Chapter 1

Why Schedule?

Behold the turtle. He only makes progress
when he sticks his neck out.
—JAMES B. CONANT

INTRODUCTION

Do you remember the slide rule? For those of you who don't, let me describe it to you. A slide rule is made up of three sticks; the two outer sticks are connected together and the center stick slides back and forth between them. There are gradient marks on all three sticks and these marks form a logarithmic scale that is used for calculations like multiplication and division. Ten years ago, understanding and using the slide rule was still part of the mandatory training in the engineering schools of most universities. Now slide rules are considered to be antiques. Why? Because they can no longer calculate? Or, because they give the wrong answer? No! The

reason the slide rule has become obsolete is because a newer, faster, and more accurate tool has been developed: the electronic calculator. Today, someone who still uses a slide rule would be considered to be a fool. A better tool exists, so why not use it?

The same is true in the use of scheduling systems. First there was the two-bin system. Next came Economic Order Quantity (EOQ). With the advent of the computer, Material Requirements Planning (MRP) became possible. And then there were additional scheduling improvements like Just-in-Time (JIT) and Theory of Constraints (TOC). With each new wave of technology came the obsolescence of the older technology. Today, running a production facility based strictly on EOQ modeling would be considered seriously outdated. We are now ready for the next wave of technology. This book will introduce the reader to the scheduling methodology for the year 2000 and beyond: Finite Capacity Scheduling (FCS).

The appearance of Finite Capacity Scheduling (FCS) systems in the early 1980s created heated and extended debates about the value of traditional MRP infinite scheduling methods versus the newer finite scheduling methods. The resistance to finite scheduling was particularly high among MRP vendors and long-term MRP users. The introduction of FCS represented a paradigm shift, and paradigm shifts upset the status quo.

WHY SWITCH?

> Planning cycle time has been reduced from two days per line to just four hours for all lines. This allows us to integrate the company's manufacturing lines and supply

> chain with assurance that a balanced schedule will secure our industry-leading quality standard.
>
> —JAMES SYPNIEWSKI, manager, business analysis, Volvo Trucks NA[1]

Headquartered in Greensboro, North Carolina, Volvo Trucks North America has approximately half a million trucks on the roads of North America. Volvo manages its production process through I2 Technologies' RHYTHM®[2] FCS system utilizing 70 to 80 constraints. It adds and subtracts constraints as needed. Integrating this with material requirements generates a single schedule for all Volvo facilities and, following the supply chain, down to its vendors. Volvo has the flexibility to schedule truck model production while respecting capacity constraints and maintaining efficient flow.

> The biggest benefit we have seen is an improved ability to respond to customer requests. If we can respond quickly in our scheduling, we can get that information out to our supply base so that they can respond quickly too.
>
> —JAMES SYPNIEWSKI, manager, business analysis, Volvo Trucks NA[3]

[1]Taken from an article on Volvo Trucks NA in the February 1997 issue of *Manufacturing Systems* and from an I2 customer case study sheet.

[2]RHYTHM is a registered trademark of I2 Technologies, Inc. I2 Technologies is headquartered in Irving, Texas.

[3]From *Manufacturing Systems*, February 1997, and I2 customer case study sheet.

The question "Why switch?" for traditional scheduling devotees has drawn firm firing lines. The traditionalists believed that the slide rule did an adequate job and that the new technology was not necessary. Even in the mid-1990s, most members of the American Production and Inventory Control Society (APICS) manufacturing information database (MFG-INFO) unequivocally expressed this same attitude when the list requested responses from members regarding the virtues of infinite and finite scheduling.

Infinite capacity scheduling has been strongly endorsed by the MRP community for the past 25 years and any suggestion of an improvement was treated as heresy. In the late 1990s attitudes had changed and MRP vendors started offering FCS solutions. The question shifted away from "Why switch?" to "What to switch to?" Potential users were interested in learning which vendor system would be the long-term winner and would remain at the forefront of FCS technology.

