step in the process is its approval by the leader in each functional area.

When the new-product, demand, supply, and financial plans are in balance, final preparation for the formal management business review takes place. The sales and operations planning packet, which contains the management business review's objectives, agenda, performance reviews with charts, assumptions including opportunities and risks, product family plans, new program and project reviews, and open action items, is compiled. This packet is distributed to the meeting's participants 24 to 48 hours prior to the formal session.

The final step in the recurring monthly process is the management business review itself. Upon completion of the review, the approved new product (engineering), demand (sales), supply (manufacturing), and financial (funds) plans are distributed along with the review's minutes and open action items to all relevant managers. Of course, this includes the supply manager and master scheduler.

Sales and operations planning generally covers a planning horizon of two years, and deals with demand and supply volumes at the product family level. Unlike the overall business plan of the company, which is stated in financial terms, S&OP speaks in the language of sales and manufacturing: forecasts, bookings, production, units, hours, and so on. In addition to serving as a means of generating other plans, S&OP is a process for developing a budget for the master schedule.

Workable, Adjustable Plans

One of the principal benefits of the S&OP process is its focus on workable plans. Natural optimism and business units planning in isolation are factors that lead to plans that cannot be fulfilled. Workable plans can be created only by systems that have built-in reality checks. The S&OP process offers those checks by starting at the top and providing verification at lower levels. The participation of all major functions is mandated by the process, and the feasibility of each function's plans is scrutinized by the others. Feedback loops ensure that plans are adjusted to the capabilities of related functions. Thus, an optimistic sales plan put forth by marketing and sales is critiqued by manufacturing, which may not have nearly the resource capacity to deliver product at

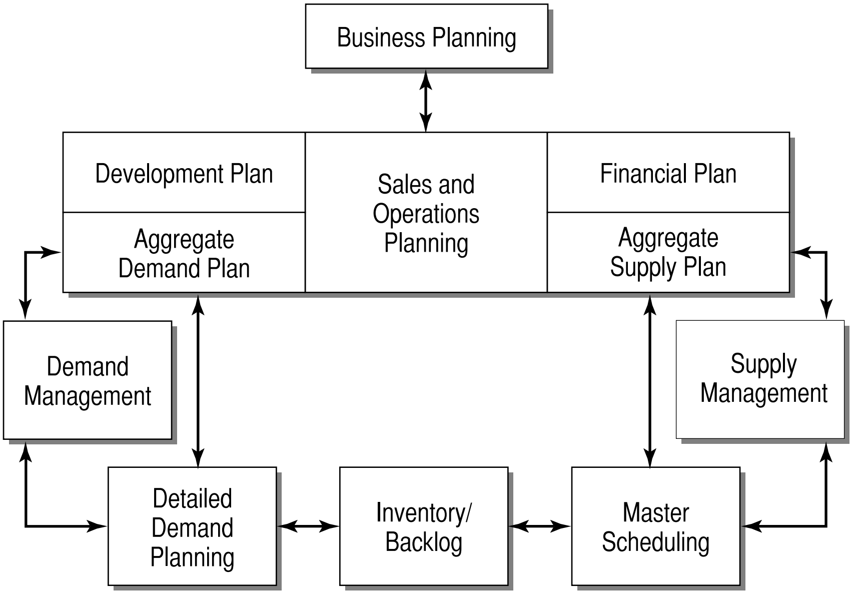

Figure 13.3 Sales and Operations Planning and Other Company Functions

the requested level, assuming planned sales volume is reached. Figure 13.3 indicates where S&OP fits into the scheme of other company activities and shows the points where feedback can and should take place. Here, S&OP serves as a link between the highest-level business planning (and strategy) and operations. Sales and operations planning ties the company's high-level business and strategic plans to the operations of each department. The feedback loops in Figure 13.3 indicate how each department participates in the process. All major functions of the company are involved, ensuring that plans are attainable from the top down. The absence of this linkage creates the potential for loss of control and for significant miscommunication within the organization. For example, production operations might be working from one set of numbers while sales is planning on something quite different. The potential for confusion and failure in such a case is obviously great, and S&OP can eliminate its occurrence.

Customers cancel firm orders; unexpected new orders miraculously appear; manufacturing capacity slips as unanticipated breakdowns occur. British Prime Minister Benjamin Disraeli once said that "what we anticipate seldom occurs, what we least expect generally happens." This statement applies equally to politics, war, and business. The events we plan often unfold in ways we do not expect. Even well-coordinated plans can lead us into failure if they are carved in stone. To be successful, we need plans that are sufficiently flexible, or *robust,* to accommodate the contingencies that naturally occur. Fortunately, the S&OP process, with its regular monitoring and inputs from many sources, provides an opportunity for planning adjustments as needed. As a result, it is an exceptional process for managing change. All the information needed to make adjustments ends up on the table, and each of the parties whose agreement to those adjustments is critical has a seat at the table. Moreover, because S&OP links high-level plans together while the Enterprise Resource Planning system links high- and low-level plans, changes made at the S&OP level are formally communicated down into detailed plans. This channel of information enables different functions in the company to seize opportunities and avoid potential disasters.[2]

Sales and operations planning also allows companies to better manage finished-goods inventories and backlog. The right people come together to make decisions in a structured planning process that reflects top management's expectations. And finally, S&OP provides a basis for measuring performance, which is critical to any organization that is serious about continuous improvement.

S&OP and the Master Schedule

The past few pages painted a picture of S&OP in very broad strokes, demonstrating its benefits to the company as a whole. From the perspective of the master scheduler, smaller strokes are needed. The

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[2] For a more complete review of sales and operations planning, see Richard Ling and Walter Goddard, *Orchestrating Success* (New York: John Wiley & Sons, 1988).

business plan must be converted into a supply plan specifying production rates (volume), which in turn must be converted to a detail product-mix plan (master schedule). To understand how this conversion takes place, we will eavesdrop on an S&OP meeting and observe the interaction among engineering, sales, marketing, manufacturing, and finance.

THE CASE OF S&OP AT AUTOTEK

Members from all key departments arrived at the monthly sales and operations planning meeting of AutoTek Corporation, a manufacturer of automotive parts and a subsidiary of the industrial giant Execor Industries. After exchanging pleasantries, they settled down to business. The meeting began with a discussion of special items, the most important being a report from AutoTek's general manager, Jack Saunders, about the recent budget meeting at Execor's corporate headquarters. Saunders cleared his throat and began.

"Good third-quarter news: It looks like we'll see a significant upturn in AutoTek sales—the new sales promotion has really grabbed the marketplace. We think that the business could grow by fifteen percent over the next six months . . . maybe by twenty percent if our most optimistic projections come true."

Cheers rang out, and several at the table raised their hands triumphantly in a *V* sign.

"Yeah, and what's the *bad* news?" snickered old Dave "Razor Tongue" Wilcox, vice president of finance.

Hisses and groans filled the room. "Will somebody tell Dave to send his wet blanket to the laundromat?" someone called out from the other side of the room.

"Okay, people, let's settle down," said Saunders. "Unfortunately, Dave's right, there is some bad news—or should I say a 'window of opportunity.' Because of our success at turning our division around, corporate has asked us to be responsible for five percent more of overall corporate profits."

More groans. Saunders raised both hands, as if to hold back a wave of protest. "Folks, let's not stew about that. Let's get down to work and figure out how we're going to hit those targets."

For the next 10 minutes, the S&OP team reviewed the company's aggregate performance in comparison to the business plan. They talked about how they had performed with respect to demand, supply, and inventory projections. The team also examined the backlog and shipment projections. Next, they reviewed their assumptions for the coming period, which included the hiring and training of 10 new people in the next 60 days. This added personnel was expected to help AutoTek increase production rates if necessary. In addition, the company directors speculated about their major competitors. Jelco was facing a general strike, and JDR Enterprises was threatened with acquisition by Murco & Watts. Everyone agreed that there were both opportunity and danger for AutoTek in these developments.

The master scheduler had been following the discussion with interest. But his adrenaline really began to flow when the general manager announced that it was time to conduct the regular review of each product family. This was the main course for the master scheduler. Saunders again reminded everyone that the new product review would commence next month.

Saunders turned the meeting over to Sally Lattimer, the vice president of sales, who made an announcement. "Before we get into the product family review," she said, "please note that this is a landmark day for the S&OP team—we're now going high-tech! Instead of working from printed reports, we will be projecting output from the computer onto the screen using our new in-focus projector. Ted Glass of marketing has loaded the usual S&OP data into the new database, and as we make changes, we will see the results right on the screen."

"Big deal," snorted Wilcox.

Saunders flashed Wilcox a warning glance, then nodded to Lattimer to proceed with her sales review of the product families, the first of which was the stocked muffler family (see Figure 13.4). "We now have ninety days of history, beginning in February," Lattimer explained. "We had anticipated selling 32,000 units per month. But as you can see, we actually booked 36,000 units in February, 34,000 in March, and 37,000 in April. The third line on the screen shows the monthly differences between planned demand and actual demand; the fourth line

Stocked Muffler Family		History			S&OP Plan	Future Planning				
Demand Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		32,000	32,000	32,000	Original	32,000	32,000	32,000	32,000	32,000
Actual		36,000	34,000	37,000	New	36,000	36,000	36,000	36,000	36,000
Monthly Difference	109% Performance	+4,000	+2,000	+5,000						
Cumulative Difference	Starting Point 0	+4,000	+6,000	+11,000						
Supply Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		35,000	35,000	35,000	Original	35,000	30,000	30,000	25,000	25,000
Actual		34,000	33,000	33,000	New	35,000	35,000	37,000	37,000	37,000
Monthly Difference	95% Performance	–1,000	–2,000	–2,000						
Cumulative Difference	Starting Point 0	–1,000	–3,000	–5,000						
Finished Goods Inventory		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		23,000	26,000	29,000	Original	32,000	30,000	28,000	21,000	14,000
Actual	Starting Point 20,000	18,000	17,000	13,000	New	12,000	11,000	12,000	13,000	14,000
Difference	45% of Plan	–5,000	–9,000	–16,000						

Figure 13.4 Demand and Supply Plans, Stocked Muffler Family

shows cumulative differences by month, which increased to 11,000 units in April. On the whole, we're pretty pleased with our performance," said Lattimer. "Not only are we selling over the plan, we're within ten percent of what we said we would do."

Applause rang out. Even Razor Tongue Wilcox nodded his approval.

Next, Bill Weston, vice president of manufacturing, stepped to the head of the table to begin discussion of the production plan. "We had a planned supply rate of 35,000 mufflers for February, March, and April, but we fell short by 1,000 in February, 2,000 in March, and another 2,000 in April, making us short by 5,000 overall. Still, our performance over these ninety days was ninety-five percent of plan—not bad over the aggregate period."

"Not great either," Wilcox muttered. "Your group is *always* under plan."

A suggestion by Weston that constant overselling by Lattimer's group was creating a problem for production set off a heated debate. Saunders motioned that it was time to move on to the inventory position on mufflers, one of his areas of responsibility. "As you can see from the data, we entered February with a starting balance of 20,000 units and planned to boost that level to 29,000 units by the end of April to meet the expected growth in our business. But the higher-than-expected sales and lower-than-planned production have resulted in a net depletion of our muffler inventory—just the opposite of our plan."

The master scheduler studied the information, noting how every month's pattern of higher-than-planned demand and lower-than-planned supply had progressively reduced inventory. That was good in the sense that AutoTek had less inventory to finance during those three months, but it was abundantly clear that unless this pattern was reversed, demand would very quickly outpace the company's supply (from production and from inventory), resulting in angry customers, missed sales, and opportunities for competitors to expand market share at AutoTek's expense.

He wondered how management planned to deal with this problem, knowing that the decision would affect him directly. He wanted to know how production rates would be adjusted; these, he knew, would be driven by whatever demand projections the sales and marketing people assumed for the coming periods.

Sally Lattimer pointed to the information on the screen. "The plan that we all agreed to last month called for demand of 32,000 units each month. We've been doing some analysis since the last meeting, and we are prepared to boost the forecast by 4,000 units per month through September. We believe the demand is very real and that our overselling the plan in each of the past three months is not a fluke. What does everyone else think?"

"I like that number," said Jack Saunders. "It looks realistic to me, and it correlates with other information I am getting from the field."

From the master scheduler's perspective, this was a critical point in the process. He needed to know the projected supply rate—something that could not be determined without considering future sales.

Discussion ensued as the S&OP team members debated how they could achieve the plan. First, they looked back at the previous month's inventory projection, noting its shortfalls. To satisfy the expected demand and to provide some demand protection for variation to plan, Saunders had authorized raising inventory levels to a maximum of 32,000 units in May, then gradually reducing it to 14,000 units in September. The current inventory position was planned to be at 29,000 units; however, due to the situation described by Saunders, muffler inventory had fallen to 13,000 units.

"How are we ever going to get back on plan?" Wilcox asked.

The new demand projections and shortfall in inventory demanded a workable response from manufacturing. Bill Weston offered the manufacturing perspective: "It sounds like we need to ramp up production to meet the increased demand plan. But I can't do it instantly. I need to hire and train a few more people and bring in some new equipment, and that will take time."

"How much time?" Saunders asked.

"Probably forty days or so," Weston responded. "I am confident that we will be able to sustain a run rate of 35,000 for the next two months while we are getting prepared for the increased supply rate. We have had problems coming up to 35,000 units in the past, but I think those problems are now behind us. The way I figure it, our inventory position will be at 11,000 units in forty days if we produce at a rate of 35,000 per month and sell at a rate of 36,000 per month. In principle, I believe that we can meet the higher-demand projection, but I want to figure out a way to meet it and still run the plant at a reasonable and level rate of production."

Weston wanted to keep the supply plan level because shifts in production rates were expensive due to changeovers, adding and laying off personnel, and so forth. Therefore, he computed a level supply plan as follows:

- Sum the forecast or demand plan, then add or subtract the expected or desired change in the inventory levels.
- Divide the result by the number of months in the planning period.

For July, August, and September, Weston began with total demand of 108,000 units (36,000 per month). To compute the desired change in inventory levels stipulated by Saunders, he looked at the target for the last period, September, which was 14,000, then subtracted the expected beginning inventory for July of 11,000 units. Thus, he found that ending inventory needed to increase by 3,000 units. It made sense to just add this requirement to the projected customer demand of 108,000 to get a total demand for July through September of 111,000 units, or a production rate of 37,000 per month (111,000 divided by 3 [months]).

Would this approach satisfy the plan? To find out, the new demand and supply figures were entered into the system and a new inventory projection was calculated (Figure 13.5). In July, August, and September, the company would produce 1,000 more units than it planned to sell and ship. That surplus production would increase AutoTek's inventory. The ending September inventory figure would be 14,000 units—just what Saunders had asked for. Before pronouncing the new plan workable, however, the group needed to check plant capacity as well as its key or critical suppliers. (Assume for now that the plan has been checked for feasibility and the group is ready to move on with its analysis of the customized muffler product family. A detailed discussion of how to sanity check the proposed production plan against capacity and key resources follows in Chapter 14 on rough cut capacity planning.)

Even though the S&OP team had determined that the plan was realistic, questions remained. "What's the high-water mark?" Weston asked the sales vice president. "How high could sales really go?"

Lattimer shuffled through her papers and responded: "We could possibly hit 38,000 from May through September."

"And if you bomb out?" asked Dave Wilcox.

"Worst-case scenario, 30,000," she shot back before Wilcox could open his mouth. "We've already studied that possibility in the pre-S&OP meetings."

With the best- and worst-case scenarios numerically defined, the group was then able to project inventory levels for either case (Figure 13.5). If sales succeeded on the high side, inventory would drop to a low of 4,000 units in September; if sales were poor, AutoTek would find itself with 44,000 units on the shelf at the end of that month. Saunders noticed Dave Wilcox grow pale as that figure passed before his eyes.

Stocked Muffler Family		History			S&OP Plan	Future Planning				
Demand Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		32,000	32,000	32,000	Original	32,000	32,000	32,000	32,000	32,000
Actual		36,000	34,000	37,000	New	36,000	36,000	36,000	36,000	36,000
Monthly Difference	*111% Performance*	+4,000	+2,000	+5,000	High	38,000	38,000	38,000	38,000	38,000
Cumulative Difference	*Starting Point* 0	+4,000	+6,000	+11,000	Low	30,000	30,000	30,000	30,000	30,000
Supply Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		35,000	35,000	35,000	Original	35,000	30,000	30,000	25,000	25,000
Actual		34,000	33,000	33,000	New	35,000	35,000	37,000	37,000	37,000
Monthly Difference	*95% Performance*	–1,000	–2,000	–2,000						
Cumulative Difference	*Starting Point* 0	–1,000	–3,000	–5,000						
Finished Goods Inventory		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		23,000	26,000	29,000	Original	32,000	30,000	28,000	21,000	14,000
Actual	*Starting Point* 20,000	18,000	17,000	13,000	New	12,000	11,000	12,000	13,000	14,000
Difference	*45% of Plan*	–5,000	–9,000	–16,000	High	10,000	7,000	6,000	5,000	4,000
Approved	*RBV*	*BES*	*JFP*	*DSP*	Low	18,000	23,000	30,000	37,000	44,000

Figure 13.5 Recalculation of Demand, Supply, and Inventory

"Now that we know what the opportunities and risks are, is everyone still breathing?" Saunders asked. "Can we meet the plan?" All nodded in agreement. "Okay. Let's get on with it. Sally, go get those orders. Bill, you've told us that you can get up to 37,000 units in forty days. Go make it happen. Dave, you need to be ready to support both Sally and Bill with additional financing, if needed. Now, unless there is further discussion, let's move on to the manifold product family."

The new supply plan is the budget that will be used by the master scheduler when constructing the master schedule for the product family individual members. It's not enough for the master scheduler to just create the master schedule; he must also ensure that when aggregated by product family it equals the supply plan by volume.

The S&OP team went through the same routine with manifolds, adjusting and testing the plan in terms of demand, supply, and inventory, carrying out a validity check at each step. When they finished with all make-to-stock (MTS) families, Jack Saunders suggested a five-minute break before switching over to make-to-order (MTO) products, which included customized mufflers and spoilers. The make-to-order items represented a smaller, but higher-margin, part of the business.

After the break, Ted Glass from marketing displayed the data for the customized muffler family (Figure 13.6), and at Jack Saunders's suggestion, Sally Lattimer again kicked off the discussion. The format was basically the same as the one used for the make-to-stock products, with the demand plan on top, followed by the supply plan. The make-to-stock planning screens displayed finished-goods inventory, whereas the make-to-order plan focused on backlog. (These should not be confused with back orders, which are past-due customer orders. Generally, backlog refers to orders promised to customers but not shipped. In the make-to-order business, orders are generally accepted for future deliveries. A company in Portland, Oregon, appropriately labeled these customer orders "future history.")

Sally Lattimer began with the demand plan, showing the actual versus planned lines, explaining the difference (180 over plan for the last three months). She noted that her department's performance to the sales plan was right at 108% (see Figure 13.6). Once again, applause greeted the conclusion of her report.

As with the make-to-stock muffler example, Lattimer proposed that the company would experience an increase in sales, from 800 to 850 in May and June, from 800 to 900 in July and August, and from 900 to 1,000 in September.

When she finished, Jack Saunders suggested moving on to the company's backlog position, shown on the bottom of the matrix. "Ninety days ago we had 1,020 units in the backlog. We wanted to take that 1,020 and work it down to 820 by the end of September. The 820 units represent approximately one month's production. What has happened is that as we look back over the last three months, the actual backlog went from 1,020 to 1,130. That means that we're looking at about

Customized Muffler Family		History			S&OP Plan	Future Planning				
Demand Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		800	800	800	Original	800	800	800	800	800
Actual		840	860	880	New	850	850	900	900	1,000
Monthly Difference	*108% Performance*	+40	+60	+80						
Cumulative Difference	*Starting Point* 0	+40	+100	+180						
Supply Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		850	850	850	Original	850	800	800	800	800
Actual		820	830	820	New	850	850	1,050	1,050	1,050
Monthly Difference	*97% Performance*	–30	–20	–30						
Cumulative Difference	*Starting Point* 0	–30	–50	–80						
Backlog		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		970	920	870	Original	820	820	820	820	820
Actual	*Starting Point* 1,020	1,040	1,070	1,130	New	1,130	1,130	980	830	780
Difference	*130% of Plan*	+70	+150	+260						

Figure 13.6 Demand and Supply Plans, Customized Muffler Family

five to six weeks of backlog, based on the original plans. This is not the direction in which we want the backlog to go."

Next, Bill Weston of manufacturing stepped up to the screen. "We came in a tad low," he confessed, "but we're nevertheless ninety-seven percent performance to plan. The problem is that the backlog simply isn't decreasing because sales is booking at a higher rate than planned and we are producing slightly below the plan. If we are sitting on five to six weeks of backlog, we should be quoting lead times of five to six weeks—assuming, of course, that the customers requested delivery as early as possible. [The shape of this backlog curve is important to know since it affects the lead times used to quote and promise customer deliveries.] We need to change something if we are to achieve Jack's plan.

If quoted lead times are to be reduced to one month or less, we'll have to create a production plan that works off part of the backlog over the next few months.

"As we evaluate the plan, let's bear in mind that ramping up production in May and June will be difficult," Weston cautioned. "But with the training discussed earlier today, I believe we'll achieve our planned supply of 850 units in May and June. In July, we can increase production to satisfy the increase in demand and begin to work down that backlog."

Weston agreed that at the end of June he could increase production to 1,043 units.[3] For the months of July, August, and September, a level supply plan was computed by taking the projected beginning backlog (1,130 in June) and subtracting the desired ending backlog (800 units, which equals the originally planned production for July through September). That left a desired change of 330 units. Adding that to the 2,800 expected bookings in the demand plan for the planning period July through September (900 + 900 + 1,000) yielded 3,130 units that needed to be shipped if the company was to hit its goal by the end of September. The 3,130 units divided by 3 [months] gave a level production rate of 1,043 units per month. If both Weston and Lattimer achieved their respective plans, Saunders's target of a one-month backlog would be realized. However, if Weston could raise production to 1,050, the goal of less than one month quoted lead time could be achieved by September (see Figure 13.6, projected backlog of 780). The next step was to do a sanity check of the proposed supply plan by running it through rough cut capacity planning (see Chapter 14).

Once everyone agreed that these two plans were reasonable and realistic, the next step was to combine the make-to-stock and make-to-order muffler families on the same S&OP matrix (Figure 13.7). This required computing an aggregate demand plan, supply plan, inventory projection, backlog projection, and shipment projection derived by summing the make-to-stock (MTS) and make-to-order (MTO) product family data.

[3] Weston reached the figure of 1,043 by summing the new demand plan numbers over July through September, adding to this the desired change in backlog, and then dividing the total by the number of months in the planning period.

Combined Muffler Family		History			S&OP Plan	Future Planning				
Demand Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		32,800	32,800	32,800	Original	32,800	32,800	32,800	32,800	32,800
Actual		36,840	34,860	37,880	New	36,850	36,850	36,900	36,900	37,000
Monthly Difference	*111% Performance*	+4,040	+2,060	+5,080						
Cumulative Difference	*Starting Point* 0	+4,040	+6,100	+11,180						
Supply Plan		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Planned		35,850	35,850	35,850	Original	35,850	30,800	30,800	25,800	25,800
Actual		34,820	33,830	33,820	New	35,850	35,850	38,050	38,050	38,050
Monthly Difference	*95% Performance*	–1,030	–2,020	–2,030						
Cumulative Difference	*Starting Point* 0	–1,030	–3,050	–5,080						
Inventory/Backlog		FEB	MAR	APR		MAY	JUN	JUL	AUG	SEP
Inventory	*Starting Point* 20,000	18,000	17,000	13,000	New	12,000	11,000	12,000	13,000	14,000
Backlog	*Starting Point* 1,020	1,040	1,070	1,130	New	1,130	1,130	980	830	780
Shipment Projections		36,820	34,830	37,820	New	36,850	36,850	37,050	37,050	37,050

Figure 13.7 Demand and Supply Plans, Including Inventory, Backlog, and Shipment Projections

In May, for example, the new MTS demand plan calls for 36,000 units (Figure 13.4 on p. 383), while the new MTO demand plan calls for 850 units (Figure 13.6 on p. 389), summing to 36,850 units (Figure 13.7). The process of aggregating the demand plans is continued for each month through completion. The same logic is used to aggregate the supply plan, using the MTS supply plan and the MTO supply plan figures.

The next step is to look at the inventory, backlog, and shipment projections. The muffler family inventory is the result of make-to-stock planning, while the backlog position is the result of make-to-order planning. Therefore, the projected muffler family inventory at the end of May (Figure 13.7) is equal to the MTS muffler inventory at the end of May (Figure 13.4, p. 383). The projected muffler family backlog at the end of May (Figure 13.7) is equal to the MTO muffler backlog at the end of May (Figure 13.6, p. 389). This process is continued for the remaining months (June through September).

The last thing that needs to be determined are the projected shipments. Here the group takes the demand plan (bookings and expected shipments) from the muffler make-to-stock family (in MTS companies, products are generally shipped from inventory as orders are received and booked) and adds these totals to the muffler make-to-order supply plan (in MTO companies, products are shipped as they are built; they do not go to inventory). The result is an aggregate shipping projection for the muffler product family. If we again look at May, Figure 13.4 shows expected shipments of 36,000 units (demand plan) for the stocked muffler family. Figure 13.6 shows expected shipments of 850 units (supply plan) for the customized muffler family. Therefore, the total expected shipments are 36,850 units (Figure 13.7). This process is continued for the remaining months (June through September).

Once everyone at the AutoTek sales and operations planning meeting had agreed to the basic numbers, the group generated a rough cut capacity plan for the entire muffler family to ensure that the resources and capacity were, or would be, available when needed. This was done during the pre-S&OP meeting as well as the S&OP meeting, using the sales and production data along with the computer. Team members then watched as the computer software changed unit numbers into financial numbers, making it possible to compare the total demand (sales) and supply (production) plans to the business plan. This was yet another check, determining if the business plan could be fulfilled if Lattimer, Weston, Wilcox, and Saunders accomplished their stated plans with respect to demand, supply, inventory, backlog, shipments, and finances.

With the product family business settled, the group discussed new products and their possible impact on future business. This was an important area of concern to the master scheduler since he needed to gather data relevant to each new-product introduction. Saunders reminded everyone that the new-product development discussion would be moved to the beginning of the management business review (preceding the demand review) starting next month. Again, Saunders emphasized the fact that new products were becoming more and more important to the business. Once this part of the agenda was complete, Saunders led a discussion covering the major projects the company was currently working on. This discussion included an update on the new production line being installed.

The main business over, team members began glancing at their watches and thinking about the work that awaited them in their respective areas. The minutes highlighting the action items were reviewed with the team. Jack Saunders asked if anyone had any questions or further issues for discussion. There being no takers, he started the critique process, which entailed his asking each person at the meeting for input on how future meetings and the S&OP process could be improved. This opportunity for each member of the team to suggest improvements had, over time, proven to be effective in AutoTek's efforts to make the meeting and the entire process more productive.

From the master scheduler's perspective, this meeting has provided the numerical ingredients of new product, demand, supply, inventory, backlog, and shipments that will guide his activities between this point and the end of the next scheduled S&OP meeting. He knows that the numbers will not hold up in the absolute sense, but they have the benefit of reflecting the best judgment of a roomful of people who have intimate knowledge of the company's operations. Further, the supply plan he will work with has been subject to a reality check called *rough cut capacity planning,* which compares the supply plan to the internal as well as external capabilities of the company. Just how that reality check is accomplished is the subject of the next chapter.

Before proceeding to the discussion on rough cut capacity planning, let's take a look at the next enhancement to the sales and operations planning information AutoTek may choose to use in the future. Numbers are the facts that tell the story (of course, accurate numbers make for an accurate story). However, before top management dives into the detailed numbers, they may want to look at a few charts (graphs) to get an overall picture.

Synchronizing Demand and Supply

Sales and operations planning is an integrated demand-driven supply planning process. Once the demand (including new products) is known or anticipated, a supply plan is put together. To get started, three supply plans may be created. The first supply plan would match the demand. This way, rough cut capacity planning can highlight potential resource problems over the planning horizon. The second supply plan would use the planned capacity (demonstrated capacity plus planned changes to the process) to highlight potential shortfalls in product availability (when demand exceeds supply) as well as potential excess inventory creation (when supply exceeds demand). The third supply plan would be a compromise between the first two plans, or what would become the recommended supply plan. To highlight for top management and the supply manager possible issues and concerns, a synchronization chart showing demand, supply, and inventory may be helpful (Figure 13.8).

Reviewing the chart, the reader sees bars, lines, and background highlights. The bars in the example synchronization chart represent demand over a two-year period (24 months). The bars in the first three periods (–3, –2, –1) show historical data regarding actual demand. As the reader looks at future time periods 1–7, the lightly shaded part of the bars represents firm customer orders (not yet delivered), while the darkly shaded part of the bars represents anticipated demand (orders expected to be received or forecasted). Using this information, it is easy to see in what time periods demand and supply are not equal. If the demand and supply are unequal (decoupled), the result is an increase or decrease in inventory (negative inventory indicates that there will be a shortage of product).

The background in the figure shows the inventory position by time period. As one can see, the inventory in period 1 is equal to the demand, which is in line with management's desires (at the top of the

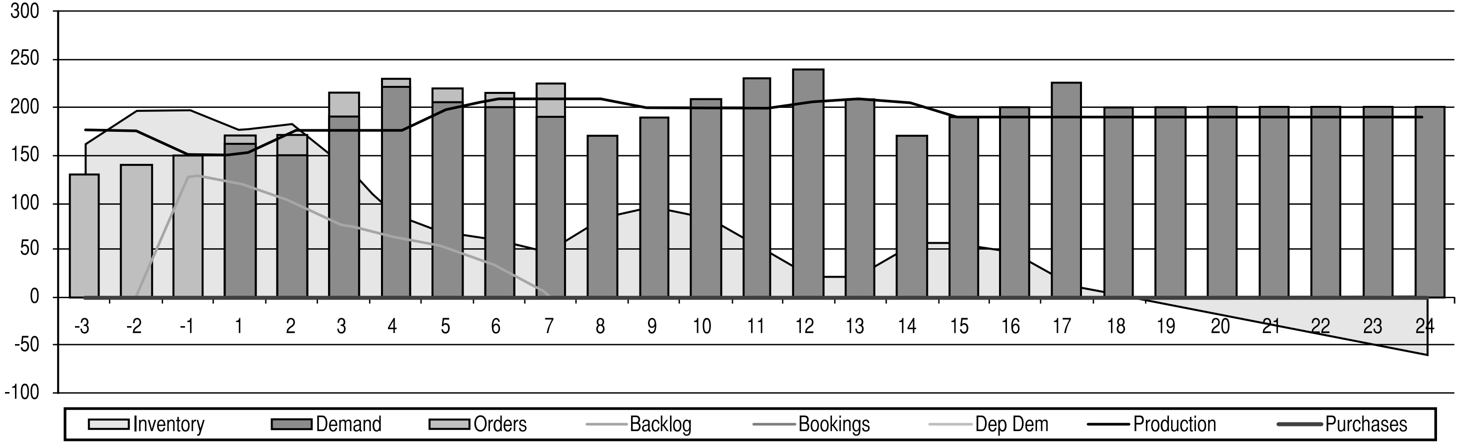

Figure 13.8 Synchronization of Demand, Supply, and Inventory

Note: Figure is a sample output from Oliver Wight's Enterprise Sales and Operations Planning tool.

figure—inventory target equal to four weeks or one month). However, as one looks out into the future starting with period 3, the inventory is expected to drop (rapidly through period 7) and continue to drop until a stockout is projected in period 19 (inventory drops below zero—back-order position with quoted lead time).

Someone once said a picture is worth a thousand words, and in this example one is worth a thousand numbers. The synchronization of demand, supply, and inventory is so important in sales and operations planning. This type of information chart brings time-phased demand together with time-phased supply and the resulting time-phased inventory projections. Once the demand and supply plans are synchronized for all product families, management takes a look at the total dollars projected to be tied up in finished-goods inventory. Figure 13.9 displays total inventory by dollars for the supply chain or business.

The example in Figure 13.9 shows 8 months of history plus 24 months of future projections. Looking at the chart, it appears the total inventory dollars for months 1–16 averages $35 million before dropping to $30 million over the remainder of the horizon. This information is valuable to top management, who must decide whether the supply chain or business can carry these dollars in finished-goods inventory. The chart also shows the product families that make up the inventory (shading on the bars).

The final piece of information required for supply management (and master scheduling) in sales and operations planning is rough cut capacity planning. Here again, a chart can be used to quickly highlight issues, concerns, problems, and balance. Figure 13.10 is an example of a rough cut capacity plan for a defined resource.

This chart uses bars to represent the required capacity to meet the supply plan (proposed or approved). The example also shows two lines (really three, but one line is hidden behind one of the other lines). The lower line represents the demonstrated and planned capacity over time.[4] The top line is the maximum capacity (see Chapter 14).

Using this information, one can see that periods 1–3 balance fairly well to the planned capacity. However, periods 4–9 show that required

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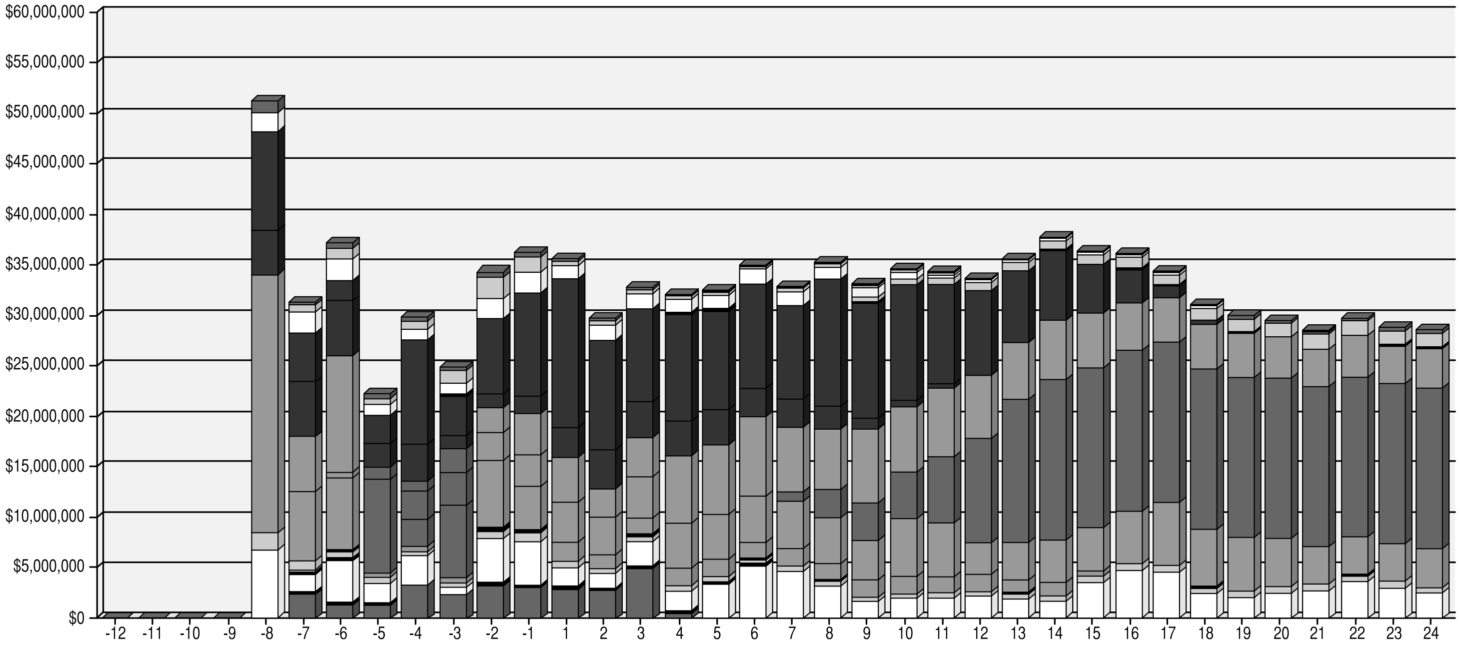
[4] An explanation of required, demonstrated, planned, and maximum capacity follows in the next chapter.



Bars represent inventory dollars. The different shading on the bars represent the product family (or product) that makes up the total inventory dollars

Figure 13.9 Total Inventory Projection in Dollars

Note: Figure is a sample output from Oliver Wight's Enterprise Sales and Operations Planning tool.

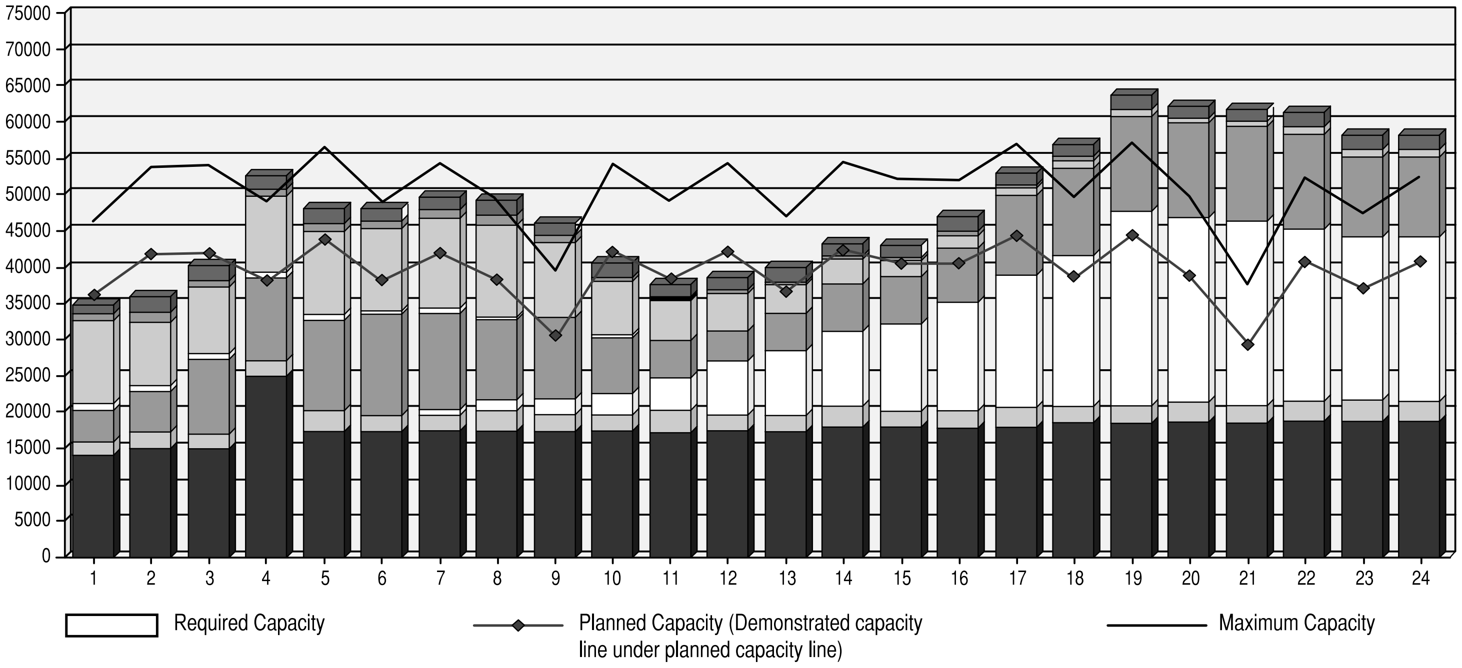


Figure 13.10 Rough Cut Capacity Plan

Note: Figure is a sample output from Oliver Wight's Enterprise Sales and Operations Planning tool.

capacity exceeds the planned capacity but is within the maximum capacity. Therefore, if this supply plan is approved as currently written, the company must be able to sustain maximum capacity for this resource for that six-month period. Periods 10–15 look to be in relative balance, while periods 16–24 highlight an upcoming problem. In these periods (remember that these periods are 16 to 24 months from the current planning period) the required capacity is expected to exceed not only the planned capacity but maximum capacity as well.

So, what do top management and the supply manager do with this information? First of all, the company probably doesn't want to approve this plan without some action plan in place that will answer these questions:

- Do we move to maximum capacity in periods 4–9?
- What will it take to raise current production to maximum capacity in periods 4–9?
- Can the company run at maximum capacity for six months?
- Can we raise the maximum capacity in periods 16–24?
- What will it take to raise the maximum capacity in periods 16–24?
- When does top management need to make these decisions?

As one can see, these charts don't solve the problems; they highlight the problems. People solve the problems. As was stated earlier, the numbers supported by graphics tell a story. When the story is told, it's up to the supply manager and top management to change the story if they do not like what they are reading. This is what sales and operations planning is all about—creating, challenging, and changing the supply chain's or company's story. Now that we have a general understanding of sales and operations planning and the information available in the process, let's turn our attention to a detailed discussion of rough cut capacity planning.

14

Rough Cut Capacity Planning

It is forgivable to be defeated, but never to be surprised.

Imagine that your job is hauling stacks of crates from Los Angeles to San Diego on a flatbed truck. You have decided to take Interstate 5, a highway that you know travels beneath several underpasses. Along the way you discover that your cargo is loaded 15 feet high, but the underpasses have only 14 feet of clearance. How can you continue your journey? Here are some possibilities:

- Crash on through, knowing that your top crates will wind up as two-dimensional displays on the pavement.
- Unload just enough crates to allow the truck to pass under each overpass; then reload the truck on the other side.
- Let some air out of the tires to lower the truck's height.
- Take an exit or back the truck up the on-ramp and take a detour.
- Reconstruct the underpasses.

None of these options are either practical or acceptable. You should have planned ahead, loading the truck with respect to the height of the underpasses. This could mean stacking the boxes to a compatible height or picking a route that allows for safe passage of your cargo.

Perhaps other constraints force you to stack the boxes to a certain height, making clearance under two of the underpasses impossible. In that case, you might still take I-5 but seek other roads as you approach the two low underpasses. Either way, as the old saying goes, the best time to make an escape plan is before you need one.

Know Before You Go

The overloaded truck has a direct analogy in manufacturing. Managers cannot just take a supply (production) plan and a master schedule and toss them onto the shop floor and hope for the best. Chances are that this approach will bump into some low underpasses: a work center with too few people to assemble the product as called for in the production plan or master schedule, too little lead time in another work center, a production line overloaded due to equipment constraints, insufficient space on the manufacturing floor that month or week, a lack of design engineers available to start the process, the inability of the sole supplier of a critical material to deliver on time.

To avoid being caught by such unpleasant surprises, team leaders and master schedulers need a manufacturing road map called *rough cut capacity planning* (RCCP). Rough cut capacity planning basically answers one question: Do we have a *chance* of meeting the supply (production) plan and master schedule as currently written? Rough cut capacity planning helps to identify the material and personnel shortages, the lead-time constraints, and the capacity issues that make it possible to create a supply (production) plan and master schedule that can be executed with every expectation of success. It also suggests possible options for navigating around process and material constraints. In short, rough cut capacity planning makes it possible (1) to test the validity of a supply (production) plan and master schedule before doing any detailed material/capacity planning, and (2) to initiate action for making mid- to long-range capacity adjustments.

One way or another, everyone does some form of rough cut capacity planning. It might be as simple as saying, "My plan calls for shipping 3 million dollars' worth of product this month, and we've always been able to ship 4 million dollars' worth per month. Therefore, we have the proven capacity to meet the plan." Alternately, one might say, "Management wants to ship 7 million dollars' worth a month during the summer season. We have no precedent for being able to do that. Therefore, management's new plan appears to be unrealistic at this time." At the other extreme, a formal rough cut capacity plan might be carried out that evaluates all key resources and determines the feasibility of fulfilling the approved sales and operations plan.

This chapter focuses on the formal approach and covers all of the essential elements and techniques needed to make rough cut capacity planning understandable and workable. Rough cut capacity planning is used to test validity and initiate action for making capacity and/or supply (production) plan adjustments. The remainder of this chapter uses the production plan as the principal driver to the rough cut capacity planning process. The difference between a supply plan and production plan is that a supply plan can include purchased product whereas a production plan is strictly for production.

Rough Cut Revealed

Simply put, rough cut capacity planning attempts to identify 80% to 90% of the issues or potential problems that may occur on the manufacturing floor *before* detailed production schedules and capacity plans are either developed or contemplated. The other 10% to 20% typically surface in the course of material and capacity requirements planning. These problems might be related to space or machinery, or the ever-present bottlenecks that ultimately limit output. Similarly, a gateway work center where the entire production process begins may be a potential problem. Perhaps limited storage tank space will cause a problem. Because every manufacturing process has potential limitations to output, the list could go on for pages and would be unique to each company.

With RCCP, team leaders and master schedulers can quickly identify obstacles to the plan without wading through all the detail. They do this by focusing on the key or critical resources in the company. These key resources may include labor, equipment, materials, floor space, suppliers' capabilities, and, in some cases, money.

The Rough Cut Process

To carry out rough cut capacity planning in a company with simple products and bills-of-material, recipes, or formulas, a clipboard, a pencil, and a simple hand-held calculator may suffice. If a company has products of average complexity and more extensive bills-of-material, recipes, or formulas, a personal computer with a spreadsheet program or master scheduling software is very helpful. For very complex planning operations, master scheduling software that includes a rough cut capacity planning module as well as a finite loader may be necessary. These programs run on mini- or mainframe computers. Whatever the situation, rough cut capacity planning tools must be interactive with the user.

As a starting point, we need to understand a few key terms:

REQUIRED CAPACITY. The capacity needed to meet the production plan and/or master schedule. This is derived by taking the production plan and/or master schedule and extending it by the setup time and run time necessary to produce the product.

AVAILABLE CAPACITY. The capacity that a work center would have if it operated at a 100% productivity level (based on present staffing, equipment, and number of shifts worked).

Demonstrated capacity. The proven or historical capacity of a key resource, work center, or production line calculated on the basis of actual output performance.

Planned capacity. Demonstrated capacity plus anticipated adjustments to that capacity in the future. Adjustments might include the addition of equipment or people, or reductions in machines or staff.

Maximum capacity. The highest level of capacity at which a production system is able to operate without additional capital expenditures.

With these basic definitions understood, we can consider the rough cut capacity planning process itself, which entails three basic steps:

1. Calculate the capacity required to meet the proposed production plan and master schedule.
2. Compare the required capacity to the planned capacity.
3. If necessary, adjust the planned and/or required capacity so that the two are in balance.

As Figure 14.1 indicates, the validation process begins when data from the production plan and/or master schedule is entered into the rough cut capacity planning system. Data from two other sources is then drawn upon: the resource or load profile database, which contains information about the company's use of key resources to build products; and the production and supplier database, which has information about the *available* as well as the *demonstrated* and *planned* capacity of each key resource used to manufacture the products in question.

Combining information from the production plan and the resource profile, the rough cut capacity planning software module determines the *required capacity* necessary to meet the production plan. This required capacity is then compared to the production's and supplier's *planned capacity* and *capabilities* to determine if adequate capacity exists or will exist. If the key resource's planned capacity is adequate, the production plan is deemed realistic and is used to create the mas-

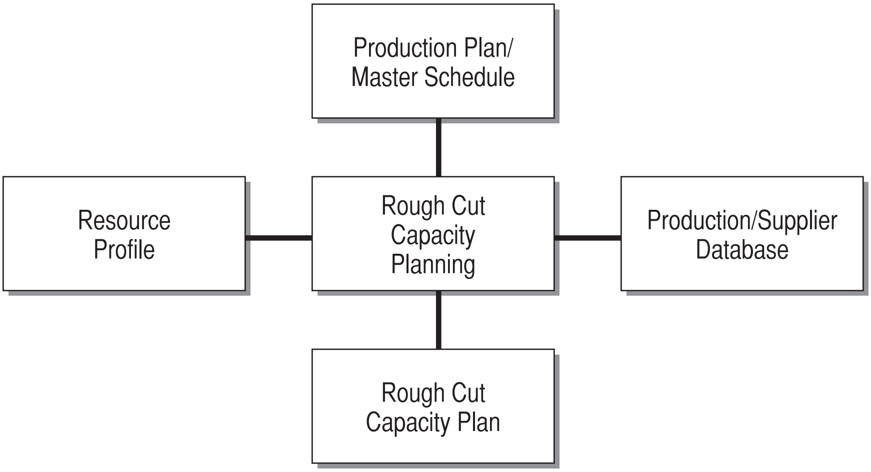


Figure 14.1 Rough Cut Capacity Planning Process

ter schedule as well as detailed material/capacity plans, if necessary. If rough cut capacity planning determines that the key resource's planned capacity cannot support the plan, that information is given to management and the master scheduler, who then must either alter the production plan or increase the resource's capacity.

Essentially, management must balance the production plan's required capacity against a key resource's planned capacity by asking these questions:

- What is the required capacity by time period?
- What is the planned capacity by time period?
- Do the required and planned capacities balance by time period?
- What is the difference between the two?

These questions make it possible to identify potential problem areas and to make adjustments before moving on to any required detailed material/capacity planning.

The next two sections explain the creation of resource profiles and work center or production line capacity data. Be aware that this activity involves both science and art, resulting in a refined guess, albeit one with high predictive value.

Creating Resource Profiles

A resource profile is a statement of the key or critical resources needed to build the product being evaluated by RCCP. It is created through the following process:

IDENTIFY THE KEY WORK CENTERS, PRODUCTION LINES AND CRITICAL RESOURCES NEEDED TO SUPPORT THE PRODUCTION PLAN. This is done by a quaint but effective method: asking people in manufacturing, in purchasing, in design, and in engineering. Those who deal with the engineering and production process every day know what the key resources, process constraints, and bottlenecks are for any particular product normally run through the plant. Typical responses will be influenced by the following elements:

- Constraining or bottlenecked work centers or cells
- One-of-a-kind or special tooling needed in a particular work area
- Processes that are difficult to subcontract because they require special skills or equipment
- High "mix sensitivity" where large numbers of options exist
- Physical properties of the product that make it easy for the production process to get out of control, causing yields to vary
- Unwillingness to offload work because of technology issues

To be systematic in identifying all the key resources, the person charged with identifying the key resources and creating the resource

Key Resources	Reasons							
	Bottleneck or Process Constraint	Not Easy to Off-Load	Mix Sensitivity	Physical Properties	Can't Change Over Quickly	Costly to Underutilize	Special Skills Required	Travel Distance
Tooling (Dies)	✓	✓				✓		
Packing Operations	✓	✓			✓			
Semifinished Operations			✓	✓				
Assembly/Test						✓	✓	
Design Engineering		✓				✓	✓	
Plating				✓				✓
Press 1	✓	✓						
Press 2	✓				✓	✓		
Random, Inc. (Special Material)		✓		✓				✓
Fabrication		✓	✓			✓	✓	

Figure 14.2 Key Resources Worksheet

profiles may find it helpful to use a matrix like the one in Figure 14.2. On the left side, the key resources required to support the production plan and/or master schedule are listed. Across the top, the reasons these resources may pose obstacles to achieving the plan are listed. For example, assembly, drilling, mixing, blending, and fabricating, among other resources, could be listed in the left column. Across the top such obstacles as bottlenecks, difficulty of offloading, special skills requirements, reluctance to share technology, or single-source suppliers may be listed.

