APPLYING SYNCHRONOUS MANUFACTURING CONCEPTS TO IMPROVE PRODUCTION PERFORMANCE IN HIGH-TECH MANUFACTURING

GREGORY V. FRAZIER
PEDRO M. REYES
Information Systems and Management Sciences Department, College of Business Administration, University of Texas at Arlington, Arlington, TX 76019-0437

To compete successfully in high-tech industries manufacturers must continuously improve their operational performance. For some companies, achieving substantial levels of production improvement may require changing the way production is managed and controlled. This article describes one high-tech manufacturer's experience in obtaining substantial improvements in its production performance.

Synchronous manufacturing embodies many concepts related to focusing and synchronizing production control around bottleneck resources. Another common name for these concepts is theory of constraints, or simply TOC. Much of the development of these concepts and ideas is widely attributed to Eliyahu Goldratt. He creatively presented and explained the concepts in a popular fictional novel titled *The Goal* [5]. Goldratt explained his ideas further in two subsequent books: *Theory of Constraints* [3] and *The Haystack Syndrome* [4]. Umble and Srikanth [8] present these concepts in a more instructional manner in their book *Synchronous Manufacturing*. Another term sometimes used to describe this set of ideas is the *drum-buffer-rope* approach. This term is based on the examples Goldratt presented in *The Goal*. Still other names that have been used to describe these concepts are *bottleneck management*, *constraint theory*, and the *goal system*.

Regardless of the name used, this set of ideas and concepts has the potential to substantially improve a company's operational and financial performance. One of the main focuses of synchronous manufacturing is to efficiently utilize the resource that is most constraining and that thus prevents additional production output or sales. The output rate of this bottleneck resource can be considered the *drum* that sets the pace for the entire production system. To ensure that the bottleneck resource never runs out of work, a *buffer* of work-in-process inventory is kept just in front of the resource. To keep the level of work-in-process (WIP) inventories in production from being too high, the release of materials onto the shop floor is tied to the rate of production at the bottleneck resource (referred to as the *rope*). In this way, the entire production system is viewed as being synchronized.

One of the most commonly used production and inventory planning tools in the past 20 years has been material resources planning (MRP). At the planning level, MRP can be considered a pull system that attempts to minimize inventories and coordinate materials management with production control. But at the operational level many companies using MRP still experience huge amounts of inventories, and work centers still push batches to the next machine. So from an operational perspective and as evidenced in practice, MRP may still be a push system [6]. Another disadvantage of MRP is that it ignores capacity constraints to a large extent, although capacity requirements planning (CRP) when used along with MRP tries to alleviate that shortcoming. The desire to better manage resources that are at or near capacity is one reason many companies have supplemented their MRP systems with synchronous manufacturing.

Since the early- to mid-1980s, the concepts and approaches related to synchronous manufacturing have made a significant impact on production management practice and research. Gardiner et al. [2] detailed many of these benefits and effects. One particularly important benefit resulting from synchronous manufacturing is reduced production lead times. Increasingly, companies must compete on response time and order-to-delivery lead times. Reduced lead time can also result in substantial savings in costs [1]. On the research side, the *Production and Operations Management* journal recently published a special issue on capacity constrained planning and scheduling, with the focus being on synchronous manufacturing issues [7].

In the rest of this article, we discuss the process of applying the concepts of synchronous manufacturing to a high-tech manufacturer. The previous production