International competitive pressures "to be considered the best" slowly forced users to reconsider their selection of a scheduling technique. The change was inevitable; FCS works. It has always been self-evident that making illogical assumptions, like assuming that a factory had an infinite amount of capacity, would yield illogical answers. A better solution exists when logical assumptions are made. The reason behind the strong resistance was that both the MRP vendors and the long-term users would be required to make significant changes. Additionally, there would be large financial commitments for the MRP vendors in a change of this type. These were not comfortable conditions, and it took some time to convince vendors and users of the value behind the change.

The August 1998 issue of *APICS—The Performance Ad-*

vantage published Bill Kirchmier's article entitled "Selecting an Application: Finite Capacity Scheduling Methods." An excerpt of the article follows (the full article can be found in Appendix 1.1):

> The question regarding finite capacity scheduling (FCS) is not so much "Is my company ready for FCS?" but "Can we afford to wait?" Companies that have implemented FCS systems and made the necessary cultural changes have reaped productivity improvements and realized competitive advantages.
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> I'd like to begin by quoting Laura D'Andrea Tyson, dean of the Haas School of Business at the University of California at Berkeley and previous economic advisor to President Clinton, who said: "Productivity growth is the key variable not only in the trade-off between inflation and unemployment, but also in the economy's long-run growth performance. Over time, output growth is determined by the improvement in productivity."
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> Improved productivity through better utilization of resources is what finite capacity scheduling is all about.
>
> FCS systems have evolved and matured over the past 10 years, and more than 100 packaged software alternatives are now commercially available. The capabilities and costs of these systems vary dramatically, with no single system reigning supreme. With the growth and success in the number of FCS systems, plus a continuing increase in installations by early adapters, many companies today use such scheduling methods.
>
> But the emergence of FCS systems has created tension in the ranks of devoted MRP/MRP II/ERP users, with heated debates swirling about the value of FCS. In reality, however, there should be no conflict. MRP systems solve material and, to some degree planning problems, whereas FCS systems solve only scheduling problems.

Minus the perceived conflict, MRP/ERP systems and FCS systems are truly natural partners.

To appreciate the value of FCS systems, one should realize that moving from traditional scheduling techniques to any FCS system would improve productivity, if appropriate cultural changes were implemented. Two of the major motivating factors for moving from traditional scheduling to FCS scheduling are the universal demand for short cycle times and predictability of delivery dates.

Many companies perceive the discipline required for implementing and maintaining FCS systems as being too great to justify moving to FCS. Ultimately, however, the commitment must be made. The increased success of companies that make the move will put pressure on competitive companies that stick with traditional scheduling.

TYPES OF FCS METHODS

There are three major categories of FCS scheduling methodologies. These are:

- ➢ Job-based.
- ➢ Resource-based.
- ➢ Event-based.

Future chapters will discuss these in detail. Additionally, there are methodologies that carry the FCS banner and therefore deserve mention. However, these have only a limited number of installations. For example, genetic algorithm and linear programming are the most notable. Some FCS vendors also refer to heuristics as another method. However,

since some, if not all, of the job-based, resource-based, and event-based systems use heuristics as a technique within their primary approach, it is difficult to consider this an alternative method.

With a variety of methods and many vendors to choose from, it is little surprise that traditional MRP advocates are concerned about the future direction of scheduling technology. Part of the confusion stems from a lack of clear distinctions between planning systems and scheduling systems.

Planning versus Scheduling

Material Requirements Planning (MRP) systems claim to have both planning and scheduling. However, with today's finite scheduling advances, MRP with its infinite capacity backward pass approach is not capable of producing a schedule that could be followed on the shop floor. Infinite scheduling was used for many years by MRP systems with limited results. Its long-term use has created a feeling that infinite scheduling is an acceptable and effective scheduling method. In reality, the best that can be said about infinite scheduling is that it functioned as a modest planning system. A lot has recently been published about the inadequacy of infinite capacity scheduling.

Planning is the process of calculating material and capacity demands as accurately as possible based on forecast orders, actual orders, or both over a specified time. The terms forecasting and planning both imply error. The output document to the shop floor from an infinite capacity system is a dispatch list that specifies which products are to be produced and in what quantities. The document includes the due date of each work order and the sequence of events but not the

time the events will take place at each work center. This document is typically used by the manager to assist in determining the sequence of tasks through each work center. This approach limits the ability to coordinate work throughout the entire plant. Infinite scheduling compares to a 30-piece band with each musician playing a different tune.

