LEARNING OBJECTIVES

After completing this chapter, you should be able to:

■ Define the concept Just-in-Time/Lean (JIT/Lean).
■ Explain the rationale for JIT/Lean.
■ Summarize the development of JIT/Lean from its beginnings.
■ Explain the relationship of JIT/Lean to total quality and world-class manufacturing.
■ List the benefits of JIT/Lean.
■ Explain the requirements of JIT/Lean.
■ Describe how JIT/Lean relates to automation.

JUST-IN-TIME/LEAN MANUFACTURING (JIT/LEAN)

The manufacturing system we will be discussing in this chapter was initially developed by Taiichi Ohno in the 1950s as the successor to Henry Ford’s mass production system. Ohno named it the Toyota Production System (TPS). Since it involved making products only when needed from materials that were made available by suppliers only as required, just-in-time (JIT) became its generic name. For 30 odd years, Toyota Production System or Just-In-Time were the names used for Ohno’s remarkably efficient manufacturing system. Then in 1990, three senior managers of MIT’s International Motor Vehicle Program (IMVP), Jim Womack, Dan Jones, and Dan Roos, published a book that has had a great influence on the way industries around the world make things. That book, entitled The Machine That Changed the World: The Story of Lean Production, was the result of a five-year, in-depth scholarly study of the Toyota Production System. It detailed in clear terms the superiority of the TPS to the mass production system used by the rest of the world, and virtually unchanged since World War I, and concluded that mass production simply could not compete with the Japanese system. One of IMVP’s researchers, John Krafcik, is credited with coining the term “Lean production.” The system uses less of everything involved in production: manpower, investment, engineering, inventory, facilities, and so on, thus the term “Lean” fits well. Over the two-plus decades since the book was published, Lean has become the tag for the TPS and JIT, and has reached out across all kinds of industries and organizations to represent a wide variety of adaptations of TPS. In Chapter 19, we devoted several pages to Lean and its role in continual improvement, and even its marriage with Six Sigma and the Theory of Constraints. So this book uses the name just-in-time/Lean manufacturing, or JIT/Lean, for this chapter.

As is so often the case, we find that the same product is being repackaged under other names. This is sometimes done by those searching for clarity of description. Sometimes it is done by those wanting to be seen as having something new and different, when in fact it is not. You may come across the term focused factory in reference to a JIT production cell. If you encounter a production system called demand flow, or demand flow technology, it is JIT with a new label. These are not bad names, and in fact, some may project a clearer picture of the production system than JIT/Lean. But in this book, and in most others, the generic name for pull-system manufacturing, just-in-time/Lean, is preferred.

JIT/LEAN DEFINED

When people who should know are asked to define JIT, the typical response is that JIT “is getting your materials delivered just when you need them.” Probing a little deeper may elicit a response that suggests JIT manufacturers let their suppliers keep their materials inventory until the manufacturers need it. The first statement demonstrates an inadequate understanding of JIT/Lean, and the second is simply wrong. Even so, many companies under the auspices of JIT/Lean have indeed pushed their warehousing back to the suppliers for a net gain of zero. If these are not the right answers to the question “What is JIT/Lean?” then what is it? Although not exactly what was originally intended, just-in-time/Lean manufacturing, by any of its names, has become a management philosophy that seeks to eliminate all forms of waste in manufacturing processes and their support activities. JIT/Lean permits the production of only what is needed, only when it is needed, and only in the quantity needed. This must apply not only to the just-in-time/Lean manufacturer, but also to its suppliers if the system is to eliminate all possible waste. Those companies that have required their suppliers to do their warehousing clearly have not gotten the point. The supplier should not produce the material until the JIT/Lean manufacturer needs it. In that mode, there is no warehousing...
and, therefore, no wasted resources for buildings, maintenance, people to care for the material, spoilage, obsolescence, or other related problems.

JIT/Lean is not so much related to supplier activities, although they are important, as to events on the manufacturing floor. For example, assume that a company manufactures motion sensors. There are five discrete processes involved, each carried out by one worker, as illustrated in Figure 21.1a. The traditional production process places a big supply of input materials in the warehouse, doling them out to the production line at the rate of so many pieces per unit time. The electronic assembly and the mechanical assembly processes convert their respective input materials into input materials for the final assembly process, which, in turn, converts them into completed motion sensors. Each of the five work areas produces at the rate necessary to meet a quota, or to consume all the input materials. The completed sensors are sent to the warehouse for storage until someone buys them.

Figure 21.1a is the simplest possible depiction of this particular combination of the steps required to manufacture the motion sensors. What happens in the traditional manufacturing setting takes on a much more complicated and convoluted series of events. This is depicted in Figure 21.1b. In Figure 21.1b, the materials warehouse sends kits of appropriate materials and parts to the first three assembly/fabrication stations (1, 2, and 3) according to a predetermined schedule. Working to their own assigned schedules, each of the three stations converts the kits into semifinished assemblies or parts and pushes that output to the succeeding stations, 4 and 5. At this point, we would see a more efficient and streamlined process.

**FIGURE 21.1a** The Traditional Production Process (Simplest Depiction).

**FIGURE 21.1b** Actual Practices in the Traditional Production Process.
may run into a problem. Ideally the output of stations 1, 2, and 3 would go directly to stations 4 or 5, but for a variety of reasons, it is common that the local staging areas for stations 4 or 5 may, at any given time, be unable to accept more input. When that happens, the excess partially built goods, also known as work-in-process (WIP), must be sent to a remote staging area, as shown in Figure 21.1b. The same thing can happen between stations 4 and 5. A comparison of Figure 21.1a with Figure 21.1b reveals how complicated a simple manufacturing job can become. What is not obvious from Figure 21.1b is the expense involved in this kind of waste in traditional manufacturing. All of that WIP that cannot go straight through the system, as it appears to do in Figure 21.1a, must be transported to a suitable area for storing it; someone has to keep track of its completion status, and where it is; withdrawal from the WIP staging area must be managed; salaries must be paid for the extra people involved; overhead costs for the staging area must be absorbed; and carrying costs for the WIP itself has to be paid. Even finished goods may go to a warehouse to await customer orders, adding even more costs. Not one of those costs add value to the product, therefore, it is pure waste. All these functions have costs that add up to making the company uncompetitive and are targets for elimination in a JIT/Lean organization. A similar case can be made for competitive damage caused by time lost in the process, which can easily add an order of magnitude to the manufacturing cycle time.