Once the matrix is complete, determine if any of the resources identified can be combined. For example, three drill presses might be grouped into "drilling department"; a drilling and milling machine might be grouped into “fabrication”; mixing, filling, and packing operations might be grouped into a production line. Keep the resource profile as simple as possible and with as few entries as absolutely necessary, remembering that the purpose of RCCP is to answer the question: Do we have a *chance* of meeting this production plan or master schedule as currently written?

DETERMINE THE TIMES AND STANDARDS ASSOCIATED WITH EACH OF THE KEY RESOURCES. *Times* and *standards* refer to setup time and run time (processing time required), as opposed to queue time, waiting time, and move time (interoperational times). In traditional manufacturing, setup and run times impact the workload on a resource because they actually tie up that resource. In contrast, the queue, wait, and move times impact the time it takes to move work through the facility, but they do not affect the load at any particular resource, which is the real consideration when it comes to testing the validity of the production plan and/or master schedule.

Here is a four-step method for deriving the resource profile’s processing time:

1. Select the product family for which the resource profile is being created.
2. Explode the product family using the entire bill-of-material, recipe, or formulation.
3. Search each of the associated detail routings to determine whether a previously identified key resource is involved in the manufacture of the product family.
4. For each identified key resource, determine its profile time. This can be time consuming, but is readily done using one of the following methods:
    - *Choose a typical or representative item,* one that most ideally represents the entire product line—perhaps one or more from a similar product family—and use it as a proxy for the planned item.

- *Compute an arithmetic average for the resource.* Add up the time spent on all items within the family that pass through the key resource and divide that time by the number of items processed.
- *Compute a weighted average.* This requires that a weight, which correlates to the anticipated product mix, is applied to the individual item's time. The weighted times are then summed to create a weighted average for the resource.
- *Estimate the time it takes for the planned product to pass through a work center or down a production line.* Ask people on the floor or in the plant how long it takes for an average lot size or batch to go through the key resources and extrapolate the time for the planned product from this.

These methods will yield estimated times that are useful for developing predictive resource profiles. If detailed routings and process sheets are available with engineering standards, the resource profile times created using one of the above methods can be quite accurate.

Once they are estimated, enter the times for each resource in a matrix that breaks out each key resource by family, as shown in Figure 14.3 on page 410. This matrix constitutes a "resource profile by product family."

We also need to determine what is called the *lead-time offset.* The lead-time offset is the time between the *need* for the resource and the date that the product has been *promised.* The application of lead-time offset is necessary if a product has longer lead times—generally more than a month or two. In that case, you may have to use the offset so that the need for the resource can be identified in the proper period in the rough cut capacity plan.

Figure 14.4 on page 411 shows a simple two-level bill-of-material for a customized pen, detailed routings for the pen and body assembly, and a time line for the pen product. A review of the bill-of-material (Figure 14.4A) indicates that the pen is composed of one body assembly and one cap. The body assembly in turn is made up of one barrel, one ink filler, and one filler cap. The expected ship date or promised

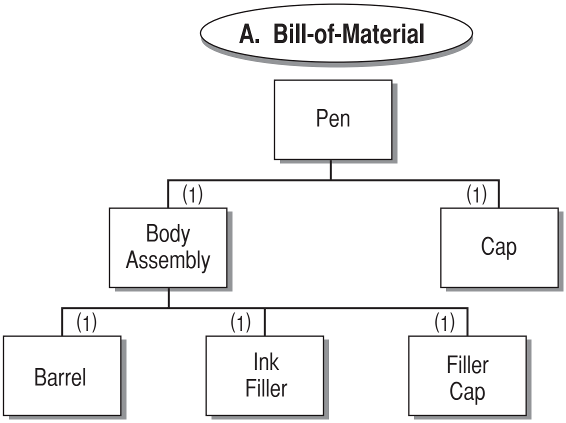
Key Resources	Unit of Measure	SOP Family A	SOP Family B	SOP Family C	SOP Family D	SOP Family E
Filling Lines 1&2	Machine Hours	1.1	1.1		0.8	1.5
Filling Line 3	Machine Hours	0.8	2.0		2.2	2.25
Filling Line 4	Machine Hours	1.0		4.0		
Finishing Line	Worker Hours	15.0	28.0	48.0	24.0	26.0
In-Process Storage	Lbs.	15,000				
Processing Department	Equipment Hours	265.0		22.0	33.0	20.0
Incoming Test	Worker Hours	13.0		8.0	26.0	6.0
Supplier 100	Lbs.	450		215	335	
Supplier 200	Cases	250		1,000		

Figure 14.3 Resource Profile by Product Family (Per 1,000)

date for delivery of the product is identified with the completed pen. But body assemblies must be manufactured or assembled before pens can be produced.

For purposes of discussion, assume that we have identified two key resources, work centers 250 and 900. The detail routing (Figure 14.4B) for the body assembly reveals four operations. As we look at the routing, we notice that the first key resource encountered in the body assembly is operation 20, which takes place at work center 250. On the time line shown at the bottom (Figure 14.4C), operation 20 in work center 250 for body assemblies is required 35 days prior to the due date assigned for the product pen. Therefore, this resource has a lead-time offset of 35 days.

The next key resource encountered is operation 40 for the body -assembly, which is to be performed in work center 900. In this case, the resource is required 16 days prior to the completion of the pen and is assigned a lead-time offset of 16 days. The customized pen's



B. Routing

Pen

Operation Number	Operation Description	Work Center	Setup Time	Run Time
10	Silk Screening	100	1.2	1.0
20	Drying	600	.5	—
30	Assembly	250	—	.2
40	Inspection	900	1.5	.1
50	Monogramming	400	—	.2
60	Inspection	900	.6	.1

Body Assembly

Operation Number	Operation Description	Work Center	Setup Time	Run Time
10	Assembly	200	1.6	1.2
20	Assembly	250	.4	.3
30	Test	800	.3	.6
40	Inspection	900	.75	.2

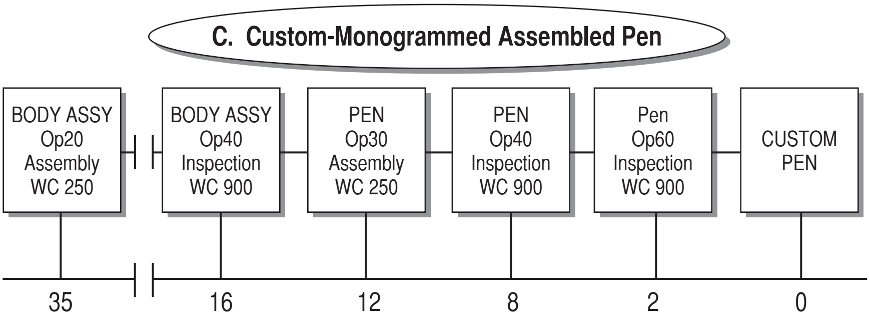


Figure 14.4 Two-Level Bill-of-Material and Time Line Illustrations Lead-Time Offsets, Pen Product

routing is shown at the top of Figure 14.4B, and also contains the two key resources: one pass through work center 250, and two passes through work center 900. As the time line shows, the lead-time offsets assigned are 12 days, 8 days, and 2 days, respectively, from the pen's planned completion date.

By definition, *every* key resource has a lead-time offset. But in practice, if the offset is less than 30 days, it does not need to be entered into your calculations when you are evaluating the validity of the production plan (rough cutting the master schedule may require more precision). This is because production planning is generally done on a monthly basis. In fact, some companies even represent lead-time offset in months. Every resource required within 30 days falls within the month that the order is due. Offsets between 30 and 60 days fall in the month immediately preceding the month the product is due, and so forth. The choice is arbitrary and one that a company must make prior to implementing rough cut capacity planning.

This arbitrary choice might compromise overall accuracy. But it doesn't really matter—with rough cut capacity planning, the goal is to balance simplicity and speed with accuracy and to determine if the production plan is realistic. The team leader or master scheduler is not trying to match the precision of a space shuttle launch. Rough cut capacity planning is applied common sense, not hard science, and should be considered only a general guideline. If a resource has an offset of 35 days and production planning is done in months, the extra 5 days will not make much of a difference in determining whether the production plan is realistic. The lead time of a resource with a 120-day offset, on the other hand, must be taken into account if the rough cut capacity plan of its production plan is to have any predictive value.

Finalizing the Resource Profile

At this point it is possible to take all of the concepts presented and demonstrate how resource profile computations are actually made for key resources. The computations are simple if you understand the fundamental principles involved.

Profile Times

When using detail routings or process sheets to create the resource profile, use the following equation to determine the profile times:

(Run time × BOM quantity)
+ (Setup time × Number of setups required)

This yields the time required for the resource in question. Refer to Figure 14.4 on page 411. For pens there are two key resources: an assembly operation (work center 250) and an inspection operation (work center 900). Each operation has a setup and run time that can be used in the profile time equation.

At this point, the resource profile is complete and the master scheduler can move on to the other input for the rough cut capacity planning process: planned capacity, which is compared to the required capacity.

Capacity Inputs

The sales and operations planning (S&OP) process yields a production plan, establishing volume requirements by product family item. An example of such a plan is shown in Figure 14.5 on page 414.

This particular plan covers five product families with three future months' worth of data. Here we will see what happens when the production plan is exploded through the resource profile. The production plan calls for 30,000 units of family A in July. Referring back to the resource profile for family A (see Figure 14.3 on p. 410), the required time for the first key resource, filling lines 1 and 2, is 1.1 hours per 1,000 units. That means 30,000 units will require 33 hours on either the 1 or 2 line—(30,000 × 1.1) ÷ 1,000 = 33. For family B, the

Month	Family A	Family B	Family C	Family D	Family E
July	30,000	10,000	4,000	3,000	3,000
August	25,000	5,000	4,000	3,000	3,000
September	25,000	5,000	5,000	4,000	3,000
Total	80,000	20,000	13,000	10,000	9,000

Figure 14.5 Production Plan

resource profile indicates that 1.8 hours per 1,000 units are required on the 1 and 2 lines. Since the production plan for family B calls for 10,000 units in July, the required capacity will be 18 hours—(10,000 × 1.8) ÷ 1,000 = 18.

Continuing this simple calculation for each family in the production plan, the required capacity for the entire plan can be determined. Figure 14.6 shows this required capacity for the production plan shown in Figure 14.5 using the resource profile developed in Figure 14.3.

Once the production plan's required capacity has been calculated by the rough cut method, the next step is to compare that required capacity to the actual capacity at the master scheduler's disposal. The comparison determines whether adjustments need to be made to available resources or the production plan. A company's capacity really consists of several types of capacities, two of which (demonstrated and planned) are described in further detail in the following sections.

DEMONSTRATED CAPACITY. This was earlier shown to be the proven or historical capacity of a key resource or work center. To illustrate demonstrated capacity, consider a racing car. Imagine that you've been working for the past five years to design a very fast vehicle. During the design process, you have determined that the car should be able to achieve a speed of 200 miles per hour (mph). Actual time trials, however, reveal that the car never exceeds 180 mph. No matter what your engineers and mechanics do, the car never exceeds 180 mph. So,

Key Resource	Unit of Measure	Month	Family A	Family B	Family C	Family D	Family E	Required Capacity
Filling Lines 1&2	Machine Hours	July	33.0	18		2.4	4.5	58
		August	27.5	9		2.4	4.5	44
		September	27.5	9		3.2	4.5	44
		TOTAL	88.0	36		8.0	13.5	146
Filling Line 3	Machine Hours	July	24	20		6.6	6.75	57
		August	20	10		6.6	6.75	43
		September	20	10		8.8	6.75	46
		TOTAL	64	40		22.0	20.25	146
Filling Line 4	Machine Hours	July	30		16			46
		August	35		16			41
		September	25		20			45
		TOTAL	80		52			132
Finishing Line	Worker Hours	July	450	280	192	72	78	1,072
		August	375	140	192	72	78	857
		September	375	140	240	96	78	929
		TOTAL	1,200	560	624	240	234	2,858
In-process Storage	Lbs.	July	450,000					450,000
		August	375,000					375,000
		September	375,000					375,000
		TOTAL	1,200,000					1,200,000
Processing Department	Equipment Hours	July	7,950		88	99	60	8,197
		August	6,625		88	99	60	6,872
		September	6,625		110	132	60	6,927
		TOTAL	21,200		268	330	180	21,996
Incoming Test	Worker Hours	July	390		32	78	18	518
		August	325		32	78	18	453
		September	325		40	104	18	487
		TOTAL	1,040		104	260	54	1,458
Supplier 100	Lbs.	July	13,500		860	1,005		15,365
		August	11,250		860	1,005		13,115
		September	11,250		1,075	1,340		13,665
		TOTAL	36,000		2,795	3,350		42,145
Supplier 200	Cases	July	7,500		4,000			11,500
		August	6,250		4,000			10,250
		September	6,250		5,000			11,250
		TOTAL	20,000		13,000			33,000

Figure 14.6 Rough Cut Required Capacity

what is the demonstrated speed of the vehicle? Obviously, it is 180 mph or less, and it would be foolish to enter the vehicle in a race that requires 200 mph.

The same mechanism applies in manufacturing. It is foolish to adopt a plan that loads a factory, plant, production line, or a key resource with 200 units of work per month when past experience indicates that 180 units of work per month is the best that has been achieved. More than a few manufacturing companies do just that. While this can-do attitude may appear admirable, attempts to exceed demonstrated capacity are invariably doomed to failure and should not receive support.

Adequate demonstrated capacity in itself, however, is not sufficient to make the decision to adopt the production plan—demonstrated capacity could potentially change if resources are added or if operations are altered. Planned adjustments to capacity must be considered before making an evaluation of the production plan.

PLANNED CAPACITY. This is demonstrated capacity plus or minus anticipated changes or adjustments to the product-flow process. To understand this better, let us return to the racing car analogy for a moment. Perhaps later tests determine that by installing an exotic, special-purpose air blower, your car can achieve 200 mph. The air blower manufacturer indicated that it can deliver the new part at the end of five weeks. This means the car can be expected to clock at 180 mph for the next five weeks and at 200 mph in the sixth. Now you have a decision to make: Should you adjust your racing strategy in week 6? Here you need to analyze the possibility of really being able to compete at 200 mph in the future. If you are confident that the design is good, that production will deliver as promised, and that you will be able to achieve 200 mph six weeks out, then it seems reasonable to adjust your planned racing speed for the car.

Likewise, if a manufacturing unit has regularly demonstrated its ability to produce 180 units per month, an upward adjustment to 200 units per month beginning sometime in the future might be reasonable if operators are scheduled for special training or additional equipment is expected to be available.

With this sort of knowledge in hand, the management team and master scheduler can begin to make valid comparisons of the required capacity and the planned capacity (Figure 14.7).

In some cases, there are underloads (i.e., less capacity is required

Key Resource	Unit of Measure	Month	Required Capacity	Net Difference	Planned Capacity	Maximum Capacity
Filling Lines 1&2	Machine Hours	July	58	56	114	152
		August	44	16	60	80
		September	44	100	144	192
		TOTAL	146	172	318	424
Filling Line 3	Machine Hours	July	57	76	133	171
		August	43	27	70	90
		September	46	122	168	216
		TOTAL	146	225	371	477
Filling Line 4	Machine Hours	July	46	49	95	114
		August	41	9	50	60
		September	45	75	120	144
		TOTAL	132	133	265	318
Finishing Line	Worker Hours	July	1,072	68	1,140	1,596
		August	857	–257	600	840
		September	929	511	1,440	2,016
		TOTAL	2,858	322	3,180	4,452
In-process Storage	Lbs.	July	450,000	690,000	1,140,000	1,140,000
		August	375,000	225,000	600,000	600,000
		September	375,000	1,065,000	1,440,000	1,440,000
		TOTAL	1,200,00	1,980,00	3,180,000	3,180,000
Processing Department	Equipment Hours	July	8,197	2,253	10,450	12,350
		August	6,872	-1,372	5,500	6,500
		September	6,927	6,273	13,200	15,600
		TOTAL	21,996	7,154	29,150	34,450
Incoming Test	Worker Hours	July	518	14	532	551
		August	453	–173	280	320
		September	487	185	672	768
		TOTAL	1,458	26	1,484	1,639
Supplier 100	Lbs.	July	15,365	29,635	45,000	45,000
		August	13,115	31,885	45,000	45,000
		September	13,665	31,335	45,000	45,000
		TOTAL	42,145	92,855	135,000	135,000
Supplier 200	Cases	July	11,500	7,500	19,000	23,000
		August	10,250	–250	10,000	12,000
		September	11,250	12,750	24,000	29,000
		TOTAL	33,000	20,000	53,000	64,000

Figure 14.7 Required Capacity Versus Planned Capacity

than is planned to be available), while in other cases there may be overloads. For example, in the finishing operation shown in Figure 14.7 (fourth row), a total of 857 hours are required in August, yet current plans have only 600 hours available. Do such potential overloads truly indicate that the production plan cannot be met? Not necessarily.

Management might be able to increase the capacity at selected key resources. This prompts our next subject: maximum capacity.

MAXIMUM CAPACITY. By definition, this is the heaviest load a resource can handle under any reasonable set of circumstances and without capital expenditures. It can be achieved through a number of means. In the case of personnel, the use of overtime, including added shifts and weekends, or outright staff additions can increase the resource. In the case of a critical supplier, some work might be offloaded to another supplier, the company could agree to pay extra for supply priority, or premium freight methods could be used to expedite material delivery. In the case of machine time, an extra shift might be added. Attempts to operate a production system beyond its maximum capacity generally lead to confusion in manufacturing and almost always lead to a failure to achieve planned production quantities.

Evaluating the Plan

Clearly, flexing capacity up or down or using any other approaches to boost or lower capacity may have a cost impact, and must therefore be carefully evaluated by management. Rough cut capacity planning answers questions about critical capacity and material requirements in terms of numbers. It points out where potential problems are likely to occur and reveals what happens when alternatives (e.g., maximum capacity) are applied. The rough cut capacity plan provides an opportunity for people to exercise skill, knowledge, and creativity in balancing demand for product with the supply of resources. It makes it possible to “manage by the numbers” and to evaluate whether a production plan and/or master schedule is achievable or merely an unrealistic gleam in someone’s eyes.

Rough cut capacity planning can also determine where the energies of management should be focused. If product family A is an elephant (refer to Figure 14.6 on p. 415) compared to the other product families—that is, if it has by far the largest need for capacity and creates the biggest problems—management can focus its efforts on that product family.

Overloading Demonstrated Capacity

Panware has a work center that makes saucepans and matching covers. Assume that it takes the same amount of time to make the saucepan as it takes to make the cover. The resource in question has a demonstrated capacity of 5,000 units per period. Therefore, manufacturing can build 2,500 complete packages during any given time period (2,500 saucepans and 2,500 covers).

Management wants 2,750 packages per period. The master scheduler appropriately responds, “Yes, we can do that. But we will need a new piece of equipment.” To this, management counters, “No, we are not going to buy any new equipment.”

“Okay, we'll need to work an extra shift.”

“No, we're not going to work another shift.”

“Okay, we will work a few weekends of overtime.”

“No, we are not going to work any overtime.”

“Okay, how about offloading some work to a subcontractor?”

Management replies, “No, we will not offload any work.” At some point, the master scheduler needs to respond with a firm “no” to the requested 2,750 packages per period.

After a few minutes of thought, management goes through this logic: “If we ask for 2,500 packages, the most we will get is 2,500 packages. However, if we ask for 2,750 packages, we may not get 2,750 packages, but we may get 2,650 packages. This is closer to the 2,750 than the 2,500 packages, and we didn't authorize any additional spending. So let's schedule more than we can do, just in case.” (See Figure 14.8 on p. 420.)

As directed, the master scheduler has scheduled 2,750 packages per period over the next four periods. Work authorization for the four lots of 2,750 packages has been given. Manufacturing commences work on the 2,750 saucepans due in period 1. Once this work is done, a changeover is made to the pan covers. The scheduler has released

Time Periods	Package Schedule	Saucepan Builds	Pan Cover Builds	Package Shipments	Saucepan Inventory	Pan Cover Inventory
1	2,750	2,750	2,250	2,250	500	0
2	2,750	1,750	3,250	2,250	0	1,000
3	2,750	3,750	1,250	2,250	1,500	0
4	2,750	750	4,250	2,250	0	2,000

Figure 14.8 Overloading the Master Schedule

an authorization for 2,750 covers. However, only 2,250 covers can be completed during period 1 due to capacity constraints (2,750 saucepans plus 2,250 saucepan covers equals 5,000 total units). Therefore, only 2,250 completed packages can be shipped at the end of period 1.

As period 2 commences, manufacturing will complete the open order for 2,750 saucepan covers (500 remain to be completed). Now, since the resource is already set up for pan covers, the decision is made to continue working on the 2,750 covers scheduled for completion in period 2. When this work is completed, a total of 3,250 units of capacity have been spent. The production line is changed over to saucepans, and 1,750 of the 2,750 pans scheduled are completed. Manufacturing takes these 1,750 saucepans plus the 500 in inventory, adds the 2,250 saucepan covers, and ships 2,250 packages. And so it goes. . . .

Managing to demonstrated capacity is critically important in effectively running a manufacturing operation. More isn't always better. As Figure 14.9 suggests, the total packages shipped per period continues to be 2,250 units over the four-period horizon. The most packages that can be shipped in the example is 2,500—the demonstrated and planned capacity. Scheduling more has proven disastrous.

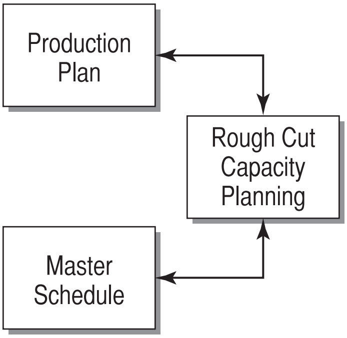


Figure 14.9 Rough Cut Capacity Planning and Operational Relationships

Rough Cut at the Master Scheduling Level

Figure 14.9 recaps the relationship between sales and operations planning, the master schedule, and rough cut capacity planning. Here, the production plan is developed in the sales and operations planning process. Next, the production plan is checked for validity through the rough cut capacity planning process and adjusted as necessary. Once the executive team determines that a realistic plan exists, the production plan becomes the driver and constraint in the master scheduling process, which translates the production plan into discrete part numbers, quantities, and due dates. This accomplished, the master schedule drives the material and capacity planning processes.

While all companies need to do rough cut capacity planning at the production planning level, many manufacturing environments require a second or even a third pass through the rough cut analysis, this time at the master schedule level. Companies with highly varied mixes of product are among these. This section covers techniques for carrying out rough cut capacity planning for complex product mixes.

Rough cut capacity planning at the supply management and master scheduling levels uses the same principles as rough cut at the production plan level, but extends the calculations down one or two additional levels. This is done by exploding the master plan or master schedule, instead of the production plan, through an item resource profile to generate the required capacity to meet the master plan or schedule. As Figure 14.10 indicates, each S&OP family may be divided into constituent items. Family A, for example, consists of items A1, A2, A3, and A4.

The key resources are listed on the left side of the resource profile, along with the associated times and standards. In addition, the resource profile contains the predicted mix probability for each item. In the case of family A, for example, each product is indicated as having a 25% probability; that is, there is a 25% probability that demand of an A will be as an A1, A2, A3, and as an A4.[1] This product mix percentage is very important at the master schedule level, because it yields a much more detailed estimate of how the various key resources will be deployed for each item within the family. Consider family D, which has just two items, the first of which (D1) constitutes 33% of the mix. That means that when you need a product D, one-third of the time you would expect to need a D1, and two-thirds of the time you would need a D2.

Jump back to the B product family. This is different. Three of the items (B1, B2, and B3) are very much alike and use the same key resources. The same is true for items B11, B12, and B13. Therefore, two groups are formed and resource profiles are created to cover the two groupings. As shown in Figure 14.10, when a product of the B family is needed, 60% of the time we expect it to be a B1, B2, or B3. The remaining 40% of the time we expect to need a B11, B12, or B13.

In addition to this breakout by individual items within a family, the master schedule item rough cut resource profile also shows the average resource times developed for the aggregate family (see Figure 14.10, average columns). Now take a close look at filling lines 1 and 2 for the S&OP family A. In the resource profile for product family A, we learned that lines 1 and 2 required 1.1 hours per 1,000 units. Using

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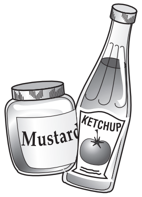
[1] These probabilities are established by management as part of the S&OP process.

S&OP Family		A					B			C			D			E		
Key Resource	Unit of Measure	A1	A2	A3	A4	Average	B1 B2 B3	B11 B12 B13	Average	C1	C2	Average	D1	D2	Average	E1	E2	Average
Typical Mix %		25%	25%	25%	25%	100%	60%	40%	100%	50%	50%	100%	33%	67%	100%	50%	50%	100%
Lines 1 & 2	Hours	2.0	2.4			1.1	3.0		1.8				2.4		0.8	3.0		1.5
Line 3	Hours			3.1		0.8		5.0	2.0					3.3	2.2		4.5	2.25
Line 4	Hours				4.0	1.0				3.0	5.0	4.0						
Finishing Department	Hours	12.0	12.5	16.7	20.0	15.0	18	45	28	36	60	48	19	26	24	24	27	26
In-Process Storage	Lbs.	10,000	10,000	20,000	20,000	15,000												
Processing Department	Hours	160.0	260.0	320.0	320.0	265.0				15.0	29.0	22.0	24.0	45.0	38.0	13.0	27.0	20.0
Incoming Test	Hours	8.0	12.0	16.0	16.0	13.0				7.0	9.0	8.0	18.0	30.0	26.0	5.0	7.0	6.0
Supplier 100	Lbs		1,800			450				150	280	215	225	390	335			
Supplier 200	Cases				1,000	250				1,000	1,000	1,000						

Figure 14.10 Resource Profile by MPS Item (Per 1,000)

the master schedule resource load profile by item, we review the computation of this weighted average for lines 1 and 2.



Item A1 requires 2.0 hours per 1,000 units.

Item A2 requires 2.4 hours per 1,000 units.

Items A3 and A4 do not use lines 1 and 2.

Since all items are 25% of the mix, the times for each unit would be

A1 = 2.0 × 25% = 0.5

A2 = 2.4 × 25% = 0.6

A3 = 0.0 × 25% = 0.0

A4 = 0.0 × 25% = 0.0

Weighted average = 1.1 hours

The same calculation is performed for each key resource in the resource profile for each family. Once average hours or standards have been computed for each key resource, rough cut capacity planning can be used to evaluate the capacity for each resource on a month-by-month basis using the production plan and on a week-by-week basis using the master schedule. This process has already been examined at the production plan level. Now we examine the process at the master plan and schedule level.

The example shown in Figure 14.11 provides the quantities scheduled for each master schedule item. Note that the totals for these master schedule items are identical to those stipulated in the production plan (see Figure 14.5, p. 414). What's different is that the item quantities have been broken out as components of the production plan totals. These item quantities are the result of the master scheduler's taking the production plan and translating it into discrete items, quantities, and weekly due dates based on the predicted mix and inventories available. In other words, firm planned orders have been created by the master scheduler for the items as shown in the figure.

Family	A	B	C	D	E	Total
July Week 1		B1 4,000 B2 4,000 B3 2,000				10,000
Week 2	A1 6,000		C1 1,000	D1 2,000 D2 1,000	E1 3,000	13,000
Week 3	A3 2,000 A4 10,000		C2 1,000			13,000
Week 4	A4 12,000		C2 2,000			14,000
Total	30,000	10,000	4,000	3,000	3,000	50,000

Figure 14.11 Master Schedule for July

During the rough cut capacity planning process, the quantities for each master scheduled item are multiplied by the time requirements in the resource profile. This results in a week-by-week summary of total required capacity. The total required capacity is then compared to the planned and maximum capacities for each master schedule item (see Figure 14.12 on p. 426).

Again, note that the production plan quantities by family (Figures 14.5 and 14.11) equal the totals of the master schedule quantities within each family. But the master schedule rough cut capacity plan clearly yields more detailed information, since it is at the item level. This additional detailed information allows us to assess whether the master schedule is valid given the planned and maximum capacity. As we begin looking at specific master schedule line items, a couple of guidelines (which the author has used for years) may be useful.

If the required capacity is:

- No more than 10% greater than the planned capacity, the master schedule seems to be realistic and more detail should be pursued (detailed material/capacity requirements planning plus plant scheduling).

Family		A	B	C	D	E	Required Capacity	Net Difference	Planned Capacity	Maximum Capacity
Lines 1 & 2	Week 1		30				30	–6	24	32
	Week 2	12			5	9	26	4	30	40
	Week 3						0	30	30	40
	Week 4						0	30	30	40
	Total	12	30	0	5	9	56	58	114	152
Line 3	Week 1						0	28	28	36
	Week 2				3		3	32	35	45
	Week 3	6					6	29	35	45
	Week 4						0	35	35	45
	Total	6	0	0	3	0	9	124	133	171
Line 4	Week 1						0	20	20	24
	Week 2			3			3	22	25	30
	Week 3	40		5			45	–20	25	30
	Week 4	48		10			58	–33	25	30
	Total	88	0	18	0	0	106	–11	95	114

Figure 14.12 Rough Cut Capacity Plan by MPS Item

- More than 20% greater than the planned capacity, the master schedule seems to be unrealistic and a corrective action plan should be derived before proceeding.
- Between 10% and 20% greater than the planned capacity, the master schedule is in the gray area, and prior resource behavior (what we know about the resource in question) must determine what is to be done.

At this point we can apply the general guidelines to an analysis of the weekly rough cut capacity requirements in July for lines 1 through 4 (Figure 14.12). Whereas the aggregate plan revealed an underload for lines 1 and 2, at the master scheduling level, we observe an expected overload in the first week of July (required capacity versus planned capacity) and underloads in the third and fourth weeks. Is the overload a reason for changing the master schedule? Maybe not, because it is within the 20% guideline. Besides, the maximum capacity is 32 hours. Remember, you only want to know if we have a chance to achieve the master schedule, not if we will be able to accomplish it in every detail. Of course, in selected environments, such as the process industry, these guidelines most likely need tighter tolerances, say, 5% to 10%, or even 2% to 5%.

For line 3, significant underloads are indicated in each week, and for line 4, an underloaded condition appears in weeks 1 and 2, and overloads in excess of 20% in weeks 3 and 4. In fact, required capacity in weeks 3 and 4 greatly exceeds maximum capacity.

Handling Under- and Overloads

Several options exist for dealing with under- and overloads. First, for lines 1 and 2, it might be possible to move some of the load from week 1 of July into June or into weeks 3 and 4 of July, where underloads are projected. By looking back at the master schedule (Figure 14.11, p. 425), B1, B2, and B3 are the candidates for load shifting since they are the only units planned to run during the first week in July. Each 1,000-unit run requires three hours. Therefore, if we want to balance required and planned capacity, we must either shift 2,000 units of B1, B2, or B3 into another time period or increase the planned capacity or a combination of the two. Of course, any discussion of moving out a master scheduled item requires consideration of the impact of that move on the ability to meet the customer promise dates.

Analysis of weeks 3 and 4 in July for line 4 indicates a significant potential overload. What is causing this potential problem, and what can be done about it? To determine the cause of the overload, look back at Figure 14.11 to see which master scheduled items are scheduled to run in weeks 3 and 4. There we note that A3, A4, and C2 are scheduled for production. Items A3 and C2, however, do not use line 4 (Figure 14.11, p. 425). Therefore, we need concern ourselves only with the 10,000 units of A4 scheduled in week 3 and the 12,000 units of A4 scheduled in week 4. What started out to be a potential problem that we may not have even recognized has been reduced to a single master scheduled item over a two-week period, further illustrating another payback of rough cut capacity planning. Now, the master scheduler must determine if load shifting from weeks 3 and

4 to weeks 1 and 2 can be accomplished within the framework of the master schedule.

When dealing with the underloaded condition in weeks 3 and 4 in July for lines 1 and 2, the master scheduler may decide to allow the equipment on these lines to sit idle in weeks 3 and 4 and do preventive maintenance. Another possibility is to plan to move people from one work area to another. The people who work on lines 1 through 4 may be people with the same skills, or they could all be people who work on various filling lines and therefore possess similar skills. Perhaps these workers could be moved to line 4 in weeks 3 and 4, along with a group of operators from line 3, who will be virtually without activities for the entire month.

By using rough cut capacity planning to validate the master schedule, it is possible to validate whether the production plan derived during the S&OP process can be met at the product mix level. This validity check brings us full circle in the rough cut capacity planning process.

Working the Rough Cut Capacity Plan

Now that the method and use of rough cut capacity planning at both the production plan and master schedule level has been explained, it is time to look more deeply into the evaluation process. Continuing with the rough cut capacity planning example already developed in this chapter (refer to Figure 14.7 on p. 417), a review of the necessary capacity shows that for lines 1 and 2, the potential problem is a projected underload in July (58 hours required versus 114 planned), August (44 hours required versus 60 planned), and September (44 hours required versus 144 planned). This indicates that the plan is realistic in terms of having *sufficient* resources to satisfy demand, at least at the aggregate level. The same appears to be true for lines 3 and 4.

So far so good. Now consider the next key resource, finishing. Here the situation is tight—1,072 required hours versus 1,140 planned hours in the month of July. If everything goes smoothly, the plan should work. But if anything goes astray or unexpected orders roll in the door, the situation could quickly shift from an acceptable condition to an overload situation. There is definite trouble in August—an overload of 257 hours, which represents a potential overload of approximately 30%. In September the finishing work center appears to have sufficient capacity.

Up to this point, only one of four key resources has a potential problem—finishing, in August. As you can see, this analysis has narrowed down the key resources that are potential obstacles to meeting the production plan.

Move down the list of key resources in Figure 14.7 and compare required and planned capacities. Here the capacity planner finds that in-process storage contains no problem for any of the three months. The processing department, however, contains a potential overload, again in August; but adequate capacity in July and September for this resource suggests that some load shift may alleviate the problem.

For the incoming test resource, capacity is marginally adequate for July, but August is overloaded by 50%. September appears to be in good shape. Material from supplier 100 is more than adequate in all three months, and for supplier 200, material is sufficient for July and September, but marginal for August.

In effect, this exercise has reduced the potential obstacles to meeting the production plan from nine to four. Within those four problematic resources, only three—finishing, processing, and incoming test—represent significant issues, and then only in the month of August. Knowing the locations and depth of these problems makes the search for solutions possible. The example also points out the importance of evaluating resources on at least a monthly basis. Look at the three-month totals. From a quarterly, aggregate perspective, sufficient resources are available for all key resources. But the month of August is clearly problematic now, since three resources and one key supplier will be overloaded during that month. The process thus entails moving from the aggregate to the pegged-detail level as you determine that more information is necessary to answer the question, Do we have a chance of meeting the production plan and master schedule as currently written?

Taking Action

Once the problem resources have been identified and analyzed as much as possible, the next step is to evaluate potential solutions. First, determine whether action really needs to be taken in August for each of the key resources identified. Recall the general action guidelines stated earlier—the challenge is to have the required capacity equal the planned capacity *within the tolerances* established by such guidelines.

In an out-of-balance situation, there are only three choices of action: (1) modify the production plan so that required capacity equals planned capacity; (2) adjust the planned capacity to equal required capacity; and (3) do a combination of the two actions just noted. The second option is generally preferable. Let us see how this might be achieved to resolve the problems anticipated for August.

Overloads

Several actions may be taken in order to adjust the planned capacity for each overloaded resource:

1. Work overtime or extra shifts.
2. Transfer people from underloaded work areas to boost the resources in the overloaded work areas.
3. Reroute some of the work to an alternate work area (work center, work cell, or production line) if one is available.
4. Subcontract all or a portion of the work.
5. Hire temporary workers.

6. Install more equipment.
7. Build a new facility.

Underloads

As the example in Figure 14.7 on page 417 demonstrates, a number of underload situations exist (lines 1 through 4). These may be undesirable situations, but they also present opportunities to

1. Deploy workers on other lines.
2. Conduct education and training sessions.
3. Do preventive maintenance on idle equipment and housekeeping in idle work areas.
4. Reduce shifts and/or overtime.
5. Assign line workers to other functions like design or engineering. The workers can then learn what these functions have in mind as they develop a product. The line workers can give engineers ideas of manufacturing-related problems that appear in the plant.
6. Run a promotion to increase demand and thereby increase required capacity.
7. Establish a task force to reduce setup and changeover times.

And the list goes on. Clearly, dealing with underloads, like overloads, requires good communication among marketing, sales, finance, engineering, manufacturing, purchasing, and human resources.

Each option must be examined in light of the capacity needed as well as the maximum capacity available. In the case of the finishing resource, for example, we see that the most capacity that can be expected is 840 hours (maximum capacity). But the required capacity is 857 hours. Therefore, even bringing the finishing resource up to its maximum capacity of 840 hours by moving people from lines 3 and 4 would not alleviate an overloaded condition. Moreover, the movement of workers from one work center to another might create negative impacts elsewhere. There generally is no free lunch. The key question is whether the action alleviates the original problem or creates a new one.

Finessing the Situation with Customers

In addition to looking for possible move-ins and move-outs in the plant, marketing and sales may find customers willing to receive their orders early or late. Financial incentive may be cost effective in getting them to accept rescheduled deliveries. For example, Multitek, Inc., may be happy to take delivery of a commercial vehicle a month sooner if it is offered an added option or engine upgrade at no additional cost. Turbo Brothers might be willing to take early delivery of a vehicle from the manufacturer's current inventory without all the features it originally ordered if a special warrantee package is offered. In cases like these, the production plan and master schedule can be modified by moving some orders forward in the schedule and others back.

Lot Splitting

Another alternative is to do a *lot split.* For example, an August run of 10,000 might be split into a run of 5,000 in July and 5,000 in August, thus alleviating a predicted capacity shortage. The master scheduler could also plan to ship the product early (if the customer agrees) or hold the early build and ship the entire lot as planned and continue to honor any promises made to the customer. Of course, in some industries, the splitting of lots or batches is controlled by product specifications, recipes, and formulations.

When Capacity Cannot Be Adjusted

If the planned capacity for the finishing line cannot be adjusted in August, it may become necessary to modify the production plan and master schedule. This requires asking what the plan hoped to achieve in the first place. If the plan was trying to build product to satisfy firm customer orders, marketing and sales must decide which customer orders, if any, can get moved out of the problem period. If the plan was devised to satisfy a combination of customer orders and replenish some warehouse stock, marketing and sales must again decide whether the customer or the warehouses take priority. Perhaps the demand includes one very large order from a new customer. This order may be a candidate for splitting or moving in or out.

What-If Analysis and Rough Cut Capacity Planning

Sales and marketing have just notified the master scheduler that because of an unexpected strike at a competitor's plant several key changes will take place in the production plan for product family C (Figure 14.13). For family C, the anticipated demand in July and August will increase from 4,000 to 6,000 units per month. In September, the old plan called for 5,000 units, while the new plan calls for 10,000.

Month	Family A	Family B	Family C	Family D	Family E
July	30,000	10,000	6,000	3,000	3,000
August	25,000	5,000	6,000	3,000	3,000
September	25,000	5,000	10,000	4,000	3,000
Total	80,000	20,000	22,000	10,000	9,000

Figure 14.13 Modified Production Plan, Product Family C

Key Resource	Unit of Measure	Month		Family C		Required Capacity	Net Difference	Planned Capacity	Maximum Capacity
Filling Lines 1 & 2	Machine Hours	July				58	56	114	152
		August				44	16	60	80
		September	...		...	44	100	144	192
		Total				146	172	318	424
Filling Line 3	Machine Hours	July				57	76	133	171
		August				43	27	70	90
		September				46	122	168	216
		Total				146	225	371	477
Filling Line 4	Machine Hours	July		24		54	41	95	114
		August		24		49	1	50	60
		September		40		65	55	120	144
		Total		88		168	97	265	318
Finishing Line	Worker Hours	July		288		1,164	–24	1,140	1,596
		August		288		953	–353	600	840
		September		480		1,169	271	1,440	2,016
		Total		1,056		3,286	–106	3,180	4,452
In-process Storage	Lbs.	July				450,000	690,000	1,140,000	1,140,000
		August				375,000	225,000	600,000	600,000
		September				375,000	1,065,000	1,440,000	1,440,000
		Total	...		...	1,200,000	1,980,000	3,180,000	3,180,000
Processing Department	Equipment Hours	July		132		8,241	2,209	10,450	12,350
		August		132		6,916	–1,416	5,500	6,500
		September		220		7,037	6,163	13,200	15,600
		Total		484		22,194	6,956	29,150	34,450
Incoming Test	Worker Hours	July		48		534	–2	532	551
		August		48		469	–189	280	320
		September		80		527	145	672	768
		Total		176		1,530	–46	1,484	1,639
Supplier 100	Lbs.	July		1,290		15,795	29,205	45,000	45,000
		August		1,290		13,545	31,455	45,000	45,000
		September		2,150		14,740	30,260	45,000	45,000
		Total		4,730		44,080	90,920	135,000	135,000
Supplier 200	Cases	July		6,000		13,500	5,500	19,000	23,000
		August	...	6,000	...	12,250	–2,250	10,000	12,000
		September		10,000		16,250	7,750	24,000	29,000
		Total		22,000		42,000	11,000	53,000	64,000

Figure 14.14 Revised Rough Cut Capacity Plan

What will be the impact on the identified key resources over and beyond the problems we have already examined?

The new capacity requirements are shown in Figure 14.14. As can be seen, the same four key resources that were identified as potential problems are affected by this change, but the predicted capacity overloads in August are more severe. In addition, the underloads for finishing and incoming tests in July have now vanished, and an overloaded condition is predicted. Also, remember we were thinking of shifting workers from lines 3 and 4 to the finishing line to alleviate the overload condition, but the change indicates a greater load on line 4, making that shift questionable.

Rough cut capacity planning makes it possible for management to see the impact of the proposed changes very clearly. Additionally, the what-if capability built into rough cut capacity planning software makes it possible for management to juggle the numbers—shifting workers, rescheduling-in and -out, splitting lots, and so forth—until the production plan becomes realistic and achievable.

Screen and Report Formats

There are several screen and report formats among current off-the-shelf planning systems. The choice is a matter of preference. A few of the more commonly used formats are discussed here.

Information Displayed Horizontally

In this screen format, the units of time are displayed across the top (e.g., July, August, September). The left side displays the maximum, planned, and required capacities, followed by the period and cumulative variances (see Figure 14.15 on p. 436). In some software, this arrangement is reversed to display units of time vertically.

KEY RESOURCE: FINISHING (HOURS)

	July	August	September	Total
Maximum Capacity	1596	840	2016	4452
Planned Capacity	1140	600	1440	3180
Required Capacity	1164	953	1169	3286
Difference	–24	–353	271	–106
Cum. Difference	–24	–377	–106	–106

Figure 14.15 Horizontal Format, Rough Cut Capacity Plan Screen

KEY RESOURCE: FINISHING (HOURS)

	Required Capacity	Planned Capacity	Period Difference	Cum. Difference	Maximum Capacity
July	1164	1140	–24	–24	1596
August	953	600	–353	–377	840
September	1169	1440	271	–106	2016
Total	3286	3180	–106	–106	4452

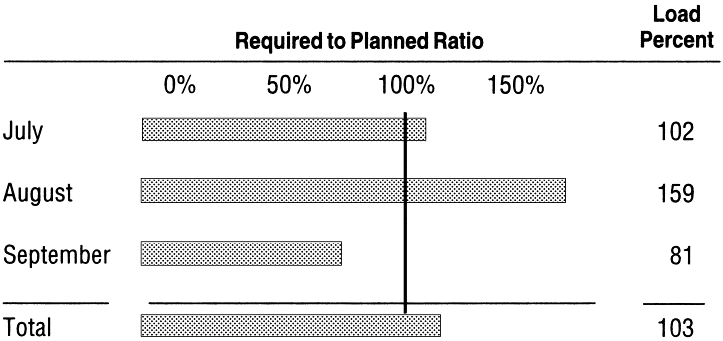


Figure 14.16 Combined Tabular and Graphic Screen

Combined Tabular/Graphic Report

A variant of the horizontal and vertical screens includes a graphic representation of the capacity situation. In the sample screen shown in Figure 14.16, an additional column has been included. This provides a graphic view of the required capacity versus the planned capacity for the key resource.

Exception Screen

The exception screen shows only the problematic work centers (see Figure 14.17). It is useful for highlighting underloads and overloads. The middle of the screen lists the key resources that have an exception to parameters entered by the user. This means that the user defines an underload or overload condition in its own terms. This is done by setting target levels for underloads (e.g., 60%) and overloads (e.g., 120%).

The left side of the screen shows the potential underloads, represented by periods of time (months, quarters, etc.). When a load ratio

Underload Indicators Percent: 60			Key Resource	Overload Indicators Percent: 120		
July	August	September		July	August	September
51		31	Lines 1 & 2			
43		27	Line 3			
57		54	Line 4			
			Finishing Line		159	
39		26	In-Process Storage			
		53	Processing Dept.		126	
			Incoming Test		168	
35	30	33	Supplier 100			
			Supplier 200		123	

Figure 14.17 Rough Cut Capacity Plan Exception Screen

is shown in any column, it indicates that the required capacity is less than 60% (the target level of the minimum capacity chosen for this example). Again, the target percentages are determined by the user.

Overloads are represented on the right side of the screen. When a load ratio is shown in any column, the key resource is projected to be overloaded in excess of 120%. (Again, the 120% was arbitrarily chosen for this example.)

The Limitations and Benefits of Rough Cut Capacity Planning

Like all tools, rough cut capacity planning provides benefits to the user in particular situations. But, again like all tools, its very design limits those situations for which it is appropriate.

Limitations

It is important to bear in mind that resource profiles are based on representative products for an entire family. Incoming orders, however, may not exactly fit the predicted mix, causing discrepancies between aggregate and detail planning. Also, the manner in which setup time is handled may affect load predictions in various ways. For instance, suppose that a particular machine requires eight hours for setup, and the rough cut resource profile assumes runs of 10,000 pieces. If it turns out that only 100 units of one product line are actually run, the rough cut assessment may be invalid. The reason for this is that the setup time (say, 8 hours) either is assumed to be required for any run quantity, or it has been divided by the expected run quantity to establish the setup time per unit. Thus, suppose you plan to run 100 units. What's the setup time required? Is it 4.8 minutes (8 hours × 60 minutes × 100 units divided by the 10,000 unit lot size), or is it 8 hours (the setup time per lot)? Someone must make a decision.

Another limitation of rough cut capacity planning is that it ignores work-in-process and work completed. This negates its value as a short-term planning tool—where these balances matter—and limits it to an intermediate- and long-range planning tool. To understand this fully, let us review the logic of rough cut capacity planning. The logic starts by exploding the production plan or master schedule through the resource profile to determine the required capacity. The results of this explosion are compared to the planned capacity, and from this comparison an action plan is created. At no time during this process does rough cut capacity planning look at the work-in-process or at what work was completed. This work-in-process netting does not take place until material requirements planning, capacity requirements planning, and shop floor control systems are run (refer to Chapter 2's discussion of closed-loop Enterprise Resource Planning). Thus, RCCP data is often invalid in the short term. It is not useful in planning for this week's production; its eyes are on the future.

Finally, rough cut capacity planning is limited by the fact that it considers only *key* or *critical* resources. Actual building of a product, however, requires the resources in *all* work centers. It is in this sense that rough cut capacity planning is limited to answering the questions: Do we have a *chance* to meet the production plan? and Do we have a *chance* to meet the master schedule? Thus, execution of the production plan and master schedule is always vulnerable to contingencies not highlighted during the rough cut process.

Benefits

One of the major benefits of rough cut capacity planning is that master schedulers do not need a detail routing for every item in the plan. This is what makes rough cut capacity planning a simple and quick tool to use. In contrast, detail capacity requirements planning (CRP) requires master scheduling, material requirements planning, inventory control, bills-of-material, detail routings, and shop floor control. In addition, CRP requires a high degree of accuracy in bills-of-material, detail routings and inventory records. Only then can accurate detail capacity planning be done.

On the average, rough cut capacity planning can be productively used in as few as 30 to 90 days after implementing a rough cut capacity system. In the standard implementation scheme, detail capacity requirements planning (CRP) is not generally effective until 12 to 15 months after the manufacturing resource planning implementation is commenced.

A related benefit is that rough cut capacity planning can be run as often as needed prior to execution of the production plan and master schedule. Because it requires minimal computer time (relative to CRP), it is a better simulation tool than CRP, though its output is more of a shadow of reality, owing to its use of only key resources. Simulations possible with rough cut capacity planning cover scenarios such as the effect of changing the mix of expected demand, the booking of a large order, or the shifting of replenishment orders either in or out. Since rough cut capacity planning is a simple simulation tool, you can use it to test the impact of proposed actions before putting the actions into practice. Rough cut capacity planning also allows the master scheduler to test the proposed master schedule if necessary before obtaining more detail via material requirements planning and CRP. Figure 14.18 illustrates the differences between rough cut capacity planning (RCCP) and detailed capacity requirements planning (CRP).[2]

Implementing the Rough Cut Process

Unlike most other manufacturing systems, rough cut capacity planning does not generally require lengthy cost justification, a large budget, a full project team, or a major educational effort. As mentioned earlier, for products with simple bills-of-materials and steady mixes,

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[2] For a detailed discussion on capacity requirements planning, see James G. Correll and Kevin Herbert, *Gaining Control: Capacity Management and Scheduling* (New York: John Wiley & Sons, 2006).