In contrast, scheduling implies accuracy. Scheduling is the process of accurately defining the operating conditions for production on a minute-by-minute basis. Unlike planning, the scheduling function covers a relatively short interval of time. Scheduling used in this context implies that any resource that will affect production needs to be accurately scheduled (i.e., machines, personnel, fixtures, tools, outside vendors, etc.). The output document from a finite scheduling system accurately defines the sequence of all tasks through each work center on a minute-by-minute basis and coordinates all work centers to improve overall plant throughput. The fact that FCS schedules are calculated to such accuracy causes concern that it may not be possible to follow this schedule on a minute-by-minute basis. True, it is not possible to precisely follow a schedule to that degree; however, if the schedule is not calculated to that degree of accuracy, errors would be imposed before it gets to the shop floor.

Actual conditions will oscillate around the FCS-generated scheduled conditions but will be within acceptable limits. When the actual conditions deviate to an unacceptable degree, an update of conditions is required and a new schedule is created. When routings are reasonably accurate and data input is reliable, following the schedule is not a problem and schedules are often followed to the end of the expected cycle without the need for interim rescheduling.

In summary, planning is a close approximation of future conditions over an extended period and scheduling is an ac-

curate list of events based on current conditions over a short interval. Some industries may be able to continue to function and remain competitive with only a planning system and without the need for a detailed scheduling system, but they will be the exception.

The Spectrum of Manufacturing

A variety of processes exist in manufacturing with flow shops and job shops at opposite ends of the spectrum. Although FCS is a benefit to companies at either end of the spectrum, the benefit is more prominent toward the job shop end of the spectrum. Most companies operate somewhere between these two extremes. However, the trend is moving toward the job shop end because customer orders, lot sizes, and cycle time demands are all getting smaller. Even product areas that are traditionally flow shops are beginning to look more like job shops. To be competitive in the future, most companies will have to resort to better scheduling technology. Planning systems alone will not fill the bill.

Why Schedule?

When considering the question "Why schedule?" it is necessary to focus on three universal business success factors:

1. Quality.
2. On-time delivery.
3. Price.

Scheduling impacts the first two of these three items. American industry today is striving to improve its efficiency and effectiveness and to shorten product cycle times. Two strong fads are Total Quality Management (TQM) and Business Process Reengineering (BPR). The Holy Grail is reliable production in the shortest time. The measure of success is almost always time-based.

The first time-based measure is predictability—the ability to deliver when quoted. Thus we get the TQM mantra of "Say what you do, and do what you say." The second measure is cycle time reduction. This is the shortening of the time needed to produce an order. To accomplish these two time-based criteria requires capacity management, which requires effective scheduling. As Peter Drucker persuasively argues, the new measure of competitive success is, or should be, time. The true measure of productivity is output per unit of time given finite resources.

The time-based objective of scheduling should be to define when jobs will be completed and to deliver the jobs on that schedule; to deliver the product when promised. The cost of late delivery is high. At worst, it means lost orders or even lost customers, but it often also means excess inventory with high buffer inventories, poor customer relations, and excessive expediting. The bottom line costs are easily calculable. In contrast, the ideal schedule will:

1. Maximize resource utilization.
2. Decrease inventory costs.
3. Increase inventory turnover.
4. Improve customer service.
5. Improve communication and coordination.
6. Produce a to-do list that can be followed.

Scheduling Starts with a Strategic Plan

A strategic plan should address conditions that promote company objectives; these objectives are modeled in the scheduling system to promote adherence to the company strategy. Some important issues, which have often been left out of a company's strategy, include:

1. Methods of quoting due dates.
2. Periodic evaluations of the strategic plan.
3. Sufficient attention to companywide communication (data accessible to all personnel when and where needed).

Failure to define and follow each of the points at all levels will tend to undermine the scheduling objectives. The end result will be a tendency to deviate from the schedule and lose its intended effectiveness.

Even the best companies tend to be reactive because of poor scheduling. Often their employees prefer being reactive because they are so used to operating in this mode. The shoot from the hip approach is very common in the American culture. The West was won with a six-shooter and many shop floor managers continue to function in the shoot from the hip mode. While there are some conditions that might benefit from this philosophy, modern, competitive, and complex manufacturing is not one of them.