Just-in-time/Lean approaches the manufacturing process from the opposite end of the line. Rather than pushing materials into the processes and storing them whenever they cannot be accommodated, JIT/Lean controls the line from the output end. Indeed, it can be said that the customer controls the line because nothing is built until there is an order for it. After an order is received for a product, the final assembly process is turned on to put together the required number of units. The assembler pulls the required input materials from the electronic module and frame fabrication processes—only enough to make the required number. Similarly, the electronic module assembly and frame fabrication processes pull input materials from their preceding processes, and so on back up the line. At the top of the line, input materials are pulled from suppliers in the exact quantity needed, and no more.

Following the JIT/Lean procedure, no step in the production process ever overproduces or produces before a demand is made. Therefore, there is no need for a staging area or the people required to move materials into it and out of it, account for it, and so on. No money is tied up in inventory of raw materials, WIP, or finished goods. If there are no stored materials, there is no spoilage or obsolescence. The elimination of these wastes alone makes JIT/Lean the most powerful manufacturing concept to come along since Henry Ford’s moving assembly line of 1913. JIT/Lean contributes to the elimination of many more forms of waste, as discussed later in this chapter.

So, the definition of JIT/Lean as used in this book is this:

*Just-in-time/Lean is producing only what is needed, when it is needed, and in the quantity that is needed.*

**RATIONALE FOR JIT/LEAN**

Mass production manufacturers set their production schedules based on a forecast of future needs, which, in turn, is based on historical data and trend analysis (see Figure 21.2). The great weakness of this system is that no one can predict the future with sufficient certainty, even with a complete and perfect understanding of the past and a good sense of current trends in the marketplace. One does not have to search long to find examples of failed attempts to correctly project the marketability of products. The Edsel is one of many automobiles that were released with great fanfare to a disinterested public. A new formula for Coca-Cola introduced in the late 1980s is another example of market predictions gone awry. IBM has case after case involving personal computers, such as the unlamented IBM PC Jr. (which failed in the marketplace in spite of the best market research IBM could muster). These failures demonstrate the difficulty of trying to determine beforehand what will sell and in what quantity.

Even products that are successful in the market have limits as to the quantities that buyers will absorb. When production is based on predictions of the future, risk of loss from overproduction is far greater than when production is based on actual demand. The previous section defined JIT/Lean as producing what is needed, only when it is needed, and only in the quantity that is needed (see Figure 21.3). The result of JIT/Lean is that no goods are produced without demand. This, in turn, means no goods are produced that cannot be sold at a price that supports the viability of the company.

![Diagram of JIT/Lean process](image-url)
1. Overproducing
2. Waiting (time)
3. Transporting
4. Processing itself
5. Having unnecessary stock on hand
6. Using unnecessary motion
7. Producing defective goods

The elimination of these wastes is at the heart of the rationale for just-in-time/Lean: eliminate these wastes, and you will produce better products at lower cost. If the competition gets there first, your rationale for JIT/Lean is survival.

**DEVELOPMENT OF JIT/LEAN**

We have identified Ohno as the creator of the just-in-time/Lean system, and it is true that he was responsible for developing the system as it is now known. However, other names should be remembered, at least to the extent to which they
CHAPTER TWENTY ONE Just-in-Time/Lean Manufacturing (JIT/Lean)

contributed by inspiration. The first is Henry Ford, creator of mass production. Because of Ford's great appreciation of the expense of waste, Ohno said that if Ford were alive today, he would have developed a system much like Toyota's. In his 1926 book Today and Tomorrow, Henry Ford talked about the waste of inventory in raw materials, work-in-process, and finished goods in the pipeline to market—and about the efforts taken to reduce the investment in this waste. Between 1921 and 1926, Ford output doubled, but investment in inventory of raw materials, semifinished goods, and finished goods actually declined. Based on 1921 performance, Ford could have had $170 million tied up in this inventory but in fact had (in 1926) less than $50 million. Ford also recognized the waste arising from transportation, waiting (time), and inefficiency on the factory floor. He believed in planning ahead to eliminate the waste before it happened. This is very contemporary thinking, and Ohno may be correct that Henry Ford, had he been living in the past 40 years, might well have developed a Toyota-like system. When Ohno wrote his book on the Toyota Production System, it was titled Just-in-Time for Today and Tomorrow. It is not known whether the book's title was a tribute to Henry Ford's book, but it is at least an interesting coincidence.

Ford was a great influence on the Toyoda family—Sakichi, Kiichiro, and Eiji. Sakichi Toyoda, a designer of looms and founder of Toyota, is credited with the concept of automonation, or automation with a human touch. His automatic loom could determine whether a thread was broken or missing, shutting itself down instead of making a defective product. Autonomation is one of the two pillars of the TPS, the other being just-in-time/Lean. Kiichiro Toyoda, Toyota's founding chair, planted the seeds of the TPS prior to World War II with his planning for the introduction of the assembly line at Toyota's Kariya plant. He wrote a booklet about how production was to work, and it contains the words just-in-time. His original meaning in English was "just-on-time," intending that things be done exactly on schedule, with no surplus produced. World War II halted further work on the system, and after the war, it was Taiichi Ohno who revived and developed it into the present-day Toyota Production System, which we call JIT/Lean.