	RCCP	CRP
What	Projected Gross Capacity Requirements for Key Resources	Project Net Capacity Requirements for Each Work Center
How	Explode Production Plan or Master Schedule Through Resource Profiles	Explode MPS & MRP Planned Orders Through Detailed Routings: Combine With Current WIP Status from Shop Floor Control
When	As Required for Simulation	Annual & Quarterly Budget Development; Weekly, Monthly
Why	1. Pre-MRP Evaluation of Production Plan and/or MPS 2. Intermediate- to Long-Range Planning	1. Post-MRP Detailed Analysis 2. Periodic Check of All Work Centers
Precision	Aggregate or Gross—Key Resources Only	Detailed—Considers Inventory, Lot Sizing, WIP Completions, Work Center Lead Times—Voluminous Data
Complexity	Much Less Than CRP	Usually Exceeds MRP
Planning Horizon	Production Plan Limits	MRP Horizon Less Lead-Time Offsetting
Implementation	Short (Manual or PC/Spreadsheet at First)	Requires Work Centers, Routing, MPS, MRP, and WIP Status from SFC

Figure 14.18 Differences Between Rough Cut Capacity Planning and Capacity Requirements Planning

a laptop computer using a spreadsheet or even a number 2 pencil, a piece of paper, and the steps outlined in this chapter will do. Those steps can be summarized as follows:

1. Identify the key resources using the resource matrix.
2. Develop resource profiles for the key resources using the best times and standards available.

3. Get production plan numbers from the S&OP process and the master schedule from the master scheduler.
4. Calculate the required capacity by exploding the supply (production) plan and/or the master schedule through the appropriate resource profiles.
5. Compare required capacity and planned capacity.
6. Identify the potential over- and underloads by time period.
7. If necessary, identify alternatives that balance required capacity and the planned capacity.
8. Determine the best course of action and implement solutions by either increasing/decreasing the planned capacity or increasing/decreasing the supply (production) plan or master schedule.

The payback from following these steps can be immense in terms of better schedules and a more refined planning process.

Final Thoughts

Remember the time-honored expression KISS (Keep It Simple, Stupid!). This should be our motto when designing a rough cut capacity planning system and deciding what to rough cut. Every company should rough cut at the production plan before converting that plan into a master schedule. But is this enough to proceed with detail material and capacity planning? The answer is simple: If you do not require rough cut capacity planning beyond the supply(production) plan, do not do it. There is no reason to rough cut at a detail level just to put numbers on a screen or paper. A general guideline when using rough cut capacity planning is expressed with one word: *simplify.* Remember, the idea is to look only for information necessary to making quick, informed decisions.

Pareto's Law tells us that 80% of our results typically come from just 20% of our efforts. This is a rule of thumb that has proven its value in many fields. With respect to capacity planning, Pareto's Law explains why a small number of key resources can be used to predict large-scale outcomes, and it is used to reduce the number of constraints in a production system to just a small number of problems.

If a key work center represents a problem, you need to take another step—identify what makes it a problem. Perhaps there are six reasons for a particular work center's being a production bottleneck—the equipment, the suppliers, the operators, and so forth. Now ask which of the six reasons would yield the highest benefit if it were eliminated. Equipment overheating might represent 80% of the problem in this particular work center; eliminating overheating as a problem through preventive maintenance would represent the most efficient course to take. Using the Pareto technique in this way helps managers and master schedulers to refine their analysis of key resources and to improve the predictive value of the rough cut system.

Since Enterprise Resource Planning (ERP) and Supply Chain Management (SCM) requires a realistic production plan as a starting point, Class A ERP and SCM companies use rough cut capacity planning simulation tools to assist in creating valid production plans. Since the manufacturing part of ERP and SCM begins with the production plan, that plan must be realistic. Rough cut capacity planning allows companies to check their production plans as well as their master schedules and, consequently, get the very most out of enterprise resource planning.

Production plans, master schedules, and manufacturing schedules are only half of the equation—the supply half. In order for SCM, ERP, and master scheduling to work well in a company, the other side of the equation—demand— must also be addressed. Chapters 15 and 16 address these important integrated processes.

The next chapter will give the reader a flavor of supply planning and supply management as viewed through the perspective of master scheduling. Since ERP is an integrated demand-driven supply planning process, the master scheduling process is very dependent upon the demand and supply management activities. The better it is done, the better the master scheduling process will be.

15

Supply Management

Don't change the schedule faster than the real world can respond.

Imagine a company that manufactures two families of computer equipment, Quantum and Phaser. Lightning Computer Company has hundreds of suppliers and thousands of customers in different parts of the world. Its six assembly plants are located on three continents. Each of these plants has a master scheduler whose responsibility is to balance the supply of material and capacity with the customer and stock orders that come into the plant. If Lightning Computer is well managed, it is because someone above the plant level has taken responsibility for understanding overall demand for the company's different computers and has optimized the way in which that demand will be satisfied.

Lightning Computer Company has two Asian assembly plants, one in Malaysia and another in Taiwan. These plants are near some important component suppliers, but are far away from others. The Asian plants are the company's newest and most productive, but the fact that most of their finished goods must be shipped to North America and Europe offsets part of their cost-effectiveness. Of the company's other four assembly plants, two are in the United States (specifically, California and Colorado), one is in Canada, and another is in Spain; these are much closer to the majority of customers but are less cost-efficient assemblers. Despite these drawbacks, the non-Asian plants are slightly better on quality ratings and better suited to building most members of the Quantum and Phaser product families. The Malaysian plant is new and qualified to build only one of the Quantum and one of the Phaser computers, products that can be built in other plants as well; the Taiwan plant can build only one Quantum and one Phaser computer, and is the *only* plant capable of doing so.

Since this company normally builds and ships several thousand computers each month, optimizing its production through the six different plants really pays off at the bottom line. As a result, someone must be proactive in making a number of difficult decisions about how work will be assigned.

Previous chapters of this book have presented the subject of master scheduling through the eyes of the plant-level scheduler. This individual most likely must support production of several products utilizing the capacity of one or more production lines. Here we raise our sights a notch from the plant level to the regional or corporate level. Again, we find that some individual (or individuals) must take responsibility for balancing supply and demand. We will call this individual the supply manager.[1] The supply manager does not schedule any of the various plants; instead, he or she requests certain types and quantities of products to be built in order to meet anticipated demand.

To appreciate the role of the supply manager, let's revisit the top portion of the Enterprise Resource Planning chart (Figure 15.1), introduced earlier in the book as Figure 2.7 (p. 36). The relationships between corporate-wide sales and operations planning, demand management, supply management, and master scheduling are shown to be highly integrated. Rough cut resource planning is also an important process used in each of these functions.

The ball begins rolling during the corporate sales and operations planning (S&OP) process.[2] Forecasted demand for a horizon of 24

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[1] Size of the company, number of businesses, number of plants, plant locations, number of products, and the like are variables that need to be considered when creating the supply management function. This function consists of one or more individuals.

[2] The reader may wish to review S&OP, which was covered in Chapter 13.

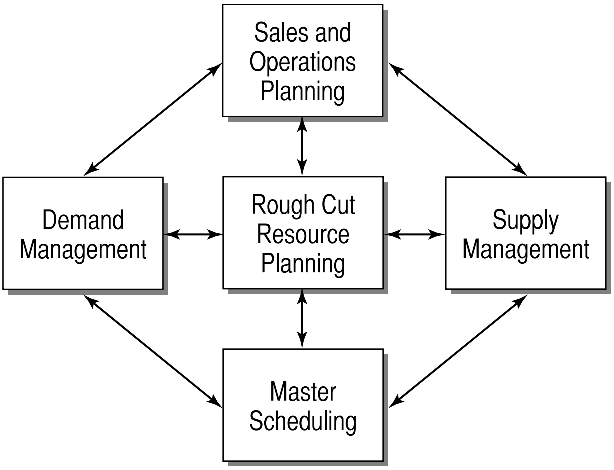

Figure 15.1 Enterprise Resource Planning and Supply Management

months is discussed by corporate leaders and managers. This anticipated demand is described in aggregate—that is, in terms of volume of expected business per month by product family. However, when it comes to multiple business units and multiple plants, the S&OP process takes on a different posture (Figure 15.2).

The goal of sales and operations planning in a multibusiness/multiplant environment is to balance corporate-wide demand—which may originate on several continents—with the production capability and capacity of the enterprise and to assign manufacturing responsibility to the various plants within the enterprise. A sales plan for each product family for each month of the planning horizon is created, and the vice president of sales is assigned responsibility for selling that number of units. Likewise, a production plan for each product family is created covering the same planning horizon, and the vice president of manufacturing takes responsibility for producing that number of units. The job of the supply manager is to make sure that the approved sales plan is satisfied with product and the approved production plan is optimally assigned to the different production facilities. Additionally, the supply manager monitors projected inventory and backlogs to ensure that neither gets out of S&OP tolerances. Thus, the supply manager acts as a corporate-level balancer of supply and

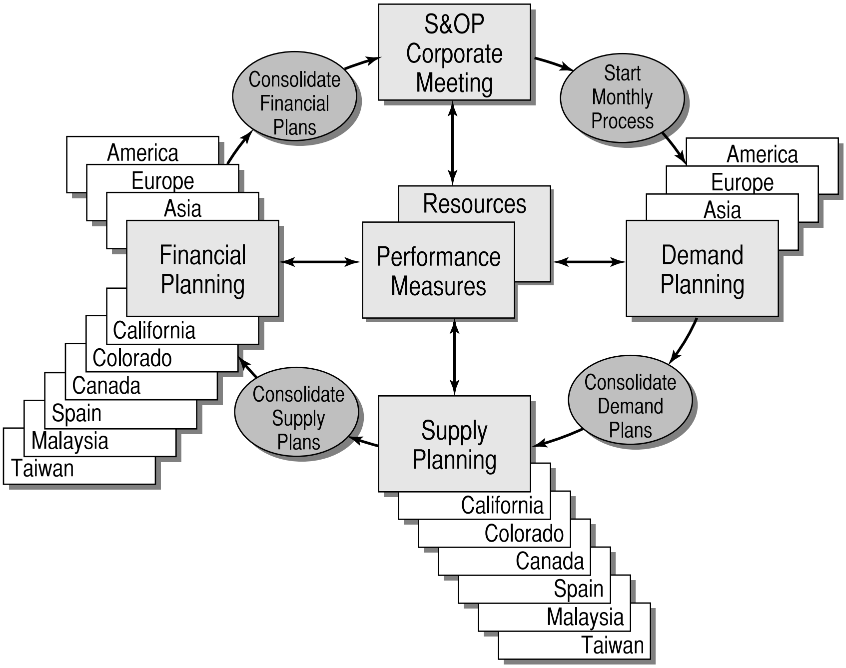

Figure 15.2 Sales & Operation Planning: Lightning Computer Company

demand using many of the same techniques used by the plant-level master schedulers.

A properly educated and trained supply manager is practically indispensable for the multibusiness/multiplant company. This person must understand the importance of customer service, the productive capacities of the company's different plants, their relative efficiencies, output quality, lead times, and the ability of individual plants to deliver on their promises. Given this knowledge, a competent supply manager (assisted by the demand manager) can do the following things:

- Create sufficient production volume to meet corporate-wide demand
- Optimize product manufacturing across all plants
- Ensure that product build requests only go to plants that have the capability and capacity to build those products

- Plan inventory stocking levels while taking transportation issues into account
- Reduce backlogs and thereby reduce customer lead times
- Reschedule production among the plants as problems occur
- Consult with the demand manager on customer priorities and allocation issues

In the absence of centralized supply management, a multiplant company runs these risks:

- Some plants being idle while others are buried under backlogs (some being back orders) and running three shifts per day
- Being out of stock on some items and overstocked on others
- Requesting work from different plants without regard to relative cost and quality factors
- Carrying excess inventories at one plant and minimal or zero inventories at others
- Building products without regard to logistic and storage considerations
- Putting customers on back order out of one plant when another plant could solve the problem

Our computer company is a good example of how a multibusiness/multiplant company can effectively deal with supply questions. Lightning Computer Company has three business units; these handle sales in North America (from Los Angeles), Europe (from Barcelona), and Asia (from Hong Kong). Of its six manufacturing plants, three are in North America, one is in Europe, and two are in Asia. The company conducts its business, including the monthly sales and operations planning process, from its headquarters in Los Angeles, California.

The monthly S&OP meeting is preceded by substantial preparation. Each business unit must add a new month's sales forecast to a rolling

24-month plan, dropping the current month at the same time. For example, as July 1999 approaches its conclusion, the sales forecast for July 2001 is added to the rolling 24-month plan, and July 1999 falls into history. The three business unit plans are then rolled into the Lightning Computer Company aggregate demand plan. The corporate demand manager analyzes and adjusts the aggregate and unit demand plans as needed to satisfy the company's all-important customers while staying within defined constraints. When this task is completed, the demand plans are forwarded to the supply manager.

Using the various demand plans, the supply manager creates supply plans for both the individual plants and the company as a whole. This exercise aims to optimize the capabilities and capacities of the company's six plants. Once the supply plans and demand plans are in balance, they are forwarded to the financial manager, who renders these plans into monetary terms.

During the pre-S&OP process, the financial manager will identify and evaluate anticipated revenues, overhead expenses, manufacturing costs, and so on, and summarize them into financial plans for each of the business units, the manufacturing plants, and the entire company. These plans are then compared with Lightning's overall business plan to ensure alignment. After making any necessary adjustments, the financial manager pulls these diverse plans together into a single set of numbers, which is distributed to all direct and indirect participants of the S&OP meeting 24 to 48 hours prior to the actual meeting. The approved demand and supply plans that emerge from the S&OP meeting are distributed to Lightning's supply and demand managers, business units, and manufacturing plants.

Supply Management in Action

We can use Lightning Computer Company to illustrate how a supply manager might request work for various products from multiple plants.

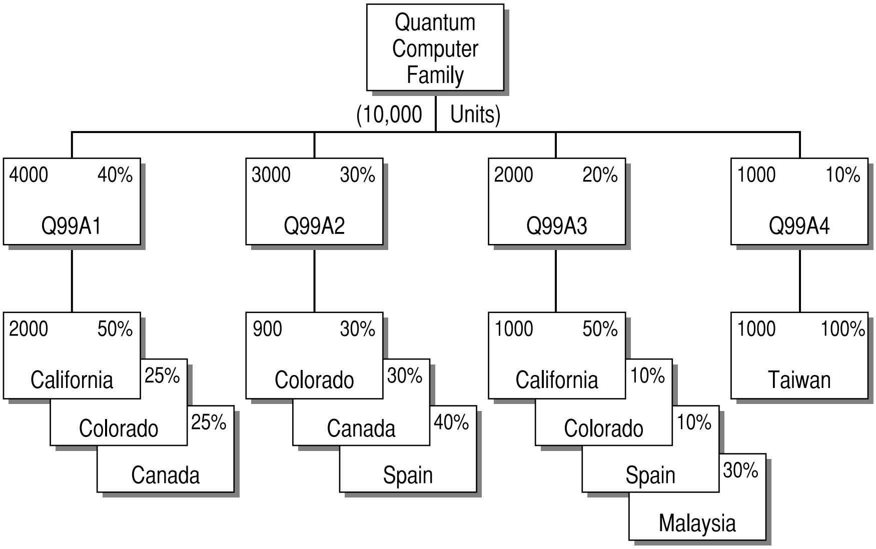

Figure 15.3 Planning Network for Quantum Computers (Multiple Plant Environment—Make-to-Stock)

To make our discussion more manageable, Figure 15.3 maps out the details for the Quantum product family. Here we consider a make-to-stock environment. The Phaser computer family will be used later to demonstrate the same issues in a make-to-order environment.

The Quantum is a specialized and powerful computer that can be configured in four different ways to meet customer needs: products Q99A1, Q99A2, Q99A3, and Q99A4. Experience indicates that 40% of Quantum customers will request the Q99A1 configuration, 30% will specify the Q99A2 configuration, 20% will specify the Q99A3 configuration, and the remaining 10% will request the Q99A4 configuration, as shown in the figure. Assuming that a particular month's approved demand for Quantum family computers is 10,000 units, the company translates this product family rate into the demand for specific computers in each of the four configurations:[3]

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[3] Experienced demand and supply managers know that actual orders rarely match the forecasted demand for the different family member products. Safety stocking, as well as option overplanning, are two ways a company protects itself from demand variation.

- 4,000 Q99A1 (10,000 × .40)
- 3,000 Q99A2 (10,000 × .30)
- 2,000 Q99A3 (10,000 × .20)
- 1,000 Q99A4 (10,000 × .10)

At this point, the supply manager must ask, "Given what I know about the current and future workloads of our six plants, their capabilities and capacities, cost efficiencies, and distances from customers and suppliers, what is the optimal approach to requesting work for this particular month's Quantum family production?" Some schedulers use computerized algorithms to answer this question, while others simply use the computers between their ears and draw on their years of experience. Still others use a combination of computer models and experience. To get us started, the planning bill in Figure 15.3 displays the percentages used to plan the Quantum computer family mix demand.

When requesting the total number of computers during the period in question from the six manufacturing plants, the supply manager must also recognize the following:

1. The company will have some level of finished-goods inventory for each computer configuration at the beginning of the production period; and
2. it will desire some level of inventory at the end of the production period.

Product-Driven, Aggregated Inventory Planning

We normally think of computer companies like Lightning as *product* or *material driven*—that is, companies that orient their production around the particular product orders they anticipate or actually receive from their customers. Satisfying demand for these orders drives everything else. Later in this chapter, we'll see that some companies are what we call *production* or *capacity driven*—for them the need to maintain costly production facilities near full capacity drives all else. As we will see in the following sections, being product driven or production driven explains a great deal about how different companies plan their production capacity. Let's start with the product-driven environment.

To simplify the problem a bit, we will assume for now that Lightning Computer has one central warehouse in Los Angeles, California, where the different manufacturing plants ship their output.[4] The supply manager in this scenario is merely concerned with inventory *in the aggregate—where* the finished computers are located does not really matter. Later, we will consider what happens when the six production plants maintain finished-goods inventory on site.

For Quantum computers, the projected beginning inventory and desired level of ending inventory for each specific configuration at the central warehouse for the time period in question are given in the following table:

Inventory	Q99A1	Q99A2	Q99A3	Q99A4
Beginning	1,600	0	600	800
Ending	800	600	400	200
Change	–800	+600	–200	–600

Thus, if demand for the Q99A1 product during the period is 4,000 units (see Figure 15.3 on p. 451), the desired ending inventory is 800 units, and the beginning inventory is 1,600 units, the required supply (production) for the period will be 3,200 units, as shown in Figure 15.4. This is the total Q99A1 production that the supply manager will

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[4] Having a centralized warehouse for this global company is, of course, unrealistic; we use this contrivance for purposes of demonstration only. If the company had all of its plants clustered in one geographic region, the example would be feasible.

Supply Plan SP = Demand Plan DP + Ending Inventory EI – Beginning Inventory BI

Q99A1	Q99A3
SP = DP + EI – BI SP = 4,000 + 800 – 1,600 SP = 4,000 – 800 SP = 3,200	SP = DP + EI – BI SP = 2,000 + 400 – 600 SP = 2,000 – 200 SP = 1,800
Q99A2	**Q99A4**
SP = DP + EI – BI SP = 3,000 + 600 – 0 SP = 3,000 + 600 SP = 3,600	SP = DP + EI – BI SP = 1,000 + 200 – 800 SP = 1,000 – 600 SP = 400

Figure 15.4 Quantum Computers Supply Plan Calculations (Aggregated Inventory Planning)

need to request from the three plants that build this computer. So, to calculate the total required production for any member of a product family in a product-driven, aggregated inventory-planning environment, the supply manager adds the desired change in inventory to the anticipated demand. Using this logic, Figure 15.4 indicates the production required for each member of the Quantum computer family.

Once the aggregate production by computer configuration is known, the supply manager must decide *which* plants should build these products and in what quantities. For instance, the supply manager may decide that half of the 3,200 Q99A1 computers should be built in California (1,600 units), with the rest divided equally between the Colorado (800 units) and Canadian (800 units) plants. This division of total required production is a *request for production* from each plant. The top half of Figure 15.5 shows the result by plant of the request for production calculation for each specific computer configuration.

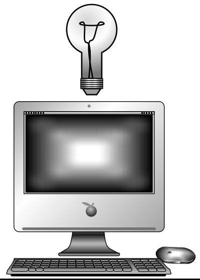
	PRODUCT						
PLANT	Q99A1	Q99A2	Q99A3	Q99A4	Required Capacity (Units)	Planned Capacity (Units)	Maximum Capacity (Units)
California	1,600	0	900	0	2,500	1,800	2,200
Colorado	800	1,080	180	0	2,060	1,800	2,200
Canada	800	1,080	0	0	1,880	900	1,100
Spain	0	1,440	180	0	1,620	900	1,100
Malaysia	0	0	540	0	540	1,800	2,200
Taiwan	0	0	0	400	400	1,800	2,200
Supply Plan	3,200	3,600	1,800	400	9,000	9,000	11,000
Demand Plan	4,000	3,000	2,000	1,000	10,000		
Beginning Inventory	1,600	0	600	800	3,000		
Desired Ending Inventory	800	600	400	200	2,000		
Projected Ending Inventory	800	600	400	200	2,000		

Figure 15.5 Quantum Computers Supply Plan (Product-Driven, Aggregated Inventory Planning)

The bottom of the figure shows the totals by planning period for each configuration. In this case,

- supply equals total production from all plants;
- demand equals total demand by product configuration;
- beginning inventory equals the projected starting on-hand balances by product configuration;
- desired ending inventory equals what the company would like to have on hand; and
- ending inventory is the quantity projected to be in inventory.

Will the Plan Work?

The supply manager must then ask, “How realistic is this plan? Will each of the plants be able to comply with these production requests during the time period in question?” The supply manager could answer these questions by calling the master schedulers at each of the six plants. A more fruitful first step, however, would be to rough cut or sanity check the plan in Figure 15.5 against planned plant capacities; doing so would indicate whether the plan has a chance of succeeding. As Figure 15.5 indicates, overloaded conditions exist in California (140%), Colorado (115%), Canada (200%), and Spain (180%). The two Asian plants are severely underloaded: Malaysia by 70% and Taiwan by almost 80%.[5] In this particular case, we will assume that none of the six plants can materially alter its maximum capacity, at least in the short to intermediate time frame. Therefore, the supply manager must make some adjustments to the plan before releasing it to the plants.

As the supply manager begins looking for adjustment opportunities, the Taiwanese plant will surely catch his or her attention. As shown in Figure 15.5, this plant has a planned capacity of 1,800 units per period, and that number could be expanded to 2,200 in a crunch (through subcontracting, overtime, added shifts, and so on). Since this plant is only being asked to build 400 Q99A4 units, it has plenty of excess capacity. But remember, this plant can *only* build Q99A4 Quantum computers! As a result, that idle capacity cannot help us alleviate overloading elsewhere in the system. Taiwan is locked in![6]

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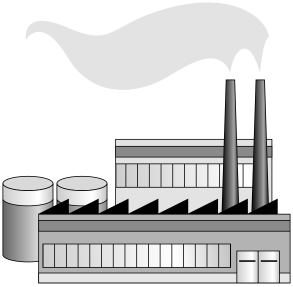
[5] The over- and underload percentages are calculated by dividing the required production by the planned productions (rounded for simplicity).

[6] If serious underloading at the Taiwan plant was chronic, occurring in many periods, senior management would have to consider either upgrading the plant to handle other product configurations or reducing its capacity. Alternatively, marketing schemes to increase the demand for Q99A4 computers could be used to more closely match demand and this plant’s capacity.

The situation in Malaysia appears more promising. The initial supply plan is only requesting 540 Q99A3 units against this plant's 1,800-unit capacity (which is entirely devoted to Q99A3 units). Given the overload situations in California, Colorado, and Spain, the supply manager would be tempted to shift *all* Q99A3 production to this location. Doing so would bring the Malaysian plant up to capacity; it would also solve *all* overloading problems in California and some—but not all—elsewhere. Further adjustments, such as moving some planned Q99A1 production from Colorado and Canada to California, would solve the Colorado plant's overload problem, but Canada and Spain would continue to be overloaded. For example, Spain would be asked to build 1,440 Q99A2 units and nothing else, but this single request would be in excess of its *maximum* production capacity.

Of course, getting these under- and overloading conditions worked out involves more than simply matching demand with the capabilities and capacities of various plants. A number of other issues must also be considered:

- Differences in shipping costs
- Customer bundling requirements
- Plant-specific manufacturing costs
- Inventory storage areas
- Product build sequences
- Availability of components
- Distances from suppliers and customers
- Quality differences between plants



These issues must enter into the supply manager's final analysis and decision making. In this case the supply manager may have little choice but to request that capacity be increased to near maximum in California, Colorado, Canada, and Spain while decreasing capacity in Taiwan. In a product-driven environment like this one, failing to meet demand *on time* can drive customers into the arms of competitors, perhaps permanently!

The complexity of optimizing product demand, plant capacities, and the many other factors mentioned here is usually beyond the processing ability of the human mind, which explains why so many companies are beginning to use computerized finite-capacity scheduling programs to plan and schedule production. The next step is to move these advanced production planning and scheduling systems into the hands of the supply manager.

What we've described so far seems simple enough, but what happens when we make the problem more realistic and consider the fact that each of our plants has and maintains inventory? The supply manager must then plan production by taking plant inventory and customer location into account.

Product-Driven, Disaggregated Inventory Planning

The previous section made the assumption that *where* finished computers were inventoried did not affect supply planning. This assumption simplified our explanation of Lightning Computer's supply planning. A company with plants clustered in one region (e.g., the northeastern United States), and possibly operating out of a single centralized warehouse in that region, could plan production using this convenient assumption. Companies operating in different regions or nations, however, cannot; they generally must plan to hold finished-goods inventories at multiple locations—for example, in the finished-goods stockrooms of their far-flung manufacturing facilities or strategically located distribution centers. We'll now assume that Lightning Computer is one of these companies.

Figure 15.6 shows Lightning's projected inventory, by plant, at the beginning of the planning period. Figure 15.7 indicates the leadership team's desired inventory at the end of the period. We can see that the aggregate beginning inventory for Q99A1 is 1,600 units; 1,000 of these are inventoried at the California plant with the balance at the Colo-

	PRODUCT				
PLANT	Q99A1	Q99A2	Q99A3	Q99A4	Totals
California	1,000	0	150	0	1,150
Colorado	600	0	150	0	750
Canada	0	0	0	0	0
Spain	0	0	150	0	150
Malaysia	0	0	150	0	150
Taiwan	0	0	0	800	800
Totals	1,600	0	600	800	3,000

Figure 15.6 Beginning Inventories for Quantum Computers

	PRODUCT				
PLANT	Q99A1	Q99A2	Q99A3	Q99A4	Totals
California	400	0	200	0	600
Colorado	200	180	40	0	420
Canada	200	180	0	0	380
Spain	0	240	40	0	280
Malaysia	0	0	120	0	120
Taiwan	0	0	0	200	200
Totals	800	600	400	200	2,000

Figure 15.7 Desired Ending Inventories for Quantum Computers

rado plant. By the end of the period, Lightning Computer would like to have a total of 800 Quantum computers on hand: 400 in California, 200 in Colorado, and 200 in Canada.

The desired ending inventory by plant creates another factor for the supply manager to consider when allocating production requests to the six plants slated to build Quantum computers. For example, the California and Colorado plants might be the optimal source of Q99A1 production during this particular time period, and they might have the capacity to handle the *entire* 3,200 units needed. However, since the inventory plan calls for an ending balance of 200 units at the Canadian facility, the fact that Canada has zero inventory as a projected starting balance might induce the supply manager to allocate *at least* 200 units of production to it. The alternative would be to build in California and/or Colorado and ship to Canada—possibly a bad idea when transportation costs are considered.

Considering all factors, the supply manager in this example is using the same logic explained in the product-driven, aggregated inventory planning section. The only difference is the fact that inventory needs to be planned by plant. Refer to Figure 15.8 on page 461 for all the calculations.

With the results of these calculations taken into account, the production required for each computer by plant is shown in the top half of Figure 15.9 on page 462; the bottom half shows total supply, demand, and inventory by computer model.[7] Reviewing production by plant, the reader will again observe overloaded conditions in California, Canada, and Spain, while Malaysia and Taiwan remain underloaded. Colorado, fortunately, is near full capacity. Thus, before releasing this plan, the supply manager must think about *re*balancing the plan while keeping all planning parameters in mind. He or she will seek ways to offload some work from California and Spain to Malaysia, as discussed in the previous section. This is the type of complex situation in which the computing power of finite planning and scheduling plus advanced supply planning software is extremely helpful.

It should be clear that the job of requesting production from multiple plants requires the supply manager to take into account many different policies and constraints. The next section adds still another variable: backlog. Backlog and lead time to the customer must be considered in the make-to-order environment.

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[7] The format of this figure is the same as Figure 15.5, which was explained earlier in the chapter. The numbers differ here because we have considered *disaggregated* inventory.

Supply Plan SP = Demand Plan DP + Ending Inventory EI – Beginning Inventory BI

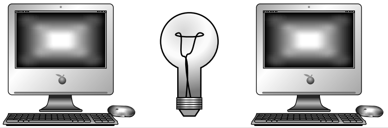
Plant	**Q99A1** SP 3,200	Plant	**Q99A3** SP 1,800
California	SP = 2,000 + 400 – 1,000 SP = 2,000 – 600 SP = 1,400	California	SP = 1,000 + 200 – 150 SP = 1,000 + 50 SP = 1,050
Colorado	SP = 1,000 + 200 – 600 SP = 1,000 – 400 SP = 600	Colorado	SP = 200 + 40 – 150 SP = 200 – 110 SP = 90
Canada	SP = 1,000 + 200 – 0 SP = 1,000 + 200 SP = 1,200	Spain	SP = 200 + 40 – 150 SP = 200 – 110 SP = 90
Plant	**Q99A2** SP 3,600	Malaysia	SP = 600 + 120 – 150 SP = 600 – 30 SP = 570
Colorado	SP = 900 + 180 – 0 SP = 900 + 180 SP = 1,080	Plant	**Q99A4** SP 400
Canada	SP = 900 + 180 – 0 SP = 900 + 180 SP = 1,080	Taiwan	SP = 1,000 + 200 – 800 SP = 1,000 – 600 SP = 400
Spain	SP = 1,200 + 240 – 0 SP = 1,200 + 240 SP = 1,440		

Figure 15.8 Quantum Computers Supply Plan (Disaggregated Inventory Planning)

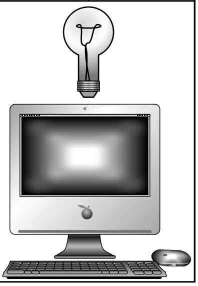
	PRODUCT						
PLANT	Q99A1	Q99A2	Q99A3	Q99A4	Required Capacity (Units)	Planned Capacity (Units)	Maximum Capacity (Units)
California	1,400	0	1,050	0	2,450	1,800	2,200
Colorado	600	1,080	90	0	1,770	1,800	2,200
Canada	1,200	1,080	0	0	2,280	900	1,100
Spain	0	1,440	90	0	1,530	900	1,100
Malaysia	0	0	570	0	570	1,800	2,200
Taiwan	0	0	0	400	400	1,800	2,200
Supply Plan	3,200	3,600	1,800	400	9,000	9,000	11,000
Demand Plan	4,000	3,000	2,000	1,000	10,000		
Beginning Inventory	1,600	0	600	800	3,000		
Desired Ending Inventory	800	600	400	200	2,000		
Projected Ending Inventory	800	600	400	200	2,000		

Figure 15.9 Quantum Computers Supply Plan (Disaggregated Inventory Planning)

Product-Driven, Aggregated Backlog Planning

We have now covered various situations the supply manager must contend with in a product-driven, inventory-based environment. This type of environment generally looks very much like a make-to-stock company. But what about the make-to-order company? The job of supply management is similar to that used in the make-to-stock company except that the company deals with changing backlogs instead of inventories.

Backlog is defined as orders that have been booked but not shipped. In the make-to-order environment, a salesperson takes the order and commits to a delivery date. When the customer's order is taken, it is placed in the backlog. When the product is built and shipped, the order is removed from the backlog.

Let's return to the Lightning Computer Company to consider how demand, supply, and backlogs can be handled in the planning process, using the company's other product family, the Phaser computer, as an example. In this section, we'll deal with the simpler case: backlogs in aggregate. Here, as in the Quantum aggregated inventory planning example, we'll assume that the company has a centralized order-entry and customer support function; orders are treated in aggregate. We'll drop this assumption in the next section.

There are four members of the Phaser product family: P99B1, P99B2, P99B3, and P99B4. Again, the company has estimated the percentage of total demand that each of these configurations is likely to represent. These estimates are represented in Figure 15.10, which also indicates the company's expectation of which of its six plants will build those computers, again in terms of percentages. For example, it expects 40% of total Phaser demand during the planning period to be for the popular P99B1 model; the California plant is expected to build half of these units, with the balance shared equally by the plants in Colorado and Canada.[8]

Since Phaser computers are make-to-order, most individual configurations offered have orders on the books. Looking at the projected demand for the Phaser computer family in the planning period in question, the supply manager can quickly translate this volume (1,000 computers) into the anticipated mix demand using the percentage

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[8] The author has chosen to use the same numbers as the Quantum example so that the reader can more easily recognize the differences between the make-to-order and make-to-stock environments. The demand for the Phaser line is 10% of demand for the Quantum line of computers.

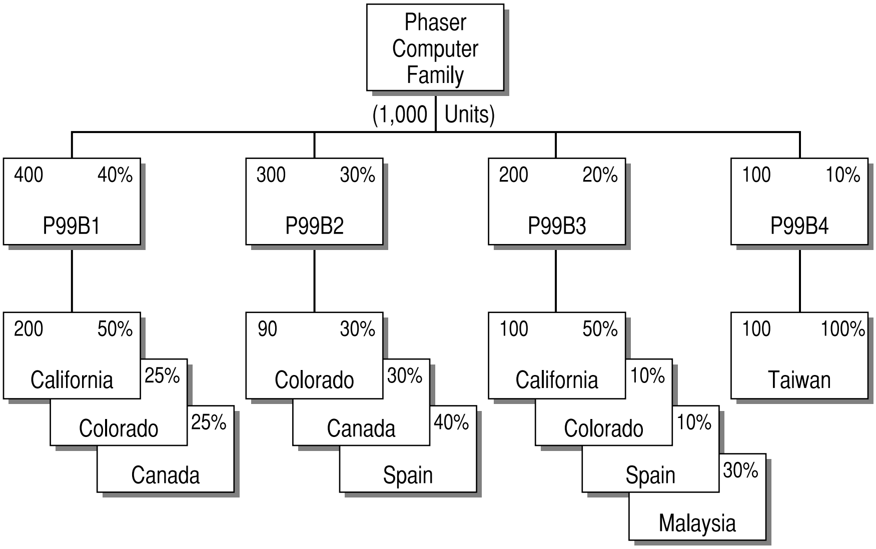


Figure 15.10 Phaser Computers (Multiple Plant Environment—Make-to-Order)

figures contained in the Phaser planning bill (Figure 15.10). (The reader will note that this procedure is the same procedure used in the inventory situation described earlier.)

For our Phaser computers, the projected beginning and desired level of ending backlogs for the time period in question are given in the following table:

Backlog	P99B1	P99B2	P99B3	P99B4
Beginning	160	0	60	80
Ending	80	60	40	20
Change	–80	+60	–20	–60

From these numbers, coupled with the anticipated product demand, a total supply plan is generated (Figure 15.11)—again, without respect to *where* backlogs exist. The result is very reminiscent of the supply plan developed for the Quantum family. As the reader can see, the supply manager anticipates needing 480 units of P99B1, 240 units

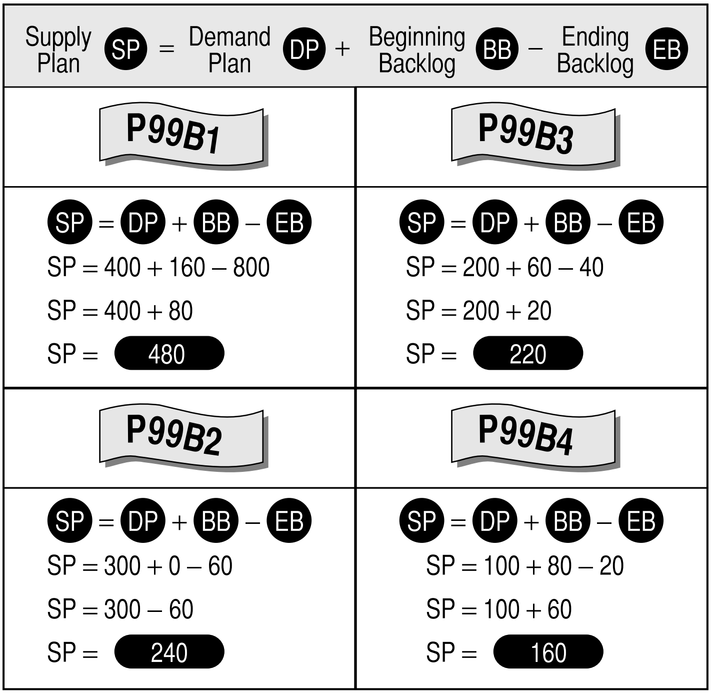


Figure 15.11 Phaser Computers Supply Plan Calculations (Aggregated Backlog Planning)

of P99B2, 220 units of P99B3, and 160 units of P99B4. The supply manager must then determine from which plants to request this production. Using the planning bill in Figure 15.10 on page 464 for P99B1, the initial plan would request 240 units from the California plant and 120 units each from Colorado and Canada. This follows precisely the percentages dictated by Figure 15.10. The process continues until the entire initial supply plan is created (Figure 15.12). But is this initial plan workable? Unfortunately, a quick scan of the required capacity (in units) and the planned capacity (in units) indicates some under- and overloaded conditions. California and Canada are severely overloaded, while Malaysia and Taiwan are severely underloaded. Some adjustment—moving some work from here to there—will have to be made prior to requesting production from these plants.

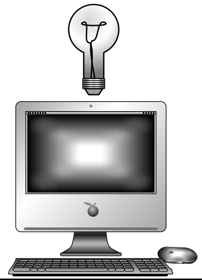
	PRODUCT						
PLANT	P99B1	P99B2	P99B3	P99B4	Required Capacity (Units)	Planned Capacity (Units)	Maximum Capacity (Units)
California	240	0	110	0	350	220	300
Colorado	120	72	22	0	214	220	300
Canada	120	72	0	0	192	110	150
Spain	0	96	22	0	118	110	150
Malaysia	0	0	66	0	66	220	300
Taiwan	0	0	0	160	160	220	300
Supply Plan	480	240	220	160	1,100	1,100	1,500
Demand Plan	400	300	200	100	1,000		
Beginning Backlog	160	0	60	80	300		
Desired Ending Backlog	80	60	40	20	200		
Projected Ending Backlog	80	60	40	20	200		

Figure 15.12 Phaser Computers Supply Plan (Aggregated Backlog Planning)

This section has been a condensed version of the multibusiness/multiplant supply planning process found in a make-to-order environment. As the reader can see, the supply planning process is similar for backlog and inventory planning. For this reason, we will not go into every detail.[9] Continuing with this condensed approach, let's turn our attention to product-driven, disaggregated backlog planning.

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[9] For more detail on supply and backlog planning, the reader should review Chapter 13 on sales and operations planning as well as the previous two sections of this chapter.

Product-Driven, Disaggregated Backlog Planning

In the previous section Lightning Computer Company treated its backlog as a total, paying no attention to which plant would satisfy that backlog. What if this was not the case? What if orders were received by the individual plants and satisfied by them directly? This would create a different situation for the supply manager. Two figures provide the details for our computer company using this disaggregated scenario. Figure 15.13 shows the beginning backlog for the Phaser computer line, while Figure 15.14 displays management's desired level of backlog at the end of the planning period in question.

To determine a supply plan for each manufacturing plant in this scenario, the supply manager will follow the same steps outlined in the section "Product-Driven, Disaggregated Inventory Planning." Again,

	PRODUCT				
PLANT	P99B1	P99B2	P99B3	P99B4	Totals
California	100	0	15	0	115
Colorado	60	0	15	0	75
Canada	0	0	0	0	0
Spain	0	0	15	0	15
Malaysia	0	0	15	0	15
Taiwan	0	0	0	80	80
Totals	160	0	60	80	300

Figure 15.13 Beginning Backlog for Phaser Computers

	PRODUCT				
PLANT	P99B1	P99B2	P99B3	P99B4	Totals
California	40	0	20	0	60
Colorado	20	18	4	0	42
Canada	20	18	0	0	38
Spain	0	24	4	0	28
Malaysia	0	0	12	0	12
Taiwan	0	0	0	20	20
Totals	80	60	40	20	200

Figure 15.14 Desired Ending Backlog for Phaser Computers

the difference is a changing backlog instead of a changing inventory level. Figure 15.15 on page 469 shows the calculations for each Phaser computer by plant.

The anticipated demand for each product and plant is derived using the planning bill shown earlier in Figure 15.10. That demand is added to the desired change in backlog by plant. The initial supply plan (results of the calculation in Figure 15.15) is shown in Figure 15.16. As the supply manager reviews this initial plan, he or she once again observes that the required capacity in units exceeds the planned capacity in units in four of the six manufacturing plants; again, the two Asian plants show underloads. The supply manager notices overloads in Canada, Colorado, Spain, and California. The first three of these overloads could be solved by increasing capacity. California represents a more difficult case. Maximizing output there would solve some of the overload problem, but not all. At maximum capacity, it would remain overloaded by 55 units. However, these could be offloaded to Colorado if it raises its capacity to maximum. Alternatively, some production could be offloaded to Spain if planned production were raised at that location.

Of course, the Asian underload condition cannot be solved by raising the capacity of the other plants. As we observed earlier, Taiwan

Supply Plan SP = Demand Plan DP + Beginning Backlog BB – Ending Backlog EB

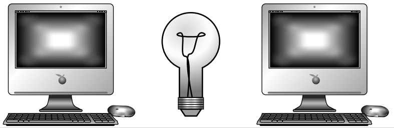
Plant	P99B1 SP 480	Plant	P99B3 SP 220
California	SP = 200 + 100 – 40 SP = 200 + 60 SP = 260	California	SP = 100 + 15 – 20 SP = 100 – 5 SP = 95
Colorado	SP = 100 + 60 – 20 SP = 100 + 40 SP = 140	Colorado	SP = 20 + 15 – 4 SP = 20 + 11 SP = 31
Canada	SP = 100 + 0 – 20 SP = 100 – 20 SP = 80	Spain	SP = 20 + 15 – 4 SP = 20 + 11 SP = 31
Plant	P99B2 SP 240	Malaysia	SP = 60 + 15 – 12 SP = 60 + 3 SP = 63
Colorado	SP = 90 + 0 – 18 SP = 90 – 18 SP = 72	Plant	P99B4 SP 160
Canada	SP = 90 + 0 – 18 SP = 90 – 18 SP = 72	Taiwan	SP = 100 + 80 – 20 SP = 100 + 60 SP = 160
Spain	SP = 120 + 0 – 24 SP = 120 – 24 SP = 96		

Figure 15.15 Phaser Computer Supply Plan Calculations (Disaggregated Backlog Plan)

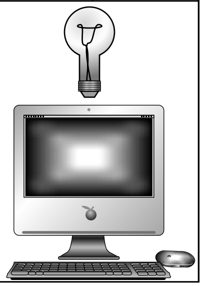
	PRODUCT						
PLANT	P99B1	P99B2	P99B3	P99B4	Required Capacity (Units)	Planned Capacity (Units)	Maximum Capacity (Units)
California	260	0	95	0	355	220	300
Colorado	140	72	31	0	243	220	300
Canada	80	72	0	0	152	110	150
Spain	0	96	31	0	127	110	150
Malaysia	0	0	63	0	63	220	300
Taiwan	0	0	0	160	160	220	300
Supply Plan	480	240	220	160	1,100	1,100	1,500
Demand Plan	400	300	200	100	1,000		
Beginning Backlog	160	0	60	80	300		
Desired Ending Backlog	80	60	40	20	200		
Projected Ending Backlog	80	60	40	20	200		

Figure 15.16 Product-Driven, Disaggregate Backlog Planning

is the *only* plant capable of building P99B4 computers; in fact, it can build nothing else in the Phaser line. Therefore, not much can be done to immediately relieve its 25% undercapacity problem. Malaysia is another matter. Since it builds P99B3 computers, all requests for production of that particular model now directed to California, Colorado, and Spain could be shifted to that location.

But there's another problem: Building computers in Malaysia and shipping them halfway around the world to customers in Europe and North America may not be cost effective. And so it goes.

This condensed example points out the need for computer software support. A supply manager who deals with the balancing and optimizing of multiproduct/multiplant production should seriously consider implementing an advanced finite-capacity planning and scheduling software package. There are so many parameters that our between-the-ears computers are incapable of storing and processing them all in a timely way. Without some electronic computer assistance, the task is often reduced to an ineffective sequence of trial and error. This is particularly true in a production-driven environment, which is the subject of the next section.

Production-Driven Environments

Supply planning does not have to begin with the product and work down to plant assignments, as shown in the previous sections. Instead, the supply manager may begin at the plant level, determining what percentage of the anticipated gross demand should be handled by each, and only then determine which family members should be built in each plant. This approach may be preferred when keeping production facilities fully utilized is the overwhelming concern—more important than the mix of products built. For example, a company with highly capitalized new plants and customers who will buy just about all of their production may choose this approach. In this environment, the supply manager's mission is clear: keep those plants rolling!

Let's suppose that Lightning Computer Company found itself in this type of production-driven (or capacity-driven) environment: Its computers are in such demand that management's policy is to run all plants at full capacity.[10] Figure 15.17 indicates the supply manager's production plan by plant for each of the company's Quantum configurations. Note that the requested capacity for each plant matches planned capacity in equivalent units. This plan meets customer

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[10] This may be unrealistic for a computer company, but it is certainly likely for a company in food processing, chemicals, and other highly capitalized manufacturing businesses.

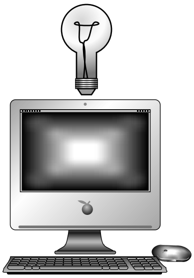
	PRODUCT						
PLANT	Q99A1	Q99A2	Q99A3	Q99A4	Required Capacity (Units)	Planned Capacity (Units)	Maximum Capacity (Units)
California	1,800	0	0	0	1,800	1,800	1,800
Colorado	600	1,200	0	0	1,800	1,800	1,800
Canada	0	900	0	0	900	900	900
Spain	0	900	0	0	900	900	900
Malaysia	0	0	1,800	0	1,800	1,800	1,800
Taiwan	0	0	0	1,800	1,800	1,800	1,800
Supply Plan	2,400	3,000	1,800	1,800	9,000	9,000	9,000
Demand Plan	4,000	3,000	2,000	1,000	10,000		
Beginning Inventory	1,600	0	600	800	3,000		
Desired Ending Inventory	800	600	400	200	2,000		
Projected Ending Inventory	0	0	400	1,600	2,000		

Figure 15.17 Quantum Computer's Supply Plan (Inventory Planning)

demand and satisfies the desire of management to keep its plants fully loaded. However, management cannot have its cake and eat it too: Satisfying this policy has created a problem of mix inventory. The company is projected to be overstocked in some product configurations and understocked in others. Perhaps the company's marketers can solve the overstock problem through a special promotion of Q99A4s, of which there are projected to be 1,400 more than desired. The understocked condition of Q99A1 and Q99A2 is very serious for Lightning Computers. Management desires an ending inventory for both of these configurations at the end of this planning period. But the initial supply plan projects zero ending inventory for both. This both fails to satisfy management's requirement and creates a dangerous situation for the company. Therefore, the company's leadership team may want to turn its attention to the plant in Taiwan, which is seriously underloaded because of its ability to produce only one Quantum model. If this plant were equipped, staffed, and qualified to produce Q99A1s and Q99A2s, the company's inventory shortcomings for those products could disappear; the overstock of Q99A4 models at that location would also be reduced.

Most examples are not this simple, and the use of finite-capacity planning and scheduling or advanced supply planning software is practically a must in creating a viable supply plan. Unfortunately, explaining all of the optimizing features in these systems is beyond the scope of this book.[11]

Interplant Integration

The problem of multiplant scheduling and supply management becomes even more difficult when executed within a *multiple-tiered* corporate system of component, intermediate, and finishing plants. In this environment, the finished output of one plant is a component of another plant's product. The traditional method of scheduling and rescheduling these relationships from the top (i.e., at the level of the finishing plants) and driving the production of lower-level plants often has adverse consequences. The following example illuminates this common problem and offers a solution.

Minuteman Electronics Company is a manufacturer of a new line of laptop computers sold throughout the Western Hemisphere and is owned by the same holding company that owns the Lightning Computer Company. Final production is done at three facilities in the

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[11] Readers who desire more information about advanced planning (production) scheduling software should see the many articles published on the subject. Other sources include software suppliers and consultants specializing in production- and capacity-driven environments.

United States: Boston, Massachusetts (in a plant adjoining corporate headquarters); Raleigh, North Carolina; and Birmingham, Alabama. These finishing plants ship completed goods to one of three warehouses, which are located in Boston (at the plant); Chicago, Illinois; and San Francisco, California.

Minuteman's finishing plants are supported by component plants located in Durham, North Carolina, and Waco, Texas; these in turn are supported by two subcomponent plants located in Durham and in Pomona, California. Both subcomponent plants produce printed circuit boards used in the component plants' circuit board assemblies.

In the world of modern manufacturing, in which vertically integrated companies may have several finishing plants for different product lines and several component and subcomponent plants serving these and outside customers, the level of complexity increases dramatically for the supply manager and master scheduler.

Figure 15.18 on page 475 describes just such a situation. Here the company operates three levels of production facilities: finishing plants, component plants, and subcomponent plants. Customers and company-owned distribution centers provide demand to the finishing plants, and the finishing plants in turn create demand for components and subcomponents. This demand is placed on the various plants through a series of iterations using the master scheduling and material requirements planning systems.

Where should the master scheduling function be located in this interplant system? In a centralized scheduling approach, master scheduling is located at the finishing plant level. Demand comes down from customers, distribution centers, or centralized supply management; the production to satisfy that demand is master scheduled at the finishing plant; and the material requirements planning system reaches back through the underlying layers of component and subcomponent facilities to schedule and order all necessary materials and capacity for the facilities. This approach is the norm in many companies, but it has severe negative side effects, as any plant manager at a lower-tier plant will confirm.