Capacity Requirements Planning (CRP) as discussed in MRP systems is based on infinite capacity scheduling. However, very few companies ever implement the MRP Capacity Requirements Planning (CRP) modules because they are not effective. They cannot produce feasible schedules.

Most MRP systems issue a report to the shop floor referred to as the dispatch list. This report is simply a list of the jobs with due dates. No document is delivered to the shop floor that details when each task should be produced at each work center. Fortunately, this is starting to change. Some MRP software companies are slowly becoming aware of and taking steps to provide better scheduling. It will, however, take years before management's current expectations are met.

This book will repeatedly point to the scheduling inadequacies of MRP systems and it may appear at times that we think MRP systems are of little use. This is not the case; to set the record straight, MRP systems and next-generation Enterprise Resource Planning (ERP) systems are here to stay, and they contribute greatly to the material management function. But as a capacity management function, current MRP systems are totally inadequate and produce unfeasible results due to the assumption that capacity is infinite. This book shows how MRP systems can make a quantum leap in effectiveness by implementing Finite Capacity Scheduling (FCS) methods within the MRP structure.

MANAGEMENT INVOLVEMENT IN SCHEDULING HARDWARE AND SOFTWARE SYSTEMS

Scheduling is computer intensive, and until the advent of cheap computing in the 1980s computer power posed a prohibitive technical barrier. Sophisticated solutions to scheduling are fairly new. Implementation of modern scheduling systems remains rather obscure. Scheduling is a management problem, yet most often scheduling decisions are relegated to the shop floor. We suspect that most managers believe that

meaningful, precise scheduling is not possible. Very few managers understand the dimensions of scheduling. Operations management is not a popular subject since it requires more technology, demands more education, and gets in the way of the traditionalist's shoot from the hip philosophy.

Newer system concepts are now entering the scene and will be discussed. These new systems tend to offer functions beyond the typical MRP systems. The most prominent new concepts now being promoted and receiving significant attention are Enterprise Resource Planning (ERP), Finite Capacity Promising (FCP), Schedule-Based Manufacturing (SBM), and Supply Chain Management (SCM). These systems deal with a broader base of information than the typical MRP systems. However, at the time of writing this book, most of the mentioned disciplines have not yet made a full commitment to modern scheduling technology.

Modern scheduling technology is now moving ahead at an impressive rate. Vendors are being faced with a continuous array of new customer demands. As new requirements are realized, vendors add features and functions. Vendor systems are beginning to converge toward similar characteristics, and this trend toward standardization will continue. As vendors win new and more clients, each vendor must ultimately match each new application to the satisfaction of clients or be eliminated from the competition. The result is that vendor systems begin to appear similar even though they use different scheduling methods.

A major objective in moving toward modern scheduling is to motivate management to get involved in the process of scheduling. Most companies seem content to accept the standard approach of infinite scheduling and to assign materials management the scheduling function. Most often the default position is to accept the traditional MRP approach without

considering new and advanced methods that yield better solutions and reduce cycle times. A major function of this book is to demonstrate to management why implementation of time-based manufacturing is necessary for the coordination of material and capacity.

It will be necessary to influence a large number of high-level management personnel throughout the manufacturing sector before FCS becomes an accepted approach. This chapter will be dedicated to convincing upper-level management that infinite capacity scheduling is bankrupt and produces unfeasible schedules. The chapter will also expose the need for upper-level management to coordinate the scheduling method with the management style of the company.

We are now ready to move forward and learn what FCS is all about. How can FCS make a manufacturer more competitive? Let's find out.

MANAGEMENT STYLES

Experience in implementing FCS systems over the past 14 years has resulted in some observations. One of the most discernible and useful observations is that practically all scheduling management has been based on a style that we refer to as job management. Wherever we implemented FCS, regardless of the product being manufactured, there was a recurrence of expediting. After several years of observing excessive expediting, it occurred to us that the problem was related to the inability to predict finish dates of customer orders. Finish dates were often later than due dates or would require expediting and overtime to meet the established due date commitment.