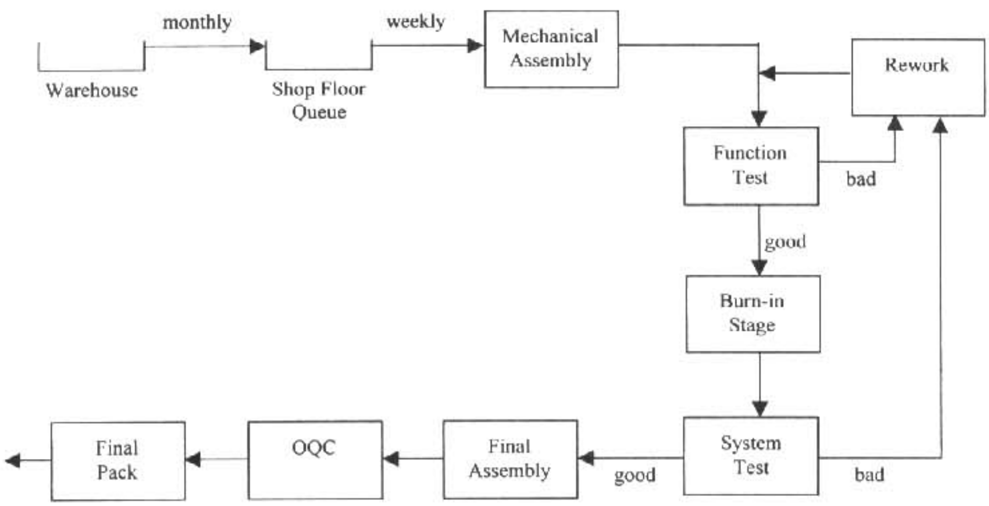

FIGURE 1: Manufacturing process

control approach is described, changes to production and inventory control are detailed, impacts on production performance are presented, and conclusions based on the experience are offered.

PREVIOUS CONDITIONS

The company described is a high-tech manufacturer in the cable TV and telecommunications industries, with multiple plant locations. The plant studied here is in the Dallas/Fort Worth area and has a direct labor force of about 100 employees. The plant produces products for a niche market and historically had been the market leader. However, recent changes in the cable TV and telecommunications industries resulted in fast market growth, and continued strong growth was expected. At this plant, the company primarily produced make-to-stock products based on a rolling 12-month forecast provided by the marketing department. The plant's products were divided among three strategic business units of the company.

The following discussions describe the production system at the beginning of this study. Production quantities for an entire month were determined from the sales forecasts provided. One work order was created for each product each month. The entire month's worth of materials needed to fill each work order were released from the warehouse to a shop floor queue at the beginning of each month. The monthly quantity in a work order was spread evenly across the weeks of the month. At the beginning of each week, a week's worth of each monthly work order was started through the production line. All work orders were due to be completed at the end of each month. On average, production lead times, or throughput times, ranged from 10 to 15 days for most product batches.

The manufacturing process was designed as a flow shop type of layout. The processing steps consisted of mechanical assembly, functional test, live burn-in stage, systems test, final assembly, outbound quality inspection, and final pack. These processing steps were common to all products. The live burn-in stage required about 18 hours. If a part failed the functional test or systems test, it was sent to a rework station and then put back at the end of the queue for the functional test station. The queue selection rule used at each workstation was first come, first served. The rest of the batch was held in the final assembly queue until the faulty part was fixed and successfully tested. Figure 1 shows a flowchart of the manufacturing process.

Four primary measures were used to assess production performance and were reported at the end of each month: percentage of work orders completed in the month released, average weekly (for that month) schedule adherence, month-end raw material inventory level, and month-end WIP inventory level. Weekly schedule adherence was computed as the percentage of batches that were not behind schedule at the end of the week.

Because of competitive pressures in this fast-changing industry, the company decided to change its production and inventory control approach in an effort to improve its production performance. The next section details the analysis and the changes that were made.