What happens in this automated, fully integrated arrangement is that demand changes at the top (at the finishing plant level) cascade

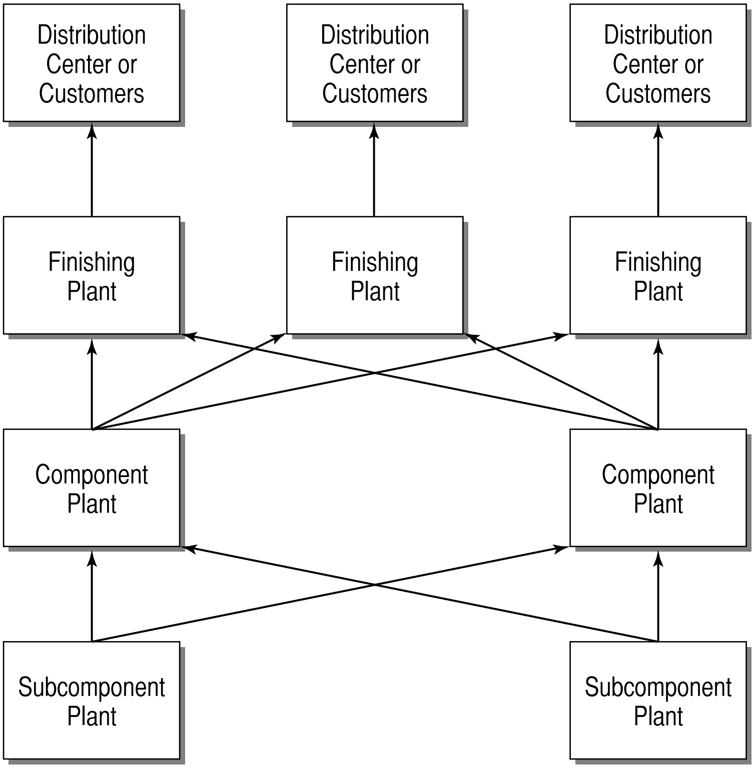

Figure 15.18 Interplant Supply and Demand

downward through the material requirement planning system, creating a whipsaw effect at lower levels. Component and subcomponent plants, which must respond mindlessly to order changes from above, are burdened with constant production and material schedule adjustments. They cannot decouple themselves from demand at the finishing plant level, nor can they refuse an order that is beyond their capacities. They cannot—in a sense—control their own destinies. The result is often chaos for all facilities involved. Figure 15.19 diagrams this situation. On the left-hand side of the figure is the traditional method just described, in which demand is accommodated through master scheduling at the finishing plant level; the material requirement planning system is activated through the finishing plant to the component plant to the subcomponent plant. Any change in demand at the top races

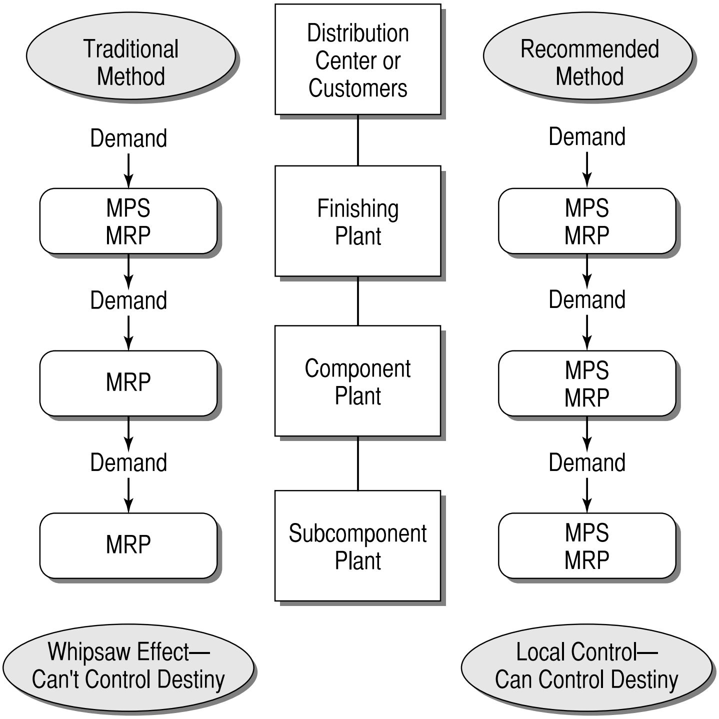

Figure 15.19 Interplant Master Schedule and Material Requirements Planning

through this system. If the finishing plant makes a change in a supply order, all lower-level plants are directed to reschedule-in or reschedule-out the required components and material. They are never asked if they can accomplish the reschedule.

A better way to operate is shown on the right-hand side of Figure 15.19. This is the recommended method. Here, demand from customers, distribution centers, and supply management is accommodated through master scheduling at the finishing plant and the plant's Enterprise Resource Planning system. The required materials produced by the component plant's (printed circuit board assemblies in the Minuteman example) become demand, which is entered into the master schedule system at the component plant level. This demand is reviewed and analyzed before the component plant master scheduler adjusts the master schedule to support it. It is only put into the schedule when the master scheduler believes that demand can be met while keeping the component plant within defined policies. This leads to a very important principle: People should be held accountable *only* for those things they can control. When finishing plants change their production schedules, and supporting plants are directed to fall in step—without regard to their capabilities and/or capacities—supporting plants are almost automatically set up for failure. In many instances, these supporting plants miss schedules or build and carry unnecessary levels of inventory.

Component and subcomponent plants are in business to support upstream plants. They want to satisfy them as customers, but they need a chance to do it right. What is needed is a way to prevent changes in the finishing plant's master schedule from causing automatic reschedules at lower level plants. This can be done by using the planning time fence and firm planned order capability of master scheduling software.[12] Driving the finishing plant's component demand into the master schedule at the component plants can decouple (by using a planning time fence) demand from supply. In other words, as demand at the component plant changes, the master schedule at the component plant will not change inside the planning time fence unless the master scheduler makes a move to do so. The computer cannot make any automatic changes inside the planning time fence. The decoupling of supply and demand gives lower-level plants the opportunity to say yes or no to any change in component demand. When the supply plant cannot satisfy that component demand, that information needs to be communicated up the chain, giving the finishing plants an opportunity to find another source of supply or replan appropriately.

This same process is continued from the component plants down to the subcomponent plants. In this case, the component's master schedule drives lower-level requirements through the Enterprise Resource Planning system, generating demand for circuit boards. This demand enters the master schedule of the subcomponent plant. The process at the subcomponent plan is the same.

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[12] For a review of planning time fences and firm planned order capability, see Chapters 3 through 5.

The benefit of this recommended method is that it gives greater control to management at each level—the people with the greatest knowledge of local capabilities and constraints. If a subcomponent production line is experiencing a breakdown or scheduled maintenance, or if problems with a supplier have constrained the availability of materials, these plant personnel will know about it. Under the traditional method, schedulers who instigate change at high levels may be oblivious to these lower-level problems.

Should Companies Have Supply Managers?

This chapter has spelled out the many tasks of the supply manager. In a simpler world, when companies operated out of single manufacturing facilities, the idea of having a corporate-level associate assigned to these tasks would not have been particularly compelling. The manufacturing manager and plant master scheduler would have handled those tasks. But that simpler world has largely disappeared for a number of major companies, and someone must take responsibility for their greater supply planning and supply coordination needs. That someone is the corporate or business supply manager. Although many of these large manufacturers do not staff such a position, most should. The cost of salary and benefits for a good supply manager is minuscule when compared to the losses incurred through unnecessary overstocks, unfilled customer orders, over- and underloaded plants, and production snafus in general.

But what are the specific responsibilities of a supply manager?

1. Working closely with the demand manager to establish a supply plan consistent with company policies
2. Optimizing the performance of manufacturing plants while satisfying firm and anticipated demand

3. Evaluating current supply capabilities relative to the company supply plan and recommend production changes as required
4. Coordinating the aggregation of current and planned plant production information, and incorporating that information into the company supply plan
5. Coordinating raw material supply with purchasing and plant production to ensure their availability with respect to the company supply plan and plant master schedules
6. Ensuring that the supply manager's monthly requests for production are reflected in actual plant output
7. Advising the demand manager regarding changes in plant capabilities, particularly as they may affect the ability to satisfy customers
8. Communicating regularly with plant-level master schedulers to determine demonstrated plant capacities and the impact of production changes on the supply plan and on individual master schedules
9. Ensuring that inventory levels fall within approved ranges
10. Ensuring that backlogs are managed to competitive and approved levels

To fulfill these responsibilities, the supply manager must bring certain knowledge, experience, and personal abilities to the job. He or she must have a solid understanding of the company's plant production processes, inventory control system, order management routines, and shipping/transportation scheduling procedures. Knowledge of raw materials, plant resources and an understanding of the company's sales structure, product lines, and customer base are also very important; so too is a thorough understanding of the master scheduling process, policies, techniques, and tools.

A good supply manager also has a number of skills and personal qualities:

- Analytical, mathematical, and problem-solving skills
- The ability to communicate effectively, both verbally and through written reports
- An ability to work with personnel in many functional areas
- Good planning and time management skills

The overarching responsibilities of a supply manager are represented in Figure 15.20. There we can see that the supply manager interfaces with each of the key planning functions in manufacturing:

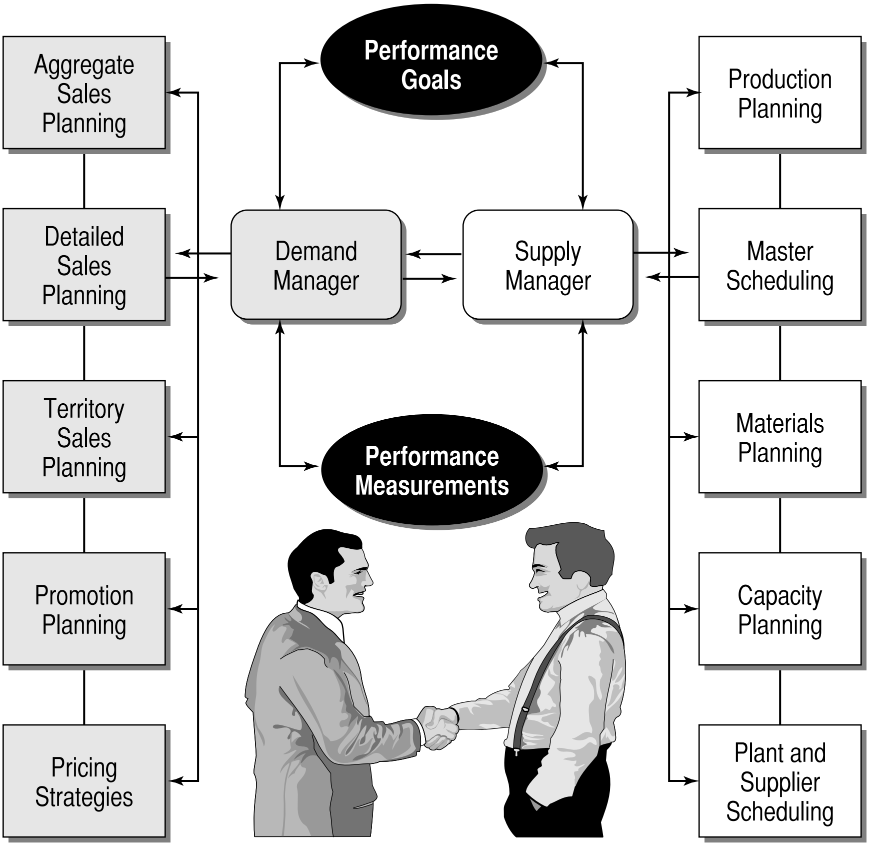

Figure 15.20 The Role of the Supply Manager

production planning, master scheduling, materials planning, capacity planning, and plant and supplier scheduling. The supply manager stands, in effect, between these planning functions and the demand side of the business, which forms the left-hand side of the figure. This central position is shared with the supply manager's counterpart, the demand manager; together they represent the yin and yang of effective and orderly manufacturing in a complex world. The supply and demand managers share common performance goals and performance measures. Thus, they must work closely together to get the job done.

The tasks of demand management parallel those of supply management and are the subject of our next chapter. Until recently, few individuals were uniquely assigned responsibility for either set of tasks. Instead, their functions were parceled out to different managers or, worse, were the responsibility of no one in particular. Fortunately, a growing number of companies have recognized the importance of supply and demand management, and many are creating management positions with those titles. Doing so is one of the most important steps that a multibusiness/multiplant company can take to ensure that supply and demand are balanced in the most cost-efficient and customer-satisfying way.

16

Demand Management

Customers can order anything they want as long as it agrees with our forecast.

In the final analysis, virtually all of us show up at work on Monday morning for one reason: to either create or satisfy demand for our company's products or services. Customer demand is the spark that ignites our entire economic system, and it serves as the controlling factor in all productive activities. While product supply can sometimes get out of balance and the imbalance appears as unsold inventory or poor customer service, the clear signal of customer demand eventually brings production back into equilibrium.

The master scheduler's role in this dynamic process has already been discussed: to harmonize the "when" and "how much" of production with actual and forecasted customer demand. If forecasted demand was always reliable, this would be a simpler job. But as we will see shortly, nothing is simple in predicting the future of customer orders.

What Is Demand Management?

The idea of supply management is easy enough to understand: It implies controlling the production process to specified levels of output.

Since production facilities and labor are under the thumb of the company's management, these ideas seem straightforward.

The concept of demand management requires more explanation. Demand generally comes from outside the company and is thus beyond the full control of the company's leadership and management teams, prompting many to ask, "What's to manage?" To a sales representative living and working a thousand miles away from the company's production facility, the idea of managing demand seems unimportant. All he or she may be interested in is managing the order book—getting as many orders booked as quickly as possible. More orders mean more commissions and more compliments from management. If February's orders are twice those of January's, that is an unqualified achievement. If everyone doubled his or her orders, however, manufacturing could be thrown into chaos, and possibly only about half of those orders would be filled on time.

Because demand is largely external to the company, it would be convenient to proceed with the notion that demand should be left to rise and fall of its own accord, with all of management's attention directed toward supply. However, this notion fails on several counts:

- Few production facilities are so flexible with respect to volume that they can operate efficiently with low output in one period and high output in the next. This violates the basic principle of load leveling.

- Not all demand is external to the company—at least in the larger sense. Much of modern production simply creates intermediates or components for use in final products manufactured by the same company or its subsidiaries. In 1992, for example, General Motors Corporation *in*sourced 70% of its components and subassemblies. Thus, even though the final customer decision is external, demand is not entirely created from outside the company.

- Demand can be created or its timing shifted through marketing. Thus, the idea of managing demand is reasonable and necessary if sales and the company's capabilities are to be kept in balance.[1] Demand management has four fundamental requirements:

1. *Prediction.* Maintaining a balance of supply and demand requires some ability to know the level of incoming orders *in advance,* especially in assemble-to-order and make-to-stock environments.
2. *Communications.* Infantry units have traditionally established listening posts to detect and give early warning of approaching enemy forces. Successful companies know that they will have a chance of preparing for incoming demand if they maintain their own listening posts near the customers. Typically this is done through the field sales force, which visits customer facilities, talks with purchasing managers, and otherwise tries to gauge the level and timing of future orders.
3. *Influence.* Communication leads to knowledge, and knowledge leads to influence. As described earlier, production works to level the load on the manufacturing facility; it abhors a situation where it works at 100% of capacity in odd-numbered months and at 50% during even-numbered months. Ideally, the plant manager would like work scheduled at 75%, 85%, 95% (sometimes 100%) of capacity *every* month. The master scheduler uses his or her influence with sales and marketing to negotiate, where necessary, the shifting of customer demand to produce a better situation on the manufacturing floor—one that makes better use of fixed assets and human resources. This might take the form of a phone call to marketing or to the sales representative to ask, "Do you really need this big order in October? Would it be helpful to you if we shipped a third in September and two-thirds in October? Or would it be a problem for you if we shipped half in October and half in November?" Marketing can also influence demand, both

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[1] For a very complete treatment of demand management and forecasting, see George E. Palmatier and Joseph S. Shull, *The Marketing Edge* (New York: John Wiley & Sons, 1989).

its quantity and timing, through the use of advertising, pricing, and incentives to dealers, sales representatives, and customers.

4. *Prioritization and allocation.* The idea behind demand management and master scheduling is to satisfy all customer demand. However, if a situation presents itself in which less product exists than requested, or the materials and resources needed to produce the required product are not available, then a decision must be made as to which customers get their orders filled as requested and which need to wait. This decision is the responsibility of sales and marketing.

   Allocation is the process used when the company cannot produce enough product to cover the demand, whereas prioritization is the process used to determine which customer's order is filled first. If a company cannot produce enough product, then some business may have to be turned away. In this case, the available product needs to be allocated so that the company does not oversell and overcommit its ability to produce.

Thus, the idea of managing demand is reasonable and has plenty of precedents.

THE ROLE OF FORECASTING IN THE COMPANY: THE CASE OF HASTINGS & BROWN

Richard Phillips sat in front of his computer, checking all the numbers he had just entered into an elaborate spreadsheet. The first column listed each of the company's 50 key products, which collectively accounted for almost 95% of company revenues. Arrayed across the top were the company's 42 sales territories. The number he entered into each cell represented a sales forecast by product as determined by a field representative, based upon contacts with customers who were just then beginning the lengthy process of making purchase decisions.

Phillips was assistant sales director for Hastings & Brown, a publisher of college textbooks with annual revenues of $38 million. H&B's customers were college professors scattered across North America who determined which textbooks their students would be required to use during the next fall semester. Their purchase decisions were generally made between April 15 and June 15.

Each April, Phillips had to prepare a sales forecast for July through September, the period during which fall semester books would be ordered. Although this was his third experience of handling the fall forecast, this year would be more difficult than ever. Many new editions of H&B texts were just now being published, and their acceptance by the marketplace would be one large question mark until actual orders came in from the field. The competition had been active in both new publications and promotions. Forecasting fall sales this year would clearly be more difficult than in any of the past few years.

In H&B's industry, every new book was an experiment. Many, in fact, joked that "the first printing is our market research." Some of the books published in the spring would catch on and be ordered in large numbers for the fall and for subsequent semesters; most, however, would be used by just a few schools and would disappear from the marketplace in a year or two. Determining the winners and losers at this point was the tough part.

Many in H&B management needed the forecast and would rely on it for a variety of purposes. Phillips's boss needed it for his report to the president. He would also comb through it for evidence of big winners to be touted to the sales force to spur them on to even larger sales.

The production manager would use the forecast to plan reprints. Since the first printing of a new title was indeed a form of market research, initial printings were deliberately kept small. Once the winners were identified by the field sales force, plans for second printings had to be made; the same had to be done for other, older publications.

The company's financial manager also had a keen interest in the forecast, as he would have to finance production and budget further expenses. Finally, H&B's president would be making his quarterly trek to New York, where he was expected to report to the parent company's board of directors on the plans and progress of the subsidiary company he managed. The fall sales forecast would be his primary resource in preparing for that important meeting.

All forecasted sales figures were submitted directly by the field sales representatives, who were (or were supposed to be) in regular contact with their customers. As a former field representative who knew most of the field staff, Phillips was suspicious of many of their forecasts. The Nashville representative, Rhett Farnsworthy, he remembered as a self-styled big shot. Farnsworthy's forecasts were always higher than just about everyone else's, yet his optimism was never supported by actual sales. Joan Sommerville of Seattle, on the other hand, was a high-performing sales representative who invariably turned in a low forecast.

Phillips liked to think that the overly optimistic and overly pessimistic figures submitted by individual field representatives would naturally cancel each other out when the figures were aggregated into a final forecast. But he had neither the time nor a method to empirically evaluate that theory.

Some field representatives he suspected of simply pulling numbers out of a hat. Because the forecast played no part in establishing sales quotas for their territories, and since no rewards or penalties were ever assessed for accurate or inaccurate forecasts, the largely unsupervised field representatives had no particular incentive to take the forecasting job seriously. To many, it was an annual chore that took away from their selling time. H&B management had never emphasized the importance of good sales forecasting to the overall workings of the company, nor had it provided them with a methodology for doing the job systematically.

One who did take the forecasting job seriously was Arthur Petersen, of the Wisconsin territory. Petersen had a reputation for being diligent in developing his territory forecast for each major project. He kept careful records of past order quantities, called his customers frequently about their plans, and used early order patterns to project future orders. This attention to detail paid off in booking orders and in more accurate forecasts for the Wisconsin territory. But Petersen was an exception to the rule.

Phillips continued the tedious business of compiling the forecast figures, and as he did so he determined that he would ask Petersen to develop a short training program on sales forecasting for the other sales representatives. But not until next year.

This story of sales forecasting at Hastings & Brown is not meant to be typical, but to illustrate good and bad forecasting methods and show how forecasts are used by different parties in a company.

Problems with Forecasting

Virtually every industry employs individuals to forecast future levels of business activity; in the H&B case, this task was done by unsupervised field sales representatives. Other companies use more formal processes. The many sectors of the energy industry, for example, attempt to predict demand for coal, natural gas, and petroleum so that production, distribution, and financing can be arranged in an orderly

Coping with Forecast Inaccuracies

Even though demand forecasts are imperfect, they are necessary and companies have developed a number of ways to make the most of the situation. Over the years, the author has observed how different companies cope with the inherent inaccuracies of demand forecasting. Here are the twelve most popular techniques used in today's environment, listed alphabetically:

- Accountability
- Communications
- Customer/supplier linking
- Demand management
- Forecasting systems
- Frequent reviews
- Lead-time reduction
- Manufacturing flexibility
- Performance measurement
- Reserve capacity
- S&OP and MPS policies
- Safety stocks/overplanning

fashion. Large individual companies like money center banks, auto producers, and chemical giants have traditionally employed individuals with specialized training to develop proprietary forecasts of future business activity. Whichever way demand forecasting is conducted, one thing can be said with some certainty: The forecast is never 100% accurate.

Economist John Kenneth Galbraith once remarked, "We have two classes of forecasters: those who don't know, and those who don't know they don't know." Predicting the behavior of thousands if not millions of individual decision makers is by nature a questionable business, no matter how scientifically done. The result is that forecasts are invariably inaccurate to some degree. Economic and stock market forecasters are often held up for special ridicule; indeed, many joke that economic seers exist solely for the purpose of making astrologers look good.

It's about Quantities

To be useful to the master scheduler, forecasts must be expressed as items (or product families), quantities, and dates. A forecast of $10 million in sales revenue is of little value to the multiproduct company when it needs to schedule its production. A forecast of 1,000 red golf shirts, 2,000 blue golf shirts, and 1,500 blue sport shirts with red trim is more useful. Getting from a useless to a useful demand forecast is a challenging activity in which marketing, sales, and manufacturing can participate for mutual benefit.

Breaking Down the Forecast

For the company with multiple product lines, the forecast may be developed in the aggregate but must then be broken down into manufacturable segments. Consider an office furniture manufacturer with a very simple offering of two products whose forecast for a period looks like Figure 16.1.

If these products were made in one style and color, this forecast would be directly usable by the master scheduler. There would be two discrete products to be built in specified quantities, and each of these would have a specific bill-of-materials. But business is rarely that simple, and each of these chairs is actually a product family that comes in three colors: black, gray, and burgundy.

In a make-to-order environment in which the color variety can be made as part of the finishing process, master scheduling can be done to the point where the color items are added. But assuming that this is not the way the chairs are built, or if the finishing stage is to be scheduled, then marketing needs to break down its forecast into color-specific categories for each period, as in Figure 16.2.

This is a product mix forecast for the company's two product families in one time period. Here, the marketing and sales department

Product Line	Forecast (in units)
Deskmate Secretarial Chairs	5,000
Executive Chairs	1,000

Figure 16.1 Demand Forecast for the Two-Product Company

Color	Secretarial		Executive	
	Percentage	Forecast	Percentage	Forecast
Black	20	1,000	70	700
Gray	50	2,500	20	200
Burgundy	30	1,500	10	100
Total	100	5,000	100	1,000

Figure 16.2 Deskmate Secretarial Chair Family

estimated how, as percentages, orders would be distributed among the product options within the family. In most cases, breaking down an aggregate forecast is not this simple as there are usually many more product items, colors, and options.

It's about Time

Knowing the "what" of the forecast is just half of what is needed by the master scheduler. The other half is when those items are needed.

Book Date and Demand Date

Since most forecasts are made by marketing personnel, the forecasted date is typically expressed by booking (or order) date—that is, when the order is to be received. This is the red-letter day for marketing and sales, as getting orders is the reason for its existence. But master scheduling is concerned with satisfying demand with a complete product while balancing the requirements for capacity and materials. Therefore, the master scheduler needs to know the demand date (or company's desired shipping or customer's desired delivery date). The degree to which booking and demand dates differ depends upon the nature of the business and its manufacturing strategy. In a make-to-stock business, for example, the two dates may be separated by just a few hours or a day—just long enough to pack, ship, and invoice the items from finished goods. In a make-to-order business, a greater gap typically exists because the items are in some incomplete stage of production when the orders are booked. Here, a lead time is added to the booking date to get the true demand date. Figure 16.3 on page 492 illustrates the difference for make-to-stock and make-to-order environments. For general learning purposes, a make-to-order situation in which a single blanket order with multiple shipments is also shown.

Period	1	2	3	4	5
MTS					
Bookings	100	150	125	150	
Demand	100	150	125	150	
MTO (1 period-lead time)					
Bookings	100	150	125	150	
Demand		100	150	125	150
MTO—Scheduled shipments, blanket order (1 period-lead time)					
Bookings	1,000				
Demand		250	250	250	250

Figure 16.3 Bookings Versus Demand

The master scheduler's focus on the demand date pays off particularly well when the customer is focused on the same date. Consider a candy company whose big seasons are Easter and Halloween. Customers may give the candy company's sales representative an order for chocolate Easter eggs in January, but they have a definite delivery date in mind—not January (the booking date), but sometime just before Easter, which is in March or April.

Spreading the Forecast by Time Period

Forecasts are typically made for large blocks of time: "The current year's sales forecast is 3.2 million units." That may be helpful information to the board of directors, but down in the trenches the figure is not that useful. Since master scheduling needs information to established ship dates, a call goes over to marketing and sales.

"Can you give me some shipping or delivery dates for next month?" the scheduler asks.

The sales director checks his computer. "No dates, but we've forecasted 12,000 units of product number 7352. Does that help you?"

"Yes," the master scheduler says with suppressed sarcasm, "that information is of tremendous help."

If sales and marketing do not know when forecasted customer orders will need to be shipped or delivered during November, it is certain that the master scheduler does not know either. One approach to scheduling 12,000 units would be to look at the record of actual shipments of product number 7352 during November of the previous two or three years. Is there a pattern? In a seasonal business, like a producer of chocolate Easter eggs or ski apparel, a strong pattern may exist.[2]

If no strong pattern exists, the company may simply spread the 12,000 forecasted units evenly over the days or weeks in the month. With this many units forecasted, the Law of Large Numbers favors this even distribution. The Law of Large Numbers holds that, barring some internal bias, outcomes will be evenly distributed around the mean (average). Thus, the shipping dates for the 12,000 units should be scattered evenly through November, and the master scheduler can earmark them for production in this fashion. If the company's products are something like furniture, in which just 100 to 150 units were forecasted for November, no such assumption of even distribution can be made; half of them might be part of a single large order, due for shipping on one particular date. Sales should be asked directly if these units are expected to come in many small orders or from one or two large customers.

A monthly forecast can be broken down, based upon the number of working days in a given week, taking into account holidays and plant maintenance shutdowns. This could also take into account the

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[2] *Warning:* If the pattern shows past November orders skewed toward the end of the month, do not automatically assume that this is when the customers wanted the product. It may merely indicate the company's tendency to experience the end-of-the-month nightmare described in Chapter 1.

Small Numbers and the Master Schedule

While the Law of Large Numbers is a useful tool in a number of statistical applications, small numbers frequently confront the unwary master scheduler.

Consider a situation in which the product mix demand is being determined. The marketing and sales department states that one particular option of a product family will account for 6 percent of its total demand, which is figured as follows using Enterprise Resource Planning software:

Period	**1**	**2**	**3**	**4**	**5**	**6**	**Totals**
Forecast	10	10	10	10	10	10	60
6% Option	0.6	0.6	0.6	0.6	0.6	0.6	▨
Demand (rounded up)	1	1	1	1	1	1	6

Because some software rounds less than whole numbers, demand for this option is not 6 percent of the product family, but 10 percent (6/60).

Virtually all Enterprise Resource Planning software includes this troublesome feature. One way the problem can be eliminated is by entering fractional "remainders" as artificial inventory that is carried over from period to period. When this artificial inventory reaches a value equal to or greater than the demand, it is accommodated in the demand line. (The answer is rounded down and the fraction is reduced by the amount needed.)

This is a way of keeping the fractional values in the system and making the mathematics work correctly. To see how this works, consider the same example, but with remainders carried over.

Period	**1**	**2**	**3**	**4**	**5**	**6**	**Totals**
Forecast	10	10	10	10	10	10	60
6% Option	0.6	0.6	0.6	0.6	0.6	0.6	▨
Demand (rounded up)	1	1	0	1	0	1	4
Cumulative Remainder	0.4	0.8	0.2	0.6	0	0.4	▨

In this situation, demand has totaled to 4, which is 6 percent of the total forecasts for the six periods (4/60).

fact that the month in question may begin and end in the middle of a week. Here forecasts from different months need to be blended within weekly periods. For example, Monday and Tuesday might be part of October and Wednesday through Sunday part of November.

Demand and Forecast Adjustment

In addition to discussing how the forecast is developed, it is also necessary to understand how to use it in the master scheduling (MPS) process. Consider Figure 16.4, which contains a one-month forecast of 400 units. This demand came from the sales and operations planning process described in Chapter 13; the breakdown of this aggregate figure of 400 into weekly periods was accomplished through collaboration between production and marketing. Thus, weeks (periods) 1 through 4 are each forecasted at 100 units, which both parties deemed reasonable in terms of past order patterns and future expectations. The figure also contains lines for normal actual demand, abnormal actual demand, and total demand, all of which will be addressed soon.

	1	2	3	4
Product Forecast	100	100	100	100
Actual Demand	85	0	90	50
Abnormal Demand				
Total Demand				

Figure 16.4 Aggregate Forecast of 400 Spread Over Time

Actual Demand

The second line of the example in Figure 16.4 represents normal actual demand, that is, the quantity of product for which the company has firm customer commitments against what was forecasted. In the figure, each week has less actual demand than what had been forecasted. The actual demand line is updated as confirmed orders are received.[3] These quantities remain in this line, however, until those items are produced and shipped.

Forecast Consumption

As normal actual demand appears and is entered into the matrix, that demand consumes part of the forecast. Thus, in Figure 16.5, the 85 units of normal actual demand in period 1 consume that same amount of the forecast, leaving 15 units of forecast remaining. The 90 units of normal actual demand in period 3 consume all but 10 units of that period's forecast, and half of the original forecast of 100 in period 4 is consumed by normal actual demand in that period. Notice, however, that *total demand* remains the same as the original forecast of 100 per week. Here an assumption has been made that the normal actual demand represents demand already anticipated during the development of the forecast.

Timing versus Demand Problems

Time passes, and as the end of week 1 is reached, the forecasting system automatically drops that column and shifts the remaining three weeks to the left. But if no new orders came in to consume the remaining 15 units of the original forecast in week 1, what would we do with those 15 units? This question highlights a perennial problem for supply and demand managers: determining whether the forecast was inaccurate in quantity—in which case those orders will never ap-

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[3] Updating of normal actual demand may be accomplished automatically through the company's order entry system.

	1	2	3	4
Unconsumed Forecast	15	100	10	50
Actual Demand	85	0	90	50
Abnormal Demand				
Total Demand	100	100	100	100

Figure 16.5 Consumption of the Forecast

pear—or whether the forecasted orders are simply delayed. Here, two options are available:

1. Assume that orders for the 15 units will *never* come in and drop them entirely.
2. Assume that the orders for the 15 units are merely delayed and carry them over as part of the unconsumed forecast.

The first option involves a change in the forecast—from 400 to 385—which may require consultation with other parties in the company (marketing, sales, and finance in particular). Many Enterprise Resource Planning software systems will automatically drop the 15 unsold units as they update the records with the passage of time. This may not be prudent, however, and the demand manager and/or master scheduler would be advised to check with marketing and sales about any variance between actual demand and the forecast before the period is closed out.

If the second option is chosen—that is, the missing orders that total 15 units are merely delayed—no change to the overall forecast of 400 units for the month is made, and the unsold 15 units are rolled forward. But how? There are many possible approaches to this problem, and Figure 16.6 on page 498 shows just a few.

In the first option, all 15 units are front-loaded into the next period; subsequent options spread the 15 in other ways. Master schedulers

	Past Due	1	2	3
Original Forecast	100	100	100	100
Unconsumed Forecast	15	100	100	100
New Forecast (Option 1)		115	100	100
New Forecast (Option 2)		110	105	100
New Forecast (Option 3)		105	105	105
New Forecast (Option 4)		100	100	115
etc.		etc.		

Figure 16.6 Rolling the Forecast

should know that there is no best way of rolling the forecast that fits all companies and all situations. Ultimately, they must exercise judgment based upon demand patterns experienced by their own companies and the input of knowledgeable and affected parties.

One general decision rule that bears following, however, is that *orders that fail to materialize in an aggregate forecasting period should not be automatically rolled into the next forecasting period.* For example, the situation in Figure 16.6 represents an aggregate forecasting period—four weeks; 400 units of demand are anticipated during that period. The 15 units that failed to materialize in the past-due week might be rolled forward into new weeks 1, 2, and 3 by any means viewed as reasonable. However, a new aggregate forecasting period would take effect in weeks 5 through 8, and it should not be burdened by any inaccuracies that manifested themselves in the previous forecasting period. Prudence dictates that—barring reliable information to the contrary—demand that fails to materialize in weeks 1 through 4 could be assumed to be lost, and therefore need not be rolled forward into weeks 5 through 8. Instead, it could be dropped. If that demand were still lurking in the market, one would expect that the new forecast would have picked it up. The best way to handle this situation is

Computer Alert

One peril of almost all master scheduling software is the fact that it looks at the forecast and the actual demand for each period and takes the *greater of the two* as total demand. On the surface this seems to make sense: If actual demand outstrips the forecast, the master scheduler needs to build to that level. If the forecast exceeds actual demand, we might assume that the orders are late.

Look at the situation below. Marketing and sales forecasts the need for 400 units over 4 periods. But the software logic has automatically taken the greater of the forecast and actual demand, thus increasing the forecast by 20 units, to 420.

Period	**1**	**2**	**3**	**4**	**Total**
Product Forecast	100	100	100	100	400
Actual Demand	100	80	110	110	400
Abnormal Demand					
Total Demand	100	100	110	110	420

Now consider what happens when a customer calls to request a rescheduling-out of an order, so that 40 units of actual demand are shifted from period 2 to period 3 (80 – 40 = 40 and 110 + 40 = 150). Remember, this is not an *increase* in demand, just a reschedule-out. As shown below, the software logic does its thing, taking the greater of forecast and actual demand in determining total demand, and in so doing increases total demand by 40 units (from 420 to 460) out of thin air!

Period	**1**	**2**	**3**	**4**	**Total**
Product Forecast	100	100	100	100	400
Actual Demand	100	40	150	110	400
Abnormal Demand					
Total Demand[4]	100	100	150	110	460

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[4] Greater of forecast and actual demand lines.

to have someone in marketing and demand management review the prior period's forecast and make a determination as to whether the unconsumed forecast should be rolled forward or dropped. Doing this prevents loss of accountability for forecast accuracy.

Tracking Cumulative Demand

In the case described in Figure 16.5 on page 497, a shortage of normal actual demand in the first period would most likely be rolled over. Demand managers and master schedulers would not be losing any sleep at this point, knowing that the forecast is most likely inaccurate to some degree and that the division of the 400 units into four discrete demand periods was, after all, based more on intuition than on science. Besides, there are three more weeks available in the forecast planning horizon.

As the days and weeks slip by, however, variances between normal actual demand and the forecast have fewer and fewer opportunities to come into balance. How can we deal with variances as time passes?

One useful approach to dealing with deviations from the forecast over periods of time is through the tracking of demand on a cumulative basis—that is, by comparing the *total* of normal actual demand over a period of time to the *total* forecasted for that same elapsed period. This technique filters out the effects of timing problems from inaccuracies in the forecast quantity. Figure 16.7 applies this technique to the example we have been following. Here a range using high and low indicators is established to accommodate the inevitable inaccuracy of the forecast. This range is the sum for both the expected timing errors and the expected forecast errors. Any values that fall outside these high and low boundaries are signals to demand and supply management to investigate. Another line is added to indicate the deviation of normal actual demand from forecasted demand, expressed as a percentage of forecasted demand. Over time, this deviation should decrease and approach the acceptable forecast error for the month.

Since the first period is less likely, percentage-wise, to correspond to the forecast than would the four weeks taken as a whole, the spread between the high and low boundaries is greatest. But this spread

	1	2	3	4
Low	40	100	200	320
Forecast	100	200	300	400
High	160	300	400	480
Deviation from Forecast	60%	50%	33%	20%

Figure 16.7 Tracking Cumulative Demand

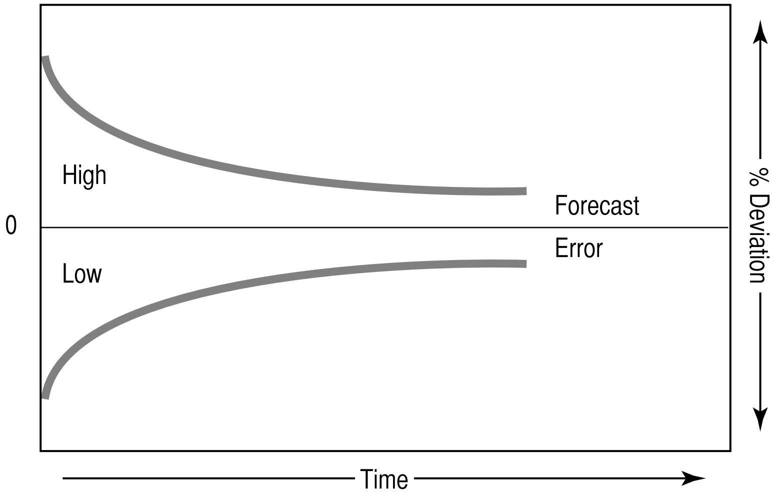

Figure 16.8 Converging Deviation from Forecast Over Time

should narrow progressively over time. Why? Simply because the passing of time allows the timing problems to work themselves out, leaving only the inaccuracies of the forecast quantity as the source of deviation. The result, in a normal situation, should look something like Figure 16.8.

How does demand management use these tracking signals? If the normal actual demand in period 1 of the example is fewer than 40 units (low), a signal is sent (flags up) to watch this product through the coming weeks because the forecast could be biased high. If the actual demand at the end of period 1 is greater than 160 units (high), a signal is sent to demand management that the forecast may be biased low or some unexpected demand may have appeared. This situation could result in the forecast's being understated. Incremental demand not anticipated is known as abnormal demand and must be recognized if demand planning and master scheduling (MPS) are to work effectively.

The Problem of Abnormal Demand

Our discussion of forecast consumption began with an assumption that orders being entered into normal actual demand were all part of the original forecast. This assumption, however, rarely holds up in a dynamic marketplace. Unanticipated bookings are made as sales representatives locate new customers and obtain orders; marketing's efforts at trade shows and with direct mail sometimes result in huge new accounts.

These unanticipated orders, or "abnormal demand," are every salesperson's dream, but they can be every master scheduler's nightmare. If these orders enter the system as actual demand and consume the forecast, big overbooking problems can result when the forecasted orders do appear. In fact, it can be stated that a master scheduling system *will not work* effectively if normal and abnormal demand cannot be differentiated. Without this ability, total demand cannot be determined with sufficient accuracy to produce a reliable projected available balance line of the MPS matrix. And it is from this projected available balance line that the master scheduling system generates the all-important action messages. If the projected available balance line cannot be calculated correctly, the generated action, or exception, messages could be misleading and could cause the master scheduler to make bad decisions.

Identifying Abnormal Demand

To enjoy the benefits of abnormal demand and to avoid its problems, it is necessary to identify abnormal orders *before* they enter the system or shortly thereafter. Customer orders should be analyzed and classified as normal or abnormal at order entry time. The following are some of the telltale signs of abnormal demand:

- A new customer account
- The wrong seasonal pattern
- A one-time order
- A larger-than-normal order
- An order that comes through a nontraditional distribution channel

Marketing and sales personnel should be encouraged to help in this process, and demand managers and master schedulers should communicate with these individuals when in doubt about any suspicious orders.

Accommodating Abnormal Demand

Once abnormal demand is properly identified, working it into the forecast and master schedule is straightforward. Figure 16.9 on page 504 demonstrates a situation in which a one-time order is submitted in period 3 as a result of attendance by marketing at an industry trade show. The customer is a foreign company that wants to buy 150 units on an experimental basis. Only time will tell if this company becomes a regular customer.

Notice here that these 150 units of abnormal demand are added to the unconsumed forecast of 10 and the normal actual demand of 90, to obtain a total demand of 250 units. The original forecast is unchanged, as is the unconsumed forecast. What is changed is the total demand, which shows an incremental amount equal to the abnormal demand.

	1	2	3	4
Unconsumed Forecast	15	100	10	50
Actual Demand	85	0	90	50
Abnormal Demand			150	
Total Demand	100	100	250	100

Figure 16.9 Treatment of Abnormal Demand

Customer Linking

The difficulty of determining customer demand has already been explained. Difficult and imprecise as it is, forecasting is nevertheless a requirement of modern business. But what if we could get the customers to do the forecasting? Who, after all, could possibly know their needs with greater certainty? A number of companies do, in fact, have such a forecasting system, which is generally known as *customer collaboration* or *linking.*[5] They are most prevalent and applicable when the customer is an upstream producer, distributor, or retailer for whom the company acts as a supplier.

Customer collaboration and linking uses the logic of Enterprise Resource Planning (ERP) and Distribution Resource Planning (DRP) to create demand plans at the manufacturing plant and master schedule level (see Figure 16.10 on p. 505).

These planning systems take the customer's product forecast, booked demand, inventories, open purchase orders, open manufac-

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[5] For a very complete treatment of distribution resource planning and customer connectivity, see Andre J. Martin, *Distribution Resource Planning* (New York: John Wiley & Sons, 1990).

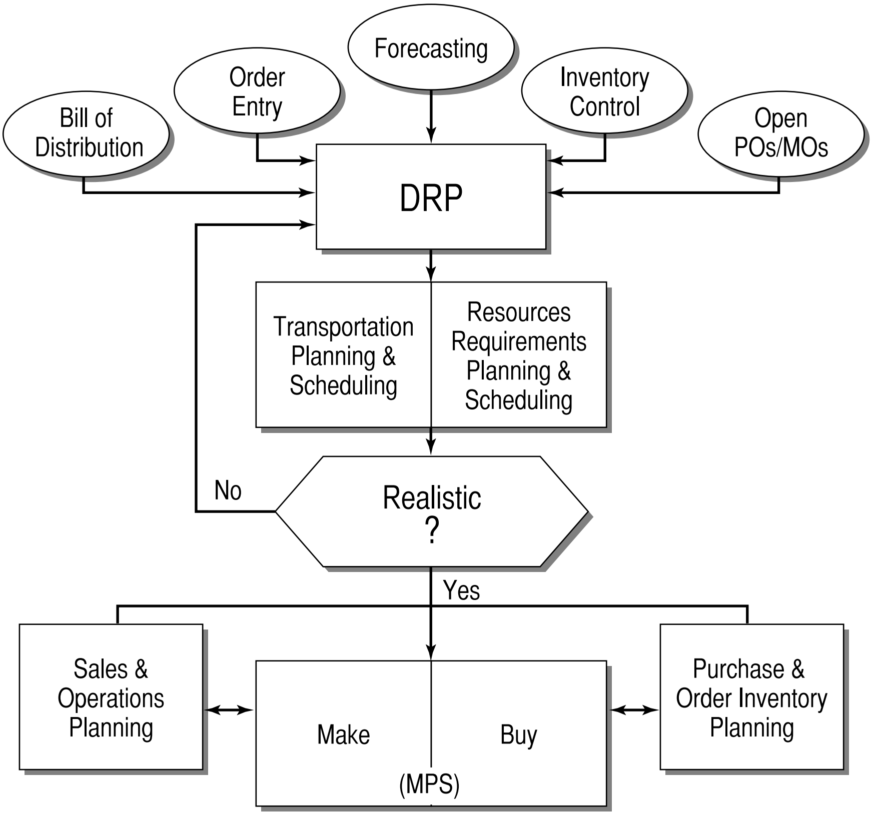

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Figure 16.10 Distribution Resource Planning

turing orders, and bills-of-distribution to create planned receipts of products needed in order to prevent stockout conditions.

Once a customer determines replenishment requirements for its various products, these demands are communicated to the supplier. This has long been done using traditional purchase orders. But why use the purchase order? Why not send the supplier the expected demand directly in the form of a shipment schedule? This can be done by having the customer's Enterprise Resource Planning or DRP system determine the plant's required shipping date by offsetting the transportation time necessary to move the product from the supplier to the customer's delivery point.

This demand along with other customer demands is aggregated and used by sales and operations planning to plan "make" items; it is used by procurement to plan "buy" items, and it is used by the master scheduler to plan both "make" and "buy" items. This same customer demand data is also used for transportation and resource requirements planning and scheduling.

While customer collaboration and linking solve many of the problems associated with demand, the master scheduler must still analyze the expected supply to see if the demand can be satisfied. If it cannot be satisfied, it is the responsibility of the master scheduler to inform the customer of the problem, either directly or through sales and marketing. If sufficient supply will be available, then no additional communication is necessary, the principle of "silence is approval" or "silence is acceptance" applies, and the product should arrive on the customer's receiving dock as requested.

Once customer collaboration and linking are understood and put into place, the entire supply/demand chain can be connected. The ultimate goal is to have the customer linked through a series of events directly with the manufacturing plant.

Look at Figure 16.11 on page 507. The top of the figure shows the typical flow of product as it moves from the manufacturing facility to the manufacturer's distribution center or to its customer's manufacturing site. From here the product continues its journey possibly to a retail distribution center, which sends it to a retail store, which ultimately puts it in the hands of the customer. Of course, a manufacturing site could produce its product, send it to other manufacturing sites or warehouses, and eventually have the product wind up at the customer.

Through this process, inventories are built up at various points along the way. These inventories and demands (many times affected by lot sizes and safety stocks) are quite often out of balance, as shown in the center of the figure. The bottom of the figure is where we all would like to be, a smooth flow with pockets of reduced inventories that are balanced with the feeding operations (suppliers) and the needing

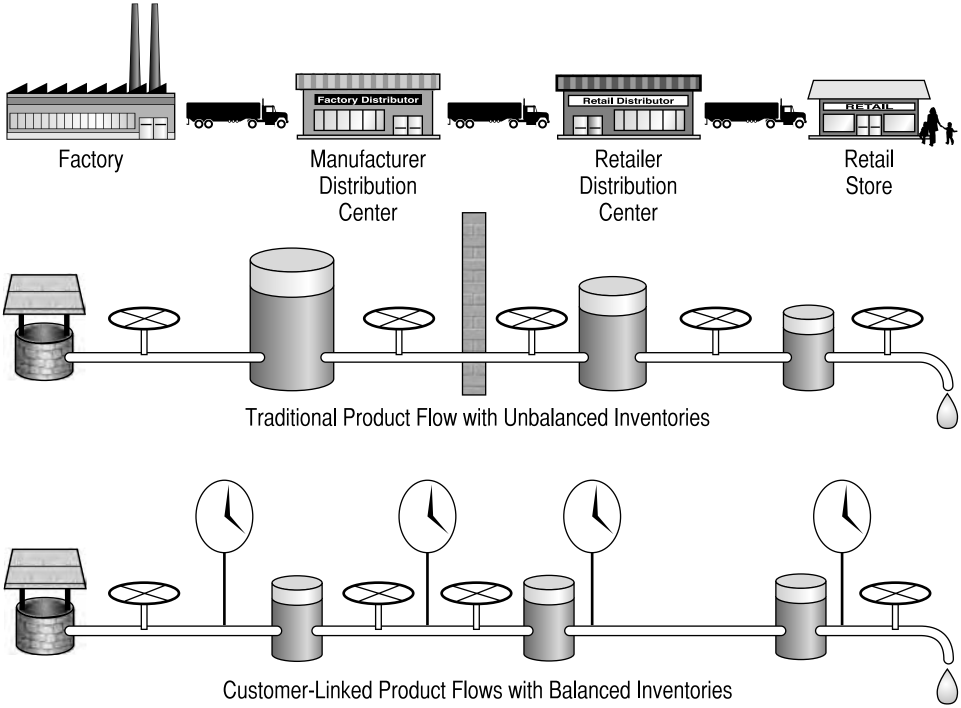

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Figure 16.11 Typical and Improved Pipelines

operations (customers). The challenge is to link all these operations together and balance the flow.

Getting Pipeline Control

Customer and supplier linking offers many opportunities for the manufacturing company using master scheduling. We have already discussed how forecasting can be improved by connecting up to the customer's requirements. We have also discussed the opportunity to

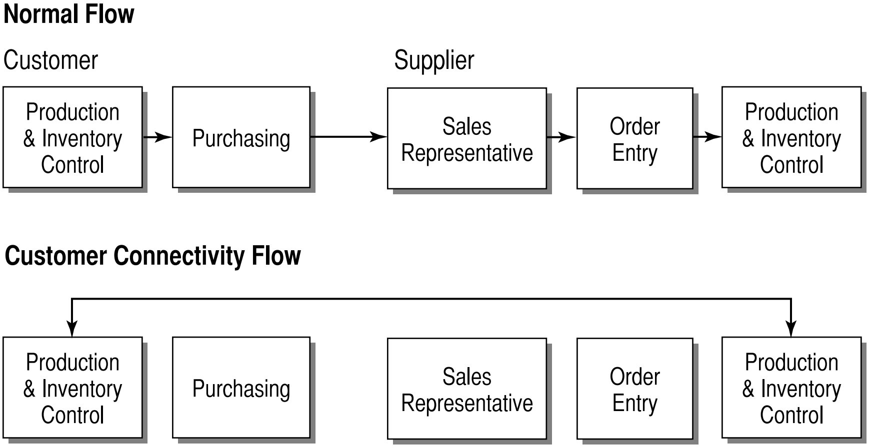

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Figure 16.12 Customer/Supplier Information Flow

eliminate the use of purchase orders by using the customer's supplier schedules. In fact, several companies, such as Xerox Corporation, are using electronic data interchange as a means to communicate with one another.

When companies get the pipeline under control, the next logical step is to remove *all* waste that may be resident in the flow. This waste may exist in the form of multiple stocking locations, transportation, obsolete materials, damaged goods, unnecessary paperwork, and unnecessary communications. Figure 16.12 shows the typical communication links between the traditional customer and supplier.

The traditional flow shows a material planner at the customer site, reviewing requisitions with their purchasing department. The material planner typically uses some form of material requirements planning or distribution requirements planning process to determine what needs to be ordered and when. Purchasing then communicates with the supplier's sales department, who places the order (demand or request for product) into the order entry system. This demand is communicated to the scheduling department of the supplier, which further communicates it to the manufacturing function. Looks like a lot of stress filled with wasted motions.