Observing this condition led to the realization that several factors combine to create a perpetual condition of expe-

diting. The process of piecing together the various influences on production and delivery commitments led to the conclusion that infinite capacity scheduling was the primary culprit. Infinite scheduling is not the sole contributor; the effort to satisfy clients in the absence of accurate data was also a large contributor to the chaos. Acceptance of standard cycle times also contributed.

Most companies would apply some standard delivery time (predetermined product cycle time) for each product and quote the standard regardless of the load in the shop. To further exasperate the condition, because companies like to be responsive to client needs or demands, and because of pressure from the sales department, the manufacturer would usually quote whatever delivery the client insisted on.

The next chapter will go into detail about how infinite scheduling functions; a brief explanation here will give some understanding of why infinite scheduling contributes to the problem. Infinite scheduling systems assume that a task can be started whenever it arrives at a work center. This is an incorrect assumption. In an attempt to correct this assumption, estimated queue time is added to the standard production lead time at each work center. This is time above what it would take to complete the product if infinite capacity did exist. This estimated time is based on some average and does not take into account the actual current demand; ignoring variable demand is a second incorrect assumption. Other erroneous assumptions also occur; however, the two major problems are based on the following erroneous assumptions:

- A task can be started whenever it arrives at a work center.
- The average queue time can be expected.

Often a customer is on the phone ordering a product and requesting a delivery date that is much earlier than the date calculated by the system. Since everyone is aware that the system is not accurate and that the estimated dates are much longer than the actual work content, the client gets promised the date requested. If this were the only exception to the estimated cycle time, there would be no problem because with infinite capacity systems these estimates are always conservative and much longer than normal deliveries. However, when the next customer calls with a delivery date request and also gets the delivery date desired, the problem is compounded. The result is that the exception becomes the standard and soon practically all jobs end up needing to be expedited if they are to meet the due date. This is an extremely costly way to run a manufacturing facility.

SCHEDULING METHODS

Most companies that implement software of any variety, be it accounting, forecasting, or material control, use only a portion of what the software system has to offer. They do not realize the total capability of the software. Scheduling software follows the same pattern. However, users of scheduling software utilize even less of the total capability than users of most other types of software. The permutations and combinations of features and functions, constraints, rules, user priorities, due dates, setup minimization, preferred workstations, and so on are so numerous that many users continue to resort to intuition rather than using the system's capability to find the best solution.

To utilize a modern scheduling technology requires deviating from traditional practices. For example, the con-

strained work centers (bottlenecks) become the major influence in limiting throughput. Regardless of what decisions are made relative to priorities, setup minimization, rules used, and so forth, the controlling factor is that bottleneck work centers have more demand than capacity. In many applications, and particularly in a job shop environment, these constraints often move from work center to work center (wandering bottlenecks).

The user's objective is to let the scheduling system find the best solution. A good approach is to generate multiple schedules using varying parameters and compare the results. This may not be optimum because it is difficult to define a truly optimum solution when so many conflicting conditions exist. Rather, this is the best solution based on current conditions.

Using an FCS system requires experience and has a learning curve prior to reaping the rewards available from modern scheduling technology, and this requires a concerted effort. Intuitive methods should remain; however, the major emphasis should focus on making use of the power of the scheduling software. Intuition resulting from years of experience should be used in conjunction with the FCS system capability to investigate options. The combination of human ingenuity and alternative schedules from the scheduling system can generate better results in only a few minutes.

The acceleration of the acceptance of FCS in the past few years has left MRP vendors vulnerable because of their resistance in accepting FCS systems. Most good FCS development has been by independent vendors who offer only scheduling software. Some MRP vendors have attempted to develop FCS systems. However, their efforts to date have not been very impressive or rewarding, and the result

has forced MRP vendors to partner or purchase scheduling software from independent FCS developers, many of whom have over 10 years of development and implementation experience.

These MRP/ERP vendors feel they have fully integrated their new partner or their purchased software, and to some extent it is true. The ultimate solution and true integration of material and capacity would require starting over and building the material and capacity systems together as a single solution. This is no small task and will take years. Trying to solve all material and capacity conflicts in a single pass is a major undertaking. Realizing that MRP/ERP vendors have spent years rejecting FCS, how could they overnight understand how to develop a new approach that includes FCS? Also, how much influence will the new FCS partner exert over the existing ERP influence? Years have been spent analyzing approaches to the integration of the two systems. Although a major concept has been developed, writing and implementing a system is yet another hurdle.