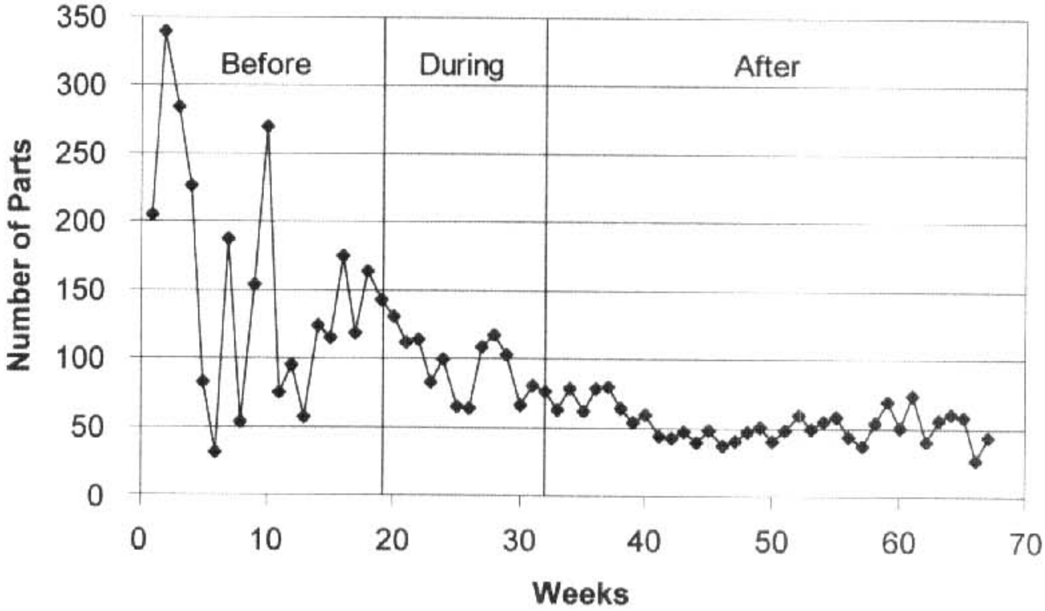

FIGURE 2: WIP inventory level (number of parts) before, during, and after synchronous manufacturing implementation

ANALYSIS AND ACTIONS

The company's objectives in this study were to improve its schedule attainment performance and reduce inventories and lead times. The managers generally felt that the testing processes were the most restrictive in trying to reduce flow times. They decided to try implementing the concepts of synchronous manufacturing because it focuses on managing bottleneck processes.

The first step was to verify that testing was the bottleneck process, as was suspected. After an analysis of average WIP queue sizes, the largest queue was found to typically be at the function test station. On average, about a week's worth of WIP was in this queue. The analysis also showed that the testing stations were occasionally starved for work because of large batches being slowed down at previous workstations.

Although the functional test station was deemed as the primary bottleneck, two other areas had occasionally been observed as bottlenecks that limited production: the outgoing quality control (OQC) station and the purchasing department. Delays at the OQC station were usually due to missing work documents for products. Occasional delays from the purchasing department were usually related to trying to obtain the entire month's worth of materials before releasing it to the shop floor queue.

The second step in implementing synchronous manufacturing was to determine how to exploit the bottleneck, or in other words, determine how to better manage the testing processes. Further analysis revealed that a significant portion of WIP inventory around the testing area was the result of batches being held up while waiting on parts to be reworked. It became clear that WIP inventories could be reduced by expediting the rework and retesting of faulty parts. Subsequently, two queues were then created in front of the function test station. One queue was for parts arriving for testing the first time, and the second queue was for parts that had already been reworked. Jobs waiting in the reworked parts queue were generally given a higher scheduling priority than those in the first-time queue.

The next step was to reduce the amount of materials being released from the warehouse to the shop floor queue at one time. It was decided to issue work orders for weekly production quantities instead of monthly quantities, so materials were moved from the warehouse to production at the beginning of each week instead of only at the beginning of the month.

The last step was to synchronize the release of parts from the shop floor queue with the functional test station. The weekly work order quantities were split into daily quantities, based on processing capacity at the testing stations. Then, the quantity released each day depended on the number of completed batches leaving the testing area (all parts having passed testing). As more parts need to be reworked, fewer completed batches leave the testing area and more of the testing capacity is