What if the company could get its purchasing function to work out a volume agreement with the supplier's sales function that covers a defined planning horizon? If this could be arranged and an agreement drawn up, then why not have the customer's production and inventory control function talk and make releases directly to the supplier's production and inventory control function? These people speak the same language. Think of all the communication and miscommunication problems we could avoid. And what about the time factor? Talk about eliminating waste! Customer collaboration and connectivity is a win-win situation.

By doing this (which resembles the supplier-linking process, but from the other side), the sales force is focused on what it's good at—selling. It removes huge amounts of administrative time requirements that are generally needed to place multiple orders and releases. And most companies that implement customer and supplier linking are finding that they do less expediting. That alone makes it worth looking into the concept.

Distribution Resource/Requirements Planning

In military operations, logistics personnel attempt to site all foreseeable people power, equipment, supply, and material requirements as close to battlefield operations as practical. This is its method for ensuring the availability of critical resources. In Operation Desert Storm, for example, a six-month supply of equipment and materials was shipped to Saudi Arabia before any major engagements were undertaken. The military, of course, does not have shareholders screaming about excess inventories! Many manufacturers follow a similar model—though tempered by concerns for inventory cost—shipping finished goods out to regional distribution points where they are more readily available to the customer. This strategy has three purposes:

1. *To reduce lead time.* If shipping from a manufacturing plant in North Carolina to a customer in Utah normally requires four days by overland truck, at least three of those days can be eliminated by sitting inventory in Utah itself. This reduction in lead time may be an important element of customer service (for both products and spares) and increase the company's competitive position.

2. *Reduce transportation cost.* Distributed inventories are sometimes motivated by greater transportation cost efficiencies. For example, in the case just given, shipping individual orders on demand by truck from North Carolina to customers in Utah would be much more costly than would sending planned, full truckload shipments to a Utah distribution center. This latter approach might also eliminate the need for periodic air-freight shipments to satisfy special customer needs.

3. *Control the market channel.* For many common consumer and industrial goods, a true market presence can sometimes be established only when a local inventory and distribution system is in place. Control of shelf space in the supermarkets of Salt Lake City, for example, could not be established or maintained by a potato chip maker in Pennsylvania unless it had a distribution center in that metropolitan area. Effective shelf stocking at supermarkets and convenience stores could not possibly be accomplished from Pennsylvania in a cost-effective way.

Distributed inventory is not a panacea for every business problem. Distribution centers are cost centers and must ultimately be judged in terms of the value their costs add to the company and its customers.

The Mechanics of Distribution Requirements Planning

Minuteman Electronics Company, the laptop computer manufacturer, was introduced earlier. As shown in Figure 16.13 on page 511, Minuteman produces the finished computers in Boston. These manufacturing

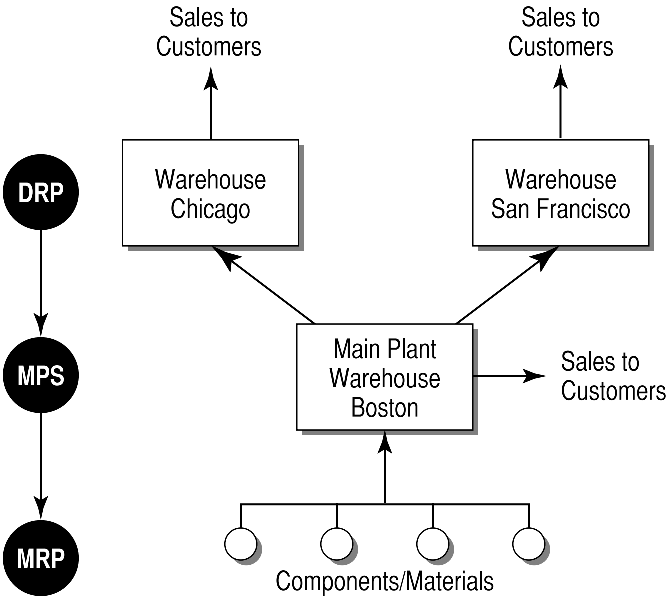
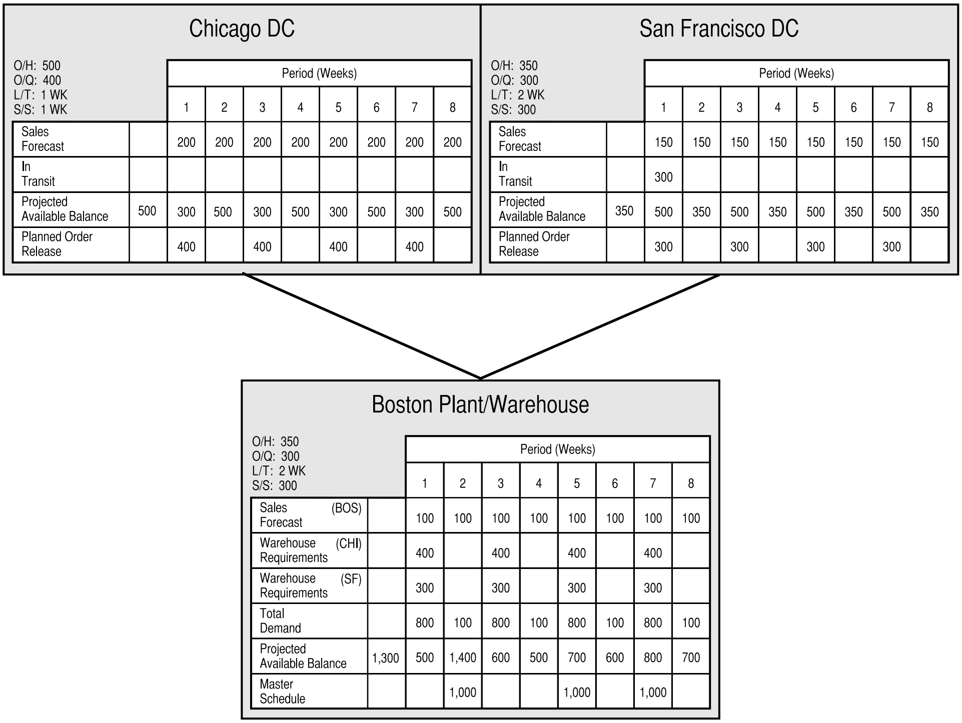


Figure 16.13 Distribution Scheme and Planning Tools, MEC

plants ship finished products to distribution centers located in Boston, Chicago, and San Francisco. Figure 16.13 illustrates the Minuteman distribution scheme and—on the left side of the figure—the planning tools used to build and move products through it.

From the master scheduler's perspective, Minuteman products are built according to the master schedule supported by an MPS system at the company's main plant, a system that reaches down to material and capacity levels using material and capacity planning (finite or infinite) logic. This same MPS system is driven by demand from three sources: direct sales to customers out of Boston, orders placed by the warehouse located in Chicago, and orders placed by the warehouse located in San Francisco—each of which is viewed as a customer. For direct customer sales—those filled from the plant warehouse—demand is forecasted by Minuteman's local marketing and sales team. Sales to Midwestern and West Coast customers, however, are forecasted by the marketing and sales organizations based in Chicago and San Francisco, respectively.



Chicago DC

O/H: 500
O/Q: 400
L/T: 1 WK
S/S: 1 WK

		Period (Weeks)							
		1	2	3	4	5	6	7	8
Sales Forecast		200	200	200	200	200	200	200	200
In Transit									
Projected Available Balance	500	300	500	300	500	300	500	300	500
Planned Order Release		400		400		400		400	

San Francisco DC

O/H: 350
O/Q: 300
L/T: 2 WK
S/S: 300

		Period (Weeks)							
		1	2	3	4	5	6	7	8
Sales Forecast		150	150	150	150	150	150	150	150
In Transit		300							
Projected Available Balance	350	500	350	500	350	500	350	500	350
Planned Order Release		300		300		300		300	

Boston Plant/Warehouse

O/H: 350
O/Q: 300
L/T: 2 WK
S/S: 300

		Period (Weeks)							
		1	2	3	4	5	6	7	8
Sales Forecast (BOS)		100	100	100	100	100	100	100	100
Warehouse Requirements (CHI)		400		400		400		400	
Warehouse Requirements (SF)		300		300		300		300	
Total Demand		800	100	800	100	800	100	800	100
Projected Available Balance	1,300	500	1,400	600	500	700	600	800	700
Master Schedule			1,000			1,000		1,000	

Figure 16.14 Distribution Resource Planning Linkages, Item 247

Figure 16.14 provides a more detailed look at the linkage between the manufacturing plant and the two MEC distribution centers with respect to just one product: item 247. As the figure makes clear, each of the distribution centers has an on-hand (O/H) balance, specific order quantity (O/Q), transit lead time (L/T), and safety stock (S/S) defined for this item. The Chicago facility, for example, begins the current period with an on-hand balance of 500, has a order quantity of 400, a safety stock of 200 (one week's worth of demand), and a lead-time requirement of one week.

How activities at the distribution centers signal activities at the manufacturing plant becomes clear as we examine several periods in Figure 16.14. Here, the Chicago distribution center's first-period forecast of 200 is expected to use all but 300 of the on-hand balance of item 247—leaving 300 as a projected available balance at the end of period 1. The second week's demand is also 200, which will leave 100 units (300 – 200) projected available balance at the end of period 2. Since that number is below the safety stock requirement, a planned order release is made for 400 units—the specified order quantity. That order is required to be received in week 2 but must be shipped from the Boston manufacturing plant in week 1 (transportation lead time is one period). When the plant acknowledges or ships the order, the planned order release will be changed into a scheduled receipt and show up on the "in transit" line by its due date, which is week 2. This process would continue through the Chicago distribution center's horizon. As the reader can see, a series of planned orders is being created for the Chicago distribution center, which will translate into request for product from the Boston plant.

A similar set of events is going on at the San Francisco distribution center, though an "in transit" shipment is expected to arrive during week 1, obviously due to a planned order released earlier (two weeks earlier, given the expected in-transit lead time to move the product to that facility). Again, a series of request-for-product notifications is being placed on the Boston manufacturing plant from the San Francisco distribution center.

The Impact of Distribution Center Orders on the Plant

The manufacturing facility that receives distribution center orders views them as another source of demand. In the current example, the MPS system at the Boston plant indicates three sources of demand: its own sales forecast of regional sales (100 per week), Chicago's warehouse requirements of 400 every other week, and San Francisco's warehouse requirements of 300 every other week. In week 1 of the example, these warehouse requirements total 800: 100 from Boston, 400 from Chicago, and 300 from San Francisco. Together, the warehouse requirements from each location and for each week in the planning horizon constitute total demand to which the master scheduler needs to respond. In addition to understanding the total demand, the master scheduler must also know where the demand comes from. This requirement is supported by the pegging capability in the MPS system.

Pegging informs the master scheduler which warehouse caused the demand. The reader should understand some of the reasons for this requirement: assigning priorities, if necessary, and effective shipping, to name just two.

Distribution Requirements Planning versus Distribution Resource Planning

The information system that makes distribution *requirements* planning possible also makes distribution *resource* planning feasible. This extends a company's ability from simply building and shipping items to the ability to maximize the total resources of the company. As an example, Minuteman's information system enables the master scheduler to intelligently manage supply and demand throughout the company and its distribution system; in addition, this same information system very likely has enough stored data to develop a shipping routine that minimizes costs and balances transportation loads. In Figure 16.15, item 247 is shown to be just one of four for which quantity, space, and weight have been calculated to facilitate balanced shipping in weeks 1 and 2.

	Week 1				Week 2			
Item No.	Qty (ea)	Space (ft^3)	Weight (lbs.)	Notes (*)	Qty (ea)	Space (ft^3)	Weight (lbs.)	Notes (*)
141	250	27	1,250		250	27	1,250	
223	100	16	824					
247	400	36	2,000					
288	200	20	1,700		200	20	1,700	
Etc.	......	......	......		......	......	......	
Total	2,900	312	16,974		1,370	135	6,650	

Figure 16.15 Transportation Plan, Chicago Distribution Center

Based upon this information, the master scheduler or transportation planner can reserve an appropriate level of transportation capabilities to move combined orders at the most effective cost from the Boston plant to the Chicago distribution center.

The next question must be this: If we can get the distribution centers to communicate their planned requirements, why can't we get the customers to communicate their planned requirements? It's the next logical step and is similar to the interplant environment, described earlier for Minuteman Electronics Company.[6] And it impacts a subject of fundamental importance to the manufacturer—load leveling.

Expected Results

Companies that use Distribution Resource Planning (DRP) and Supply Chain Management continue to experience improved customer service with reduced inventories. This is being done with less reliance on sales forecasting and improved sales productivity by keeping the sales representatives doing what they are paid to do, which is to sell. Periodic demand monitoring and transportation planning, coupled with the other DRP and Supply Chain Management processes, can lead to increased product pipeline velocity and reduced lead times from supplier to customer. And let's not forget the reduction of distribution and manufacturing costs associated with the benefits already stated. Overall, the customer-linking process can give a company the opportunity to eliminate all unnecessary activities. This is a continuous-improvement program expanding to include the distribution and logistics network.

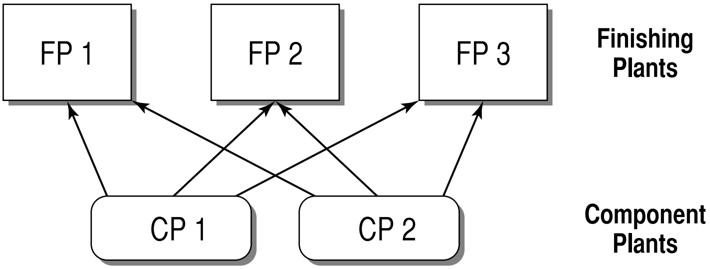
The notion of DRP and linking outside or within companies is not without its problems and risks, but also opportunities, as the following material makes clear.

[6] Both the manufacturer and its customers should be Class A companies for this to be feasible.

MULTIPLANT COMMUNICATIONS

Larger companies generally support production through a number of production plants. The automobile industry, whose finished products contain upward of 4,500 parts, is a case in point. Final assembly and finishing are supported by separate production facilities for engines, interiors, metal stamping, and so forth.

Consider a simpler example: a company with three finishing plants and two component plants.



The component plants may be total captives of the finishing plants, serving their needs exclusively. They may, on the other hand, have some outside customers to whom they sell part of their output. In either case, good communications among plants is an important element in successful manufacturing. The finishing plants establish demand for the component plants, which, in turn, attempt to produce an adequate supply. When finishing and component plants fail to communicate and fail to work together, manufacturing productivity and output generally suffer.

Scheduling practitioners recognize one problem of multiplant communications that stands out above all others: Lower-level plants have trouble controlling their own schedules and are often whipsawed by the changing demand situation at the upper-level plants they serve. Unlike the independent company, which has a right of refusal with respect to customer demand, the lower-level plant as part of the larger corporate machinery typically cannot just say no to demand from a finishing plant or corporate office. Nor does it have much latitude in shifting or splitting orders or in outsourcing the work. Overloading of the master schedule at lower-level plants is the typical result.

Management Issues

When a finishing plant passes down an order to a component plant, its knowledge of the scheduling and manufacturing situation at the component plant is often imperfect. Lack of communications and general lack of insight into production problems at the lower-level plant provoke a number of management concerns, one going directly to the heart of how people should be managed.

Most management practitioners acknowledge that an individual should never be held responsible for the results of operations over which he or she lacks control. Yet this hallowed principle is routinely violated by a great number of manufacturers whose corporate schedulers control the master schedules of their component plants. General managers of component plants are held accountable for stabilizing production, controlling costs, and meeting supply demands from finishing plants, even though the strings that control schedules on their own plant floors are often pulled by someone else, perhaps by a lower-level staffer located in corporate offices thousands of miles away. "We could be having equipment problems, materials shortages, whatever, and this would not be reflected in the schedule we're expected to follow" is a common complaint. "Just tell us what you want, and when, and let us figure out the best way to schedule the work."

Managers of lower-level plants, in the author's experience, would generally prefer a multiplant system in which they have greater autonomy in meeting the requirements of higher-level plants—their *best customers.* That greater autonomy would give them control of their own master schedules, the ability to negotiate movement and splitting of orders, the right to refuse an order—in effect, the same autonomy enjoyed by independent companies that must adhere to the sharp discipline of the marketplace if they hope to survive and prosper.

Corporate staffers are often uncomfortable with this notion of component plant independence and their own loss of control. In cases observed by the author, that discomfort stems from a lack of confidence in the scheduling capabilities of lower-level managers. But experience indicates that good things usually happen when decision-making responsibility is pushed down to the lowest possible level. This has been one of the important lessons of the quality movement and the practice of continuous improvement in manufacturing. Here, control is maintained through accountability for performance and through incentives that naturally align the interest of the component plant manager with those of the corporation.

Multiplant scheduling problems affect just about everyone, so solving them is in everyone's interests. Marketing and sales have a problem when orders are not shipped on time because the component plant fails to deliver due to overscheduling. Manufacturing managers and

Tell Us What You Want, and We'll Do the Rest, Sir

One of the lessons from America's military experience in Vietnam was that command and control cannot be exercised effectively from afar. To the great frustration of U.S. field commanders, much of the war was run directly from the Pentagon. Analysts and staffers working and living in the comfortable environments of Washington, D.C., plotted campaigns for corps commanders and selected targets for bomber pilots stationed half a world away. Lacking a feel for local resources and circumstances, many of their directives were either ineffective or outright damaging to U.S. war efforts. While overall strategy was logically the domain of the White House, high-echelon military officers, and their staffs, the business of effecting that strategy should have been left to the discretion of local commanders who had a better grasp of conditions on the ground.

This important lesson from Vietnam was not lost on the captains and majors who, twenty years later, filled the general officer ranks of the U.S. armed forces during the Gulf War. As the new generation of U.S. commanders, they defined the broader strategy of driving Iraqi forces from Kuwait, but they gave local commanders broad discretion in implementing the strategy. And it worked exceedingly well.

production supervisors at component plants often see some of their own problems as the result of scheduling failures higher up ("they just dump all of their scheduling and forecasting mistakes onto us"). Finance wonders where all the profits are going—reschedules, expediting, overtime, and the like cost money. In the long run, accountability is lost and overall performance suffers.

Available-to-Promise

A promise made is a debt unpaid! This little sentence by Robert Service ought to be posted prominently wherever demand management and master scheduling personnel work, as it articulates one of the primary responsibilities of their functions.

When a customer requests a product, the demand manager, customer service, order entry, sales representatives, supply manager, or the master scheduler must respond to that request and commit to a date for shipment. This constitutes an explicit promise to the customer, and the available-to-promise (ATP) information of the master schedule is an important tool in making good on promises. In this sense it is an important element of demand management.

The available-to-promise line of the master schedule matrix indicates the portion of scheduled production that is unconsumed after all other commitments are covered and tells demand management, customer service, order entry, field sales, and the master scheduler what is available to fill new requests. While the mechanics of ATP were briefly touched on in Chapters 3 and 9, a little refresher is appropriate here. Consider the following example of a ballpoint pen manufacturer (Figure 16.16, p. 520). This producer, which begins the current period with an on-hand balance of 150 cases of pens, has a demand forecast of 100 cases per week over an eight-week horizon. Given that forecast, the master scheduler has placed three firm planned orders of 300 cases each in periods 2, 5, and 8.

	Past Due	1	2	3	4	5	6	7	8
Product Forecast		100	100	100	100	100	100	100	100
Option Forecast									
Actual Demand									
Total Demand		100	100	100	100	100	100	100	100
Projected Available Balance	150	50	250	150	50	250	150	50	150
Available-to-Promise									
Master Schedule			300			300			300

Figure 16.16 Available-to-Promise, Pen Manufacturer

Given the on-hand balance, total demand, and existing master scheduled orders, the master scheduling system can calculate the projected available balance for all future periods as shown in the figure.

In determining the quantities available-to-promise, the master scheduler's first concern is in protecting commitments already made—namely, actual demand.

The master scheduler's second concern is in protecting those commitments in the most efficient manner; here, this means protecting demand with the closest MPS lot that immediately precedes it. Thus, if an actual order for a period 8 delivery is received and accepted, it would be more efficient to protect that commitment from supply expected to be available as near to period 8 as possible. In the situation given here, for example, an experienced demand manager or master scheduler would never protect a period 8 demand with on-hand inventory when a source of supply is anticipated in period 8.

To deal with these two concerns, the master scheduling system calculates available-to-promise (ATP) from right to left—here moving from period 8 to period 1. An available-to-promise is calculated for all MPS supply orders, the ones scheduled in periods 8, 5, and 2, plus

	Past Due	1	2	3	4	5	6	7	8
Product Forecast		100	100	100	100	100	100	100	100
Option Forecast									
Actual Demand		90	100	60	50	60			
Total Demand		100	100	100	100	100	100	100	100
Projected Available Balance	150	50	250	150	50	250	150	50	150
Available-to-Promise		60 60	90 150	150	150	240 390	390	390	300 690
Master Schedule			300			300			300

Figure 16.17 Available-to-Promise, Pen Manufacturer

period 1 since there are pens on hand and they are available to sell or promise. Since ATP is the master scheduled quantity less actual demand, the ATP for period 8 is 300 – 0 = 300 (see Figure 16.17). There are at least 300 cases of pens available-to-promise to any customer that needs delivery in that period. However, this calculation is only for the period and does not take into account previous periods' ATP.

Moving to period 5 (Figure 16.17), the next period in which supply is scheduled, the calculation is again straightforward: 300 firm planned orders – 60 actual demand = 240 ATP. Period 2 is more complicated. A demand of 100 cases of pens is committed in this period, but there is also demand in periods 3 and 4. With no other supply anticipated to intervene until period 5, all of that demand must be protected by the firm planned order of 300 cases scheduled for completion in period 2. Thus, the ATP for period 2 is 300 – (100 + 60 + 50) or 300 – 210 = 90.

Period 1 has 90 units of actual demand, and that is covered by the 150 cases on hand. The ATP for period 1 then is 150 – 90 = 60. Once the ATP by period is known, the master scheduling system can calculate the cumulative ATP (bottom row of numbers) as shown in Figure

16.17. This cumulative result is calculated by adding each period's ATP in the horizon to the prior period's cumulative ATP value. Available-to-promise logic is generally used to support the make-to-order environment more than the make-to-stock environment since customer-committed backlog reaches farther into the future in make-to-order companies than it does in make-to-stock companies.

ATP with Two Demand Streams

So far, we have looked at the classical available-to-promise calculation and use. This classical approach is valid and works for most companies as they commit product for customer delivery. However, as in most manufacturing situations, there are incidents or events that cause the standard logic to falter. This is the case when a company has multiple demand streams, such as one source of demand being from production and another source of demand being from service or spare parts. Refer to Figure 16.18 during the discussion of this expanded ATP logic.

The available-to-promise (normal) has been calculated as described earlier for periods 1, 4, and 8 (noncumulative values). As you can see, the ATP in period 1 is 11. Let's say that production calls the person committing inventory and requests that all the items available be sent to the floor no later than period 3. To satisfy this request and to ensure that other promises are protected, the person doing the committing reviews the ATP in period 1, sees that 11 are available-to-promise, and makes the commitment.

The next event that occurs is a phone call from the service parts organization requesting the 2 items that they forecasted in period 1. What does the person tell them? "Oops! Don't have them!" What about period 2? "Oops! Don't have them!" What about period 3? "Oops! Don't have them!" Okay, three strikes and you're out. The next time the service parts organization forecasts its anticipated orders, it will likely

	Past Due	1	2	3	4	5	6	7	8
Service Forecast		2	2	2	2	2	2	2	2
Production Forecast				4	4	4	4	4	4
Actual Demand		5	4						
Total Demand		7	6	6	6	6	6	6	6
Projected Available Balance	20	13	7	1	20	14	8	2	21
Available-to-Promise (Normal)		11			25				25
Available-to-Promise (Service)		7			9				9
Available-to-Promise (Production)		5			17				17
Master Schedule					25				25

Figure 16.18 Available-to-Promise with Two Demand Streams

forecast hundreds, thousands, millions, and so on. Here is a case where the forecaster tried to do what's right: tell the master scheduler what he or she really thinks will be needed. However, it didn't work, so it's back to the old way of doing business (even though that didn't work).

If a company has the two-demand-stream situation, the logic of calculating ATP may need to be changed in order to protect the forecast. In the case being addressed in Figure 16.18, three ATP lines are shown: one for the aggregate ATP (normal), one for production, and one for service. One way to calculate the ATP for production is for the MPS system to use the standard logic (on hand, which equals 20 plus the master schedule of zero minus the actual demand of 9) resulting in 11 available-to-promise. Taking this result, the MPS system can now subtract the service forecast of 6 (2 each in periods 1, 2, and 3) leaving an ATP for production equal to 5 (20 + 0 – 9 – 6). This approach in essence is reserving or allocating 6 units for the service part of the business.

	Past Due	1	2	3	4	5	6	7	8
Service Forecast		2	2	2	2	2	2	2	2
Production Forecast					3	4	4	4	4
Actual Demand		5	4	5					
Total Demand		7	6	7	6	6	6	6	6
Projected Available Balance	20	13	7	0	19	13	7	1	20
Available-to-Promise (Normal)		6			25				25
Available-to-Promise (Service)		6			9				9
Available-to-Promise (Production)		0			17				17
Master Schedule					25				25

Figure 16.19 Available-to-Promise with Two Demand Streams After Accepting Production Order for 5 Units in Period 3

Turning our attention to the service ATP, the system takes the on-hand balance of 20 plus the master schedule of zero (0) minus the actual demand of 9 minus the remaining production forecast of 4, leaving 7 units available-to-promise for service (20 + 0 – 9 – 4). Again, by subtracting the production forecast of 4 units from the available-to-promise for service, you essentially reserve or allocate those units for production.

These calculations create an interesting situation. Look at the available-to-promise results in period 1 for service and production. It is easy to see that the summation of 5 ATP for production and 7 ATP for service does *not* equal the 11 total available-to-promise (there are only 11 available-to-promise). There is 1 unit up for grabs. First come, first served! When the first request for the extra unit is satisfied, the ATP will be recalculated and adjusted to take this into account (Figure 16.19).

Let's go back to production's phone call—production needs as many as there are available by period 3. The answer to that question is now 5, not 11 (see Figure 16.18, p. 523). So, let's take the order and commit delivery in period 3. When this is done, the production forecast in period 3 is consumed and reduced to zero (0). In the example, the forecast in period 4 has been reduced to 3. This forecast consumption technique is one of many choices and is called *forward consumption.*

The new ATP for production is the on-hand inventory of 20 plus the master schedule of zero (0) minus the actual demand of 14 (5 + 4 + 5) minus the service parts forecast of 6 equaling zero (0) (20 – 14 – 6). The new ATP for service is the on-hand inventory of 20 plus the master schedule of zero (0) minus the actual demand of 14 minus the production forecast of zero (0) equaling 6 (20 – 14 – 0). As you can see, the extra unit has been committed, the production commitments have been acknowledged and protected, and the service forecast has likewise been protected.

Another method used by companies facing the two or multiple demand stream issue is to allocate the on-hand inventory balance and master schedule by percentage. Let's say the company decides that 30% of the manufactured or purchased items will be for spares, while the remaining 70% will be for production (Figure 16.20, p. 526). If the company has an on-hand balance of 20 units, 6 would be allocated for spares while 14 would be held for production's use. The same logic can be applied to the master schedule lots. In the case, 30% of 25 is 8 units (rounded up), while 70% of 25 is 17 units (rounded down).

Reviewing the first three periods' ATP, we see a spares order for 2 units in period 1 and another for 1 unit in period 2. There are 20 units in inventory. Using our percentage allocation, 30% of the 20 units is 6, which are reserved for spares. Therefore, subtracting the 3 units committed, the ATP for spares in period 1 has been reduced to 3 units. In production's case 14 units were originally allocated, establishing an opening ATP of 14 units. However, a total of 14 units have been committed to production (5 in period 1, 4 in period 2, 5 in period 3), thus reducing the ATP in period 1 for production of zero units. (Production is sold out unless spares releases some of their allocation; this is a management decision.)

These examples have shown the need to modify the standard ATP logic in order to deal with the more complex multiple-demand-stream environment. It should not be expected by the reader that standard

	Past Due	1	2	3	4	5	6	7	8
Service Forecast			1	2	2	2	2	2	2
Production Forecast					4	4	4	4	4
Actual Demand (Spares)		2	1						
Actual Demand (Production)		5	4	5					
Total Demand		7	6	7	6	6	6	6	6
Projected Available Balance	20	13	7	0	19	13	7	1	20
Available-to-Promise (Normal)		3			25				25
Available-to-Promise (Service)		3			8				8
Available-to-Promise (Production)		0			17				17
Master Schedule					25				25

Figure 16.20 Available-to-Promise Using MPS Allocation by Percentage

master scheduling software logic will support these types of calculations; most of the time the master scheduling software system must be modified in order to protect forecast as well as actual demand. What's important is that the logic of the MPS system be such that it supports the people making the decisions. In order to do this, the information presented must be accurate, timely, and factual.

Should Companies Have Demand Managers?

Hopefully, this chapter has made clear the importance of good demand management to the manufacturing organization. Without it, the production function is at the mercy of external forces over which it has little or no control.

Over the years, manufacturing companies have seen the wisdom of having an individual (or more than one individual) dedicated to the job of supply management or the managing of its manufacturing schedules; this is done by a supply manager and/or a master scheduler. Class A companies give the same attention to demand management. In many ways, these are parallel functions. A demand manager position (usually reporting to a marketing function) is not universally present in manufacturing companies, but it is highly recommended. Figure 16.21 on page 528 presents a process diagram of how a demand manager interacts with the demand side of the business and how that same function is linked with the supply management function, which benefits directly from more accurate and robust information about demand.

Sales and marketing play important roles in demand management, and their active involvement leads to improved supply planning and master scheduling. These organizations are responsible for developing and maintaining sales plans, both aggregate and disaggregated. Sales and marketing must take responsibility for predicting the product mix, customer order promising, and identification of abnormal demands.

Additionally, as members of management, sales and marketing must have a role in formulating company policies with respect to lead-time definitions, rescheduling time zones, safety stocks, overplanning, inventory levels, and customer service levels. As participants in the sales and operations planning process, sales and marketing also should have inputs to development of the production plan. Finally, they should consult with the supply manager and/or master scheduler on supply-and-demand issues.

To assist in the function of managing demand, the demand management position is responsible for the following activities:

1. Developing forecasts of anticipated demand on a monthly basis by product family for sales and operations planning
2. Providing assistance to the sales organization facilitating the sales planning process for sales and operations planning

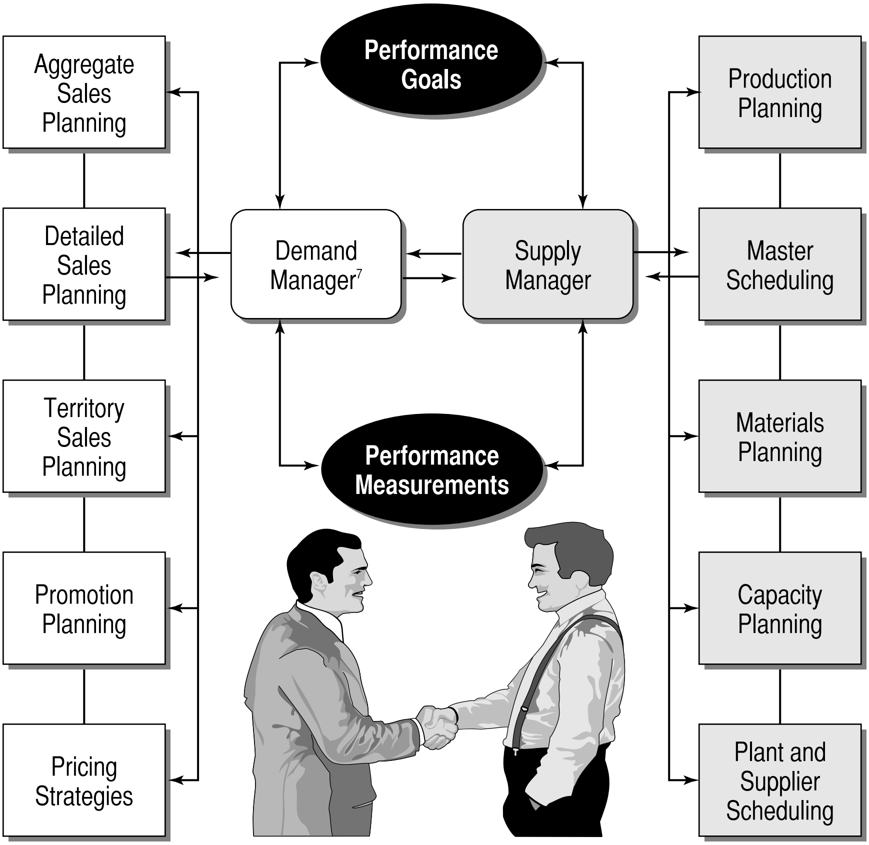


Figure 16.21 The Role of the Demand Manager

3. Providing product mix forecasts to the master scheduler for master scheduling
4. Providing forecasts of anticipated demand for new products and/or new markets, working with product and marketing managers as appropriate

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[7] Depending on the size and complexity of the organization, some companies use a demand planner in place of a demand manager and master scheduler in place of a supply manager.

5. Establishing, maintaining, and utilizing forecasting and communications tools for accomplishing the above
6. Assisting in the development of marketing/manufacturing strategies, policies, and objectives, including sales and operations planning policy, master scheduling policy, customer service objectives, inventory levels, backlog/lead time objectives, and planning/demand time fences
7. Assisting with planning bills and product structures
8. Monitoring the company's performance to plan providing detailed input to sales and marketing management for use at the sales and operations planning meetings
9. Developing and documenting the factors and assumptions supporting the company sales plan[8]
10. Advising the master scheduler on allocation and prioritization issues

Overall, the demand manager or planner is to sales and marketing what the supply manager or master scheduler is to manufacturing. Primary qualifications for the demand management (planning) position include:

- Experience in sales, marketing, customer service
- Knowledge of the company's products and services
- Knowledge of Enterprise Resource Planning including sales and operations planning, master scheduling, and demand management.
- Excellent communications skills

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[8] George E. Palmatier and Joseph S. Shull, *The Marketing Edge* (New York: John Wiley & Sons, 1989).

- Credibility throughout the company, with top management, sales, manufacturing, engineering, finance, and other support organizations
- Knowledge of the company's manufacturing processes
- Computer skills

The last 16 chapters have discussed the whys, whats, and hows of master scheduling. Much of this discussion has been in the format of what the master scheduler must do in order to become an effective scheduler. The last 4 chapters have addressed the master scheduling integration issues. The final working chapter in this book (before the epilogue, glossary, and appendices) is designed to provide the reader with a proven methodology to implement master scheduling and achieve Class A operating results.

17

Effective Implementation

If you always do what you've always done,
you will always get what you've always gotten.

Over the past quarter century, thousands of companies have taken steps in the direction of greater effectiveness, quality, and customer service. Perhaps at no time since the early years of the Industrial Revolution has the impulse toward self-improvement been so widespread. In North America and Europe, the motive for that impulse is not difficult to understand: Intense competition from foreign competitors—primarily Asian corporations—threatens both the profitability and the survival of companies in a wide range of industries.

An important set of tools used by companies in their drive toward improvement in manufacturing has been Manufacturing Resource Planning, Enterprise Resource Planning, and Integrated Demand-Driven Supply Chain Management. Thousands of companies in a variety of industries have turned to these highly effective processes and tools as a means of improving customer service, shortening delivery times, increasing productivity, and reducing inventory costs. Of these companies, hundreds have reached the coveted status of Class A in Operational and Business Excellence.

The late Oliver Wight, who did so much to develop and popularize these powerful processes and tools, in 1976 asked his colleague Darryl

Landvater to investigate and document the critical activities and steps taken by companies that had been successful in adopting Manufacturing Resource Planning and making it their operating philosophy. The purpose of this investigation was to provide implementation guidelines that others might follow—what the Oliver Wight Companies would call "The Proven Path." Not surprisingly, Landvater found that successful implementation of Manufacturing Resource Planning does not happen by chance, luck, or sorcery, but through thoughtful planning, teamwork, and execution. The second version of the Proven Path is fully documented in a book by Thomas F. Wallace, which spells out in detail the steps and activities needed to successfully implement Manufacturing Resource Planning.[1]

Master scheduling is a subsystem of Manufacturing Resource Planning (MRPII), Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Operational Excellence, and Business Excellence. Because of this, the process of implementing master scheduling has many parallels to the implementation of these processes. For that reason, it is worth taking just a few moments to review some of those processes.

Proven Path to Successful Operational Excellence

Research by the Oliver Wight Companies has found that those who pursue a course of implementing Operational Excellence spend between 12 and 24 months (longer for Business Excellence; this is explained later in this chapter and in the appendix) in a series of activities

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[1] Thomas F. Wallace, *MRPII: Making It Happen,* 2nd ed. (New York: John Wiley & Sons, 1990).

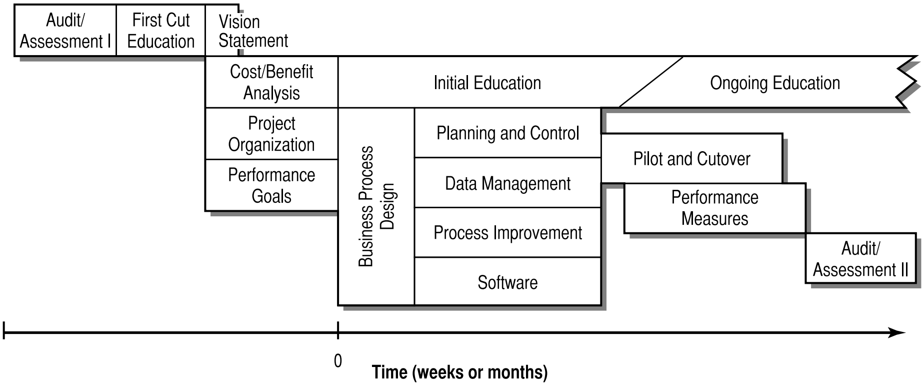

Figure 17.1 The Operational Excellence Proven Path

that involve the participation of managers and technical workers from the top to the lower levels of the organization. Typically, these activities are similar to those represented in Figure 17.1.

The process begins with an *audit/assessment* of the company's current situation—its operations, problems, strategies, and opportunities—and its readiness to adopt Operational Excellence. This exercise not only forces managers to take a hard look at existing practices but forms a valuable baseline against which future programs will eventually be measured.

The next step is *first-cut education,* in which both the executive team and operating team learn about Operational Excellence: what it is, how it operates, and what it takes to implement it properly. This group must also determine whether Operational Excellence makes sense for their particular business.

Assuming that this step has a positive outcome, the same set of team leaders must then develop a *vision statement,* a written document that describes the company and its competitive capabilities once Operational Excellence is adopted and integrated company-wide. Concurrent with the beginning of the vision statement process are three critically important activities, which are performed in parallel: *benefit/cost analysis, project (initiative) organization,* and the development of *performance goals.*

Benefit/cost analysis results, again, in a formal written document that articulates all the anticipated benefits and costs that will accrue to the company if Operational Excellence is adopted and implemented. Project organization and performance goals are developed in parallel to the benefit/cost analysis. In effect, they consider two issues: If Operational Excellence is adopted, how will the implementation be organized within the company? And what levels of performance would be expected in areas touched by the Operational Excellence implementation?

The Decision Point

At this point, the company and its management are in a position to make an informed decision to either continue business as usual or adopt the Operational Excellence approach. If their decision is to go with Operational Excellence, they will face a one- to two-year period of implementation activities (longer for Business Excellence), some of which are sequential while others are approached in parallel.

The first set of these activities is the preparation for converting the company's entire process over to the Operational Excellence approach. This crossover may include the implementation of a new ERP/SCM software system or a reimplementation of the system already installed. Prior to the full cutover, a series of pilots are performed to minimize the risk of failure and to increase the overall chances of achieving Class A results. These preparation activities include the following:

- Creation of a detailed implementation plan (sample in appendix)
- Education and training of key and affected company associates
- Design of the business processes as they will look once Operational Excellence is implemented

- Writing and implementation of company policies and procedures with respect to tactical planning and control (listing in appendix)
- Development of an accurate database for inventory records, product definitions, process routings, production lines, manufacturing cells or centers, and variable parameters
- Identification and implementation of process acceleration and improvements that will make the entire supply chain system work more effectively and efficiently
- Acquisition, installation, and maintenance of the software needed to support Operational Excellence and Business Excellence as well as related activities
- Identification of performance measurements and methods of tracking them

Going on the Air

Once these activities have been successfully completed (recognizing that education is *never* completed), the company is ready to "go on the air," to use Oliver Wight terminology. There the policies, procedures, disciplines, work flows, and computer systems developed earlier around conference room tables are tested in a series of measured experiments. Generally, this is done with a small set of products, so that if the new process or system fails or contains bugs, operations within the company will not be jeopardized. Pilot operations also provide opportunities for personnel to learn to operate the process and system in measured steps.

Satisfactory pilot operations then lead to a full cutover to the Integrated Demand-Driven Supply Chain Management process and system—again, in measured steps. At this point data on performance is collected for comparison to the performance goals set earlier.

The Path to Master Scheduling Implementation

Presentation of the essential activities on the Operational Excellence Proven Path to successful implementation is appropriate here because so many master scheduling (MPS) issues must be addressed by the aspiring Operational Excellence company if it hopes to progress successfully along the Proven Path. In fact, an Enterprise Resource Planning/Supply Chain Management system will not work if master scheduling is not in place and operating correctly; quantities driven down through the ERP and SCM system will be too many, too few, too early, or too late if there is no master schedule to connect production supply and market demand in an intelligent fashion.

Master scheduling issues appear frequently on the Proven Path. For example, in first-cut education, the importance of master scheduling to the smooth functioning of Operational Excellence is made clear, often for the first time, to many participants. Again, in the development of performance goals, goals for master scheduling are as relevant and important as are those for inventory record accuracy, quality, and management of the ERP and SCM system. The importance of master scheduling to Enterprise Resource Planning and Supply Chain Management is perhaps nowhere greater than in the planning and control area, where the defined methodology to balance supply and demand at the item mix level is implemented. If a company cannot effectively manage this balance, it will have trouble planning and controlling materials and capacities, and creation of a valid master schedule will be difficult.

The implementation of a solid master scheduling process has a path of its own, one that shares many of the characteristics of its Operational Excellence father or mother but also has several unique characteristics. These are schematically described in Figure 17.2.

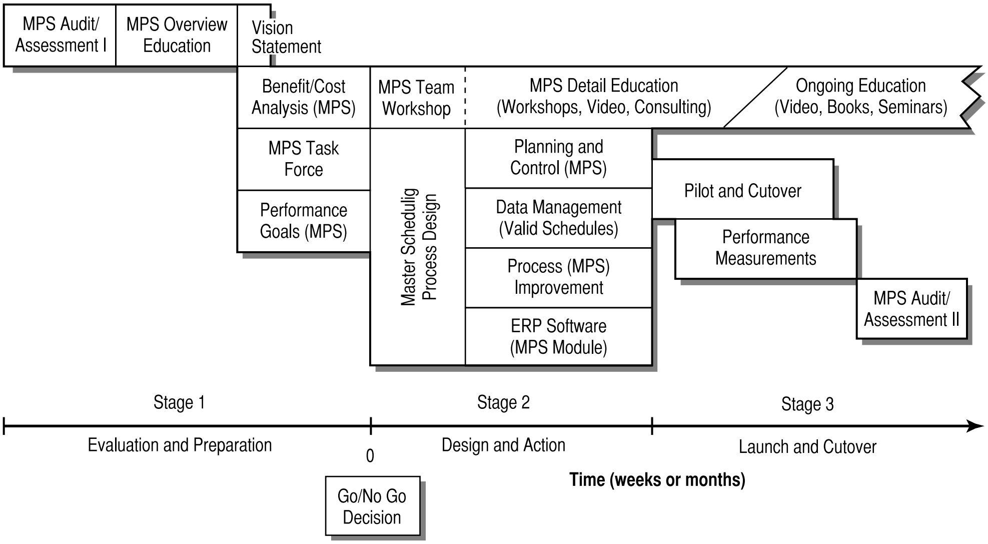

Figure 17.2 The Proven Path to Effectively Implementing Master Scheduling

Implementation of master scheduling takes place within three broad stages:

- *Stage 1* is an evaluation and preparation period in which key personnel in the company gain a general knowledge about master scheduling, determine where they currently stand with respect to best practices of master scheduling, analyze the benefits and costs of a state-of-the-art master scheduling process and system to their company, and decide what will have to happen to get a Class A master scheduling process up and running. At the end of this stage, a decision is made to either move forward with master scheduling, reject it, or go on hold; this point in time is referred to as *point zero.*

- *Stage 2* is devoted to the organizational issues required to launch and sustain a successful master scheduling process. This is a period of design and action. Like the previous stage, this one also features education. It features regular business meetings by the personnel charged with implementing and operating the process as well as the system and, to a lesser extent, others in the company who will be touched by master scheduling in important ways. Master scheduling task force personnel must iron out the details with respect to supply management, demand management, sales and operations planning, and the other features of master scheduling discussed in earlier chapters. When this stage is over, it should be clear what is to be done, who will do it, and when.

- *Stage 3* is launch and cutover. This is when the company takes its first deliberate steps toward putting the processes in place (some processes may actually be implemented during stage 2) and bringing the master scheduling computer software system on line. Because newly developed processes may not be fully understood and the chance that software bugs still may be present in a newly adopted system, introduction is conducted in small steps. Eventually, as the processes become familiar, the computer software is proved to work as designed and documented, and as personnel learn more about using their new policies, procedures, and tools, the master scheduling system goes company-wide.

Stage 1: Evaluation and Preparation

Audit/Assessment I

The first step in preparing for a lengthy journey is to determine just where you are, the distance to the destination, and the time the company needs and has to get there. This is the purpose of the audit/assessment step. The company needs to understand the current state of its master scheduling capabilities—systems, practices, and the skill of its operating personnel. It needs to rate itself against some standard of good practice and, if the evaluation stage results in the decision to go forward with the master scheduling implementation, a baseline of performance against which future progress can be measured needs to be established.

The Oliver Wight ABCD Checklist for Operational Excellence contains a list of comprehensive criteria that companies can use to rate themselves on critical points in strategic planning, people and teams, new-product development, total quality management, planning and control, and continuous improvement. The Checklist includes a rating system that defines Class A, B, C, and D companies.[2] While this publication was written to address the larger concerns of modern manufacturing, it does contain a section on master scheduling and its related disciplines. The criteria in that section can be used to determine where the company stands in terms of Class A master scheduling process and performance. (See Appendix A.) The findings of this initial audit/assessment should be systematically recorded for comparison against future progress.

The Oliver Wight Class A Checklist for Business Excellence contains a list of comprehensive criteria that companies can use to rate themselves on critical points in managing the strategic planning process, managing and leading people, driving business improvement, integrated business management, managing products and services, managing demand, managing the supply chain, managing internal supply, and managing external sourcing. This Checklist includes a rating system that defines Class A Business Excellence, Business Unit Class A Accreditation, and Class A Recognition Award. Class A Business Excellence is achieved when the entire business meets the requirements of all chapters in the checklist. Business Unit Class A Accreditation is achieved when a stand-alone business within a multiunit business meets the requirements of its appropriate chapters. Class A Recognition Award is achieved when predetermined projects and milestones in a business improvement program have delivered their planned business gains on the journey to Class A Business Excellence. The master scheduling criteria are defined in *The Oliver Wight*

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[2] *The Oliver Wight ABCD Checklist for Operational Excellence,* 5th ed. (New York: John Wiley & Sons, 2000).

Class A Checklist for Business Excellence in the chapter "Managing the Internal Supply Chain" under the subject "Master Supply Planning," which is supported by definitions and topics.[3] (See the appendix.)

First-Cut Education

In the Operational Excellence Proven Path, management receives about two to six hours of classroom-based education on master scheduling as part of the overall Operational Excellence first-cut education program. In a program to implement master scheduling specifically, several people from supply chain management and other disciplines need more education and should take a concentrated course on master scheduling.[4] During first-cut education, the company is making itself aware of best master scheduling practices used throughout industry. At this point on the proven path, the details of master scheduling are not critical; the details will come later (see master scheduling detail education).

Vision Statement

Once the core group has received a solid base of first-cut education about master scheduling, the group needs to think deeply about what the company would be like if Class A master scheduling was thoroughly integrated into its operations. From this thinking the group should develop a master scheduling vision that describes the ways in which the company would be different or improved.

Since the typical company already has some form of vision and mission statement, or is following a defined strategy that features an all-embracing focus for its business future, the vision statement that

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[3] See *The Oliver Wight Class A Checklist for Business Excellence*, 6th ed. (New York: John Wiley & Sons, 2005).

[4] Ideally, this group would include master schedulers, plant schedulers, material planners, demand managers, production control supervisors, materials managers, manufacturing supervisors, systems analysts, and managers from marketing, engineering, and finance.

emerges from the master scheduling implementation process should logically address the central tenets of that primary mission or strategy. For example, if customer service is the strategic thrust of the company, the master scheduling vision may describe how customer service will be improved by the adoption of Class A master scheduling: for example, on-time delivery and reduced lead times.

While it may seem premature to develop a vision at this early stage, the core master scheduling group will have learned enough in the first-cut education process to understand how master scheduling can improve operations, and optimism about that prospect is the normal result. The steps that follow are filled with hard work and constant reminders about the difficulties of fully integrating master scheduling

Master Scheduling Vision Statement

(A sample written in present tense)

The manufacturing environment is more even-paced and less chaotic. Month-end backorders and reliance on expediters have essentially been eliminated as production dates and customer requirement dates have become the same. The manufacturing facility runs at a level pace, leaving adequate time for line changeovers, repairs, preventive maintenance, and emergency orders.

The company is in a more competitive position as its ability to deliver on promises to customers with respect to product specifications, quantities, and delivery dates exceeds 95 (sometimes as high as 99.5%) percent. This has resulted in improved financial results for shareholders and company associates. Sales personnel spend more time selling and earning commissions and less time apologizing for late deliveries; manufacturing personnel have gained the satisfaction of producing orders on-time, with a margin of time available for quality and process improvements; and production bonuses have increased. Management has benefited from improved financial results and has more time to dedicate to planning, education, training, and process improvements.

into company operations. The unencumbered optimism of a vision is needed during those difficult stages to remind everyone of the future value of their efforts.