Merging ERP and FCS together is an interim process. While the trend of interfacing FCS/ERP by a series of multiple passes until both the material and capacity systems are feasible is a great improvement over the traditional approach using infinite capacity, a preferred approach for the clients is to have both the material and capacity functions in a single module so that capacity and material calculations are simultaneous in a single pass. To accomplish this will mean a complete revision in how MRP/ERP systems were originally designed. Until then, the best solution for clients is thoroughly to investigate interfaced solutions.

Many clients are committed to the long-term use of their existing MRP/ERP systems. In this case, a client inter-

ested in adding FCS capability requires investigating if the MRP/ERP vendor has developed capable FCS software. The alternative is the purchase of an independent FCS system that already interfaces or that the vendor commits to interfacing to the client's existing MRP/ERP. Clients should not conclude that the MRP/ERP supplier has interfaced a partner scheduling system that is best for the client application. Each company should evaluate the MRP-supplied FCS system to determine if it is a good fit for the company's application. The alternative is to consider purchasing an independent FCS/APS (Advanced Planning and Scheduling) system to interface with the existing MRP/ERP systems.

The predominant systems that are in vogue today, such as Supply Chain Management (SCM) and Enterprise Resource Planning (ERP), currently have the major influence over how manufacturing companies are managing their resources. Numerous system designations are available that add value and interface with the SCM and ERP systems. Examples in addition to FCS and APS are Manufacturing Execution Systems and Shop Floor Tracking. Many of them are difficult to distinguish by the designated name. Overlap in capability is prominent among these designations. As time progress, the ERP and SCM vendors will include some or all of these peripheral systems as integrated systems. As in the past, clients will have to decide when to purchase the entire package and when to elect to use an independent vendor. History seems to indicate that smaller companies that develop specialty packages usually have better functionality than those that adopt the packaged software by the large vendors. The decision becomes which is better—an all-encompassing integrated system or a best-of-breed collection of system modules.

Y2K

For several years companies have been actively instituting solutions to manage the millennium bug. Resources being exerted for this effort continue to increase. As noted daily on all news channels, the concern over the Y2K problem is enormous and the financial and personnel commitment to solving the problem is proportionally high. Interest in FCS systems during this corresponding period has also been very high. However, the implementation of FCS systems is not keeping pace with interest. The excessive financial and personnel commitment that companies have to make to solve the Y2K problem contributes to the slow implementation of FCS systems. The ERP and SCM stocks, which were elevated in the past several years, have recently experienced major declines, apparently because most companies have made commitments to solve the Y2K problem and orders are slowing.

The need to solve the Y2K problem has had a negative effect on FCS sales. We believe this period is ending and that by the year 2000 there will be a surge by manufacturing companies purchasing and implementing modern scheduling techniques. There will be a flurry of effort by the MRP/ERP suppliers to add scheduling capability. If they have not been working on a solution for several years, they will have to purchase it from an independent FCS supplier or be left behind. Scheduling will become the most important addition to the ERP chain of modules.

SUMMARY

Industry Week (*IW*) recently published the results of a census survey it conducted. It reported that Advanced Planning and

Scheduling (APS) was the area of technology most often cited by respondents as the next system to be implemented. The report stated that APS was cited by 47.6 percent of plant level respondents and was well ahead of the second most often cited on the list, which was to have Electronic Data Interchange (EDI) links to suppliers (39.7 percent). *Industry Week* went on to state that the rapid growth and use of the Internet would reduce the degree of EDI implementation in the future since the Internet is more accessible and less expensive.

In the past, FCS has experienced an extensive era of resistance. However, world-class competitiveness requires MRP/ERP users and vendors to reconsider their hard-line stance against FCS. They are realizing that there is a difference between planning and scheduling systems, and that both are needed. More and more vendors are in the process of integrating FCS into their existing packages. By early in the next decade, most if not all MRP/ERP vendors will be including Finite Capacity Scheduling. It will become a critical tool for competitive success.

Common sense is not common.

—WILL ROGERS