Eiji Toyoda, Toyota's president and chairman from 1967 to 1994 and Taiichi Ohno's boss for 35 years, is credited with the JIT/Lean philosophy: "In broad industries, such as automobile manufacturing, it is best to have the various parts arrive alongside the assembly line just-in-time." Eiji Toyoda's greatest contribution may have been his support for Ohno's trial-and-error approach, shielding him from the inevitable controversy of his endeavors. Ohno claims that Eiji never told him to back off or slow down. He absorbed the heat and let Ohno press on unimpeded.

Taiichi Ohno's motivation, like that of the Toyodas, was to eliminate all forms of waste from the production process. He was well schooled in the Ford mass production system and observed that the system itself created waste in huge proportions. If one was determined to violate the seven wastes, a mass production line would do it. Mass production is prone to overproducing; having people or materials waiting; transporting work-in-process back and forth across the plant; retaining inefficient processes; maintaining costly inventories of stock on hand; requiring non-value-added motion because lines were set up to accommodate product, not workers; and producing defective goods because the line must continue to move. The italicized words represent the seven wastes.

Ohno believed that a production system based on just-in-time/Lean could eliminate the wastes. To appreciate fully what is involved here, one must understand that the mass production system as defined by Henry Ford was not ir-rational. Ford's objective was to produce huge quantities of the same product using an assembly line technology that required little expertise of its workers. The result was a reliable, cheap car that millions of buyers could afford. In that, he and others who used his mass production technology were eminently successful. But mass production is inflexible and wasteful—inflexible because it is driven by the great stamping presses and other machines that do not easily accommodate a variety of products, and wasteful because the underlying philosophy of mass production is that the line must pump out products that spring from market forecasts in a never-ending high-volume stream. To support that high-volume stream, there must be stockpiles of the materials that go into the product because the lack of a single part can shut down the mass production line. Machines must be capable of high output and are so costly they cannot sit idle without creating trauma in the accounting department. Therefore, even when fenders are not needed, the machines must continue to stamp them out. The overproduction will be warehoused until it is needed—perhaps when the press breaks down. So it is with all the parts and subassemblies that make up the complete product. They are stored in large quantities, just in case something goes wrong in their production or transportation cycle, when they might be needed to keep the final assembly line moving—fenders for a rainy day, so to speak.

This is the norm with mass production. The problem with this is that the building space in which these parts and materials are warehoused is expensive. It requires a small army of people to care for the stored materials and parts, and these people add not a whit to the ultimate value of the product. Spoilage occurs by loss, damage, or obsolescence of stored parts—all waste: part waste of inventory, part waste of overproduction.

Mass production advocates emphasize that the lines need to keep moving and that the only way to do this is to have lots of parts available for any contingency that might arise. This is the fallacy of just-in-time/Lean according to mass production advocates. JIT/Lean, with no buffer stock of parts, is too precarious. One missing part or a single failure of a machine (because there are no stores of parts) causes the JIT/Lean line to stop. It was this very idea that represented the power of JIT/Lean to Ohno. It meant that there could be no work-arounds for problems that did develop, only solutions to the problems. It focused everyone concerned with the production process on anticipating problems before they happened and on developing and implementing solutions so that they would not cause
mischief later on. The fact is that as long as the factory has the security buffer of a warehouse full of parts that might be needed, problems that interrupt the flow of parts to the line do not get solved because they are hidden by the buffer stock. When that buffer is eliminated, the same problems become immediately visible, they take on a new urgency, and solutions emerge—solutions that fix the problem not only for this time but for the future as well. Ohno was absolutely correct. JIT/Lean’s perceived weakness is one of its great strengths.

Mass production is a push system (see Figure 21.5). The marketing forecast tells the factory what to produce and in what quantity; raw materials and parts are purchased, stored, forced into the front end of the production process, and subsequently pushed through each succeeding step of the process, until finally the completed product arrives at the shipping dock. It is hoped that by then there are orders for these goods, or they will have to be either stored or pushed (forced) into the dealers’ hands, a widespread practice in the automobile business. The whole procedure, from imperfect forecast of marketability to the warehouse or the dealer, is one of pushing.

What if the market will take only half of the predicted amount or wants none? What if the final assembly process can accommodate only two-thirds of the preceding processes’ output? These situations present big problems in terms of cost and waste, and they are common.

Just-in-time/Lean, on the other hand, is a pull system (see Figure 21.6; the term kanban in the figure will be clarified soon). The production schedule does not originate in a market forecast, although a great deal of market research is done to determine what customers want. The production demand comes from the customer. Moreover, the demand is made on the final assembly process by pulling finished products out of the factory. The operators of that process, in turn, place their pull demands on the preceding process, and that cycle is repeated until finally the pull demand reaches back to the material and parts suppliers. Each process and each supplier is allowed to furnish only the quantity of its output needed by the succeeding process.

Figures 21.5 and 21.6 also show a difference in the relationship between the customer and the factory. In the mass production system, no real relationship exists at all. The market forecasters take the place of the customers and place demands on the factory months in advance of production. In the JIT/Lean system, however, the customer’s demand is felt throughout the system, all the way to the factory’s suppliers and even beyond that. The JIT/Lean system is simpler, eliminating entire functions such as material control, production control, and warehousing and stocking.

**FIGURE 21.5** Mass Production Push System.
In a mass production environment, question 1 matters most. The tendency is to let the machine run as long as there is product, good or bad, coming out of it. Defective parts will cause problems farther down the line, but the consequences of shutting the machine down to fix it are seen as an even bigger problem. The JIT/Lean factory is more concerned about the second question because allowing a machine to produce defective parts permits the production of waste, and that, above all, is forbidden.