Benefit/Cost Analysis

Implementing a master scheduling system takes plenty of time, spent by dozens of individuals in meetings, in doing analysis, in writing reports. And that time costs the company. There are other direct costs as well—costs for computer hardware and software, education and training, achieving inventory record accuracy, getting the product and process definitions accurate, systems analysis, policy and procedure creation, programming, and coaching. The costs in time, effort, and direct outlays for implementing any new operating system are usually obvious to everyone. Less obvious are the benefits.

To win support for implementing a new master scheduling process and computer system or enhancing the current ones, leaders need to carry out a careful and unbiased analysis of the benefits and costs, which must be communicated to all parties concerned. There is no easier way to lose support for a good program than to fail to justify its costs to those who pay the bills and to those who do the work. The master scheduling task force also needs benefit/cost information to make informed decisions with respect to completing the implementation process.

Every company has its own set of implementation benefits and costs, and these need to be determined on an individual basis. In all cases, however, the categories of cost are *people, processes, data integrity,* and *tools* (computer hardware/software). Benefits invariably accrue to *sales* and various aspects of *material* and *labor* costs. Figure 17.3 on page 543 itemizes the general categories of benefits and costs that implementers should include in their analysis.

The best sources of benefits and costs are the individuals closest to the facts. For example, the sales vice president is in the best position to know what incremental increase in sales would result if the company could deliver as promised and on time. The manufacturing vice president is in the best position to identify expected productivity

BENEFITS			
Revenues	Increased sales	$ X,XXX,XXX	
People	Better order promising	XXX,XXX	
	Increased productivity	X,XXX,XXX	
	Unplanned overtime reduction	XXX,XXX	
	Less underloaded resources	XXX,XXX	
	Expediting cost reduction	XXX,XXX	
Materials	Purchase cost reduction	X,XXX,XXX	
	Inventory reduction	X,XXX,XXX	
	Fewer premium charges	X,XXX	
Plant Productivity	Better utilization rate	X,XXX,XXX	
	Level-loading, less scrap	XXX,XXX	
Freight	More complete loads	XX,XXX	
	Fewer rush shipments	X,XXX	
		Total Benefits	$ XX,XXX,XXX

COSTS			
People	Steering Committee	$ XX,XXX	
	Project team	XXX,XXX	
	Spin-off task forces	XX,XX	
	Education and workshops	XX,XXX	
	Consulting	XX,XXX	
Data-Related	Inventory record accuracy	XX,XXX	
	Product definition accuracy	X,XXX	
	Process routing accuracy	XX,XXX	
	Manufacturing capacity accuracy	X,XXX	
	Valid schedules	X,XXX	
	Planning bill accuracy	XX,XXX	
Computer	Hardware and software	XXX,XXX	
	Systems and programming	XXX,XXX	
		Total Costs	$ X,XXX,XXX

Figure 17.3 Benefit/Cost Analysis

improvements that would result from valid, level-loaded schedules. The stockroom manager knows better than anyone the costs associated with bringing inventory record accuracy up to the Class A level needed to support a first-class master scheduling process. The engineering department has the means to estimate the cost of improving the bills-of-material, recipes, or formulations it develops. Using these individuals as sources for benefit and cost figures is also a way of enlisting their *involvement* and *commitment* to those benefits and costs when the program is fully implemented.

The Task Force

The business of master scheduling, as the preceding chapters have made clear, involves a broad set of disciplines, routines, policies, and procedures: supply management, demand management, sales and operations planning, product definitions, process routings, inventory records, capacity and material planning, plant scheduling, computers and software, and linkages to other parts of the business, to name only the most obvious. As part of the implementation process, each of these tasks must be planned, staffed, and given a set of operational guidelines. The computer hardware and software requirements for master scheduling, for example, do not just appear. Someone must determine what capabilities are needed and how they would be used in the manufacturing facility.

Good implementation results when these assorted master scheduling disciplines, routines, policies, and procedures are thought out by a number of task force members. The task force itself is staffed in part by members of the core group that is dedicated to the implementation process, and in part by personnel likely to be involved in an up-and-running process using a computer system for support.

The task force is not immediately charged with developing the operational details required of a fully implemented master scheduling system. That would be premature, since the decision to go ahead with implementation has not yet been made. Instead, their job is to determine *what would have to be done and what resources would be required.* In terms of computers and software, as just one example, the task force would determine the dimensions of the requirements, who should be assigned to the job, and how much time would be required to get the computer software system into operation. Once questions like these have been answered by the task force members, their findings should be compiled for the implementation group that is charged with the "go/no-go" decision. (These findings are useful later if a "go" decision is made; at that point they become the basis for operation planning in the next stage.)

Performance Goals

The last step of the evaluation and preparation stage is for the core implementation group to consider what performance goals would be appropriate if a full master scheduling implementation were made. Operational Excellence has many performance goals, and some key ones pertain directly to master scheduling: customer service as well as master schedule (mix) and manufacturing schedule performance should be 95% or better (Class A as defined in *The Oliver Wight ABCD Checklist for Operational Excellence,* 5th ed.—higher requirement in 6th ed.). Production planning (volume) performance should be ±2% to the plan. Lead time reduction, inventory reduction, and throughput velocity improvement are other appropriate goals. Another important goal is to stabilize the master schedule; to do so requires discipline and a process that minimizes unnecessary schedule changes.

At this point the company's leaders and management team have the information they need to make an informed decision with respect to fully implementing a formal master scheduling process and computer system. The core group of decision makers has been educated on the subject; it has made an assessment of the company with respect to Class A master scheduling performance; and it has formed a vision of how the company would look and how its ability to satisfy customers would be altered if it reached the heights of Class A performance. A number of concrete facts would be laid alongside that mental image of the new company: benefit/cost analysis, a list of the resources and efforts necessary for full implementation (including potential task force members), and a set of performance goals that would be the company's new yardstick for future master scheduling and manufacturing performance. With this information, management decides to either back off or go forward.

The decision to go forward must be articulated in a way that identifies the following points:

- This is where the company now stands with respect to its master scheduling practices (from the audit/assessment).
- This is where the company can go (from the vision statement).
- Moving forward with full master scheduling implementation will result in measurable benefits supported by defined costs (from benefit/cost analysis).
- To move from the company's current practices to a Class A master scheduling environment will require this amount of time and this amount of staffing resources (from the project organization recommendations).
- This is a checklist of important tasks that will need to be performed to reach full implementation—planning bills, inventory accuracy, computer system, and so on (from the master scheduling task force investigation).
- These are the kinds of performance achievements that will be expected under Class A master scheduling (from the performance goal and measurement definitions).

Stage 2: Design and Action

The decision to go for full master scheduling implementation commits the company and many of its personnel to a long but rewarding process. Organizationally, the effort will be managed by a spin-off task force leader and many of the operational responsibilities will be doled out to other specialized task forces. The first part of that effort is to prepare the company and its personnel for the job of starting and operating a first-rate master scheduling process and computer system. This might be called the design and action stage, and its objective is to work out all the operational details that the master scheduling task force in stage 1 merely enumerated. There the task was to determine what would have to be done and what it would require. Here a full-blown operational blueprint is developed. This blueprint will take the form of a detailed *master scheduling implementation plan.* (See the appendix for a sample detailed implementation task list; add to this task list responsibilities, commencement/start dates, and complete/stop dates and you have a detailed master scheduling implementation plan.)

As in the previous stage, education is an important part of that process. Members of the master scheduling task force of stage 1 continue the education process begun earlier. Master scheduling workshops, web-based education, e-learning sessions, and video libraries are valuable for this purpose. At this stage, accelerated learning is critical, and so members of the task force along with other members of the implementation team should convene every day or every other day for a series of highly structured two-hour meetings that review current progress, provide education on specific master scheduling techniques, and feature discussion on how those techniques can be implemented within the company. Discussion should account for fully half of the business meeting. A sample of a typical meeting agenda is shown on page 548.

The end result of each such meeting should be a list of action items that individuals must do in order to implement the activities discussed. Responsibility for these items should be allocated to specific individuals with specific dates for resolution. Progress on these action items should be discussed at future meetings, and their successful resolution should be rolled into the detailed master scheduling implementation plan.

Education at this stage must also be extended to personnel outside the core implementation group, to those individuals who will be dealing either directly or indirectly with the fully implemented master scheduling process and system. These sessions are more spread out and include discussion of the overall vision.

Business Meeting Agenda

(A Sample)

Topic: Master Scheduling Time Zones

Meeting Agenda (2 hours):

- Review open action items list (10 minutes)
- Education and fact transfer of Master Scheduling methodology (30 minutes)
- Discuss how to implement methodology (70 minutes)
- Create action items and assign responsibility (10 minutes)

Key Items to Be Addressed and Resolved:

- People versus computer behavior and control
- Approval policy needed for people behavior
- System time fences needed for computer behavior

Applications:

- A policy is required defining who needs to approve changes by zone
- The approvals required will be based on timing and cost impact
- System time fences will be used to decouple supply and demand
- Maintenance responsibility will be assigned

Action Items for MPS Implementation Plan:

- Write master schedule change approval policy
- Write time fence setting and maintenance policy
- Circulate for comments
- Make modifications as appropriate
- Secure approvals
- Release and implement policies

While this master scheduling education process continues, other implementation activities take place in parallel. Before considering these, however, we should look at how the core implementation group helps to define the company's new environment.

Process Definition and Implementation Planning

Meetings of task force members provide more than learning for a core group of associates or employees—they also serve as a format in which the important details of the company's emerging master scheduling process and system begin to emerge. These details, as mentioned previously, must be captured in an implementation plan that defines the entire master scheduling process for the company. Here the master scheduling process and system are transformed from the focus on what the process *should* look like of stage 1 to the question of what the process *will* look like in the near future. Central to this definition of the master scheduling process are manufacturing strategy and process, process and material flow, customer order promising, establishing the schedule, policies, procedures, and the assignment of responsibilities and accountabilities.

A good example of an important policy that must be determined at this point is the question of manufacturing strategy, or where the company should meet the customer. Will the company follow a strategy of make-to-order, with minimal inventory and moderate levels of customer delivery lead times, or will it pursue a strategy of make-to-stock, characterized by aggressive levels of customer service and ample inventories to service demand? Or will yet another strategy be followed? This is a management issue of the first magnitude, and it requires input from all core functions of the company. As we will see shortly, the impact of the manufacturing strategy that is accepted will spill over to the procedures area of the master scheduling implementation. For example, a make-to-stock strategy generally uses different product definition schemes than does make-to-order, which uses different ones than does engineer-to-order (e.g., activity bills versus engineering bills versus planning bills versus configuration bills).

Figure 17.4 on page 550 considers primary areas within which policies and procedures must be developed and modified as well as

Policy and Procedure	Functions Involved
Manufacturing Strategy Make-to-stock Make-to-order Design-to-order	President VP Sales and Marketing VP Manufacturing Controller
Service Levels/Order Promising Fill rates, delivery to promise	VP Sales and Marketing VP Manufacturing
Backlog Levels Customer lead time	VP Sales and Marketing VP Manufacturing
Inventory Levels Finished goods Intermediates, semi-finished Bulks, raw materials Supplier managed	VP Sales and Marketing VP Manufacturing Materials Manager Controller
Sales and Operations Planning Sales planning Production planning Resource planning Design planning Financial planning	President VP Sales and Marketing VP Manufacturing VP Engineering VP Finance VP Quality
Supply Management Supply planning Request for production Inventory management Backlog management	VP Sales and Marketing VP Manufacturing VP Industrial Relations Materials Manager Manufacturing Manager Controller
Master Scheduling Rough cut capacity planning Order promising Overplanning, safety stocks Past dues	VP Manufacturing Materials Manager Master Scheduler Controller
Lead Times (Internal) Finishing, final assembly Intermediate, subassembly Cumulative, strategic material	VP Sales and Marketing VP Manufacturing Materials Manager
Order Quantity Lot size definition Multiples, if used Minimums, maximums	VP Manufacturing Materials Manager Purchasing Manager
Processes to be Improved Lead times to customers Optimal schedules Past due condition	VP Manufacturing Manufacturing Manager Manufacturing Personnel

Figure 17.4 Areas That Require Policies and Procedures

	0–1 Week	2–3 Weeks	4–6 Weeks	6–12 Weeks
Product A	President General Manager	VP Sales VP Manufacturing	Sales Director Mfg. Director	Sales Director Mfg. Manager
Product B	General Manager	General Manager	VP Sales Mfg. Manager	VP Sales Mfg. Manager
Product C	VP Sales Mfg. Director	Sales Director Mfg. Director	Sales Manager Mfg. Director	Master Scheduler

Figure 17.5 Approval Policy for Master Schedule Changes

the individuals typically assigned responsibility for them. In essence, Figure 17.4 is a rough cut of what needs to be done. The level of detail in the development of policies and procedures, and in the assigning of responsibility, is specified. The master scheduling implementation plan requirements are at a much higher level of detail. For example, the procedure for making changes to the master schedule—to pick just one area—requires full development of an approval process, naming those individuals authorized to approve changes, and describing the situations (by time period) in which they have that authority. For multiproduct companies, this may require an elaborate set of approvals. Figure 17.5 suggests how such a set of approvals might appear. (This is a more specific set of guidelines than the discussion of time zones in Chapter 4.)

Policy: Changes to the master schedule can be requested by sales, marketing, finance, production, purchasing, quality, engineering, design, and distribution. All changes to the master schedule within an item's cumulative lead time will be approved by the person(s) identified.
Process: Changing the master schedule.
Initiator: Sends the master scheduler a written request for the change.

Master scheduler: Has a maximum of two working days to respond to the initiator with one of three answers:

1. Yes, the change can be made and is being implemented.

2. The change can be accommodated, but the following schedules are affected. What is your recommendation?

3. The change cannot be made for the following reason(s). The best alternative is ____.

The definition of the master scheduling process and its implementation planning having been completed, it is then time to move directly into the functional areas where the detailed blueprint for its daily operation must be drawn up and executed. These are planning and control, data management, process improvement, and software—all of which have been treated to some degree in previous chapters of this book.

Planning and Control

The previous activity of process definition created an inclusive set of policies and procedures for all the master scheduling activities (see appendix for master scheduling policy suggestions). Here the policies are fleshed out in operational detail. An analogy to these two different levels of detail is found in the federal government, where Congress passes legislation that establishes a set of rules. Once signed by the president, those rules are handed over to the appropriate agency, whose technical staff creates a much more detailed set of operational statutes, complete with dates, amounts, and so forth, all developed to reflect the intent of Congress. Here the intent of the higher-level policy makers is specified through written policies and implemented through written procedures.

Planning and control must concentrate on demand management, supply management, rough cut capacity planning, sales and operations planning, and master scheduling. A demand management procedure needs to be drawn up in detail, focusing on the role of the demand manager (there needs to be one), sales and marketing personnel, and

Master Scheduling Policy

(A Sample)

Manufacturing, supported by a valid master schedule, will maintain a performance level of 95 percent or better on meeting schedule's completion dates.

Rough cut capacity planning will be used to check that critical resource capacity is available to satisfy the written master schedule before the master schedule is released for action.

The master schedule will be firmed up through the planning time fence using a combination of scheduled receipts such as campaigns, released orders such as work orders, and firm planned orders.

rules governing order promising. Here, many of the master scheduling procedures described earlier have to be spelled out clearly: Exactly where will planning time fences be placed? What safety stock policy will be followed? Who has authority to make a change to the master schedule, and when?

Sales and operations planning has to be institutionalized in company operations, with a regular schedule of meetings, a slate of attendees, and general agenda. For years, the Oliver Wight Companies have recommended that regular sales and operations planning meetings begin several months prior to full implementation of Enterprise Resource Planning and Supply Chain Management, and the same advice applies here. This gives everyone a chance to develop the skills needed to hand the master scheduler a credible set of aggregate demand requirements and supply constraints.

Policies and procedures for master scheduling must be developed and disseminated to all who come into contact with the system. The following is just one example of a policy and procedure. The sample policy deals with a valid master schedule, while the sample procedure deals with treatment of action messages. The sample procedure provided is not intended to be complete, but merely to provide an example.

Master Schedule Procedure
Action Message Review

(A Sample)

Purpose: To establish a process that the master scheduler will follow to evaluate and initiate action as necessary after each master scheduling computer process run.

Scope: This procedure affects master scheduling, sales, marketing, manufacturing, material control, production control, purchasing, inventory control, and engineering.

Definition: An action or exception message is an action that the master scheduling software system recommends that the master scheduler execute in order to correct an imbalance in supply and demand. Action messages may also be generated because of a past-due condition.

References:
1. Master scheduler's position description
2. Master schedule policy covering valid schedules
3. Reschedule time zone policy

Exhibits:
1. Master schedule time-phased screen/report
2. Master schedule action screen/report

Procedure:

Responsibility	*Action*
Master Scheduler	1. Receives the latest master scheduling computer output (exhibit 1).
	2. Reviews action messages (exhibit 2).
	3. Determines which action messages require action.
	4. Asks the 6 questions to determine customer, market, material, capacity, and cost impact (reference 1).[5]

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[5] Refer to Chapter 4 for a review of the six questions.

	5. Determines appropriate changes to master scheduling within production plan guidelines (reference 2).
	6. Makes changes as necessary.
	7. Forwards change recommendations needing approval to approval authorities (reference 3).
Manufacturing Vice-president	8. Analyzes recommended changes to master schedule and supporting documentation.
	9. Approves or disapproves changes.
	10. Forwards change decisions to Sales Vice-president, if necessary.
Sales Vice-president	11. Determines if changes will satisfy customer requirements.
	12. Forwards approval or change recommendations back to Manufacturing Vice-president.
Manufacturing Vice-president	13. Forwards decision to Master Scheduler.
Master Scheduler	14. Receives decision; takes appropriate action.
	15. Informs appropriate parties when action is completed and what expected results will be.

Data Management

Like Enterprise Resource Planning and Supply Chain Management, master scheduling will not be successful in the absence of data, or in the absence of *accurate* data. For ERP and SCM purposes, data can be divided into two categories: forgiving data and unforgiving data. Forgiving data need not be extremely accurate; some margin for error is possible. From the master scheduling perspective, this includes lead times, safety stocks, order quantities, maximum capacities, and—of course—the demand forecast.

The unforgiving data can trip up SCM, ERP, and MPS without exception. This includes on-hand inventory balances, scheduled receipts, allocations (components reserved for scheduled receipts), product definition, process routings, and actual customer orders. Certainly, not all of these are the responsibility of the master scheduler, but without accuracy near 100%, the integrity of the company's game plan will come apart at the seams.

This is the point in the master scheduling implementation process where a number of activities must be spelled out in detail:

- The items to be master scheduled are identified. If the inventory records for these items are not up to Class A standards, the process of making them so must be implemented. The same applies to product definition for the master scheduling items.
- The structuring of Class A planning bills, if required, is now begun.
- The key resources needed for the engineering and manufacturing job ahead are identified so that resource profiles and rough cut capacity planning can be effectively done.
- The company's approach to forecasting demand must be examined and steps outlined to improve its accuracy.
- The work center database, including capacities of the key resources, must be defined and accuracy achieved.
- The models required to support advanced planning systems and finite capacity planning/scheduling must be identified, along with the necessary data.

Process Improvement

Back in the process definition box, where policy was developed, areas for process improvement were identified. At this point, detailed plans for making improvements in those areas are developed and assigned to individuals. For example, the use of kanbans may have been articulated in the process definition box as a company policy and procedure to be followed. Here, the means to execute that policy must be spelled out in detail. A policy dictating a kanban system would naturally require far-reaching process improvement in the manufacturing plant or mill. Changeover times, a matter of concern for the master scheduler, would need to be dramatically reduced. This would not happen by itself, but would succeed only with the help of a detailed plan for which some individual was made accountable.

Software

An effective master scheduling process requires software for five purposes: the master scheduling process itself, supply management, sales and operations planning, rough cut capacity planning, and customer order management. Some software packages can handle all five purposes. Some can do one function but not the others. In certain operations, sales and operations planning may be handled on a personal computer using off-the-shelf spreadsheet software, while the master schedule, rough cut capacity planning, and finite scheduling (if used) jobs are handled on the company's main computer.

The first step in implementing the software requirements of a master scheduling system is to actually determine those requirements. This may require the hiring of outside expertise. Once the right software is acquired, a period of training for operational personnel is required, as is a shakeout period in which the software is debugged and any needed customization takes place.

Stage 3: Launch and Cutover

A friend of mine tells the story of how he spent the better part of one Sunday connecting a new shower in his basement. First he turned off the main water line; then he cut into nearby hot and cold feeder lines

Who's in Control of the Software?

Many off-the-shelf software packages for both Enterprise Resource Planning and master scheduling offer a maintenance service that provides for the "care and feeding" of the current system with periodic enhancements as the software. This practice is commonplace in most sectors of the software industry and is provided at an additional charge.

While it is reassuring to know that the expensive software being purchased today is insured against obsolescence by such an offer, and that the company will be able to convert to the newer versions as they become available, a caution should be observed. *Reliance on an outside software supplier for so important a tool as manufacturing software is unwise.* Thomas Wallace makes this warning for MRPII software, and the same caution applies to ERP and MPS software. The dangers of this reliance are threefold:

1. In the fast-paced world of software development, your software supplier may not be in business tomorrow, leaving your company with a dead-end product.

2. Software firms may be committed to upgrading their products with new versions, but the timing of these improvements will be on their schedule, not yours. Thus, allowing an outside firm to control one of the most important management tools of your business is to allow an outsider to control the pace of your own continuous improvement. Management should never accede to that loss of control.

3. You cannot fully appreciate the capabilities, the limits, and the quirks of a software system if you do not fully understand how to alter and maintain it.

and, using a dozen or so copper elbows, Ts, and straight pipes, joined his new shower to the house water system. At 6:00 P.M. he soldered in the last connection using his very last piece of flux, then proudly surveyed all the bright new copper and the professional-looking fittings and angles that he—a mere amateur—had put together. After inspecting all the soldering work he called his wife from upstairs to observe the ceremony of turning on the new shower. He proudly turned on the main water valve and watched in disgust as fine streams of water sprayed out of at least half of his pipe fittings. The last of soldering flux being used up, and the hardware store being closed for the day, my friend shut off the main water valve. He would call a plumber in the morning. The family would have no running water until then.

My friend had done everything according to plan; he had even double-checked all of his fittings. Everything had seemed ready to go. But the only way to be sure was to actually turn on the water!

A company with fixed payroll expenses, customer promises to keep, and millions invested in plant and equipment cannot take a chance that its new operating system will spring a leak. Prudence dictates that any new system brought on line in a complex business cannot be adopted cold turkey but must go through a trial period in which the system is debugged and tried out. To fully cut over to the new process and computer system without this trial period would endanger the entire operation. This applies equally to a new telephone system, information system, Enterprise Resource Planning system, Supply Chain Management system, or master scheduling system. Stage 3 concerns itself with the final step in the implementation process—the switching on of the new policies and procedures of master scheduling.

Pilot and Cutover

There are three methods for switching on the new ERP and SCM system, and these apply as well to master scheduling:

1. *The cold-turkey approach.* Here, the old system is switched off and the new system is switched on. This is like jumping out of an

airplane with a parachute packed by several unknown people—not recommended.

2. *The parallel approach.* Here, the new system is operated off line, and its results and recommendations are compared to those of the existing system, which continues in operation. When the new system can consistently provide essentially the same information as the old system, the old system is shut down and the new one continues on line.

Problems with respect to the parallel approach are that (1) it is difficult to maintain and staff two different systems, and (2) the two process and computer systems should not be expected to be comparable in results. The old process and computer system are being phased out because their performance and output were inadequate. If we're upgrading our system, why would we want to duplicate the performance and output of the process and computer system we plan to retire?

3. *The pilot approach.* This is the application of the cold-turkey approach to a small part of the company, ideally in a highly controlled environment. Here, the new master scheduling process and computer system can be tried out and monitored closely without too much risk of damage to the overall operations of the business. If a company manufactured all sorts of writing instruments—ballpoint pens, felt-tipped pens, mechanical lead pencils, traditional wooden pencils, and so on—it might use its new master scheduling process and computer system strictly in the wooden pencil operations, where a failure would not throw a wrench into the other parts of the business. The pilot approach accomplishes a number of things:

- Policies and procedures developed earlier can be tried in a real-time live exercise (or live pilot).
- Personnel can learn to operate the system using company data.
- The hardware/software system can be tested and stressed in a live exercise (live pilot).
- Problems can be identified and resolved.

- The organization has an opportunity to gain confidence in the new system.
- Company personnel can be trained in a workshop environment once the pilot is up and running.

Of these approaches, the pilot approach is recommended for reasons that should be obvious. Once a pilot testing of the new MPS system has been made in one area of the total manufacturing operation, the next step is the cutover, in which the new master scheduling process and computer system totally displace the old.

A cutover can be accomplished in one stroke or by degrees. In a small operation, or one in which the results of a small pilot have been an overwhelming success, a total cutover may be feasible, but caution normally dictates a cutover *by degrees*—that is, the gradual extension of the pilot to other operations.[6]

Performance Measurements

As early as the evaluation and preparation stage, the implementation team for master scheduling develops a set of ideas about the kinds of goals that the new process and computer system should have. But goals by themselves are not helpful unless they can be rendered into specific measurements. No one can tell how they are doing—and certainly cannot measure progress—unless performance can be measured.

In developing a set of performance measures, a number of questions must be addressed:

- What is being measured?
- What is the purpose of the measurement?
- Who does the measurement affect?

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[6] Of course, the cutover plans of the ERP system and Operational Excellence project implementation really dictate when the master schedule portion of the system will be activated.

- Who is responsible for the measurement?
- What are the targets?
- How is performance calculated?
- What tolerances are acceptable?
- Where is the data source?
- How is the measurement data secured?

Once measurements have been established, operators must know what constitutes good and bad performance. This is accomplished by setting *performance targets.* For example, master schedule performance may be defined as follows:

- Minimum acceptable performance = 92%
- Satisfactory performance = 95%
- Outstanding performance = 99.5% or better

Percent of what, though? Here tolerances must be determined. For example, we could say that manufacturing produced items within certain tolerances would be a success. Thus, production of the master-scheduled item within ±2 days of scheduled completion date and ±4% of the scheduled quantities would be considered a hit or good. Production completions falling outside those specified ranges would be considered a miss or bad. If performance to the master schedule is 95%–100%, the company would be operating at a satisfactory or Class A level of performance (as defined in *The Oliver Wight ABCD Checklist for Operational Excellence,* 5th ed.). A recommended master schedule performance measurement definition is shown in Figure 17.6.

A good system of performance measurement carries with it requirements that trigger action any time that performance falls below specified levels. For example, any time the master schedule performance slips below minimum, the people with responsibility for master schedule performance—say, the master scheduler (input)

MASTER SCHEDULE

Purpose (Purpose of the Measurement)

To ensure that the company is maintaining a Class A level of performance to the defined master schedule.

Scope (Whom Does It Affect?)

The master schedule performance measurement affects manufacturing, capacity planning, material planning, engineering, inventory control, and master scheduling.

Definition (If Necessary)

The anticipated build plan by specific configuration, quantity, and due dates.

Responsibility and Accountability

Name:	Plant Input—Materials & Capacity	Name:	Plant Output—Product
Title:	Master Scheduler	Title:	Manufacturing Manager
Signature:	As Appropriate	Signature:	As Appropriate

Target Goals and Performance

Minimum	*Satisfactory*	*Outstanding*
92%	95%	99.5%

Calculation (Reporting)

$$\frac{\text{Actual Completions (within tolerance)} \times 100}{\text{Planned Completions (for week or month)}} = \text{Performance to Schedule \%}$$

Source of Data

Numerator: Manufacturing Completed Orders or Batches by Date (weekly)
Denominator: Master Schedule (Released Plus Firm Planned Orders)

Tolerance

Date: ± Days (e.g., 2 days early, no days late)
Quantity: ± Output % (e.g., 25 pieces or kilos more, 10 pieces or kilos less, or 3% over, 2% under the scheduled quantity).

Remarks or Comments

Notes for Communication Purposes.

Figure 17.6 Master Schedule Performance Measurements

and manufacturing manager (output)—would submit a written explanation of what went wrong and the corrective action taken; that explanation would be due on a manager's desk within approximately 48 hours.

This level of detail with respect to performance needs to be developed before the pilot and cutover take place—back in the process definition phase. But the performance plan should be revisited here even as the pilot and cutover are taking place. Performance to the master schedule notifies management just how well the pilot is performing and where corrective interventions may be required. As cutover to the new MPS system is completed, performance measures become matters of ongoing importance to the operation and continuous improvement of the master scheduling process.

Audit/Assessment II

Once the master scheduling process and system are up and running, the company and its management team need to determine what is working and what is not. Comparison of performance results to the expected performance goals that were established in Audit/Assessment I is now done. Questions are asked: "Are we better off ?" and "Where do we go from here?" Typical answers are "On to the path of continuous improvement" and "Let's do more!" Many executives believe that this is the most important part in the entire process. Certainly, it is a very important ingredient for success.

Education Never Quits

The final element of the launch and cutover stage is ongoing education. Just as the modern manufacturer understands that the road to success is paved with continuous process improvements, individuals close to the field of master scheduling understand that knowledge and operational competence are among those important processes. The Class A master scheduling company maintains an ongoing education program that continues to develop more master scheduling organizational expertise. This is done through outside-sponsored seminars, web-based education sessions, computer-based education programs, internal business meetings, books, articles, certification programs, and general master scheduling meetings. Of course, education and improvement never stop in a Class A company!

Deterrents to Successful Implementation of the Master Scheduling Process

Not every attempt to implement master scheduling will be successful. Fewer still will succeed in reaching Class A status. These are some of the typical problems that get in the way:

- *Ignorance.* People do not know how to do things right because they do not understand the principles and the details of master scheduling. The antidote: *Educate key people.*

- *Not all of the important people are on board.* It is easy to believe that master scheduling is only a production issue. But if sales and marketing people do not understand the issues involved, and if they do not participate in the supply management, demand management, and sales and operations planning process, problems with demand, plant overloading, overpromising, and so forth will persist. Solution: *Get marketing and sales involved.*

- *Do sales and operations planning early.* This is where the executive team gets into the game. Master scheduling is absolutely reliant upon early sales and operations planning, and the early involvement of the leaders in this process sends a clear signal to the rest of the company that it means business. Recommendation: *You cannot start soon enough.*

- *Improve rough cut capacity planning.* This is a quick sanity check on the demand plan, supply plan, and production plan, as well as the master schedule, and prevents an unrealistic master schedule from getting into the plant. *Start rough cut capacity planning this coming Monday.*

- *Unload the overloaded master schedule.* If a friend asked your advice about learning how to swim, you would not suggest that he start by putting on a 10-pound weight belt and jumping into a fast-moving river. This would only lead to disaster. Your friend would do better to start with the least encumbrance and in a calm pool. Nevertheless, many master scheduling implementation programs start with schedules that are so overloaded and overpromised that they quickly sink and never come up for air. Word to the wise: *Give your new process and computer system every opportunity for success by starting with a clean slate.*

- *Clarify organizational responsibilities.* Many failures can be traced to the simple problem of key people not understanding their responsibilities. *Be sure that everyone understands the goal and his or her part in reaching it.*

- *Document policies and procedures.* Each policy, procedure, and instruction should be written; their implementation should be followed and enforced. Needed: *A list of required policies and procedures, assignments, expected completion dates, and execution.*

- *Measure performance.* Performance measurement is one key to success. The measurements themselves must be clearly defined so that everyone understands them. Advice: *Use master schedule performance measurements as an improvement tool, not as a report card.*

The Master Scheduler's List of Responsibilities

It is only fitting that this chapter on effective implementation (indeed, the entire book) should end with some discussion of the individual at the center of the process: the master scheduler. In the end, he or she must implement the policies and procedures that the president, various vice presidents, controller, sales director, and others had a hand in crafting. It is the master scheduler who must be the artful leader and manager, responsible on a daily basis for the fine balance between what the customers have ordered and what the company can deliver. If the responsibilities of this position were distilled into a list of responsibilities, they would appear as follows:

Master Scheduler Position Description

Objective

Create and maintain a valid master schedule for material and capacities by effectively balancing supply and demand for product. A valid master schedule is one in which priority due dates equal need dates, and planned capacity equals required capacity.

Responsibilities

Develop a working knowledge of the company's products and processes to ensure optimal master schedule stability, order creation, rescheduling, load-leveling, etc.

Analyze the demand and supply balance at the product family and master schedule levels, determining out-of-balance conditions, identifying alternatives, and recommending action for approval.

Work with sales, marketing, and manufacturing to better understand competitive lead times for master scheduled items. Seek ways to reduce internal lead times as well as lead times to the customer.

Challenge current manufacturing strategies for all product lines to be sure that the best and most customer-oriented strategy is being used. Look for ways to move the company to make-to-order manufacturing.

Conduct rough cut capacity planning prior to publishing a master schedule in which significant changes have occurred.

Summarize daily and weekly master schedules for released and firm planned orders and compare these to the production plan to ensure that the master schedule is within S&OP policy.

continued on next page

Work within policy guidelines pertaining to master scheduling. Observe and follow all stated master scheduling procedures.

Respond in a timely manner to significant action messages generated by the master scheduling software.

Act as internal educator and consultant on master scheduling issues, providing education and training throughout the company to improve company-wide understanding of master scheduling functions.

Identify, negotiate, and resolve conflicts with respect to material and capacity availability and order-promising integrity.

Maintain a master schedule following the company policy of permitting no master schedule item to have a released or firm planned order date less than the current date (no past dues at the master schedule level).

Create a monthly financial summary of overplanned stock to ensure that it is within budget. Integrate master scheduling with other company functions.

Maintain planned scheduling parameters, such as lead times, lot sizes, safety stocks, delivery times, and order file data for all master scheduled items.

Review each master scheduled item at least weekly.

Create a master schedule that satisfies customer demand with optimum inventory levels and resource utilization as dictated by company policy.

Ensure that a common master schedule is used to drive all company priorities in manufacturing, marketing, sales, engineering, and finance.

Create a master schedule that can be used for detailed material/capacity planning as well as financial planning. Master scheduling operational data should be the basis of a single set of books.

Establish a working line of communication with all company functions.

Assist demand management in setting priorities when demand outstrips the company's supply of products or the resources necessary to build the requested product.

Maintain planning bill structures, as required, however *not* responsible for mix factors, which belong to marketing and sales.

Inform management when demand cannot be met and recommend alternatives on how the requested demand could be satisfied.

Create a master schedule that levels work being released to manufacturing and at the same time satisfies customer demand.

It takes an extraordinary person to meet the requirements of this position description, but these challenging duties merely underscore the importance of effective master scheduling to the business success of a manufacturing organization.

Epilogue

Order from Chaos

May the best day of your past be the worst day of your future.

This book began with a parable about a manufacturing company whose production floor on the last business day of the month was out of control. Partially completed products waited on skids for delayed material. Frustration and frayed nerves were commonplace among managers and associates. Customers were calling to complain about late shipments. Expediters ran around the plant with hot sheets. Instead of being channeled into problem resolution and customer-oriented production, the company's energy was being dissipated through finger pointing and internal conflict.

"Is this the manufacturer from hell?" some might ask. Hardly. It is symptomatic of too many manufacturing situations today. Hopefully, this nightmarish parable will become a quaint fairy tale, an artifact of the industrial past, as master scheduling practices become more professional and as those practices diffuse through the industry. In the case of our fictional company, we can hypothesize that change will eventually come because the company could not survive and prosper if it did not.

The Place: The executive vice president's office in a typical North American manufacturing company

The Time: 9:00 A.M.

The Date: The first day of a new month

Present: The plant manager, the sales director, the manufacturing vice president, and the executive vice president

"I've had enough of this!" exclaimed the executive vice president. "And I hope that you've had enough of it, too. I am sick and tired of what we went through the other day. What we have on our hands is a situation in which we are incurring higher costs, production disruptions, and frayed nerves." The others in the room nodded their agreement. "Worse, there seem to be no winners for all this trouble on our manufacturing floor. Everyone is the loser!"

"It's starting to hurt us in the field, too," the sales director interjected. "I got a call from one of our better Florida accounts warning me that one more late shipment and they'll find a new supplier."

"I agree," said the manufacturing vice president. "Something has to change. Our people on the line are tired of every week and every month being a race against the clock, of stealing parts from one order to take care of another. It's getting hard to hold on to our best people and harder to motivate the rest."

"Then change is the thing, isn't it?" said the plant manager. "Something has to change. Something fundamental. We need to see a change in the way our plant looks and acts. No more queues, no more hot lists, no more stockouts or late deliveries. It's my responsibility to ensure that my team makes it happen."

Few companies undertake fundamental change as a natural step in the road to progress. It usually takes some extraordinary event, such as the threat of failure, to motivate the leadership to undertake a serious campaign of change. Ford Motor Company and Xerox Corporation underwent a course of internally generated change in the period

1978–1983 because both sensed that they were in a serious downward trajectory in their respective industries. General Motors, IBM, and DEC faced the same stage of awareness and change in the mid-1990s. And more companies have decided to change the way that they plan and control demand and supply in the twenty-first century. Our fictional company appears to have reached the point where something like a deathbed conversion is taking place with respect to its manufacturing.

If we were to fast-forward in time, we might see this company entering that period of self-assessment that leads to the effective implementation of a master scheduling program, as laid out in this book. Over a period of 6 to 12 months, the company would develop the internal competencies and sets of guidelines that make a full changeover to master scheduling possible. From that point, through a period of adjustment and improvement, the company would experience steady incremental increases in manufacturing efficiency as measured by the absence of production-floor disruptions, delayed shipments, hot lists, past dues, the dreaded end-of-the-month crunch, and the other ills that motivated the plant manager to recommend a course of change.

The ills of the past would eventually be replaced by the rewards that accrue to a Class A manufacturing and/or service company, the foremost of these being measurable improvements in profits and associates' morale and high levels of customer satisfaction.

Appendix A

Class A Master Scheduling Process and Performance Checklists

Nothing is worse than ignorance in action.

The Oliver Wight ABCD Checklist for Operational Excellence was published to help companies become the best they can be in operations planning and execution. Being the best of the best is what Class A is all about. Many companies take pride in achieving Class A status and the results that come along with this lofty accomplishment. Most companies that attain Class A status tend not to be completely satisfied, however. In fact, they tend to become more aggressive in pushing forward, knowing they can do even better. "Yes, we are good and probably better than our competition, but we all know that we can be even better with just a little more effort" is a comment commonly heard from Class A companies. Responding to this need, the Oliver Wight Companies created *The Oliver Wight Class A Checklist for Business Excellence* (discussed later in this appendix).

While the *ABCD Checklist for Operational Excellence* was written to address the larger concern of modern manufacturing, it does contain a section on master scheduling and its related disciplines. The criteria in that section can be pulled together and addressed to determine where a company stands in terms of Class A master scheduling processes and performance. The criteria related to master scheduling are shown in this appendix.

MASTER SCHEDULING AS PART OF OPERATIONAL EXCELLENCE

The master scheduling process is perpetually managed in order to ensure a balance of stability and responsiveness. The master production schedule is reconciled with the production plan resulting from the sales and operations planning process.

a Accountability for maintaining a valid master schedule is clear. The importance of master scheduling is reflected in the organization and reporting relationship within the company.

b The master scheduler (supply manager) understands the product, manufacturing process, and purchasing process, as well as the planning and control system.

c A formal job description exists that details the responsibilities and performance measurements for the master scheduling/supply management function.

d The master scheduler participates in and provides important detail information to the sales and operations planning process.

e The master scheduler responds to feedback that identifies areas where the master schedule impacts material and/or capacity availability by initiating problem-resolution action.

f The master scheduler has empathy for customers, sales, and marketing while being sensitive to manufacturing and supplier objectives and constraints.

g The master schedule takes into account all demands, including forecasts, contracts, customer orders, samples, specials, prototypes, spares, interplant, etc. The master schedule directs and drives all manufacturing, purchasing, and manufacturing related engineering activities.

“Master Scheduling as Part of Operational Excellence” checklist items were taken directly from *The Oliver Wight ABCD Checklist for Operational Excellence,* 5th ed. (New York: John Wiley & Sons, 2000).

h The master scheduler is notified of all abnormal demand entering the planning and control system. Since abnormal demand may be incremental to the expected demand, appropriate action is taken to ensure total customer satisfaction and support the business strategy, not just identification of the abnormal demand order.

i The system has a firm planned order (FPO) capability that is used to take control of the master schedule covering the horizon within the planning time fence (PTF).

j A formal process is in place that defines how planning bills (if appropriate) are used to plan material and capacity as well as to direct the finishing/final assembly operations.

k Planning bills of material (if used) are maintained jointly by master scheduling, demand management, sales, and marketing.

l A written master schedule policy is followed to monitor stability and responsiveness; goals are established and performance is measured.

m The master schedule is "firmed up" over a sufficient horizon to enable stability of operations. Guidelines for this firmed horizon include: cumulative material and manufacturing lead time, lead time to plan and adjust capacity, and lead time to establish and maintain supplier agreements.

n Master schedule changes within the planning time zones are managed; changes are authorized by the appropriate people, measured, and reviewed for cause.

o Policies govern the use of safety stock and/or option overplanning when used to increase responsiveness and compensate for inconsistent supply and/or demand variations.

p Available-to-promise (ATP) information is monitored for completeness and accuracy. The use of ATP is governed by a written policy and not violated except when approved by top management.

q The master schedule is summarized appropriately and reconciled with the agreed-to production rate (production plan) from the sales and operations planning process.

r No items on the master schedule are past due. The master scheduler and other affected company personnel recognize that an item cannot be manufactured, purchased, or shipped in past time periods.

s All master schedule exception-driven action messages are reviewed, analyzed, and acted upon at least weekly.

t The master schedule is expressed in weekly, daily, or smaller time periods. It may be work order or rate based and is replanned at least weekly.

u There is a defined process to determine what levels in the product structure are to be master scheduled. Criteria such as customer expected lead times, willingness to invest in capacity, desired production flexibility, priority control, and marketplace demands are all taken into account during the selection process.

v The alternative approaches used with planning bills to develop option and production forecasts for master scheduled items are well understood and an appropriate process is used to maintain them.

w Rough cut capacity planning, or its equivalent, is used to evaluate the impact of significant master schedule changes on critical resources. Planned capacity is compared to required capacity and appropriate adjustments are made to ensure a balanced capacity plan and master schedule.

x A finishing/final assembly mechanism or kanban approach is integrated with the master schedule to ensure orderly transition from planning to execution (control). The finishing process guides customer orders or finished goods replenishments to completion.

y A weekly master schedule communications meeting exists and is attended by all affected functions.

z When applicable, the linearity or levelness of output is measured; the graphic illustration of results should reflect weekly or daily performance to a planned linear output; reasons for deviations are highlighted with appropriate analysis.

Working in conjunction with the master scheduling processes defined above, a Class A company in master scheduling must satisfy the performance measurement directly related to master scheduling. The master scheduling performance measurement states that accountability for master scheduling has been established and the goals and method of measurement agreed upon. The performance criteria further state that all goals, metrics, and performance results are communicated to appropriate company functions. Master schedule performance must be 95%–100% of the plan. Graphs or charts showing actual performance versus planned performance are maintained along with the appropriate analysis, highlighting the primary causes of all deviations from established and management approved tolerances.

MASTER SCHEDULING AS PART OF BUSINESS EXCELLENCE

The Oliver Wight Class A Checklist for Business Excellence takes on a new format and broader scope than the Operational Excellence volume. The checklist is now about business, whether it be manufacturing or service. Although past users of the Oliver Wight Checklists may find this one different, the main features remain unchanged. The checklist is direct and practical. The contents of the checklist are not theoretical, but rather a collection of best practices that really good companies do every day.

The chapters are divided into two parts: those processes and practices that are common throughout the entire business, and those that enable the entire business to be successful. Following are the nine chapter titles (master scheduling is addressed in "Managing Internal Supply"):

- Managing the Strategic Planning Process
- Managing and Leading People

"Master Scheduling as Part of Business Excellence" checklist items were taken directly from *The Oliver Wight Class A Checklist for Business Excellence,* 6th ed. (New York: John Wiley & Sons, 2005).

- Driving Business Improvement
- Integrated Business Management
- Managing Products and Services
- Managing Demand
- Managing the Supply Chain
- Managing Internal Supply
- Managing External Sourcing

As stated, master scheduling is addressed in the "Managing Internal Supply" chapter. Today's business is focused on improving the supply chain, from customers to suppliers. However, a company will serve itself well if it gets its own house in order before worrying about the outside. Since this book covers master scheduling, let's take a more detailed look at the contents of "Managing Internal Supply."

The "Managing Internal Supply" chapter is divided into 10 subjects, one of which is master supply planning. The master supply planning section is supported by two definitions and several topics. The two definitions, along with their related topics, are shown in the following list (definitions and topics are taken directly from the *Oliver Wight Class A Checklist for Business Excellence*):

- A master supply planning process exists to ensure completeness and management of internal supply.
    - The Supply Planner—The supply planner manages the plan to ensure that commitments to customers are met in full and to optimize both inventory and the efficiency of the business. The supply planner operates within current policies and is a major contributor to their improvement.
    - Plans—Demands are considered in the master supply plans, which drive all supporting supply plans. The master supply plan at an appropriate level of detail extends over the Integrated Business Management horizon, allowing sufficient visibility to incorporate future requirements.
    - Strategies and Tactics Creating Valid Plans—There is an intense focus on creating and delivering valid plans that are aligned with strate-

  gies and derived from tactics. The plans are customer focused and integrated, and utilize appropriate management and planning techniques.

  - Rough Cut Capacity Planning—A formal process defines key resources and indicates their criticality to changing business conditions. Critical resources are managed, and goals are set to optimize those resources, both internal and external.

  - Systems, Tools, and Data—Required systems and tools are provided, fully understood, and operated by educated and trained people. These tools are fully integrated and can be operated at various levels of detail, over varying time frames. Employees routinely seek opportunities to improve the use of planning tools and techniques and are confident that data are accurate.

  - Planning and Scheduling Techniques—The planning process provides clear direction on appropriate planning and scheduling techniques and the setting up and use of key planning parameters and rules, all of which are clearly understood and formally applied. Decision support tools and advanced planning systems are applied where appropriate.

  - Manage the Master Supply Plan—The master supply plan is established to enable management by exception across the entire cumulative lead time and at the appropriate level of detail. Planners' activity is driven from system-generated action messages that are prioritized, reviewed, and resolved in a timely manner.

- Capable people are managing all supply plans, including logistics planning.

  - Planner Competence and Accountability—Those responsible for planning and scheduling are educated and trained to operate at best-practice standards. They understand supply and material processes and systems and are held accountable for creating and maintaining valid plans to support business goals. Planners are responsible for creating, maintaining, reviewing, and analyzing the validity of planning parameters and rules.

  - Managing Change with Time Fences—Time Fences have been identified, recognized, and actively used to manage change. Supplier time fences are known and rules are recognized, to ensure that promises or changes are not made that cannot be honored. Processes are in place to actively reduce lead times and to align time fences with greater business agility.

- What-If Analysis and the Impact of Change—Requests for change are modeled within the formal planning and scheduling system to determine their overall effect, such as their impact on customer service, all supply plans, and costs.
- Driving Improvements—Those responsible for planning and scheduling understand performance measures and proactively use root-cause analysis to identify improvements opportunities. Challenging the status quo is common behavior, with documented improvements in many areas, such as reduced lead times, order quantities, and reduced reliance on safety buffers.
- Policies, Process, and Procedures—Formal documentation addresses all policy, process, procedure, and work instructions requirements for supply planning and scheduling. The planning process is not reliant on key individuals whose absence may inhibit best practice and attaining excellent results.

As with the *Oliver Wight ABCD Checklist for Operational Excellence,* standards have been set for performance in supply planning and execution. The standard for each performance measurement is either upper quartile, a minimum standard of 99.5%, or attainment of business plan. The two main performance measurements related to master scheduling are customer service (on-time delivery to promise) and aggregate supply plan (achievement of the supply plan approved through the Integrated Business Management process).