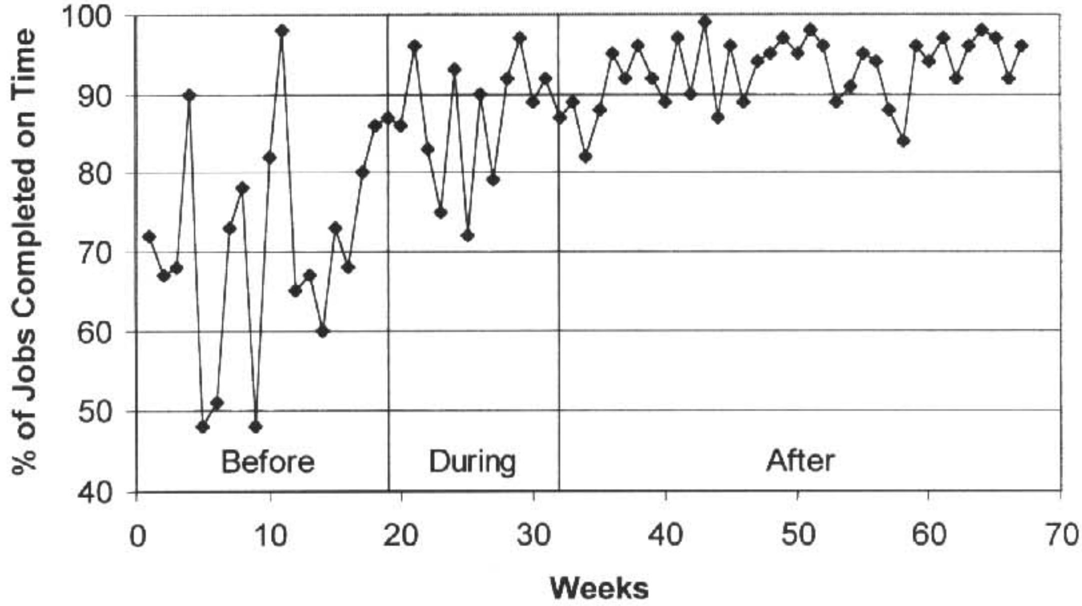

FIGURE 3: Percentage of on-time work orders before, during, and after synchronous manufacturing implementation

used for rework instead of for first-time testing, so fewer parts would be released to the production line.

The time frame to implement a synchronous manufacturing approach was relatively short. Approximately three months were required to analyze the current conditions, decide on improvement actions, and implement the changes. The next section discusses benefits and improvements that were observed.

PERFORMANCE RESULTS

A number of operational improvements were realized as a direct result of applying the concepts of synchronous manufacturing.

By releasing materials from the warehouse to the shop floor queue weekly instead of monthly, more than half of the previous shop floor queue area was freed up. Also, the number of production delays caused by the purchasing department decreased because it was no longer necessary to procure an entire month's worth of materials at one time, and smaller quantities were generally faster to procure. Lower raw material inventories resulted as well.

Releasing daily sublots of the weekly work orders resulted in smaller batches going through the production system and provided a smoother flow of materials through the system. This resulted in lower WIP inventories. Lower WIP inventories also resulted from giving reworked parts a higher sequencing priority at the testing stations. When a batch of parts had to wait on a part to be reworked, the wait was shorter after the changes. Figure 2 shows the end-of-week WIP level (number of units) before, during, and after the implementation of synchronous manufacturing. The chart shows 18 weeks of data before the implementation, 14 weeks during, and 35 weeks after. Both the level of WIP inventory and its variability decreased as a result of synchronous manufacturing. Before the changes, the average end-of-week WIP level was about 150 product units. After the changes were completed, the WIP level dropped to an average of about 50 product units.

Also contributing to smoother work flow was the synchronization of the bottleneck workstation with the release of materials to the production line. This action helped to keep WIP from growing large and allowed for more consistent flow times.

Less WIP inventory and a smoother flow of materials through the production system resulted in shorter production lead times and improved due date performance. Figure 3 shows the percentage of work orders completed on time each week before, during, and after implementation of synchronous manufacturing. Before the changes, the weekly percentage of on-time jobs averaged about 70%. After the changes were completed, the average weekly percentage of on-time jobs increased to about 93%. As with the WIP inventory level, variation of weekly percentage of on-time jobs decreased substantially.