Common sense dictates that machinery should always be maintained properly, but that can be very difficult in a mass production plant. Unfortunately, in many North American factories, machines tend to be ignored until they break down, in keeping with the grammatically incorrect but telling expression “If it ain’t broke, don’t fix it.” Toyota eliminated the machine problem through a systematic preventive maintenance process that keeps all machinery in top shape, modifying it for better reliability or performance, and even predicting when parts should be replaced or adjustments made to maintain the highest-quality output. This has come to be known as total productive maintenance or total preventive maintenance (TPM). It has found widespread acceptance in forward-looking companies. Total preventive maintenance, by keeping the machines available for use when they are needed, eliminates a great many line stoppages. We will discuss TPM in more detail later in the chapter.
Process Problems

Process problems can be eliminated when people thoroughly understand the processes, optimize them, and use statistical methods (i.e., SPC) to keep them under control. In addition, the processes are continually improved, most often through the efforts of the same people who work with them every day. Time is allocated for these kinds of efforts in all JIT/Lean factories.

The most difficult conceptual problem with JIT/Lean is the precise control of production and the flow of material or parts through the complete production process. For that, Ohno developed the kanban to signal the pulls through the system. Mass production demonstrated that one should not start the control at the beginning of the process. Too many things can go wrong at the bow wave of the flow. Ohno decided that the control had to start at the output end of the factory. From this concept, he introduced kanban, which is a Japanese word meaning “card.” Ohno used kanban cards to trigger activity and the flow of materials or parts from one process to another. When a succeeding process has used the output of the preceding process, it issues a kanban to the preceding process to produce another.

Although Ohno describes the kanbans as slips of paper in a vinyl pouch—close enough for “card”—kanban devices have evolved to a number of forms. A square painted or taped on a workstation may be a very effective kanban. For example, a process produces a subassembly and places it on the marked area of the succeeding process workstation. When the succeeding process uses the subassembly, the marked area—the kanban square—becomes empty and signals the preceding process to make another subassembly and fill the square. The same is done with totable bins. When the parts from a bin have been used, the empty bin is sent back to the preceding process as a signal for more production. Both of these kanban devices work when the part or subassembly in question is the only possible output of the preceding process. Should there be a variety of part or subassembly models, however, the kanban square alone will not provide sufficient information, and the bin with a descriptive card or the kanban card, or its electronic equivalent, must be used. (More information about kanban is provided later in this chapter.)

Lot Size

A final issue to be overcome by JIT/Lean production concerns lot size. Mass production is keyed to the largest possible lot size: set up the machines and parts streams to make as many as possible of the same item, like Henry Ford’s identical black Model T’s, before changing to another model or product. So-called economic lot size is still being taught in many universities. Just-in-time/Lean seeks to build in the smallest possible lots. The modern consumer demands variety. No auto company could survive today with a single car model, with each unit the same in all respects including equipment and color. JIT/Lean accommodates variety by being flexible. That is, the factory is set up so that changes can be rapidly implemented and at little cost.

Traditionally, it has been a major problem to change models on a production line because breakdown and setup of the machines that have to be changed take a lot of time. Hours and days and even longer for new setups are not uncommon. Ohno saw that the inherent inflexibility of the mass production line was in the setup time for the machines. Too much setup time meant that a manufacturer had to have a second line—or even a new factory—for the other model, or the customers’ demand for the second model was simply ignored until the run on the current model was finished. By attacking the problem head-on, Toyota was able to reduce setup times to the point where they were no longer significant. Other companies, using the Toyota approach, found that they could quickly reduce setup times by 90% and even more with some effort.

Omark Industries was one of the first American companies to study the Toyota Production System. Using Toyota’s techniques, it reduced the setup time for a large press from eight hours to one minute and four seconds. After setup time became irrelevant, it was possible to manufacture in small lots—even lots of one—thereby permitting the intermixing of models on the same line. This meant that customer responsiveness was possible without huge inventories of prebuilt stock in all models. It also meant that one production line (or factory) could do the work of several. This ability is crucial if the factory is to respond to customer demand in a pull system.

The development of just-in-time/Lean production required more than the kanban, a point lost on many Westerners. JIT/Lean came about from the understanding of the seven wastes and the need to eliminate them. The key elimination of nearly all material and parts inventories dictated the requirement for reliability and predictability of the plant’s machinery and processes. This led to total productive maintenance and made necessary the use of statistical process control and continual improvement.

With the customer as the driver of production, the control technique for production changed from push to pull, and kanban was introduced as the controlling system. The requirement for small lot sizes, both for elimination of waste and for responsiveness and investment economy, led to the effort to reduce setup time. With all of these factors in place, JIT/Lean was born. Without doubt, JIT/Lean, by any of its names, is the manufacturing system for today. It is adaptable to operations both large and small, high-volume/low-variety, and low-volume/high-variety as well as anything in between. In JIT/Lean, costs, lead time, and cycle time are reduced, quality is improved constantly, and both the customers and the producers and their employees benefit.

RELATIONSHIP OF JIT/LEAN TO TOTAL QUALITY AND WORLD-CLASS MANUFACTURING

The traditional production line pushes product from the front of the line to the final output, and even to the customers, whereas kanban is the controlling agent in a pull system.
CHAPTER TWENTY ONE  Just-in-Time/Lean Manufacturing (JIT/Lean)

The two are incompatible. Similarly, implementing JIT/Lean in the absence of a comprehensive total quality system that includes the entire organization can be a problem. The traditional organization is incompatible with JIT/Lean, just as the traditional push production system is incompatible with kanban. In a typical manufacturing company, separate departments exist for engineering, manufacturing, purchasing, accounting, and so on, each with distinct boundaries and agendas. JIT/Lean is no respecter of boundaries. It requires all departments to respond to its needs. If the manufacturing department has embraced JIT/Lean, but the organization as a whole has not at least started a total quality effort, manufacturing personnel will soon encounter obstacles. More often than not there will be outright resistance because JIT/Lean’s requirements represent change and departments without a commitment to change will fight it at every step.