Appendix B

Master Scheduling Sample Implementation Task List

Task Number	Task Description	Responsibility	Commence	Complete
010	Project Administration in Place			
020	Process Owner Identified			
030	Process Operator Identified			
040	Process Operator in Place			
050	Create Master Scheduling (MPS) Team Reference Binder			
060	Master Scheduling Team Formed			
070	Select Subteam Members			
080	Subteam Members in Place			
090	Team Roles and Responsibilities Defined			
100	Team Roles and Responsibilities Assigned			
110	Weekly Meeting Scheduled			
120	Master Scheduling Team Charter			
130	Identify Tasks			
140	Identify Deliverables			
150	Write Charter			
160	Charter Approved			
170	Assess Master Scheduling Using Checklist			
180	Assessment One Report			

Task Number	Task Description	Responsibility	Commence	Complete
190	Assessment Review			
200	First-Cut Education			
210	Integrated Supply Chain Management Course			
220	Key Influencers to Master Scheduling Course			
230	Vision Statement for Master Scheduling			
240	Affinity Process Session			
250	Create Vision for Categories Identified			
260	Rework Individual Visions			
270	Tie Vision for Master Scheduling Together			
280	Final Draft of Master Scheduling Vision			
290	Submit Vision to Management			
300	Rework Vision with Management Feedback			
310	Resubmit Vision for Management Approval			
320	Publish Master Scheduling Vision			
330	Benefits Statement			
340	List of Benefits Developed			
350	Benefits Statement Draft			
360	Master Scheduling Task Team Discussion			
370	Benefits Statement Final Draft			
380	Submit Benefits Statement to Management			
390	Rework Benefits Statement with Management Feedback			
400	Resubmit Benefits Statement for Management Approval			
410	Publish Benefits			
420	Performance Goals and Measurements			
430	List of Accuracy and Performance Goals Developed			

Task Number	Task Description	Responsibility	Commence	Complete
440	Measurements Defined			
450	One-Page Definition Documents Created (One-Pagers)			
460	Master Scheduling Task Team Discussion			
470	One-Pagers Final Draft for All MPS Goals and Measurements			
480	Submit One-Pagers to Management			
490	Rework One-Pagers with Management Feedback			
500	Resubmit One-Pagers for Management Approval			
510	Publish One-Pagers			
520	Initial Education and Training			
530	Master Scheduling Education Workshop			
540	Supply Chain Management Library Established			
550	Determine How Mass Education Will Be Done			
560	Education/Training Plan Created			
570	Education/Training Plan Approved			
580	Session Schedule Created and Approved			
590	Broadcast of Education and Training Sessions			
600	Sessions Run (Education and Training)			
610	Attendance Documented			
620	High-Level Design			
630	Mindmap Master Scheduling Process			
640	Create Design Document Using Mindmap (MPS)			
650	Mindmap Rough Cut Capacity Process			

Task Number	Task Description	Responsibility	Commence	Complete
660	Create Design Document Using Mindmap (RCCP)			
670	Education for MPS Team on Flowcharting			
680	Flow Diagram Master Scheduling Process			
690	Create List of Policies Required			
700	Create List of Procedures Required			
710	Identify Main Reporting Requirements			
720	Highlight Master Scheduler's Responsibilities			
730	Glossary of Master Scheduling Terms Created			
740	Integrate Assessment, Vision, Benefits, Organization,			
750	Goals, Measurements, Education, Training, Mindmaps,			
760	Flow Diagrams, Policies, and Procedures into Master			
770	Scheduling High-Level Design			
780	Submit to Project Team for Feedback			
790	Rework High-Level Design with Project Team Feedback			
800	Prepare High-Level Design Presentation			
810	Present High-Level Design to Management			
820	Document Management Feedback from Presentation			
830	Create Action Plan for Management Feedback			
840	Secure Management Approval to Move to Detailed Design			
850	Detailed Design			

Task Number	Task Description	Responsibility	Commence	Complete
860	Identify Master Scheduling Process Flows Required			
870	Create Detailed Process Flows			
880	Update List of Policies and Procedures Required			
890	Assign Responsibilities for Policies and Procedures Creation			
900	Identify Policy and Procedure Format to Be Used			
910	Write Key Policies (See List in Effective Implementation Chapter)			
920	Submit Key Master Scheduling Policies to Management			
930	Rework Policies with Management Feedback			
940	Resubmit Policies for Management Approval			
950	Identify Key Decisions That Need to Be Made			
960	Integrate Vision, Organization, Measurements, Flow Diagrams,			
970	Policies, Procedures, Decisions Needed, and Implementation			
980	Implications into Master Scheduling Detailed Design			
990	Submit to Project Team for Feedback			
1000	Rework Detailed Design with Project Team Feedback			
1010	Prepare Detailed Design Presentation			
1020	Present Detailed Design to Management			
1030	Document Feedback from Presentation			

Task Number	Task Description	Responsibility	Commence	Complete
1040	Create Action Plan for Management Feedback			
1050	Secure Management Approval to Move to Analysis Work			
1060	Determine What to Master Schedule			
1070	Review Typical Product Profiles			
1080	Discuss Where to Meet the Customer			
1090	Generate Indented Bill-of-Material (BOM) for Pilot Product Family			
1100	Add Lead Times to Indented Bill-of-Material (BOM)			
1110	Create Time-Phased Bill-of-Material			
1120	Secure Customer and Marketplace Lead Time Expectations			
1130	Overlay Customer/Marketplace Expectations on Indented BOM			
1140	Identify Point on Indented BOM to Meet the Customer			
1150	Define What to Master Schedule for Pilot Product Family			
1160	Repeat Steps Above for All Product Families			
1170	Master Scheduling Preparation			
1180	Assign the Master Scheduler(s)			
1190	Define Roles and Responsibilities of the Master Scheduler			
1200	Determine Planning Horizon Length			
1210	Determine Master Scheduling Period (Bucket) Size			
1220	Identify Where to Place the Planning Time Fence (by Item)			

Task Number	Task Description	Responsibility	Commence	Complete
1230	Assign Responsibility for Maintaining Planning Time Fence			
1240	Determine How to Use Firm Planned Orders (FPOs)			
1250	Create Planning Bills to Support Disaggregation of Product Families			
1260	Develop Long-Term MPS Requirements for Software			
1270	Complete Policies Creation			
1280	Submit All Policies to Management			
1290	Rework Master Scheduling Policies with Feedback			
1300	Resubmit Policies for Management Approval			
1310	Publish Master Scheduling Policies			
1320	Write All Procedures Identified in Design Documents			
1330	Submit to Project Team for Feedback			
1340	Rework Procedures with Project Team Feedback			
1350	Submit Procedures to Management for Approval			
1360	Publish Master Scheduling Procedures			
1370	Educate and Train Personnel on Policies and Procedures			
1380	Data Integrity			
1390	Create List of Planning Parameters Used in Master Scheduling			
1400	Assign Responsibility for Data Cleanup			
1410	Clean Up Database Planning Parameters (Lead Times, Lot Sizes, etc.)			

Task Number	Task Description	Responsibility	Commence	Complete
1420	Print Report Showing Changes			
1430	Review All Changes Made to Database			
1440	Update Database Parameters as Required (Based on Review)			
1450	Database Ready for Use			
1460	Audit Bills-of-Material for Accuracy (Sample Size)			
1470	Audit Planning Bills for Accuracy (Sample Size)			
1480	Bills-of-Material Data Base Ready for Usage			
1490	Cycle Count Inventory (Master Scheduling Items Sample)			
1500	Audit MPS Finished-Goods Locations			
1510	Inventory Records Database Ready for Use			
1520	Software Selection for Master Scheduling			
1530	Complete Software Requirements Document			
1540	Review and Critique Master Scheduling Software Solutions			
1550	Select Master Scheduling Software (if Required)			
1560	Information Technology Computer Pilot			
1570	Conversion Checklist Defined and Delivered			
1580	Identify All Systems That Need Interfaces			
1590	Create All Interfaces/Conversion Tools			
1600	Interface Architecture and Methodology Complete			
1610	Interfaces Developed and Delivered			

Task Number	Task Description	Responsibility	Commence	Complete
1620	Master Scheduling Software Tool Configuration Complete			
1630	Master Scheduling Hierarchy Designed			
1640	Master Schedule Linked to Sales and Operations Planning (S&OP) Process			
1650	Product and Materials Configured			
1660	Running the Computer Test System			
1670	Input Planning Bills into Master Scheduling System			
1680	Create Master Schedule for Test Product Family			
1690	Run Test Case Using Planning Bills			
1700	Document Results from Test			
1710	Enter Customer order(s)			
1720	Determine Forecast Consumption Rules to Use			
1730	Review Forecast Consumption Results			
1740	Determine Available-to-Promise (ATP) Rules to Use			
1750	Update Available-to-Promise (ATP) and Check Results			
1760	Document Results from Test			
1770	All Policies and Procedures in Place (Checkpoint)			
1780	All Personnel Trained on Policies, Procedures, and System (Checkpoint)			
1790	Additional Preparation			
1800	Determine Safety Stock Level (Work with Demand Management)			
1810	Input Safety Stock Levels by Item Number into System			
1820	Use Planning Bills to Create Unit Demand at the Master Schedule Level			

Task Number	Task Description	Responsibility	Commence	Complete
1830	Tie Master Schedule to Sales and Operations Planning Output			
1840	Create Program to Aggregate MPS and Tie to S&OP Output			
1850	Tie Master Schedule to Demand Management			
1860	Tie Master Schedule to Detailed Daily Plant/Mill Schedule			
1870	Finalize ATP Rules to Be Used			
1880	Finalize Forecast Consumption Rules to Be Used			
1890	Scheduling in MPS Software Tool Configuration			
1900	Testing Procedures and Guidelines Available			
1910	Changes Requested as Needed			
1920	Modify MPS Software as a Result of Computer Pilot Test			
1930	Conference Room Pilot			
1940	Master Scheduling Process Modeled in MPS Software			
1950	MPS Software Refined as Necessary			
1960	Reports/Screens Modified, if Necessary			
1970	Task Team Ensures Process Is Working			
1980	Model Is Demonstrated to Broader Group			
1990	Testing Is Complete			
2000	Modify Model as a Result of Testing			
2010	Conference Room Pilot Is Complete			
2020	Update Implementation Plan			
2030	Refine Implementation as Necessary			
2040	Accountability for Scheduling System Assigned			

Task Number	Task Description	Responsibility	Commence	Complete
2050	Software Tool Training Program			
2060	Master Scheduling Software Overview to All Users			
2070	Master Scheduling Software Detail to All Key Users			
2080	Live Pilot and Cutover			
2090	Cutover Date Established and Approved			
2100	Go/No-Go Checklist Reviewed			
2110	Commence Scheduling with Pilot Items			
2120	Pilot Results Reviewed			
2130	Process Modifications Made as Necessary			
2140	Live Pilot Is Complete			
2150	Cutover All Products to New Master Scheduling Processes			
2160	Information Technology Support for Users as Required			
2170	Cutover Remaining Performance Measurements			
2180	Post-cutover Analysis			
2190	Master Scheduling Is Driving Material Planning and Production			
2200	Available-to-Promise (ATP) Is Functioning			
2210	Master Scheduling Is Running within S&OP Policy			
2220	Assess Master Scheduling Using Checklist			
2230	Self-Assessment Using Oliver Wight Class A Checklist			
2240	Weaknesses of Processes Identified			
2250	Process Improvements in Weak Areas			
2260	All Processes Are Strengths			
2270	Audit Shows Class A Results			

Task Number	Task Description	Responsibility	Commence	Complete
2280	Oliver Wight Class A Audit of Master Scheduling			
2290	Class A Achieved for Master Scheduling Portion of Checklist			

Appendix C

Master Scheduling Policy, Procedure, and Flow Diagram Listing

POLICY LISTING

Abnormal Demand
Abnormal Supply
Available-to-Promise (ATP)
Booking Customer Orders
Changing the Master Schedule (Approvals)
Class A in Master Scheduling
Communications with Master Scheduler
Customer Service Levels
Data Accuracy Requirements
Determining the Manufacturing Strategy (Product Family and Item)
Demand Time Fence
Dollarizing the Master Schedule
Education and Training Requirements
Exception Driven Action Messages (Working)
Inventory Levels
Master Scheduling Overall
Overplanning the Master Schedule
Past Dues (Handling of)

Performance Reporting
Planning Bills (Use of)
Planning Time Fence
Planning Time Horizon
Rough Cut Capacity Planning
Safety Stocks (Establishing the Level)
Tying Master Schedule to Detailed Production Schedule
Tying Master Schedule to Production Plan (S&OP Output)

PROCEDURE LISTING

Assessing the Master Scheduling Process
Booking Customer Orders
Communicating Changes to/from Master Scheduler
Creating a Planning Bill
Determining Manufacturing Strategy by Product Family and MPS Item
Establishing and Maintaining Demand Time Fence
Establishing and Maintaining Planning Time Fence
Establishing/Changing Inventory Targets
Establishing/Changing Safety Stock Levels
Handling Abnormal Demand
Handling Abnormal Supply
Making Promises to Customers Using ATP
Releasing the Master Schedule
Reporting Performance to Master Schedule
Requesting Changes to Master Schedule
Requesting Education and Training
Rescheduling Past Due Work
Running Rough Cut Capacity Planning (RCCP)
Running the Master Schedule
Setting/Changing the Planning Horizon
Summarizing/Comparing Detailed Production Schedule to Master Schedule
Summarizing/Comparing Master Schedule to Production Plan
Working System-Generated Action Messages

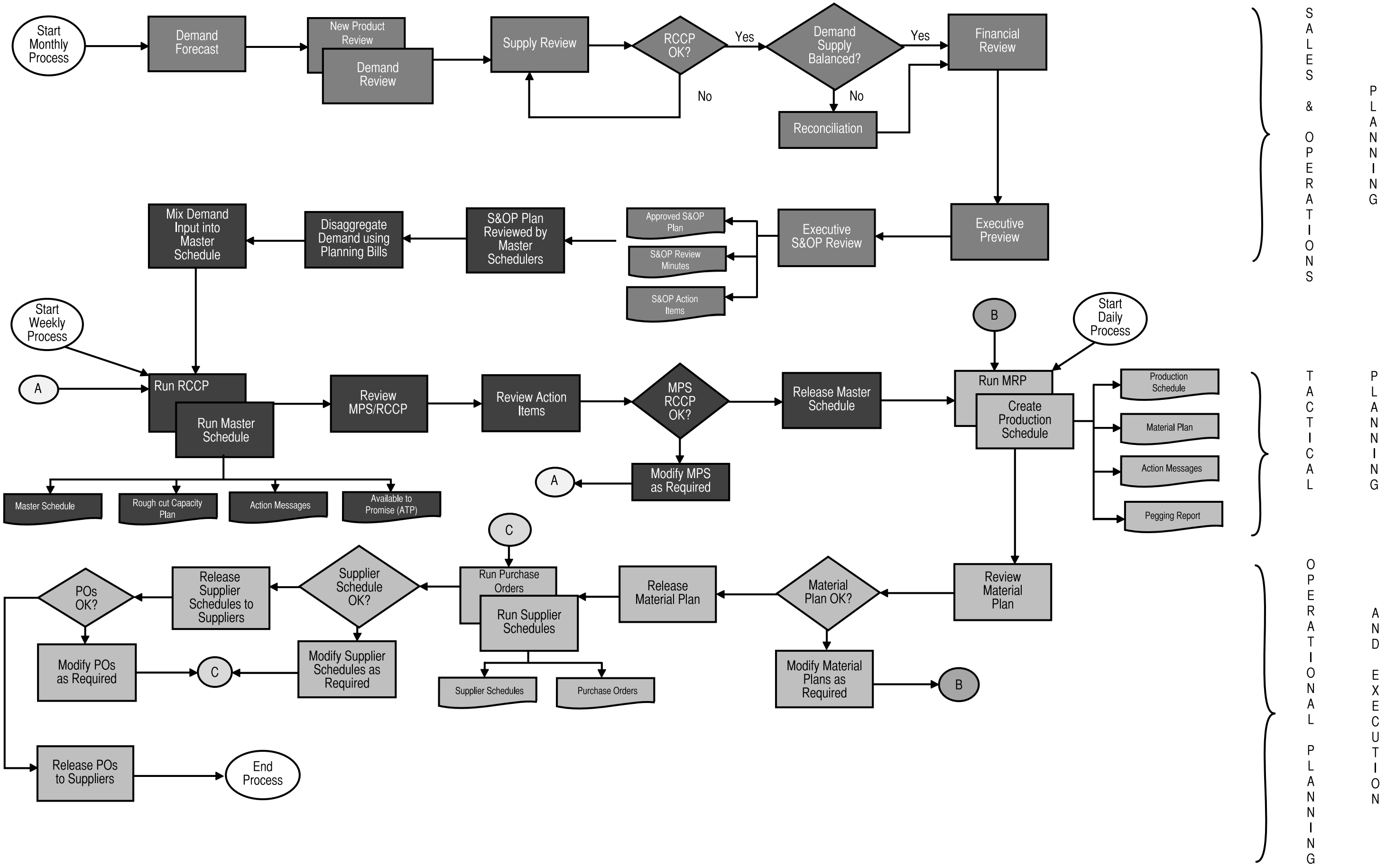
FLOW DIAGRAM LISTING

Abnormal Demand (Handling)
Action Message Review (Continuous)
Available-to-Promise (Using to Promise Customer Deliveries)
Forecast Changes (Channel of Communications)
Inputs to Pre-S&OP Process
Master Schedule Main Flow (Continuous)
Master Schedule Monthly Process
Master Schedule Weekly Process
Past Dues (Rescheduling)
Recording and Publishing Performance Metrics
Receiving Requirements from Supply Management
Updating System with Forecast

Appendix D

Master Scheduling Sample Process Flow Diagram

Here is an example of an integrated demand-driven supply management process flow that highlights the master scheduling process and its integration points. The diagram was put together with the help of Jimmie White, Class A ERP Project Leader and Materials Manager for a West Coast company. Both Jimmie and the author hope that this diagram helps the reader understand where master scheduling fits into the total demand and supply planning process.


Start Monthly Process
Demand Forecast
New Product Review
Demand Review
Supply Review
RCCP OK?
Yes
No
Demand Supply Balanced?
Yes
No
Reconciliation
Financial Review
Executive Preview
Executive S&OP Review
Approved S&OP Plan
S&OP Review Minutes
S&OP Action Items
S&OP Plan Reviewed by Master Schedulers
Disaggregate Demand using Planning Bills
Mix Demand Input into Master Schedule
Start Weekly Process
A
Run RCCP
Run Master Schedule
Master Schedule
Rough cut Capacity Plan
Action Messages
Available to Promise (ATP)
Review MPS/RCCP
Review Action Items
MPS RCCP OK?
Modify MPS as Required
A
Release Master Schedule
B
Start Daily Process
Run MRP
Create Production Schedule
Production Schedule
Material Plan
Action Messages
Pegging Report
Review Material Plan
Material Plan OK?
Modify Material Plans as Required
B
Release Material Plan
C
Run Purchase Orders
Run Supplier Schedules
Supplier Schedules
Purchase Orders
Supplier Schedule OK?
Modify Supplier Schedules as Required
C
Release Supplier Schedules to Suppliers
POs OK?
Modify POs as Required
Release POs to Suppliers
End Process
SALES & OPERATIONS PLANNING
TACTICAL PLANNING
OPERATIONAL PLANNING AND EXECUTION

Glossary

Any body of knowledge, be it accounting, engineering, manufacturing, law, or medicine, acquires a vocabulary of its own. Supply Chain Management, Enterprise Resource Planning, Sales and Operations Planning, Demand Management, Supply Management, and Master Scheduling are no exceptions. Jargon and acronyms notwithstanding, the need to use specific terminology remains. Hence, this glossary is provided to help you with terms that may not be totally familiar. Most of the definitions in this glossary have been taken directly from the *APICS Dictionary,* published by The Association for Operations Management

ABC Classification The classification of a group of items in decreasing order of annual dollar volume (price multiplied by projected volume) or other criteria. This array is then split into three classes, called A, B, and C. The A group usually represents 10% to 20% by number of items and 50% to 70% by projected dollar volume. The C class contains 60% to 70% of the items and represents about 10% to 30% of the dollar volume. The ABC principle states that effort and money can be saved through applying looser controls to the low-dollar volume class items than will be applied to high-dollar class items. The ABC principle is applicable to inventories, purchasing, sales, and so on. *Syn:* ABC analysis, distribution by value. *See* Pareto's Law

Abnormal Demand Demand in any period that is outside the limits established by management policy. This demand may come from a new customer or from existing customers whose own demand is increasing or decreasing. Care must be taken in evaluating the nature of the demand: Is it a volume change, is it a change in product mix, or is it related to the timing of the order? *See* outlier

Accuracy The degree of freedom from error or the degree of conformity to a standard; different from precision.

Action Message An output of a system that identifies the need for and the type of action to be taken to correct a current or potential problem. Examples of action messages in an MRP system include release order, reschedule in, reschedule out, and cancel. *Syn:* exception message, action report

Actual Costs The labor, material, and associated overhead costs that are charged against a job as it moves through the production process.

Actual Demand Customer orders (and often allocations of items/ingredients/raw materials to production or distribution). Actual demand nets against, or "consumes," the forecast, depending on rules chosen over a time horizon. For example, actual demand will totally replace forecast inside the "sold out" zone and partially replaces the forecast between the "sold out" and "no order" zone (known as the "partially sold out" zone).

Actual Volume Actual output expressed as a volume of capacity. It is used in the calculation of variances when compared to demonstrated capacity (practical capacity) or budgeted capacity.

Advanced Planning and Scheduling (APS) Techniques that deal with analysis and planning of logistics and manufacturing over the short-, intermediate-, and long-term time periods. APS describes any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation on finite-capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities. APS often generates and evaluates multiple scenarios; management then selects one scenario to use as the official plan. The five main components of APS are demand planning, production (supply) planning, production scheduling, distribution planning, and transportation planning.

Affinity Diagram A total quality management tool whereby employees working in silence generate ideas and later categorize these ideas.

Aggregate Forecast An estimate of sales, often time phased, for a grouping of products or product families produced by a manufacturing facility or firm. Stated in terms of units or dollars or both, the aggregate forecast is used for sales and planning (or for sales and operations planning) purposes.

Aggregate Planning A process to develop tactical plans to support the organization's business plan. Aggregate planning usually includes the development, analysis, and maintenance of plans for total sales, total production, targeted inventory, and target customer backlog for families of products. The production plan is the result of the aggregate planning process.

Anticipated Delay Report A report, normally issued by both manufacturing and purchasing to the material planning function, regarding jobs or purchase orders that will not be completed on time, giving the reasons why and stating when they will be completed. This report is an essential ingredient of the closed-loop MRP system.

APICS Founded in 1957 as the American Production and Inventory Control Society (APICS), the Association for Operations Management builds operations management excellence in individuals and enterprises through superior education and training, internationally recognized certifications, comprehensive resources, and a worldwide network of accomplished industry professionals.

Assemble-to-Order The production environment where a good or service can be assembled after receipt of a customer's order. The key components (bulk, semifinished, intermediate, subassembly, fabricated, purchased, packaging, etc.) used in the assembly or finishing process are planned and usually stocked in anticipation of a customer order. Receipt of an order initiates assembly of the customized product. This strategy is useful where a large number of end products (based on the selection of options and accessories) can be assembled from common components. *Syn:* finish-to-order

Assembly Attachment A choice or feature offered to customers for customizing the end product. In many companies, this term means that the choice, although not mandatory, must be selected before the final assembly schedule. In other companies, however, the choice need not be made at that time.

Assembly Lead Time The time that normally elapses between the issuance of a work order to the assembly floor and work completion.

Automatic Rescheduling Rescheduling done by the computer to automatically change due dates on scheduled receipts when it detects that the due dates and need dates are out of phase. *Ant:* manual rescheduling

Available Capacity The highest reasonable output rate that can be achieved with a given product mix, product specifications, workforce, plant, and equipment.

Available Inventory The on-hand balance minus allocations, reservations, back orders, and (usually) quantities held for quality problems. Often called *beginning available balance. Syn:* beginning available balance, net inventory

Available-to-Promise (ATP) The uncommitted portion of a company's inventory and planned production, maintained in the master schedule to support customer order promising. The ATP quantity is the uncommitted inventory balance in the first period and is normally calculated for each period in which an MPS receipt is scheduled. In the first period, ATP equals on-hand inventory less customer orders that are due and overdue. In any period containing MPS scheduled receipts, ATP equals the MPS less customer orders in this period and all subsequent periods before the next MPS scheduled receipt. A negative ATP generally reduces the ATP of the prior period(s).

Backflush A method of inventory bookkeeping where the book (computer) inventory of components is automatically reduced by the computer after completion of activity on the component's upper-level parent item based on what should have been used as specified on the bill-of-material and allocation records. This approach has the disadvantage of a built-in differential between the book record and what is physically in stock.

Backlog All of the customer orders received but not yet shipped. Sometimes referred to as *open orders* or the *order board. Syn:* order backlog

Backorder An unfilled customer order or commitment. It is an immediate (or past-due) demand against an item whose inventory is insufficient to satisfy the demand.

Back Scheduling A technique for calculating operation start and due dates. The schedule is computed by starting with the due date for the order and working backward to determine the required start date and/or due dates for each operation.

Baseline Measures A set of measurements (or metrics) that seek to establish the current or starting level of performance of a process, function, product, firm, and so on. Baseline measures are usually established before the implementation of improvement activities and programs.

Batch (1) A quantity scheduled to be produced or in production. *See* process batch, transfer batch. (2) For discrete products, the batch is planned to be the standard batch quantity, but during production, the standard batch quantity may be broken into smaller lots. *See* lot. (3) In nondiscrete products, the batch is a quantity that is planned to be produced in a given time period based on a formula or recipe, which often is developed to produce a given number of end items. (4) A type of manufacturing process used to produce items with similar designs and that may cover a wide range of order volumes. Typically, items ordered are of a repeat nature, and production may be for a specific customer order or for stock replenishment.

Batch Bill-of-Material A recipe or formula in which the statement of material quantity per is based on the standard batch quantity of the parent. *Syn:* batch formula

Batch Card A document used in the process industries to authorize and control the production of a quantity of material. Batch cards usually contain quantities and lot numbers of ingredients to be used, processing variables, pack-out instructions, and product disposition. *See* assembly parts list, batch sheet, blend formula, fabrication order, manufacturing order, mix ticket

Batch Formula *Syn:* batch bill-of-material

Batch Manufacturing A manufacturing facility whose resources or work centers are organized around particular types of equipment or operations, such as drilling, forging, spinning, mixing, compressing, blending, and the like. Products move through departments by individual work orders. *Syn:* job shop

Batch Number *Syn:* lot number

Bill-of-Material (BOM) (1) A listing of all the subassemblies, intermediates, parts, and raw materials that go into a parent assembly showing the quantity of each required to make an assembly. It is used in conjunction with the master production schedule to determine the items for which purchase requisitions and production orders must be released. A variety of display formats exist for bills-of-material, including the single-level bill-of-material, indented bill-of-material, modular (planning) bill-of-material, transient bill-of-material, matrix bill-of-material, and costed bill-of-material. (2) A list of all the materials needed to make one production run of a product, by a contract manufacturer, of piece parts/components for its customers. The bill-of-material may also be called the *formula, recipe,* or *ingredients list* in certain process industries.

Bill-of-Material Explosion The process of determining component identities, quantities per assembly, and other parent/component relationship data for a parent item. Explosion may be single level, indented, or summarized.

Bill of Resources A listing of the required capacity and key resources needed to manufacture one unit of a selected item or family. Rough cut capacity planning uses these bills to calculate the approximate capacity requirements of the master production schedule. Resource planning may use a form of this bill. *Syn:* bill of capacity. *See* bill of labor, capacity planning using overall factors, product load profile, resource profile, rough cut capacity planning, routing

Block Scheduling An operation scheduling technique wherein each operation is allowed a block of time, such as a day or a week.

Blow-Through The computer technique for passing requirements through pseudo and phantom bill-of-material items. This process creates requirements for the component materials needed to manufacture higher-level items.

Bottleneck A facility, function, department, or resource whose capacity is equal to or less than the demand placed upon it. For example, a bottleneck machine or work center exists where jobs are processed at a slower rate than they are demanded.

Bottom-Up Replanning In MRP, the process of using pegging data to solve material availability and/or problems. This process is accomplished by the planner (not the computer system), who evaluates the effects of possible solutions. Potential solutions include compressing lead time, cutting order quantity, substituting material, and changing the master schedule.

Bucketed System An MRP, DRP, or other time-phased system in which all time-phased data is accumulated into time periods, or "buckets." If the period of accumulation is one week, then the system is said to have weekly buckets.

Bucketless System An MRP, DRP, or other time-phased system in which all time-phased data is processed, stored, and displayed using dated records rather than defined time periods, or buckets.

Bulk Issue Parts issued from stores to work-in-process inventory, but not based on a job order. They are issued in quantities estimated to cover requirements of individual work centers and production lines. The issue may be used to cover a period of time or to fill a fixed-size container.

Business Plan A statement of long-range strategy and revenue cost, and profit objectives usually accompanied by budgets, a projected balance sheet, and a cash flow (source and application of funds) statement. A business plan is usually stated in terms of dollars and grouped by product family. The business plan is then translated into synchronized tactical functional plans through the production planning process (or the sales and operations planning process). Although frequently stated in different terms (dollars versus units), these tactical plans should agree with each other and with the business plan.

By-Product A material of value produced as a residual of or incidental to the production process. The ratio of by-product to primary product is usually predictable. By-products may be recycled, sold as is, or used for other purposes. *See* coproduct

Capable-to-Promise (CTP) The process of committing orders against available capacity as well as inventory. This process may involve multiple manufacturing or distribution sites. Capable-to-promise is used to determine when a new or unscheduled customer order can be delivered. Capable-to-promise employs a finite-scheduling model of the manufacturing system to determine when an item can be delivered. It includes any constraints that might restrict the production, such as availability of resources, lead times for raw materials or purchased parts, and requirements for lower-level components or subassemblies. The resulting delivery date takes into consideration production capacity, the current manufacturing environment, and future order commitments. The objective is to reduce the time spent by production planners in expediting orders and adjusting plans because of inaccurate delivery-date promises.

Capacity (1) The capability of a system to perform its expected function. (2) The capability of a worker, machine, work center, plant, or organization to produce output per time period. Capacity required represents the capability needed to make a given product mix (assuming technology, product specification, etc.). As a planning function, both capacity available and capacity required can be measured in the short term (capacity requirements planning), intermediate term (rough cut capacity plan), and long term (resource plan). Capacity control is the execution through the input/output control report of the short-term plan. Capacity can be classified as budgeted, dedicated, demonstrated, productive, rated, safety, standing, theoretical, or maximum.

Capacity Available The capability of a system or resource to produce a quantity of output in a particular time period.

Capacity Management The function of establishing, measuring, monitoring, and adjusting limits or levels of capacity in order to execute all manufacturing schedules—that is, the production plan, master schedule, material requirements plan, and dispatch list. Capacity management is executed at four levels: resource planning, rough cut capacity planning, capacity requirements planning, and input/output control.

Capacity Planning The process of determining the amount of capacity required to produce in the future. This process may be performed at an aggregate or product-line level (resource requirements planning), at the master scheduling level (rough cut capacity planning), and at the material requirements planning (capacity requirements planning).

Capacity Required The capacity of a system or resource needed to produce a desired output in a particular time period. *See* capacity.

Capacity Requirements The resources needed to produce the projected level of work required from a facility over a time horizon. Capacity requirements are usually expressed in terms of hours of work or, when units consume similar resources at the same rate, units of production.

Cash Cow A highly profitable product in a low-growth market.

Cell A manufacturing or service unit consisting of a number of workstations and the materials transport mechanisms and storage buffers that interconnect them.

Cellular Manufacturing A manufacturing process that produces families of parts within a single line or cell of machines operated by machinists who work only within the line or cell.

Common-Items Bill (-of-Material) A type of planning bill that groups common components or ingredients for a product or family or products into one bill-of-material, structured to a pseudo parent item number. *Syn:* common-parts bill

Component The raw material, part, or subassembly that goes into a higher-level assembly, compound, or other item. This term may also include packaging materials for finished items. *See* ingredient, intermediate part

Configuration The arrangements of components as specified to produce an assembly.

Constraint Any element or factor that prevents a system from achieving a higher level of performance with respect to its goal. Constraints can be physical, such as a machine center or lack of material, but they can also be managerial, such as a policy or procedure.

Consuming the Forecast The process of reducing the forecast by customer orders or other types of actual demands as they are received. The adjustments yield the value of the remaining forecast for each period.

Continuous Flow (Production) Lotless production in which products flow continuously rather than being divided.

Continuous Production A production system in which the productive equipment is organized and sequenced according to the steps involved in producing the product. This term denotes that material flow is continuous during the production process. The routing of the jobs is fixed, and setups are seldom changed. *See* mass production, project management

Coproduct Product that is usually manufactured together or sequentially because of product or process similarities. *See* by-product

Cumulative Lead Time The longest planned length of time involved to accomplish the activity in question. For any item planned through MRP, it is found by reviewing the lead time for each bill-of-material path below the item; whichever path adds up to the greatest number defines cumulative lead time. *Syn:* aggregate lead time, combined lead time, composite lead time, critical path lead time, stacked lead time

Cumulative Manufacturing Lead Time The cumulative planned lead time when all purchased items are assumed to be in stock. *Syn:* composite manufacturing lead time

Customer Connectivity The process of linking customers and suppliers. This is often made possible by tools such as Distribution Resource Planning and Supplier Scheduling. Frequently Electronic Data Interchange (EDI) is used as the communications medium.

Customer Order An order from a customer for a particular product or a number of products. It is often referred to as an *actual demand* to distinguish it from a forecasted demand.

Customer Service The ability of a company to address the needs, inquiries, and requests of customers. A measure of the delivery of a product to the customer at the time the customer specified.

Cycle Time In industrial engineering, the time between completion of two discrete units of production. For example, cycle time of motors assembled at a rate of 120 per hour would be 30 seconds. In materials management, it refers to the length of time from when material enters a production facility until it exits. *Syn:* throughput time

Database A data-processing file management approach designed to establish the independence of computer programs from data files. Redundancy is minimized, and data elements can be added to, or deleted from, the file designs without necessitating changes to existing computer programs.

Delivery Lead Time The time from the receipt of a customer order to the delivery of the product. *Syn:* delivery cycle

Demand A need for a particular product or component. The demand could come from any number of sources: for example, customer order or forecast, an interplant requirement, or a request from a branch warehouse for a service part or for manufacturing another product. At the finished-goods level, demand data is usually different from sales data because demand does not necessarily result in sales; that is, if there is no stock, there will be no sale.

Demand Management The function of recognizing and managing all of the demands for products to ensure that the master scheduler is aware of them. It encompasses the activities of forecasting, order entry, order promising, branch warehouse requirements, interplant orders, and service parts requirements.

Demand Pull The triggering of material movement to a work center only when that work center is out of work and/or ready to begin the next job. It in effect eliminates the queue from in front of a work center, but it can cause a queue at the end of a previous work center.

Demand Rate A statement of requirements in terms of quantity per unit of time (hour, day, week, month, etc.).

Demand Time Fence (DTF) (1) That point in time inside of which the forecast is no longer included in total demand and projected available inventory calculations; inside this point, only customer orders are considered. Beyond this point, total demand is a combination of actual orders and forecasts, depending on the forecast consumption technique chosen. (2) In some contexts, the demand time fence may correspond to that point in the future inside which changes to the master schedule must be approved by an authority higher than the master scheduler. Note, however, that customer orders may still be promised inside the demand time fence without higher authority approval if there are quantities available-to-promise (ATP). Beyond the demand time fence, the master scheduler may change the MPS within the limits of established rescheduling rules, without the approval of higher authority. *See* option overplanning, planning time fence, time fence

Demonstrated Capacity Proven capacity calculated from actual performance data, usually expressed as the average number of items produced multiplied by the standard hours per item.

Demurrage The carrier charges and fees applied when rail freight cars and ships are retained beyond a specified loading or unloading time.

Dependent Demand Demand that is directly related to or derived from the bill-of-material structure for other items or end products. Such demands are therefore calculated and need not and should not be forecast. A given inventory item may have both dependent and independent demand at any given time. For example, a part may simultaneously be the component of an assembly and also sold as a service part.

Derived Demand Demand for components that arises from the demand for final design products. For example, the demand for steel is derived from the demand for automobiles.

Design for Manufacturability (DFM) A rigorous, structured method of new-product design and introduction that intensively involves people from manufacturing, marketing, and suppliers in the development process. Done effectively, DFM can dramatically enhance a company's ability to bring new products to market quickly, at lower costs, and with fewer downstream engineering changes.

Discrete Order Quantity An order quantity that represents an integer number of periods of demand. Most MRP systems employ discrete order quantities. *See* fixed-period requirements, least total cost, least unit cost, lot-for-lot, part period balancing, period order quantity, Wagner-Whitin algorithm

Dispatch List A listing of manufacturing orders in priority sequence. The dispatch list, which is usually communicated to the manufacturing floor via hard copy or CRT display, contains detailed information on priority, location, quantity, and the capacity requirements of the manufacturing order by operation. Dispatch lists are normally generated daily and oriented by work center.

Distribution Center A warehouse with finished goods and/or service items. A company, for example, might have a manufacturing facility in Philadelphia and distribution centers in Atlanta, Dallas, Los Angeles, San Francisco, and Chicago. Distribution center is synonymous with the term "branch warehouse," although the former has become more commonly used recently. When there is a warehouse that serves a group of satellite warehouses, it is usually called a regional distribution center. *Syn:* field warehouse

Distribution Requirements Planning The function of determining the needs to replenish inventory at branch warehouses. A time-phased order-point approach is used where the planned orders at the branch warehouse level are "exploded" via MRP logic to become gross requirements on the supplying source. In the case of multilevel distribution networks, this explosion process can continue down through the various levels of regional warehouses, master warehouse, factory warehouse, and so on, and become input to the master schedule. Demand on the supplying source(s) is recognized as dependent, and standard MRP logic applies.

Distribution Resource Planning (DRP) The extension of distribution requirements planning into the planning of the key resources contained in a distribution system: warehouse space, workforce, money, trucks, freight cars, and the like.

Documentation The process of collecting and organizing documents or the information recorded in documents. The term usually refers to the development of material specifying inputs, operations, and outputs of a computer system.

Dog A slang term used to refer to a low-growth, low-market-share product.

Due Date The date when purchased material or production material is due to be available for use. *Syn:* arrival date, expected receipt date

Electronic Data Interchange (EDI) The paperless (electronic) exchange of trading documents, such as purchase orders, shipment authorizations, advanced shipment notices, and invoices, using standardized document formats.

Electronic Mail (E-mail) Messages sent between computers that are connected by other computers or by networks.

End Item A product sold as a completed item or repair part; any item subject to a customer order or sales forecast. *Syn:* end product, finished good, finished product

Engineering Change A revision to a drawing or design released by engineering to modify or correct a part. The request for the change can be from a customer or from production, quality control, another department, or a supplier.

Engineer-to-Order (ETO) Product whose customer specifications require unique engineering design, significant customization, or new purchased material. Each customer order results in a unique set of part numbers, bills-of-material, and routings. *Syn:* design-to-order

Enterprise Resource Planning (ERP) Framework for organizing, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage.

Enterprise Resource Planning (ERP) System An accounting-oriented information system for identifying and planning the enterprise-wide resources needed to take, make, ship, and account for customer orders. An ERP system differs from the typical MRPII system in technical requirements such as graphical user interface, relational database, use of fourth-generation language, and computer-aided software engineering tools in development, client-server architecture, and open-system portability. *Syn:* customer-oriented manufacturing management system

Exception Message *Syn:* action message

Exception Report A report that lists or flags only those items that deviate from the plan.

Excess Capacity A situation in which the output capabilities at a nonconstraint resource exceed the amount of productive and protective capacity required to achieve a given level of throughput at the constraint.

Excess Inventory Any inventory in the system that exceeds the minimum amount necessary to achieve the desired throughput rate at the constraint or that exceeds the minimum amount necessary to achieve the desired due date performance.

Expedite To rush or chase production or purchase orders that are needed in less than the normal lead time; to take extraordinary action because of an increase in relative priority. *Syn:* stockchase

Expeditor A production control person whose primary duties are expediting.

Fabrication Manufacturing operations for making components, as opposed to assembly operations.

Fabrication/Assembly Plant A manufacturing facility in which a configuration or geometric change is the majority of activity.

Family A group of end items whose similarity of design and manufacture facilities is planned in aggregate, whose sales performance is monitored together, and, occasionally, whose cost is aggregated at this level.

Feedback The flow of information back into the control system so that actual performance can be compared with planned performance.

Final Assembly The highest-level assembled product, as it is shipped to customers.

Final Assembly Schedule (FAS) A schedule of end items to finish the product for specific customers' orders in a make-to-order or assemble-to-order environment. It is also referred to as the *finishing schedule* because it may involve operations other than just the final assembly; also, it may not involve assembly, but simply final mixing, cutting, packaging, and the like. The FAS is prepared after receipt of a customer order as constrained by the availability of material and capacity, and it schedules the operations required to complete the product from the level where it is stocked (or master scheduled) to the end-item level.

Finishing Lead Time The time that is necessary to finish manufacturing a product after receipt of a customer order. The time allowed for completing the product based on the final assembly schedule.

Finish-to-Order (FTO) *Syn:* assemble-to-order

Finite Forward Scheduling An equipment scheduling technique that builds a schedule by proceeding sequentially from the initial period to the final period while observing capacity limits. A Gantt chart may be used with this technique.

Finite Loading Assigning no more work to a work center than the work center can be expected to execute in a given time period. The specific term usually refers to a computer technique that involves calculating shop priority revisions in order to level-load operation by operation.

Firm Planned Order (FPO) A planned order that can be frozen in quantity and time. The computer is not allowed to change it automatically; this is the responsibility of the scheduler in charge of the item that is being planned. This technique can aid schedulers working with master scheduling systems to respond to material and capacity problems by firming up selected planned orders. Firm planned orders are the normal method of stating the master schedule.

Fixed Order Quantity A lot-sizing technique in MRP or inventory management that will always cause planned or actual orders to be generated for a predetermined fixed quantity, or multiples thereof, if net requirements for the period exceed the fixed order quantity.

Fixed-Period Quantity An MRP lot-sizing technique that sets the lot size equal to the net requirements for a given number of periods.

Fixed-Period Requirements A lot-sizing technique that sets the order quantity to the demand for a given number of periods. *See* discrete order quantity

Flexibility The ability of the manufacturing system to respond quickly, in terms of range and time, to external or internal changes. Six different categories of flexibility can be considered: mix flexibility, design changeover flexibility, modification flexibility, volume flexibility, rerouting flexibility, and material flexibility (see individual terms for a more detailed discussion). In addition, flexibility involves concerns of product flexibility. Flexibility can be useful in coping with various types of uncertainty (regarding mix, volume, etc.).

Flexibility Responsiveness The ability of the firm and its management to change rapidly in response to changes in the marketplace.

Flexible Automation Automation that provides short setup times and the ability to switch quickly from one product to another.

Flexible Capacity The ability to operate manufacturing equipment at different production rates by varying staffing levels and operating hours or starting and stopping at will.

Flowchart The output of a flowcharting process; a chart that shows the operations, transportation, storages, delays, inspections, and so on related to a process. Flowcharts are drawn to better understand processes. The flowchart is one of the seven tools of quality.

Flowcharting A systems analysis tool that graphically presents a procedure. Symbols are used to represent operations, transportation, inspections, storages, delays, and equipment.

Flow Order An order filled not by moving material through production as an integral lot but by production made over time and checked by cumulative count until the flow-order quantity is complete.

Flow Shop A form of manufacturing organization in which machines and operators handle a standard, usually uninterrupted, material flow. The operators generally perform the same operations for each production run. A flow shop is often referred to as a mass production shop, or is said to have a continuous manufacturing layout. The plant layout (arrangement of machines, benches, assembly lines, etc.) is designed to facilitate product flow. Some process industries (chemicals, oil, paint, etc.) are extreme examples of flow shops. Each product, though variable in material specifications, uses the same flow pattern through the shop. Production is set at a given rate, and the products are generally manufactured in bulk. *Syn:* flow line, flow manufacturing, flow plant

Forecast An estimate of future demand. A forecast can be determined by mathematical means using historical data; it can be created subjectively by using estimates from informal sources; or it can represent a combination of both techniques. The sum of the unconsumed forecast and the booked customer orders should remain constant unless an intentional change to the forecast is desired. Abnormal demands should not consume the forecast.

Forecast Bias Tendency of a forecast to systematically miss the actual demand (consistently being either high or low).

Forecast Error The difference between actual demand and forecast demand, stated as an absolute value or as a percentage.

Format The predetermined arrangement of the characters of data for computer input, storage, or output.

Formula A statement of ingredient requirements. A formula may also include processing instructions and ingredient sequencing directions. *Syn:* formulation, recipe

Formulation *Syn:* formula

Forward Scheduling A scheduling technique where the scheduler proceeds from a known start date and computes the completion date for an order, usually proceeding from the first operation to the last. Dates generated by this technique are generally the earliest start dates (ESD) for operations. *Ant:* backward scheduling

Four Ps A set of marketing tools to direct the business offering to the customer. The four Ps are product, price, place, and promotion.

Full Pegging The ability of a system to automatically trace requirements for a given component all the way to its ultimate end item, customer, or contract number. *Syn:* contract pegging

Gross Requirement The total of independent and dependent demand for an item or an assembly prior to the netting of on-hand inventory and scheduled receipts.

Hardware (1) In manufacturing, relatively standard items such as nuts, bolts, washers, or clips. (2) In data processing, the computer and its peripherals.

Hedge In master scheduling, a quantity of stock used to protect against uncertainty in demand. The hedge is similar to safety stock, except that a hedge has the dimension of timing as well as amount. In purchasing, any purchase or sale transaction intended to eliminate the negative aspects of price fluctuations.

Horizontal Display A method of displaying output from a master scheduling or other time-phased system in which requirements, scheduled receipts, projected balance, and so on are displayed across the document. Horizontal displays routinely summarize data into time periods or buckets.

Housekeeping The manufacturing activity of identifying and maintaining an orderly environment for preventing errors and contamination in the manufacturing process.

Implementation The act of installing a system into operation. It concludes the system project, with the exception of appropriate follow-up or postinstallation review.

Indented Bill-of-Material A form of multilevel bill-of-material. It exhibits the highest-level parents closest to the left-side margin, and all the components going into these parents are shown indented to the right. All subsequent levels of components are indented further to the right. If a component is used in more than one parent within a given product structure, it will appear more than once, under every subassembly in which it is used.

Independent Demand The demand for an item that is unrelated to the demand for other items. Demand for finished goods, parts required for destructive testing, and service parts requirements are examples of independent demand. *See* dependent demand

Infinite Loading Calculation of the capacity required at work centers in the time periods required regardless of the capacity available to perform this work.

Information System Interrelated computer hardware and software along with people and processes designed for the collection, processing, and dissemination of information for planning, decision making, and control.

Information Technology The technology of computers, telecommunications, and other devices that integrate data, equipment, personnel, and problem-solving methods in planning and controlling business activities. Information technology provides the means for collecting, storing, encoding, processing, analyzing, transmitting, receiving, and printing text, audio, or video information.

Ingredient In the process industries, the raw material or component of a mixture. *See* component

Interactive Scheduling Computer scheduling whose process is either automatic or manually interrupted to allow the scheduler the opportunity to review and change the schedule.

Intermediate Part Material processed beyond raw material and used in higher-level items. *See* component

Intermittent Production A form of manufacturing in which the jobs pass through the functional departments in lots, and each lot may have a different routing. *See* job shop

Interplant Demand One plant's need for a part or product that is produced by another plant or division within the same organization. Although it is not a customer order, it is usually handled by the master production scheduling system in a similar manner.

Inventory Those stocks or items used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies), and customer service (finished goods and spare parts). Demand for inventory is dependent and independent. Inventory functions are anticipation, hedge, cycle (lot size), fluctuation (safety, buffer, or reserve), transportation (pipeline), and service parts.

Inventory Management The branch of business management concerned with planning and controlling inventories.

Item Any unique manufactured or purchased part, material, intermediate, subassembly, or product.

Item Record The master record for an item. Typically it contains identifying and descriptive data and control values (lead times, lot sizes, etc.), and many contain data on inventory status, requirements, planned orders, and costs. Item records are linked together by bill-of-material records (or product structure records), thus identifying the bill-of-material. *Syn:* item master record, part master record, part record

Job Order *Syn:* manufacturing order

Job Shop (1) An organization in which similar equipment is organized by function. Each job follows a distinct routing through the shop. (2) A type of manufacturing process used to produce items to each customer's specifications. Production operations are designed to handle a wide range of product designs and are performed at fixed plant locations using general-purpose equipment. *Syn:* jobbing. *See* intermittent production

Job Shop Scheduling The production planning and control techniques used to sequence and prioritize production quantities across operations in a job shop.

Just-in-Time (JIT) A philosophy of manufacturing based on planned elimination of all waste and continuous improvement of productivity. It encompasses the successful execution of all manufacturing activities required to produce a final product, from design engineering to delivery and including all stages of conversion from raw material onward. The primary elements of zero inventories are to have only the required inventory when needed; to improve quality to zero defects; to reduce lead times by reducing setup times, queue lengths, and lot sizes; to incrementally revise the operations themselves; and to accomplish these things at minimum cost. In the broad sense it applies to all forms of manufacturing, job shop and process as well as repetitive. *Syn:* short-cycle manufacturing, stockless production, zero inventories

Kaizen The Japanese term for improvement; continuing improvement involving everyone—managers and workers. In manufacturing, kaizen relates to finding and eliminating waste in machinery, labor, or production methods. *Syn:* continuous process improvement

Kaizen Blitz$^{(SM)}$ A rapid improvement of a limited process area; for example, a production cell. Part of the improvement team consists of workers in that area. The objectives are to use innovative thinking to eliminate non-value-added work and to immediately implement the changes within a week or less. Ownership of the improvement by the area work team and the development of the team's problem-solving skills are additional benefits.

Kanban A method of Just-in-Time production that uses standard containers or lot sizes with a single card attached to each. It is a pull system in which work centers signal with a card that they wish to withdraw parts from feeding operations or suppliers. The Japanese word *kanban,* loosely translated, means *card, billboard,* or *sign.* The term is often used synonymously for the specific scheduling system developed and used by the Toyota Corporation in Japan.

Latest Start Date The latest date at which an operation order can be started in order to meet the due date of the order.

Lead Time (1) A span of time required to perform a process (or series of operations). (2) In a logistics context, the time between recognition of the need for an order and the receipt of goods. Individual components of lead time can include order preparation time, queue time, processing time, move or transportation time, and receiving and inspection time. *Syn:* total lead time. *See* manufacturing lead time, purchasing lead time

Lead-Time Offset A technique used in MRP wherein a planned order receipt in one time period will require the release of that order in an earlier time period based on the lead time for the item. *Syn:* component lead-time offsetting, offsetting

Lean Enterprise A group of individuals, functions, and sometime legally separate but operationally synchronized organizations. The value stream defines the lean enterprise. The objectives of the lean enterprise are to correctly specify value to the ultimate customer, and to analyze and focus the value stream so that it does everything from product development and production to sales and service in a way that actions that do not create value are removed and actions that do create value proceed in a continuous flow as pulled by the customer. Lean enterprise differs from a virtual corporation in which the organizational membership and structure keeps changing.

Lean Manufacturing *Syn:* lean production

Lean Production A philosophy of production that emphasizes the minimization of the amount of all the resources (including time) used in the various activities of the enterprise. It involves identifying and eliminating non-value-adding activities in design, production, Supply Chain Management, and dealing with the customers. Lean producers employ teams of multiskilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in potentially enormous variety. *Syn:* lean manufacturing

Level Every part or assembly in a product structure is assigned a level code signifying the relative level in which that part or assembly is used within the product structure. Oftentimes the end items are assigned level 0 with the components/subassemblies going into it assigned to level 1 and so on. The MRP explosion process starts from level 0 and proceeds downward one level at a time.

Level-Loading *Syn:* level schedule, load-leveling

Level Schedule (1) In traditional management, a production schedule or master production schedule that generates material and labor requirements that are as evenly spread over time as possible. Finished-goods inventories buffer the production system against seasonal demand. *See* level production method. (2) In Just-in-Time production, a level schedule (usually constructed monthly) ideally means scheduling each day's customer demand to be built on the day it will be shipped. A level schedule is the output of the load-leveling process. *See* load-leveling

Line (1) A specific physical space for the manufacture of a product that in a flow shop layout is represented by a straight line. In actuality, this may be a series of pieces of equipment connected by piping or conveyor systems. (2) A type of manufacturing process used to produce a narrow range of standard items with identical or highly similar designs. Production volumes are high, production and material handling equipment is specialized, and all products typically pass through the same sequence of operations. *See* assembly line

Linear Decision Rules A modeling technique using simultaneous equations, for example, the establishment of aggregate work force levels, based upon minimizing the total cost of hiring, firing, holding inventory, backorders, payroll, overtime, and undertime.

Linearity (1) Production at a constant quantity. (2) Use of resources at a level rate, typically measured daily or more frequently.