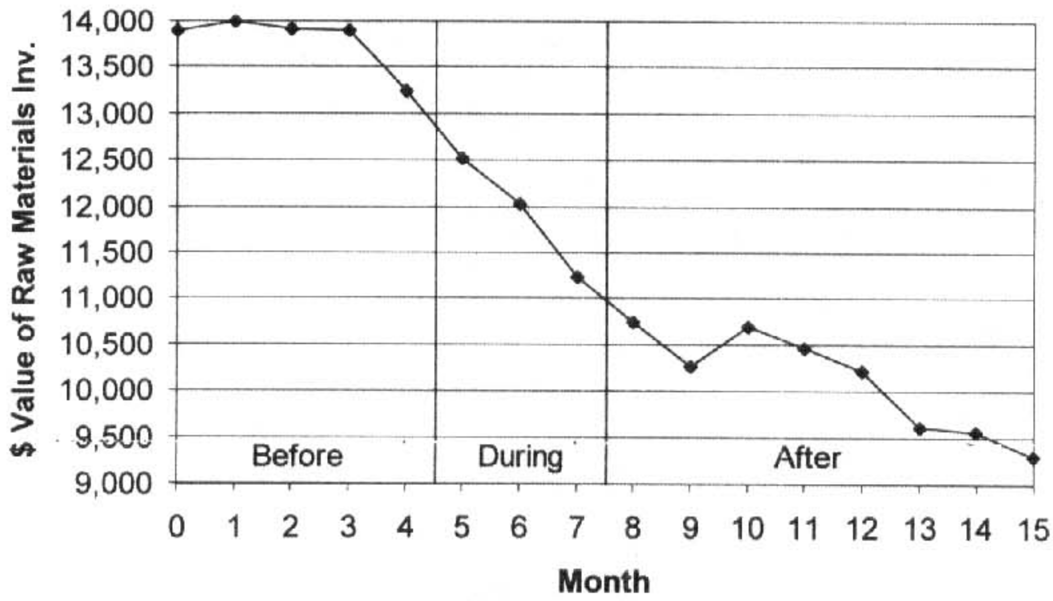

FIGURE 4: Value of raw materials inventory before, during, and after synchronous manufacturing implementation

The impact on raw materials inventory is shown in figure 4. The chart shows the end-of-month value of raw materials (purchased components) before, during, and after the synchronous manufacturing implementation. The value of raw materials decreased from close to $14,000 to less than $10,000.

SUMMARY AND CONCLUSIONS

Synchronous manufacturing has been touted by many as a valuable tactical weapon in the battle to become leaner and more efficient. This article describes how one high-tech manufacturer applied the principles of synchronous manufacturing and substantially improved its production performance. During the three-month implementation period, WIP inventory decreased to one-third of its previous level, raw materials inventory value decreased by about 30%, and percent on-time completion of jobs increased by more than 20%. Motivated by this success, the company is continuing to search for ways to further improve its production performance.

The operational changes that were made can easily be replicated in many other manufacturing companies and similar benefits can be expected.

REFERENCES

1. Chao, J.S., and S.C. Graves. "Reducing Flow Time in Aircraft Manufacturing." *Production and Operations Management* 7, no. 1 (1998): 38–52.
2. Gardiner, S.C., J.H. Blackstone Jr., and L.R. Gardiner. "Drum-Buffer-Rope and Buffer Management: Impact on Production Management Study and Practices." *International Journal of Operations and Production Management* 13, no. 6 (1993): 68–78.
3. Goldratt, E.M. *Theory of Constraints*, Croton-on-Hudson, N.Y.: North River Press, 1990.
4. Goldratt, E.M. *The Haystack Syndrome*, Croton-on-Hudson, N.Y.: North River Press, 1990.
5. Goldratt, E.M., and J. Cox. *The Goal*, Croton-on-Hudson, N.Y.: North River Press, 1984.
6. Lambrecht, M.R., and L. Decaluwe. "JIT and Constraint Theory: The Issue of Bottleneck Management." *Production and Inventory Management Journal* 29, no. 3 (1988): 61–65.
7. *Production and Operations Management* 6, no. 1 (1997).
8. Umble, M.M., and M.L. Srikanth. *Synchronous Manufacturing*, Cincinnati, Ohio: South-Western Publishing, 1990.

About the Authors—

GREGORY V. FRAZIER is an associate professor of production and operations management and the director of MBA programs at the University of Texas at Arlington. Dr. Frazier received a BS in mechanical engineering, an MBA, and a Ph.D. in production and operations management, all from Texas A&M University. He has published articles in *Production and Inventory Management*

Journal, Journal of Operations Management, IIE Transactions, International Journal of Production Research, International Journal of Production Economics, Journal of Productivity Analysis, and *Business Horizons*. He is also co-author of the textbook *Production and Operations Management*, 8th edition, with Norman Gaither. Dr. Frazier currently serves on the board of directors for the Greater Fort Worth chapter of APICS. He is a member of APICS, DSI, POMS, and INFORMS.

PEDRO M. REYES is currently a Ph.D. student in the Department of Information Systems and Management Sciences at the University of Texas at Arlington (UTA). He also received his MBA, MS in information systems, and BS in mathematics from UTA. His research interests are in the interface between information systems and operations management, specifically supply chain management and inventory planning and control. He is a member of the Greater Fort Worth APICS chapter and had served on the board of directors. He is also a member of DSI and INFORMS. Mr. Reyes is employed by Hunter Douglas, where he is currently involved in the materials management portion of its SAP implementation.