As an example, in the defense industry it is common to defray overhead expenses (buildings, utilities, indirect employees’ salaries, all fringe benefits, and others) against direct labor dollars as a means of allocating the overhead burden across all contract programs. The more direct labor on a program, the larger the share of the overhead cost that accrues to that program. Direct labor is defined as the manufacturing, engineering, purchasing, and other labor charged to specific contract programs. The company may also have more than one pool for overhead defrayment, such as a manufacturing pool and an engineering pool. Virtually all of these companies, and the U.S. Department of Defense, pay a great deal of attention to what they call overhead rate. In a typical company in the defense industry, overhead rate is calculated by dividing overhead (indirect) expenses by direct labor cost.

Suppose that for an accounting period there were indirect expenses of $200,000. At the same time, the wages paid for direct labor amounted to $100,000. The overhead rate for the period is $200,000 ÷ $100,000 = 200%. Assume that we had been operating with that 200% rate for some time, and suddenly the manufacturing department discovered JIT/Lean. After the period of time necessary for the implementation to start showing results, manufacturing finds that it can eliminate direct labor positions for production control and material control and also use fewer assemblers on the production floor to get the same number of units out the door each period. A typical early reduction in the direct labor content of the work is 30 to 35%. The next period’s overhead expense is almost the same, decreasing slightly for removal of fringe benefits for the employees no longer needed, say, to $188,000. The direct labor is down by one-third to $67,000. This yields an overhead rate of $188,000 ÷ $67,000 = 281%. That kind of an increase in overhead rate, if sustained, can cause the head of manufacturing serious problems. The accounting department uses this overhead rate as proof that JIT/Lean doesn’t work. All too often the accounting department blocks further progress in JIT/Lean. One might ask, “But isn’t that valid if the overhead rate went out of control?” The answer is nobody should care about the overhead rate. It is simply the ratio of two numbers and carries no meaning without a thorough understanding of the two. What happened to the cost of goods sold in this example? Look at the numbers before and after JIT/Lean:

<table>
<thead>
<tr>
<th></th>
<th>Before JIT/Lean</th>
<th>After JIT/Lean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect Expense</td>
<td>$200,000</td>
<td>$188,000</td>
</tr>
<tr>
<td>Direct Labor</td>
<td>100,000</td>
<td>67,000</td>
</tr>
<tr>
<td>Materials</td>
<td>500,000</td>
<td>500,000</td>
</tr>
<tr>
<td>General and Administrative Expense</td>
<td>50,000</td>
<td>50,000</td>
</tr>
</tbody>
</table>

Cost of Goods Sold $850,000 $805,000

In this example, it cost the company $45,000 less to produce the same goods after JIT/Lean implementation than it did before. Assuming the goods were sold for the same price, that $45,000 becomes pure profit. In the next competition for contracts, the lower cost becomes a competitive advantage (price to the customer can be lowered).

The solution to the overhead rate problem is to change from the obsolete accounting system and adopt an activity-based accounting system or some other more sensible method. In a total quality company, the accounting department is part of the team and would respond to the needs of a production system (JIT/Lean) that is actually improving company performance. But if the company as a whole is not involved in total quality, the accounting department, with its own walls and agendas, can be a formidable obstacle to progress. The same is true of other departments on whom manufacturing depends. This example could just as easily have been one involving the engineering department and a design philosophy called concurrent engineering. Concurrent engineering requires that from the beginning of a new product’s design, manufacturing and other departments (and even suppliers) be directly involved with engineering to make sure, among other things, that the product can be manufactured efficiently when it finally goes into production. Traditional engineering departments do not like to have this kind of help from outsiders and will resist—but not in a total quality setting, where the departments all work for the common goal.

For JIT/Lean to bring about the benefits inherent in its philosophy, it must be part of a total quality system. To bring JIT/Lean into a company not otherwise engaged in total quality can be worthwhile (and may even enlighten the leadership), but implementation will be much more difficult, and its results severely restricted.
BENEFITS OF JIT/LEAN

A discussion of the benefits of JIT/Lean must include four very important topics: inventory and work-in-process, cycle time, continual improvement, and elimination of waste. The discussion could be expanded to include such topics as reduced time-to-market, improved employee work life, flexibility, and employee ownership. All of these are definite benefits of JIT/Lean, but this discussion will be confined to the critical four mentioned. These are the usual targets of a JIT/Lean implementation.

Inventory and Work-in-Process

Just-in-time/Lean attempts to drive inventory to zero. But remember that this is a philosophical objective—an aiming point, if you will. In reality, zero inventory makes no sense. Without some inventory, you have nothing from which to produce your goods. The real objective is to minimize the inventory to the maximum possible extent without shutting down production. It is also important to recognize that there are at least three kinds of inventory. First, there is the inventory of raw materials and parts needed to make the product. Traditionally, these have filled warehouses, with enough on hand for several weeks of production, or longer. Second, there is the work-in-process inventory of semifinished goods. WIP includes all materials and parts that have been put into the production system, including the various stages from the first process to the last within the factory. WIP may be at a workstation undergoing one of the value-adding production processes, or it may be in storage between processes. In a mass production plant, the stored WIP can be substantial. Job shops—low-volume, high-variety shops not involved in mass production—are also notorious for their WIP inventory. Third, there is the finished goods inventory. These finished goods are ready for customers, but the customers are not ready for them. Therefore, they are typically stored in warehouses, although some (most notably automobiles) must be stored in yards, unprotected from the elements.