Linear Programming Mathematical models for solving linear optimization problems through minimization or maximization of a linear function subject to linear constraints. For example, in blending gasoline and other petroleum products, many intermediate distillates may be available. Prices and octane ratings as well as upper limits on capacities of input materials that can be used to produce various grades of fuel are given. The problem is to blend the various inputs in such a way that (1) cost will be minimized (profit will be maximized), (2) specified optimum octane ratings will be met, and (3) the need for additional storage capacity will be avoided.

Line Balancing (1) The balancing of the assignment of the tasks to workstations in a manner that minimizes the number of workstations and minimizes the total amount of idle time at all stations for a given output level. In balancing these tasks, the specified time requirement per unit of product for each task and its sequential relationship with the other tasks must be considered. (2) A technique for determining the product mix that can be run down an assembly line to provide a fairly consistent flow of work through that assembly line at the planned line rate.

Line Loading The loading of a production line by multiplying the total pieces by the rate per piece for each item to come up with a finished schedule for the line.

Load The amount of planned work scheduled and actual work released for a facility, work center, or operation for a specific span of time. Usually expressed in terms of standard hours of work or, when items consume similar resources at the same rate, units of production.

Load-Leveling Spreading orders out in time or rescheduling operations so that the amount of work to be done in sequential time periods tends to be distributed evenly and is achievable. Although both material and labor are ideally level-loaded, specific businesses and industries may load to one or the other exclusively (e.g., service industries). *Syn:* capacity smoothing, level-loading. *See* level schedule

Load Profile A display of future capacity requirements based on released and/or planned orders over a given span of time. *Syn:* load projection. *See* capacity requirements plan

Logistics (1) In an industrial context, the art and science of obtaining, producing, and distributing material and product in the proper place and in proper quantities. (2) In a military sense (where it has greater usage), its meaning can also include the movement of personnel.

Lot A quantity produced together and sharing the same production costs and specifications. *See* batch

Lot-for-Lot A lot-sizing technique that generates planned orders in quantities equal to the net requirements in each period. *Syn:* discrete order quantity

Lot Number A unique identification assigned to a homogeneous quantity of material. *Syn:* batch number, mix number

Lot Number Control Assignment of unique numbers to each instance of receipt and carrying forth that number into subsequent manufacturing processes so that, in review of an end item, each lot consumed from raw materials through end item can be identified as having been used for the manufacture of this specific end item lot.

Lot Number Traceability Tracking parts by lot numbers to a group of items. This tracking can assist in tracing quality problems to their source. A lot number identifies a designated group of related items manufactured in a single run or received from a vendor in a single shipment.

Lot Size The amount of a particular item that is ordered from the plant or a supplier or issued as a standard quantity to the production process. *Syn:* order quantity

Lot Sizing The process of, or techniques used in, determining lot size. *See* order policy

Lot Splitting Dividing a lot into two or more sublots and simultaneously processing each sublot on identical (or very similar) facilities as separate lots, usually to compress lead time or to expedite a small quantity. *Syn:* operation splitting

Lot Traceability The ability to identify the lot or batch number of product in terms of one or all of the following: its composition, purchased parts, manufacturing date, or shipped items. In certain regulated industries, lot traceability may be a legislative requirement.

Make-to-Order (MTO) A production environment where a good or service can be made after receipt of a customer's order. The final product is usually a combination of standard items and items custom-designed to meet the special needs of the customer. Where options or accessories are stocked before customer orders arrive, the term *assemble-to-order* is frequently used. *See* assemble-to-order, make-to-stock

Make-to-Stock (MTS) A production environment where products can be and usually are finished before receipt of a customer order. Customer orders are typically filled from existing stocks, and production orders used to replenish those stocks. *See* assemble-to-order, make-to-order

Management The function of planning, organizing, and controlling the transformation process and its utility in providing a good or service to customers.

Management Information System (MIS) Integrated approach for providing interpreted and relevant data that can help managers make decisions. This information can reflect the progress or lack of progress made in achieving major objectives.

Manufacturability A measure of the design of a product or process in terms of its ability to be produced easily, consistently, and with high quality.

Manufacturing A series of interrelated activities and operations involving the design, material selection, planning, production, quality assurance, management, and marketing of discrete consumer and durable goods.

Manufacturing Calendar A calendar used in inventory and production planning functions that consecutively numbers only the working days so that the component and work order scheduling may be done based on the actual number of workdays available.

Manufacturing Environment The framework in which manufacturing strategy is developed and implemented. Elements of the manufacturing environment include external environmental forces, corporate strategy, business unit strategy, other functional strategies (marketing, engineering, finance, etc.), product selection, product/process design, product/process technology, and management competencies. Often refers to whether a company, plant, product, or service is make-to-stock, make-to-order, or assemble-to-order.

Manufacturing Lead Time The total time required to manufacture an item, exclusive of lower-level purchasing lead time. For make-to-order products, it is the length of time between the release of an order to the production process and shipment to the final customer. For make-to-stock products, it is the length of time between the release of an order to the production process and receipt into finished-goods inventory. Included here are order preparation time, queue time, setup time, run time, move time, inspection time, and put-away time. *Syn:* manufacturing cycle, production cycle, production lead time. *See* lead time

Manufacturing Order A document, group of documents, or schedule conveying authority for the manufacture of specified parts of products in specified quantities. *Syn:* job order, manufacturing authorization, production order, production release, run order, shop order, work order.

Manufacturing Planning and Control System (MPC) A closed-loop information system that includes the planning functions of production planning (sales and operations planning), master production scheduling, material requirements planning, and capacity requirements planning. Once the plan has been accepted as realistic, execution begins. The execution functions include input-output control, detailed scheduling, dispatching, anticipated delay reports (department and supplier), and supplier scheduling. A closed-loop MRP system is one example of a manufacturing planning and control system.

Manufacturing Process The series of operations performed upon material to convert it from the raw material or a semifinished state to a state of further completion. Manufacturing processes can be arranged in a process layout, product layout, cellular layout, or fixed-position layout. Manufacturing processes can be planned to support make-to-stock, make-to-order, assemble-to-order, and so on, based on the strategic use and placement of inventories. *See* production process, transformation process

Manufacturing Resource Planning (MRPII) A method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has simulation capability to answer what-if questions. It is made up of a variety of functions, each linked together: business planning, sales and operations planning, master scheduling, material requirements planning, capacity requirements planning, and the execution support systems for capacity and material. Output from these systems is integrated with financial reports such as the business plan, purchase commitment report, shipping budget, inventory projections in dollars, and so on. Manufacturing Resource Planning is a direct outgrowth and extension of closed-loop MRP.

Manufacturing Strategy A collective pattern of decisions that acts upon the formulation and deployment of manufacturing resources. To be most effective, the manufacturing strategy should act in support of the overall strategic direction of the business and provide for competitive advantages.

Manufacturing Volume Strategies An element of manufacturing strategy that includes a series of assumptions and predictions about long-term market, technology, and competitive behavior in the following areas: (1) the predicted growth and variability of demand, (2) the costs of building and operating different-sized plants, (3) the rate and direction of technological improvement, (4) the likely behavior of competitors, and (5) the anticipated impact of international competitors, markets, and sources of supply. It is the sequence of specific volume decisions over time that determines an organization's long-term manufacturing volume strategy.

Market Demand The total need for a product or product line.

Market Driven Responding to customers' needs.

Marketing Activities associated with the pricing, promotion, and distribution of products.

Marketing Strategy The basic plan marketing expects to use to achieve its business and marketing objectives in a particular market. This plan includes marketing expenditures, marketing mix, and marketing allocation.

Mass Production High-quantity production characterized by specialization of equipment and labor. *See* continuous production

Master Planning A grouping of the business processes that includes the following activities: demand management (which includes forecasting and order servicing); production and resource planning; and master scheduling (which includes the final assembly schedule, the master schedule, and the rough cut capacity plan).

Master Production Schedule (MPS) (1) The master production schedule is a line on the master schedule grid that reflects the anticipated build schedule for those items assigned to the master scheduler. The master scheduler maintains this schedule, and in turn, it becomes a set of planning numbers that drives material requirements planning. It represents what the company plans to produce expressed in specific configurations, quantities, and dates. The master production schedule is not a sales forecast that represents a statement of demand. The master production schedule must take into account the forecast, the production plan, and other important considerations such as backlog, availability of material, availability of capacity, and management policies and goals. *Syn:* master schedule. (2) The result of the master scheduling process. The master schedule is a presentation of demand, forecast, backlog, the MPS, the projected on-hand inventory, and the available-to-promise quantity. *See* master scheduler, master scheduling

Master Schedule The master schedule is a format that includes time periods (dates), the forecast, customer orders, projected available balance, available-to-promise, and the master production schedule. The master schedule takes into account the forecast, the production plan, and other important considerations such as backlog, availability of material, availability of capacity, and management policies and goals. *See* master production schedule

Master Schedule Item A part (item) number selected to be planned by the master scheduler. The item is deemed critical in terms of its impact on lower-level components and/or resources such as skilled labor, key machines, dollars, and the like. Therefore, the master scheduler, not the computer, maintains the plan for these items. A master schedule item may be an end item, a component, a pseudo number, or a planning bill-of-material (an event).

Master Schedule Process A time-phased planning activity using firm and planned quantities of demand, supply, and inventory balances for each item. Its primary use is to help in developing the master schedule, and it contains lines for forecast and customer order demands, the MPS supply, and the available-to-promise and projected available inventory balances. Most computer systems use logic to assist the master scheduler in establishing MPS quantities and due dates that meet lead time, safety stock, and lot-size policies established for the item.

Master Scheduler Often the job title of the person charged with the responsibility of managing, establishing, reviewing, and maintaining a master schedule for select items. Ideally, the person should have substantial product, plant, process, and market knowledge because the consequences of this individual's actions often have a great impact on customer service, material, and capacity planning. *See* master production schedule

Master Scheduling The process where the master schedule is generated and reviewed and adjustments are made to the master production schedule to ensure consistency with the production plan. The master production schedule (the line on the grid) is the primary input to the material requirements plan. The sum of the master production schedules for the items within the product family must equal the production plan for that family.

Material Requirements Planning (MRP) A set of techniques that uses bills-of-material, inventory data, and the master schedule to calculate requirements for materials. It makes recommendations to release replenishment orders for materials. Further, since it is time phased, it makes recommendations to reschedule open orders when due dates and need dates are not in phase. Time-phased MRP begins with the items listed on the MPS and determines (1) the quantity of all components and materials required to fabricate those items and (2) the date that the components and material are required. Time-phased MRP is accomplished by exploding the bills-of-materials, adjusting for inventory quantities on hand or on order, and offsetting the net requirements by the appropriate lead times.

Materials Management The grouping of management functions supporting the complete cycle of material flow, from the purchase and internal control of production materials to the planning and control of work-in-process to the warehousing, shipping, and distribution of the finished product.

Mathematical Programming The general problem of optimizing a function of several variables subject to a number of constraints. If the function and constraints are linear in the variables and a subset of the constraints restricts the variables to be nonnegative, a linear programming problem exists.

Matrix A mathematical array having one, two, and sometimes more dimensions, into which collections of data may be stored and processed.

Maximum Demonstrated Capacity The highest amount of actual output produced in the past when all efforts have been made to "optimize" the resource; for instance, overtime, additional personnel, extra hours, extra shifts, reassignment of personnel, or use of any related equipment. Maximum demonstrated capacity is the most one could ever expect to produce in a short period of time but represents a rate that cannot be maintained over a long period of time. *See* demonstrated capacity

Mixed-Model Master Schedule The technique of setting and maintaining the master schedule to support mixed-model production.

Mixed-Model Production Making several different parts of products in varying lot sizes so that a factory is making close to the same mix of products that will be sold that day. The mixed-model schedule governs the making and the delivery of component parts, including those provided by outside suppliers. The goal is to build every model, every day, according to daily demand.

Mixed-Model Scheduling The process of developing one or more schedules to enable mixed-model production. The goal is to achieve a day's production each day. *See* mixed-model production

Mix Forecast Forecast of the proportion of products that will be sold within a given product family, or the proportion of options offered within a product line. Product and option mix must be forecasted as well as aggregate product families. Even though the appropriate level of units is forecasted for a given product line, an inaccurate mix forecast can create material shortages and inventory problems.

Model A representation of a process or system that attempts to relate the most important variables in the system in such a way that analysis of the model leads to insights into the system. Frequently, the model is used to anticipate the result of a particular strategy in the real system.

Modular Bill-of-Material A type of planning bill that is arranged in product modules or options. It is often used in companies where the product has many optional features—for example, assemble-to-order companies such as automobile manufacturers. *See* pseudo bill-of-material

Move Card In Just-in-Time context, a card or other signal indicating that a specific number of units of a particular item are to be taken from a source (usually outbound stockpoint) and taken to the point of use (usually inbound stockpoint). It authorizes the movement of one part number between a single pair of work centers. The card circulates between the outbound stockpoint of the supplying work center and the inbound stockpoint of the using work center. *Syn:* move signal. *See* kanban

Multilevel Bill-of-Material A display of all the components directly or indirectly used in a parent, together with the quantity required with each component. If a component is a subassembly, blend, intermediate, or the like, all of its components and all their components also will be exhibited, down to purchase parts and materials.

Multilevel Master Schedule A master scheduling technique that allows any level in an end item's bill-of-material to be master scheduled. To accomplish this, MPS items must receive requirements from independent and dependent demand sources.

Need Date The date when an item is required for its intended use. In an MRP system, this date is calculated by a bill-of-material explosion of a schedule and the netting of available inventory against that requirement.

Nervousness The characteristic in an MRP system when minor changes in higher-level (e.g., level 0 or 1) records or the master production schedule cause significant timing or quantity changes in lower-level (e.g., level 5 or 6) schedule and orders.

Net Change MRP An approach in which the material requirements plan is continually retained in the computer. Whenever a change is needed in requirements, open order inventory status, or bill-of-material, a partial explosion and netting is made for only those parts affected by the change.

Net Requirements In MRP, the net requirements for a part or an assembly are derived by applying gross requirements and allocations against inventory on hand, scheduled receipts, and safety stock. Net requirements, lot sized and offset for lead time, become planned orders.

Netting The process of calculating net requirements.

Non-Value-Added An activity that does not add value to a product; for example, moving the product from one work center to another inside a facility. One aspect of continuous improvement is the elimination or reduction of non-value-added activities.

Off-Grade A product whose physical or chemical properties fall outside the acceptable ranges.

Offload To reschedule or use alternate routings to reduce the workload on a machine, work center, or facility.

Offsetting *Syn:* lead-time offset

On-Hand Balance The quantity shown in the inventory records as being physically in stock.

On-Time Schedule Performance A measure (percentage) of meeting the customer's originally negotiated delivery request date. Performance can be expressed as a percentage based on the number of orders, line items, or dollar value shipped on time.

Open Order (1) A released manufacturing order or purchase order. *Syn:* released order. (2) An unfilled customer order.

Operation (1) A job or task, consisting of one or more work elements, usually done essentially in one location. (2) The performance of any planned work or method associated with an individual, machine, process, department, or inspection. (3) One or more elements that involve one of the following: the intentional changing of an object in any of its physical or chemical characteristics; the assembly or disassembly of parts or objects; the preparation of an object for another operation, transportation, inspection, or storage; planning, calculating, or giving or receiving information.

Operation Number A sequential number, usually two, three, or four digits long, such as 010, 020, or 030, that indicates the sequence in which operations are to be performed within an item's routing.

Operations Scheduling The actual assignment of starting or completion dates to operations or groups of operations to show when these operations must be done if the manufacturing order is to be completed on time. These dates are used in the dispatching function. *Syn:* detailed scheduling, order scheduling, shop scheduling

Operations Sequence The sequential steps for an item to follow in its flow through the plant. For instance: operation 1, cut bar stock; operation 2, grind bar stock; operation 3, shape; operation 4, polish; operation 5, inspect and send to stock. This information is normally maintained in the routing file.

Operations Sequencing A technique for short-term planning of actual jobs to be run in each work center based upon capacity (i.e., existing workforce and machine availability) and priorities. The result is a set of projected completion times for the operations and simulated queue levels for facilities.

Optimization Achieving the best possible solution to a problem in terms of a specified objective function.

Option A choice that must be made by the customer or company when customizing the end product. In many companies, the term *option* means a mandatory choice from a limited selection.

Option Overplanning Typically, scheduling extra quantities of a master schedule option greater than the expected sales for that option to protect against unanticipated demand. This schedule quantity may only be planned in the period where new customer orders are currently being accepted, typically just after the demand time fence. This technique is usually used on the second level of a two-level master scheduling approach to create a situation where more of the individual options are available than of the overall family.

Order A general term that may refer to such diverse items as a purchase order, shop order, customer order, planned order, or schedule.

Order Entry The process of accepting and translating what a customer wants into terms used by the manufacturer or distributor. This can be as simple as creating shipping documents for a finished-goods product, or it might be a more complicated series of activities, including engineering efforts for make-to-order products.

Order Management The planning, directing, monitoring, and controlling of the processes related to customer orders, manufacturing orders, and purchase orders. Regarding customer orders, order management includes order promising, order entry, order pick, pack and ship, billing, and reconciliation of the customer account. Regarding manufacturing orders, order management includes order release, routing, manufacture, monitoring, and receipt into stores or finished-goods inventories. Regarding purchasing orders, order management includes order placement, monitoring, receiving, acceptance, and payment of supplier.

Order Promising The process of making a delivery commitment—that is, answering the question "When can you ship?" For make-to-order products, this usually involves a check of uncommitted material and availability of capacity, often as represented by the master schedule available-to-promise. *Syn:* customer order promising, order dating. *See* available-to-promise, order service

Order Quantity The amount of an item to be ordered. *Syn:* lot size

Order Release The activity of releasing materials to a production process to support a manufacturing order.

Outbound Stockpoint The designated locations near the point of use on a plant floor to which material produced is taken until it is pulled to the next operation.

Overload A condition when the total hours of work outstanding at a work center exceed that work center's capacity.

Overstated Master Production Schedule A schedule that includes either past due quantities or quantities that are greater than the ability to produce, given current capacity and material availability. An overstated MPS should be made feasible before MRP is run.

Overtime Work beyond normal established working hours that usually requires that a premium be paid to the workers.

Package to Order A production environment in which a good or service can be packaged after receipt of a customer order. The item is common across many different customers; packaging determines the end product.

Parent Item The item produced from one or more components.

Pareto's Law A theory developed by Vilfredo Pareto, an Italian economist, that states that a small percentage of a group accounts for the largest fraction of the impact, value, and so on. In an ABC classification, for example, 20% of the inventory items may constitute 80% of the inventory value.

Part Generally, a material item that is used as a component and is not an assembly, subassembly, blend, intermediate, or the like.

Part Family A collection of parts grouped for some managerial purpose.

Part Number *Syn:* item number

Past-Due Order A line item on an open customer order that has an original scheduled ship date that is earlier than the current date. *Syn:* delinquent order, late order. *See* backlog, order backlog

Payback A method of evaluating an investment opportunity that provides a measure of the time required to recover the initial amount invested in a project.

Pegged Requirement A requirement that shows the next-level parent item (or customer order) as the source of the demand.

Pegging In MRP and MPS, the capability to identify for a given item the sources of its gross requirements and/or allocations. Pegging can be thought of as "live where-used" information.

Performance Measure In a performance measurement system, the actual value measured for the criterion. *See* performance criterion, performance measurement system, performance standard

Performance Measurement System A system for collecting, measuring, and comparing a measure to a standard for a specific criterion for an operation, item, good, service, business, or the like. A performance measurement system consists of a criterion, a standard, and a measure.

Performance Standard In a performance measurement system, the accepted, targeted, or expected value for the criterion.

Period Capacity The number of standard hours of work that can be performed at a facility or work center in a given time period.

Period Order Quantity A lot-sizing technique under which the lot size is equal to the net requirements for a given number of periods, for example, a week into the future.

Personal Computer (PC) A microcomputer usually consisting of a CPU, primary storage, and input/output circuitry on one or more boards, plus a variety of secondary storage devices.

Phantom An intermediate or assembly that is manufactured but is immediately consumed in the manufacture of its parent. Phantoms are "blow-through" items.

Phantom Bill-of-Material A bill-of-material coding and structuring technique used primarily for transient (nonstocked) subassemblies. For the transient item, lead time is set to zero and the order quantity to lot-for-lot. This permits MRP logic to drive requirements straight through the phantom item to its components, but the MRP system usually retains its ability to net against any occasional inventories of the item. This technique also facilitates the use of common bills-of-material for engineering and manufacturing. *Syn:* blow-through, transient bill-of-material. *See* pseudo bill-of-material

Physical Inventory (1) The actual inventory itself. (2) The determination of inventory quantity by actual count. Physical inventories can be taken on a continuous, periodic, or annual basis.

Pipeline Stock Inventory in the transportation network and the distribution system, including the flow through intermediate stocking points. The flow time through the pipeline has a major effect on the amount of inventory required in the pipeline. Time factors involve order transmission, order processing, shipping, transportation, receiving, stocking, review time, and the like. *Syn:* pipeline inventory; transportation inventory.

Plan A predetermined course of action over a specified period of time that represents a projected response to an anticipated environment to accomplish a specific set of adaptive objectives.

Planned Order A suggested order quantity, release date, and due date created by the planning system's logic when it encounters net requirements in processing MRP. In some cases, it can also be created by a master scheduling module. Planned orders are created by the computer, exist only within the computer, and may be changed or deleted by the computer during subsequent processing if conditions change. Planned orders at one level will be exploded into gross requirements for components at the next level. Planned orders, along with released orders, serve as input to capacity requirements planning to show the total capacity requirements by work center in future time periods. *See* planning time fence

Planned Receipt An anticipated receipt against an open purchase order or open production order. *Syn:* planned order receipt

Planning Bill-of-Material An artificial grouping of items and/or events in the bill-of-material format, used to facilitate master scheduling and material planning. It may include the historical average of demand expressed as a percentage of total demand for all options within a feature or for a specific end item within a product family and is used as the quantity per in the planning bill-of-material. *Syn:* planning bill

Planning Fence *Syn:* planning time fence

Planning Horizon The amount of time a plan extends into the future. For a master schedule, this is normally set to cover a minimum of cumulative lead time plus time for lot sizing low-level components and for capacity changes of primary work centers or of key suppliers. For longer-term plans the planning horizon must be long enough to permit any needed additions to capacity. *See* cumulative lead time, planning time fence

Planning Time Fence (PTF) A point in time denoted in the planning horizon of the master scheduling process that marks a boundary inside of which changes to the schedule may adversely affect component schedules, capacity plans, customer deliveries, and cost. Planned orders outside the planning time fence can be changed by system planning logic. Changes inside the planning time fence must be manually changed by the master scheduler. *Syn:* planning fence. *See* cumulative lead time, demand time fence, firm planned order, planned order, planning horizon, time fence

Point-of-Use Delivery Direct delivery of material to a specified location on a plant floor near the operation where it is to be used.

Policies Definitive statements of what should be done in the business.

Postdeduct Inventory Transaction Processing A method of inventory bookkeeping where the book (computer) inventory of components is automatically reduced by the computer only after completion of activity on the components' upper level parent item, based on what should have been used as specified in the bill-of-material and allocation records. This approach has the disadvantage of a built-in differential between the book record and what is physically in stock. *Syn:* explode-to-deduct. *See* backflush, pre-deduct inventory transaction processing

Postponement A product design strategy that shifts product differentiation closer to the consumer by postponing identity changes, such as assembly or packaging, to the last possible supply chain location.

Prediction An intuitive estimate of demand taking into account changes and new factors influencing the market, as opposed to a forecast, which is an objective projection of the past into the future.

Priority In a general sense, the relative importance of jobs; that is, the sequence in which jobs should be worked on. It is a separate concept from capacity.

Priority Planning The function of determining what material is needed and when. Master Scheduling and Material Requirements Planning are the elements used for the planning and replanning process in order to maintain proper due dates on required materials.

Probability Mathematically, a number between 0 and 1 that estimates the fraction of experiments (if the same experiment were being repeated many times) in which a particular result would occur. This number can be either subjective or based upon the empirical results of experimentation. It can also be derived for a process to give the probable outcome of experimentation.

Procedures Definitions of approved methods used to accomplish tasks.

Process (1) A planned series of actions or operations (e.g., mechanical, electrical, chemical, inspection, test) that advances a material or procedure from one stage of completion to another. (2) A planned and controlled treatment that subjects materials or procedures to the influence of one or more types of energy (e.g., human, mechanical, electrical, chemical, thermal) for the time required to bring about the desired reactions or results.

Process Batch The number of units made between sequential setups at a work center. *See* batch, exchange unit, overlap quantity

Process Flow Production A production approach with minimal interruptions in the actual processing in any one production run or between production runs of similar products. Queue time is virtually eliminated by integrating the movement of the product into the actual operation of the resource performing the work.

Process Flow Scheduling A generalized method for planning equipment usage and material requirements that uses the process structure to guide scheduling calculations. It is used in flow environments common in process industries.

Process Focused A type of manufacturing organization in which both plant and staff management responsibilities are delineated by production process. A highly centralized staff coordinates plant activities and intracompany material movements. This type of organization is best suited to companies whose dominant orientation is to a technology or a material and whose manufacturing processes tend to be complex and capital intensive. *See* product focused

Process Manufacturing Production that adds value by mixing, separating, forming, and/or performing chemical reactions. It may be done in either batch or continuous mode.

Process Plant A manufacturing facility in which a chemical or compositional change is the majority of activity.

Process Sheet Detailed manufacturing instructions issued to the plant. The instructions may include specifications on speeds, feeds, temperatures, tools, fixtures, and machines and sketches of setups and semifinished dimensions.

Process Steps The operations or stages within the manufacturing cycle required to transform components into intermediates or finished goods. From a larger perspective, the operations or stages within any business required to turn inputs into outputs.

Product Configurator A system, generally rule based, to be used in design-to-order, engineer-to-order, or make-to-order environments where numerous product variations exist. Product configurators perform intelligent modeling of the part of product attributes and often create solid models, drawings, bills-of-material, and cost estimates that can be integrated into CAD/CAM and MRPII systems as well as sales order entry systems.

Product Differentiation A strategy of making a product distinct from the competition on a nonprice basis—for example, in availability, durability, quality, reliability, and the like.

Product Grade The categorization of goods based upon the range of specifications met during the manufacturing process.

Production The conversion of inputs into finished products.

Production and Inventory Management General term referring to the body of knowledge and activities concerned with planning and controlling rates of purchasing, production, distribution, and related capacity resources to achieve target levels of customer service, backlogs, operating costs, inventory investment, manufacturing efficiency, and ultimately, profit and return on investment.

Production Capability (1) The highest sustainable output rate that can be achieved for a given product mix, raw materials, worker effort, plant, and equipment. (2) The collection of personnel, equipment, material, and process segment capabilities. (3) The total of the current committed, available, and unattainable capability of the production facility. The capability includes the capacity of the resource.

Production Control The function of directing or regulating the movement of goods through the entire manufacturing cycle from the requesting of raw material to the delivery of the finished products.

Production Forecast A projected level of customer demand for a feature (option, accessory, etc.) of a make-to-order or an assemble-to-order product. Used in two-level master scheduling, it is calculated by netting customer backlog against an overall family or product line master production schedule and then factoring this product's available-to-promise by the option percentage in a planning bill-of-material.

Production Plan The agreed-upon plan that comes from the production planning (sales and operations planning) process, specifically the overall level of manufacturing output planned to be produced, usually stated as a monthly rate for each product family (group of products, items, options, features, etc.). Various units of measurement can be used to express the plan: units, tonnage, standard hours, number of workers, and so on.

The production plan is management's authorization for the master scheduler to convert it into a more detailed plan—that is, the master production schedule.

Production Planning A process to develop tactical plans based on setting the overall level of manufacturing output (production plan) and other activities to best satisfy the current planned levels of sales (sales plan or forecasts), while meeting general business objectives of profitability, productivity, competitive customer lead times, and so on, as expressed in the overall business plan. The sales and production capabilities are compared, and a business strategy that includes a sales plan, a production plan, budgets, pro forma financial statements, and supporting plans for materials and workforce requirements, and so on, is developed. One of its primary purposes is to establish production rates that will achieve management's objective of satisfying customer demand by maintaining, raising, or lowering inventories or backlogs, while usually attempting to keep the workforce relatively stable. Because this plan affects many company functions, its is normally prepared with information from marketing and coordinated with the functions of manufacturing, sales, engineering, finance, materials, and so on.

Production Process The activities involved in converting inputs into finished goods.

Production Rate The rate of production, usually expressed in units, cases, or some other broad measure, expressed by a period of time, for example, per hour, shift, day, or week.

Production Schedule A plan that authorizes the factory to manufacture a certain quantity of a specific item. It is usually initiated by the production planning department.

Production Scheduling The process of developing the production schedule.

Product Life Cycle The stages a new product idea goes through from beginning to end; that is, the stages that a product passes through from introduction through growth, maturity, and decline. The time from initial research and development to the time at which sales and support of the product to customers are withdrawn. The period of time during which a product can be produced and marketed profitably.

Product Line A group of products whose similarity in manufacturing procedures, marketing characteristics, or specifications enables them to be aggregated for planning, marketing, or, occasionally, costing.

Product Load Profile A listing of the required capacity and key resources needed to manufacture one unit of a selected item or family. The resource requirements are further defined by a lead-time offset to predict the impact of the product on the load of the key resources by specific time period. The product load profile can be used for rough cut capacity planning to calculate the approximate capacity requirements of the master production schedule. *See* bill of resources, resource profile, rough cut capacity planning

Product Mix The proportion of individual products that make up the total production or sales volume. Changes in the product mix can mean drastic changes in the manufacturing requirements for certain types of labor and material.

Product Structure The sequence that components follow during their manufacturing into a product. A typical product structure would show raw material converted into fabricated components, components put together to make subassemblies, subassemblies going into assemblies, and so on.

Production Line A series of pieces of equipment dedicated to the manufacture of a specific number of products or families.

Production Management (1) The planning, scheduling, execution, and control of the process of converting inputs into finished goods. (2) A field of study that focuses on the effective planning, scheduling, use, and control of a manufacturing organization through the study of concepts from design engineering, industrial engineering, management information systems, quality management, inventory management, accounting, and other functions as they affect the transformation process.

Production Order *Syn:* manufacturing order

Production Process The activities involved in converting inputs into finished goods. *See* manufacturing process, transformation process

Productivity An overall measure of the ability to produce a good or a service. It is the actual output of production compared to the actual input of resources. Productivity is a relative measure across time or against common entities. In the production literature, attempts have been made to define total productivity where the effects of labor and capital are combined and divided into the output. One example is a ratio that is calculated by adding the standard hours of labor actually produced plus the standard machine hours actually produced in a given time period divided by the actual hours available for both labor and machines in the time period.

Projected Available Balance The inventory balance projected into the future. It is the running sum of on-hand inventory minus requirements plus scheduled receipts and planned orders.

Prototype (1) A product model constructed for testing and evaluation to see how the product performs before releasing the product to manufacture. (2) Model consisting of all files and programs needed for a business application.

Pseudo Bill-of-Material An artificial grouping of items that facilitates planning. *See* modular bill-of-material, phantom bill-of-material, planning bill-of-material, super bill-of-material

Pull (System) (1) In production, the production of items only as demanded for use or to replace those taken for use. (2) In material control, the withdrawal of inventory as demanded by the using operations. Material is not issued until a signal comes from the user. (3) In distribution, a system for replenishing field warehouse inventories where replenishment decisions are made at the field warehouse itself, not at the central warehouse or plant.

Push (System) (1) In production, the production of items at times required by a given schedule planned in advance. (2) In material control, the issuing of material according to a given schedule or issuing material to a job order at its start time. (3) In distribution, a system for replenishing field warehouse inventories where replenishment decision making is centralized, usually at the manufacturing site or central supply facility.

Quality Conformance to requirements or fitness for use. Quality can be defined through five principal approaches: (1) Transcendent quality is an ideal, a condition of excellence. (2) Product-based quality is fitness on a product attribute. (3) User-based quality is fitness for use. (4) Manufacturing-based quality is conformance to requirements. (5) Value-based quality is the degree of excellence at an acceptable price. Also, quality has two components: (1) quality of conformance is quality defined by the absence of defects, and (2) quality of design is quality measured by the degree of customer satisfaction with a product's characteristics and features.

Rate-Based Scheduling A method for scheduling and producing based on a periodic rate, for example, daily, weekly, or monthly. Traditionally, this method has been applied to high-volume and process industries. The concept has been recently applied within job shops using cellular layouts and mixed-model level schedules where the production rate is matched to the selling rate.

Rated Capacity The expected output capability of a resource or system. Capacity is traditionally calculated from such data as planned hours, efficiency, and utilization. The rated capacity is equal to hours available × efficiency × utilization. *Syn:* calculated capacity, effective capacity, nominal capacity, standing capacity

Raw Material Purchased items or extracted materials that are converted via the manufacturing process into components and products.

Raw Materials Inventory Inventory of material that has not undergone processing at a facility.

Real Time The technique of coordinating data processing with external related physical events as they occur, thereby permitting prompt reporting of conditions.

Receipt (1) The physical acceptance of an item into a stocking location. (2) Often, the transaction reporting of this activity.

Recipe *Syn:* formula

Regeneration MRP An MRP processing approach where the master production schedule is totally reexploded down through all bills-of-material to maintain valid priorities. New requirements and planned orders are completely recalculated or "regenerated" at that time.

Release The authorization to produce or ship material that has already been ordered.

Remanufacturing An industrial process in which worn-out products are restored to like-new condition. In contrast, a repaired or rebuilt product normally retains its identity, and only those parts that have failed or are badly worn are replaced or serviced. 2) The manufacturing environment where worn-out products are restored to like-new condition.

Repetitive Manufacturing The repeated production of the same discrete products or families of products. Repetitive methodology minimizes setups, inventory, and manufacturing lead times by using production lines, assembly lines, or cells. Work orders are no longer necessary; production scheduling and control is based on production rates. Products may be standard or assembled from modules. Repetitive is not a function of speed or volume. *Syn:* repetitive process

Required Capacity *Syn:* capacity required

Requirements Explosion The process of calculating the demand for the components of a parent item by multiplying the parent item requirements by the component usage quantity specified in the bill-of-material. *Syn:* explosion

Rescheduling The process of changing order or operation due dates, usually as a result of their being out of phase when they are needed.

Rescheduling Assumption A fundamental piece of MRP logic that assumes that existing open orders can be rescheduled in nearer time periods far more easily than new orders can be released and received. As a result, planned order receipts are not created until all scheduled receipts have been applied to cover gross requirements.

Resource Anything that adds value to a product or service in its creation, production, and delivery.

Resource Profile The standard hours of load placed on a resource by time period. Production lead-time data is taken into account to provide time-phased projections of the capacity requirements for individual production facilities. *See* bill-of-resources, capacity planning using overall factors, product load profile, rough cut capacity planning

Rough Cut Capacity Planning (RCCP) The process of converting the master production schedule into requirements for key resources, often including labor, machinery, warehouse space, suppliers' capabilities, and, in some cases, money. Comparison to planned capacity (demonstrated capacity plus or minus planned changes to the process) is usually done for each key resource. This comparison assists the master scheduler in establishing a feasible master production schedule. Three approaches to performing RCCP are the bill of labor (resources, capacity) approach, the capacity planning using overall factors approach, and the resource profile approach. *See* bill of resources, capacity planning, capacity planning using overall factors, product load profile, resource profile

Route Sheet *Syn:* routing

Routing (1) Information detailing the method of manufacture of a particular item. It includes the operations to be performed, their sequence, the various work centers involved, and the standards for setup and run. In some companies, the routing also includes information on tooling, operator skill levels, inspection operations, and testing requirements, and the like. *Syn:* bill of operations, instruction sheet, manufacturing data sheet, operation chart, operation list, operation sheet, route sheet, routing sheet. *See* bill of labor, bill of resources. (2) In information systems, the process of defining the path a message will take from one computer to another computer.

Safety Capacity The planned amount by which the available capacity exceeds current productive capacity. This capacity provides protection from planned activities such as resource contention, preventive maintenance, and so on, and unplanned activities such as resource breakdown, poor quality, rework, lateness, and the like. Safety capacity plus productive capacity plus idle or excess capacity is equal to 100% of capacity. *Syn:* protective capacity

Safety Lead Time An element of time added to normal lead time for the purpose of completing an order in advance of its real need date to protect against fluctuations in lead time. When used, the MRP system, in offsetting for lead time, will plan both order release and order completion for earlier dates than it would otherwise.

Safety Stock (1) In general, a quantity of stock planned to be in inventory to protect against fluctuations in demand and/or supply. (2) In the context of master production scheduling, the additional inventory and/or capacity planned as protection against forecast errors and/or short-term changes in the backlog. Overplanning can be used to create safety stock. *Syn:* buffer stock, reserve stock

Safety Time *Syn:* safety lead time

Sales and Operations Planning (S&OP) A process to develop tactical plans that provides management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain. The process brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans. It is performed at least once a month and is reviewed by management at an aggregate (product family) level. The process must reconcile all supply, demand, and new-product plans at both the detail and aggregate level and tie to the business plan. It is the definitive statement of the company's plans for the near to intermediate term covering a horizon sufficient to plan for resources and to support the annual business planning process. Executed properly, the sales and operations planning process links the strategic plans for the business with its execution and reviews performance measures for continuous improvement. *See* aggregate planning, production planning, sales plan, tactical planning

Sales Forecast *Syn:* forecast

Sales Mix The proportion of individual product-type sales volumes that make up the total sales volume.

Sales Plan A time-phased statement of expected customer orders anticipated to be received (incoming sales, not outgoing shipments) for each major product family or item. It represents sales and marketing management's commitment to take all reasonable steps necessary to achieve this level of actual customer orders. The sales plan is a necessary input to the production planning process or sales and operations planning process. It is expressed in units identical to those used for the production plan (as well as in sales dollars). *See* aggregate planning, production plan, production planning, sales and operations planning

Sales Planning The process of determining the overall sales plan to best support customer needs and operations capabilities while meeting general business objectives of profitability, productivity, competitive customer lead times, and so on, as expressed in the overall business plan.

Sales Representative An employee authorized to accept a customer's order for a product. Sales representatives usually go to the customer's location when industrial products are being marketed.

Schedule A timetable for planned occurrences; for example, shipping schedule, master production schedule, maintenance schedule, supplier schedule. Some schedules (e.g., project schedules) include the starting and ending time for activities.

Schedule Board *Syn:* control board

Scheduled Receipt An open order that has an assigned due date. *See* open order

Scheduling The act of creating a schedule, such as a master schedule, shop schedule, maintenance schedule, supplier schedule, and so on.

Scrap Factor A factor that expresses the quantity of a particular component that is expected to be scrapped upon receipt from a vendor, completion of production, or while that component is being built into a given assembly. It is usually expressed as a decimal value. For a given operation or process, the scrap factor plus the yield factor is equal to one. If the scrap factor is 30% (or .3) then the yield is 70% (or .7). In manufacturing planning and control systems, the scrap factor is usually related to a specific item in the item master, but may be related to a specific component in the product structure. For example, if 50 units of a product are required by a customer and a scrap factor of 30% (a yield of 70%) is expected, then 72 units (computed as 50 units divided by .7) should be started in the manufacturing process. *Syn:* scrap rate

Seasonality A repetitive pattern of demand from year to year (or other repeating time interval) with some periods considerably higher than others. *See* base series

Semifinished Goods Products that have been stored uncompleted awaiting final operations that adapt them to different uses or customer specifications.

Semiprocess Flow A manufacturing configuration where most jobs go through the same sequence of operations even though production is in job lots.

Sequencing Determining the order in which a manufacturing facility is to process a number of different jobs in order to achieve certain objectives.

Service Parts Those modules, components, and elements that are planned to be used without modification to replace an original part. *Syn:* repair parts

Service Parts Demand The need or requirement for a component to be sold by itself, as opposed to being used in production to make a higher-level product. *Syn:* repair parts demand

Setup Time The time required for a specific machine, resource, work center, or line to convert from the production of the last good piece of lot A to the first good piece of lot B. *Syn:* setup lead time

Shelf Life The amount of time an item may be held in inventory before it becomes unusable.

Shipping The function that performs tasks for the out-going shipment of parts, components, and products. It includes packaging, marking, weighing, and loading for shipment.

Shipping Lead Time The number of working days in transit normally required for goods to move between a shipping and receiving point, plus acceptance time in days at the receiving point.

Shop Packet A package of documents used to plan and control the shop floor movement of an order. The packet may include a manufacturing order, operations sheets, engineering blueprints, picking lists, move tickets, inspection tickets, time tickets, and others.

Significant Part Number A part number that is intended to convey certain information, such as the source of the part, the material in the part, the shape of the part, and the like. These usually make part numbers longer. *Ant:* nonsignificant part number

Simulation (1) The technique of using representative or artificial data to reproduce in a model various conditions that are likely to occur in the actual performance of a system. It is frequently used to test the behavior of a system under different operating policies. (2) Within MRPII, using the operational data to perform what-if evaluations of alternative plans to answer the question, Can we do it? If yes, the simulation can then be run in the financial mode to help answer the question, Do we really want to? *Syn:* what-if analysis

Single-Level Bill-of-Material A display of components that are directly used in a parent item. It shows only the relationship one level down.

Single-Level Where-Used Single-level where-used for a component lists each parent in which that component is directly used and in what quantity. This information is usually made available through the technique known as implosion.

Software The programs and documentation necessary to make use of a computer.

Sorting The function of physically separating a homogeneous subgroup from a heterogeneous population of items.

Spare Parts *Syn:* service parts

Spare Parts Demand *Syn:* service parts demand

Split Lot A manufacturing order quantity that has been divided into two or more smaller quantities, usually after the order has been released. The quantities of a split lot may be worked on in parallel or a portion of the original quantity may be sent ahead to a subsequent operation to be worked on while work on the remainder of the quantity is being completed at the current operation. The purpose of splitting a lot is to reduce the lead time of part of the order.

Standard (1) An established norm against which measurements are compared. (2) An established norm of productivity defined in terms of units of output per set time (units per hour) or in standard time (minutes per unit). (3) The time allowed to perform a specific job including quantity of work to be produced.

Standard Costs The target costs of an operation, process, or product, including direct material, direct labor, and overhead charges.

Standard Time The length of time that should be required to (1) set up a given machine or operation and (2) run one batch or one or more parts, assemblies, or end products through that operation. This time is used in determining machine requirements and labor requirements. Standard time assumes an average worker following prescribed methods and allows time for personal rest to overcome fatigue and unavoidable delays. It is also frequently used as a basis for incentive pay systems and as a basis of allocating overhead in cost accounting systems. *Syn:* standard hours.

Star A slang term for a high-growth, high-profit-margin product.

Strategic Planning The process of developing a strategic plan.

Strategy The strategy of an enterprise identifies how a company will function in its environment. The strategy specifies how to satisfy customers, how to grow the business, how to compete in its environment, how to manage the organization and develop capabilities within the business, and how to achieve financial objectives.

Subassembly An assembly that is used at a higher level to build another assembly.

Subcontracting Sending production work outside to another manufacturer.

Suboptimization A solution to a problem that is best from a narrow point of view but not from a higher or overall company point of view. For example, a department manager who would not have employees work overtime to minimize the department's operating expense may cause lost sales and a reduction in overall company profitability.

Super Bill-of-Material A type of planning bill, located at the top level in the structure, that ties together various modular bills (and possibly a common parts bill) to define an entire product or product family. The quantity per relationship of the super bill to its modules represents the forecasted percentage of demand of each module. The master scheduled quantities of the super bill explode to create requirements for the modules that also are master scheduled.

Supply (1) The quantity of goods available for use. (2) The actual or planned replenishment of a product or component. The replenishment quantities are created in response to a demand for the product or component or in anticipation of such a demand.

Supply Chain The global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution, and cash.

Supply Chain Management The design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally.

Supply Chain Planning The determination of a set of policies and procedures that govern the operation of a supply chain. Planning includes the determination of marketing channels, promotions, respective quantities and timing, inventory and replenishment policies, and production policies. Planning establishes the parameters within which the supply chain will operate.

Synchronized Production A manufacturing management philosophy that includes a consistent set of principles, procedures, and techniques where every action is evaluated in terms of the global goal of the system. Both kanban, which is part of the Just-in-Time and lean manufacturing philosophy, and drum-buffer-rope, which is a part of the theory of constraints philosophy, represent synchronized production control approaches. *Syn:* Just-in-Time; theory of constraints

Tactical Planning The process of developing a set of tactical plans (e.g., production plan, sales plan, marketing plan, etc.). Two approaches to tactical planning exist for linking tactical plans to strategic plans—production planning and sales and operations planning. *See* operational planning, strategic planning

Time Bucket A number of days of data summarized into one columnar display. A weekly time bucket in MRP would contain all of the relevant data summarized for an entire week. Weekly time buckets are considered to be the largest possible (at least in the near and medium term) to permit effective MRP.

Time Fence A policy or guideline established to note where various restrictions or changes in operating procedures take place. For example, changes to the master production schedule can be accomplished easily beyond the cumulative lead time, while changes inside the cumulative lead time become increasingly more difficult to a point where changes should be resisted. Time fences can be used to define these points. *See* demand time fence, hedge, planning time fence

Time Phasing The technique of expressing future demand, supply, and inventories by time period. Time phasing is one of the key elements of material requirements planning.

Time Standard The predetermined times allowed for the performance of a specific job. The standard will often consist of two parts, that for machine setup and that for actual running. The standard can be developed through observation of the actual work (time study), summation of standard micromotion times (predetermined or synthetic time standards), or approximation (historical job times).

Time-to-Market The total time required to design, build, and deliver a product (timed from concept to delivery).

Time-to-Product The total time required to receive, fill, and deliver an order for an existing product to a customer, timed from the moment that the customer places the order until the customer receives the product.

Tolerance Allowable departure from a nominal value established by design engineers that is deemed acceptable for the functioning of the good or service over its life cycle.

Total Employee Involvement (TEI) An empowerment program where employees are invited to participate in actions and decision making that were traditionally reserved for management.

Total Lead Time *Syn:* lead time

Transfer Batch The quantity of an item moved between sequential work centers during production. *See* batch, overlap quantity

Transit Time A standard allowance that is assumed on any given order for the movement of items from one operation to the next. *Syn:* travel time.

Transportation The function of planning, scheduling, and controlling activities related to mode, vendor, and movement of inventories into and out of an organization.

Two-Level Master Production Schedule A master scheduling approach in which a planning bill-of-material is used to master schedule an end product or family, along with selected key features (options and accessories). *See* hedge, multilevel master production schedule, production forecast

U-Lines Production lines shaped like the letter U. The shape allows workers to easily perform several nonsequential tasks without much walk time. The number of workstations in a U-line is usually determined by line balancing. U-lines promote communication.

Unit of Measure The unit in which the quantity of an item is managed; for example, pounds, each, box of 12, package of 20, case of 144.

Value Added (1) In accounting, the addition of direct labor, direct material, and allocated overhead assigned at an operation. It is the cost roll-up as a part goes through a manufacturing process to finished inventory. (2) In current manufacturing terms, the actual increase of utility from the viewpoint of the customer as a part is transformed from raw material to finished inventory. It is the contribution made by an operation or a plant to the final usefulness and value of a product, as seen by the customer. The objective is to eliminate all non-value-added activities in producing and providing a good or service.

Value Chain The functions within a company that add value to the goods or services that the organization sells to customers and for which it receives payment.

Value Stream The process of creating, producing, and delivering a good or service to the market. For a good, the value stream encompasses the raw material supplier, the manufacture and assembly of the good, and the distribution network. For a service, the value stream consists of suppliers, support personnel and technology, the service "producer" and the distribution channel. The value stream may be controlled by a single business or a network of several businesses.

Variable Yield The condition that occurs when the output of a process is not consistently repeatable either in quantity, quality, or combinations of these.

Velocity (1) The rate of change of an item with respect to time. (2) In supply chain management, a term used to indicate the relative speed of all transactions, collectively, within a supply chain community. A maximum velocity is most desirable because it indicates higher asset turnover for stockholders and faster order-to-delivery response for customers.

Vertical Display A method of displaying or printing output from a master scheduling system where requirements, scheduled receipts, projected balance, and so on, are displayed vertically, that is, down the page. Vertical displays are often used in conjunction with bucketless systems. *Ant:* horizontal display

Vision The shared perception of the organization's future—what the organization will achieve and a supporting philosophy. This shared vision must be supported by strategic objectives, strategies, and action plans to move it in the desired direction. *See* vision statement

Vision Statement An organization's statement of its vision. *See* vision

Voice of the Customer Actual customer descriptions in words for the functions and features they desire for products and services. In the strict definition, as relates to quality function deployment (QFD), the term *customer* indicates the external customer to the supplying entity.

Warehouse Demand The need for an item to replenish stock at a branch warehouse. *Syn:* branch warehouse demand

Waste (1) Any activity that does not add value to the good or service in the eyes of the consumer. (2) A by-product of a process or task with unique characteristics requiring special management control. Waste production can usually be planned and somewhat controlled. Scrap is typically not planned and may result from the same production run as waste. *See* hazardous waste

What-If Simulation An approach to conducting a what-if analysis usually found in MRPII and ERP systems.

Work Cell Dissimilar machines grouped together into a production unit to produce a family of parts having similar routings.

Work Center A specific production facility, consisting of one or more people and/or machines with identical capabilities, that can be considered as one unit for purposes of capacity requirements planning and detailed scheduling. *Syn:* load center

Work-in-Process (WIP) A good or goods in various stages of completion throughout the plant, including all material from raw material that has been released for initial processing up to completely processed material awaiting final inspection and acceptance as finished-goods inventory. Many accounting systems also include the value of semifinished stock and components in this category. *Syn:* in-process inventory

Work Order (1) An order to the machine shop for tool manufacture or equipment maintenance, not to be confused with a manufacturing order. *Syn:* work ticket. (2) An authorization to start work on an activity (e.g., maintenance) or product. *See* manufacturing order

Workplace Organization The arrangement of tools, equipment, materials, and supplies according to their frequency of use. Those items that are never used are removed from the workplace, and those items that are used frequently are located for fast, easy access and replacement. This concept extends the idea of "a place for everything and everything in its place."

Workstation The assigned location where a worker performs the job; it could be a machine or a workbench.

Yield The amount of good or acceptable material available after the completion of a process. Usually computed as the final amount divided by the initial amount converted to a decimal or percentage. In manufacturing planning and control systems, yield is usually related to specific routing steps or to the parent item to determine how many units should be scheduled to produce a specific number of finished goods. For example, if 50 units of a product are required by a customer and a yield of 70% is expected then 72 units (computed as 50 units divided by .7) should be started in the manufacturing process. *Syn:* material yield

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