One might ask, “What is wrong with inventory?” Having materials on hand allows you to produce without worrying about on-time material deliveries. Lots of WIP lets the assembly lines continue when a machine breakdown or some other problem occurs. Having an inventory of stored finished goods means that you can be responsive to customers. If those are positives (and we’ll come back to that in a minute), there are also negatives. First, there are the costs of inventorying raw materials and parts, and finished goods. There are the costs of the materials and goods; the labor costs for the storage, handling, and protection of the materials and goods; and the cost of warehouses, real estate, and capital equipment used in the inventorying of the materials and goods. Second, there is the cost of spoilage while in inventory. Spoilage can be due to damage, deterioration, corrosion, obsolescence, and so on. Third, there is the cost of taxes. While the product is in inventory, the manufacturer owns it, it has value, and the various levels of government want their share in the form of taxes.

Now go back to the suggestion made earlier that the three positives associated with inventory might not be so positive after all. The costs discussed earlier are all tangible costs. There are also intangible costs that, while difficult to measure precisely, are nevertheless significant. Foremost among the intangibles is the fact that as long as the manufacturer holds inventory of materials and WIP at high levels, it is not solving the problems and making the continual improvements that can bring efficiency. The very presence of these inventories masks the problems, so they go unnoticed and unresolved—being repeated over and over, consuming unnecessary labor, and preventing product quality improvement. Unmasking the production system’s problems through the elimination of inventories is a major strength of JIT/Lean. Many North American and European companies still tend to see the elimination of inventories as a generator of problems. In reality, the problems are already there, and they are costing a great deal in terms of money and quality, but they are just not apparent with big inventories. Through inventories maintained, tons of money is spent, but no value is added, and needed improvements are not made in the production processes. The inevitable net result is loss of competitive position and market share as enlightened competitors use JIT/Lean and total quality to improve their positions.

If a plant could get its production processes under control to the point that they could be relied on to perform as intended, it would be logical to reduce WIP and material and part inventories. However, until the processes are well understood and in control, reducing inventories substantially will certainly result in production stoppages. One philosophy of reducing WIP and lot sizes is to do so in steps. By incrementally lowering WIP and lot sizes, the problems become apparent in a gradual, manageable stream rather than in a torrent, and they can be dealt with. Once through that process, the next logical step is to work with suppliers to deliver materials and parts in smaller, more frequent lots, until finally there is no need for warehousing at all. This clearly requires that the production processes be capable and reliable and that the suppliers be similarly capable and reliable.

This leaves only the finished goods inventory. As the processes and suppliers become more proficient, and the JIT/Lean line takes hold, production will be geared to customer demand rather than to sales forecasts. The ability of the JIT/Lean line to respond quickly to customer requirements means that it is no longer necessary to store finished goods. The only stored goods should be those in the distribution system, and that level will typically be far less than has been the case under mass production.

JIT/Lean strives for zero inventory of any kind. Achieving zero inventory is not a realistic intent, but by aiming at zero and continually reducing inventories, not only do manufacturers cut costs by significant numbers, but also the whole continual improvement process comes to life, resulting in even more savings and improved product quality.

Cycle Time

Production cycle time is defined as the period bounded by the time materials are sent to the manufacturing floor for the
making of a product and the time the finished goods are dispatched from the manufacturing floor to a customer or to finished goods storage. Generally speaking, the shorter the production cycle time, the lower the production cost. That may be reason enough to pay attention to cycle time, but there are other benefits. Short cycles improve a factory's ability to respond quickly to changing customer demands. The less time a product spends in the production cycle, the less chance there is for damage.

We are accustomed to thinking of a mass production line as having the shortest of cycle times, and there have been startling examples of this. Henry Ford's Model T lines (producing up to 2 million cars per year, all the same, all black) achieved remarkable cycle times even by today's standards. For example, Ford's River Rouge facility took iron ore in the front door and shipped completed cars out the back door in four days. When one considers that the Ford cycle included making the steel, in addition to stamping, casting, machining, and assembly, it is all the more amazing. One of his secrets was no variability in the product. Modern lines have the complication of different models and virtually unlimited options.

A modern auto assembly line cannot be compared with Ford's Model T line because the complexity and variability of the contemporary car are so much greater. However, the best lines beat Ford's cycle time for assembly. The differences in JIT/Lean lines and mass production lines are substantial. For example, comparisons between JIT/Lean plants and traditional mass production plants reveal that JIT/Lean plants can assemble automobiles in 52% of the time it takes traditional lines. Because there is very little waiting in a JIT/Lean line, one can assume the cycle time is one-half of that for traditional lines. Interestingly, though not directly related to cycle time, traditional lines produce three times as many defects and require nearly twice the factory space. In addition, JIT/Lean lines can operate with a two-hour parts inventory, while traditional plants typically need a two-week supply.

Consider the following example, which helps bridge the issues of inventory and cycle time. The product was a line of very expensive military avionics test systems. The factories (two) were rather typical electronics job shops. Before being converted to JIT/Lean, they were struggling with a production schedule requiring the assembly of 75 large, complex printed circuit boards per day. They rarely met the goal, usually achieving about 50. The attempted solution involved pushing more parts into the front end of the assembly process, hoping that would force more out the other end as finished, tested boards. The computer system revealed that, at any point in time, about 3,500 boards were in the process. At the rate of 50 completed boards per day and 3,500 boards in WIP, simple arithmetic showed that the cycle time for the average board was 13 weeks. Common sense said that 13 weeks was much too long for assembling these boards, but checking with others in the industry revealed that this was a typical cycle time. The company also found that it made absolutely no difference in final output rate to force more materials into the front of the process. This merely increased the number of boards in WIP.

With a production rate of 50 boards a day and 3,500 boards in process, one can imagine the difficulty in keeping track of where the boards were, scheduling them into and out of the various processes, and storing, retrieving, and safeguarding them. Such tasks were nearly impossible. More than 100 people were charged with handling and tracking the boards, adding no value whatever to the product. Further, because the assemblers were being pushed to their limits, quality suffered. The net result was that nearly half of total direct labor was spent repairing defects. That did not add value either. Once again, however, checking with other manufacturers revealed that this was typical. A critical factor was that customer delivery schedules could not be met unless a solution was found. Initially, the company had to subcontract a great many boards, but that was a work-around, not a solution.

The eventual answer was to implement JIT/Lean techniques on the production floor. After a couple of quick pilot runs, in which it was discovered that the most difficult of the boards could be assembled and tested in eight days (versus 13 weeks), management was convinced, and JIT/Lean was implemented at both plants, following the WIP reduction and lot-size scheme outlined in the previous section. In very short order, the board cycle time fell to about five days, and board quality improved dramatically. That enabled the company to eliminate the 100-plus positions that had handled the boards and eventually many other non-value-adding positions as well. The system delivery on-time rate went to 98% (unheard of for this kind of product), customer satisfaction improved, and a respectable profit was made.

The thing to remember about cycle time is this: any time above that which is directly required by the manufacturing process is not adding value and is costing money. For example, assume we use two processes to manufacture a product, and the total time consumed within the processes is two hours. It is determined that the actual cycle time is three hours. That means that two hours of the cycle is adding value and the other hour is not. Invariably, this means a bottleneck is preventing the product from flowing from one process directly into the next without delay. The key is to detect the bottleneck and do something about it. It may be that a plant procedure requires inspection, logging, and a computer data entry. Are these tasks really necessary? Can they be eliminated? If they are necessary, can they be streamlined?

The extra hour may be the result of a problem in one of the processes. For example, it may be that the second process is no longer one hour in duration but 2. If the latter is the case, in a traditional production plant, the product flowing out of the first process will stack up at the input of the second process because process 1 will continue to crank out its product at the rate of one unit per hour—whether process 2 is ready for it or not (see Figure 21.7). The surplus product at the input to process 2 will have to be stored for safety and housekeeping reasons, thus obscuring the fact that there is a problem.
conditions could go on forever. As observed earlier, some traditional plant, with literally dozens of processes, such as a three-hour cycle. We now have a two-hour value-adding process that had two hours of value-adding work and ward, the cycle time will remain at eight hours. We started time clock has already started. If stable from this point for are seven more units through process 1, on which the cycle made it to the second process to catch up, every time process time and an eight-hour cycle. If some means is not
taken to cause the second process to catch up, every time there is a glitch in process 2, the cycle time will grow. In a traditional plant, with literally dozens of processes, such conditions could go on forever. As observed earlier, some

As long as the problem persists, WIP will build, output will stay at one unit every two hours, but cycle time will increase as backlog builds up in front of process 2; the first unit went through the production system in three hours, and one unit per hour was expected after that, but the process is actually achieving one unit every two hours. Cycle time increases by one hour for each piece—for example, eight hours later the sixth unit into process 1 will come out of process 2. Such an imbalance would not escape notice for long, and it would be corrected, but by then, several pieces of WIP would be between the processes.

Suppose that the problem in the second process was corrected as the sixth unit was completed. Everything is back to the original two-hour process time, but by now, there are seven more units through process 1, on which the cycle time clock has already started. If stable from this point forward, the cycle time will remain at eight hours. We started with a process that had two hours of value-adding work and a three-hour cycle. We now have a two-hour value-adding process time and an eight-hour cycle. If some means is not taken to cause the second process to catch up, every time there is a glitch in process 2, the cycle time will grow. In a traditional plant, with literally dozens of processes, such conditions could go on forever. As observed earlier, some

would hold that having the seven units from the first process sitting on the shelf means that process 1 could be down for a complete shift without causing a problem for the second process—it would merely draw from the seven.

In a JIT/Lean plant, the situation described here would never happen. Process 1 would not produce an additional piece until process 2 asked for it (kanban). At the start, process 1 produces one unit to enable process 2. When process 2 withdraws it, process 1 is signaled to produce another. If for any reason, when process 1 completes its second unit, process 2 is not ready to withdraw it, process 1 goes idle. It will stay idle until signaled to produce another—be it a few minutes or a week. No WIP inventory is produced. By process 1 going idle, alarms go off, quickly letting the appropriate people know that something has gone wrong. If there is a difficulty in the second process, causing it to consume too much time, it gets attention immediately. Similarly, if there is a delay getting the output of the first process to the second because of an administrative procedure, that, too, will be dealt with quickly because it will cause problems throughout the overall process until it is solved.

Any contributor to cycle time is apparent in a JIT/Lean environment, and JIT/Lean philosophy calls for continual improvement and refinement. Wait time in storage is simply

<table>
<thead>
<tr>
<th>Piece #</th>
<th>Process 1 In</th>
<th>Process 1 Out</th>
<th>Wait Time (in Hours)</th>
<th>Process 2 In</th>
<th>Process 2 Out</th>
<th>Cycle Time (in Hours)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>7 A.M.</td>
<td>8 A.M.</td>
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<td>8 A.M.</td>
<td>10 A.M.</td>
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<td>2</td>
<td>8 A.M.</td>
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<td>1</td>
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<tr>
<td>3</td>
<td>9 A.M.</td>
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<td>12 noon</td>
<td>2 P.M.</td>
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<tr>
<td>4</td>
<td>10 A.M.</td>
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<td>5</td>
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<td>6</td>
<td>12 noon</td>
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<td>13</td>
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</tr>
</tbody>
</table>

**Figure 21.7** Cycle Time Example.
not a factor in JIT/Lean because nothing is produced in advance of its need by the succeeding process. That single factor can easily remove 80 to 90% of the cycle time in a traditional factory. In the earlier example of the printed circuit board factories, the initial reduction of cycle time from 13 weeks (65 working days) to eight days was simply the elimination of storage time. That was a reduction of 88%. Further refinement, made possible because of the visibility afforded by JIT/Lean, brought the cycle to four days, or only 6% of the original cycle. Taking it further was restricted by procedural and governmental requirements. In a commercial setting, however, the same boards could probably have been produced in a two-day cycle with no new capital equipment.

Before JIT/Lean, manufacturers tried to cut cycle time with automation. But that was not the answer. The solution was found in better control of production, and that was obtained with JIT/Lean. JIT/Lean is the most powerful concept available for reducing cycle time.

Continual Improvement

Continual improvement has been discussed in several other chapters and sections of this book. By now, you should have a good understanding of its meaning as applied in a total quality context. Continual improvement seeks to eliminate waste in all forms, improve quality of products and services, and improve customer responsiveness—and do all of this while also reducing costs. A note of caution should be added in regard to interpretation of what constitutes improvement: Problem solving is not necessarily improvement. If a process that had previously been capable of producing 95 out of 100 good parts deteriorates to a level of 50 good parts and the problem is found and corrected to bring the process back to where it had been—that is maintenance not improvement. Maintenance is restoring a capability that previously existed. On the other hand, if a process was capable of 95 good parts out of 100 produced and a team developed a way to change the process to produce 99 good parts—that would be improvement. It is important to differentiate between maintenance and improvement. Maintenance is important, and it must go on, but in the final analysis, you end up where you started. Improvement means becoming better than when you started. Continual improvement is to repeat that improvement cycle, in W. Edwards Deming’s words, constantly and forever.12

The discussion of continual improvement in this chapter explains how JIT/Lean supports continual improvement. The traditional factory effectively hides its information through inventories of parts, WIP, and finished goods—people are scurrying about, everybody busy, whether any value is being added or not. The JIT/Lean factory is visual: its information is there for everyone to see and use. Quality defects become immediately apparent, as do improper production rates—whether too slow or too fast. Either of these, for example, will result in people stopping work. While that is not acceptable behavior in a mass production factory, in a JIT/Lean plant it is encouraged and expected.

A true story from Toyota tells of two supervisors, one from the old school and unable to adapt to JIT/Lean and the other ready to try JIT/Lean even if it did seem strange.13 The first supervisor refused to allow his line to be stopped, whereas the second didn’t hesitate to stop his. At first, the line operated by the second supervisor was producing far fewer cars than the other line because it was stopping for every little problem. These problems had been common knowledge among the workers but not among the supervisors. The problems were solved one by one as a result of stopping the line for each. After three weeks, the second supervisor’s line took the lead for good. The first supervisor believed that stopping the line would decrease efficiency and cost the company money. As it turned out, the reverse was true. By stopping the line to eliminate problems, efficiency and economy were enhanced. The only reason for stopping a line is to improve it, eliminating the need for stopping again for the same reason.

In a mass production plant, the sight of idle workers will draw the ire of supervisors in no uncertain terms. But in a JIT/Lean situation, the rule is if there is a problem, stop. Suppose that a preceding process has responded to a kanban and provided a part to a succeeding process. The succeeding process finds that the part is not acceptable for some reason (fit, finish, improper model, or something else). The succeeding process worker immediately stops, reporting the problem to the preceding process and to supervision. Perhaps an andon (a Japanese word meaning “lamp”) signal will be illuminated to call attention to the fact that his process is shut down. The problem is to be solved before any more work is done by the two processes, which means that downstream processes may soon stop as well because their demands through kanban cannot be honored until the problem is fixed and the processes are once again running. This is high visibility, and it is guaranteed to get the proper attention not only to solve the immediate problem but also to improve the process to make sure it does not happen again.

Consider the following example. A few weeks after JIT/Lean was implemented in a New York electronics plant, there was a line shutdown. At the end of this line was a test station that was to do a comprehensive functional test of the product. There was an assembly all set up for test, but the technician had stopped. The line’s andon light was illuminated. A small crowd gathered. The problem was that the test instructions were out of date. Over time, the test instruction document had been red-lined with changes and had, up until that point, been used without apparent difficulty. But a company procedure required that any red-lined document be reissued to incorporate the approved changes within one year of the first red line. The one-year clock had expired months earlier, and the technician, with guidance from quality assurance, properly stopped testing. When management asked why the document had not long since been updated, it was found that the documents seldom were updated until the entire job was completed. In many cases, jobs lasted several years. Holding all formal revisions until a job was completed meant that documentation was revised just once, thereby saving considerable expense. Of course, in the meantime, manufacturing was using out-of-date or questionable information. The standard work-around seemed to be that when
a system couldn’t be completed for delivery, waivers were generated, allowing the tests to be conducted with the outdated red-lined procedures. This had been going on for years but never became apparent to the levels in manufacturing and engineering that could solve it. In this case, it took about 20 minutes to solve the problem. Without JIT/Lean to highlight it, the problem would, in all probability, still exist.

What had happened because of JIT/Lean was a stop at the test station. That also shut off kanbans through the preceding processes. In short order, the line stopped, getting the attention needed to eliminate the problem. If the plant had been operating in the traditional (non–JIT/Lean) way, the assemblies would have piled up at the test station for a while and then the production control people would have carted them off to a work-in-process storage area—out of sight. Eventually, the inventory of previously tested assemblies would have been consumed, and there would have been a “brushfire” from which a procedural waiver would have emerged to enable the test technician to pull the untested assemblies from WIP stores and quickly get them tested so system deliveries could be made. This would have been repeated time and again, just as had been happening surreptitiously in the past.

This is not an uncommon scenario. Fundamentally, it is the result of departments not communicating. Engineering is trying to save money by reducing the number of documentation revisions. Meanwhile, manufacturing may be producing obsolete and unusable product because the documentation is not up-to-date. At best, it results in the continual “firefighting” that saps the collective energy of the organization, leading to quick-fix, work-around “solutions” that let you get today’s product out but only make each succeeding day that much more difficult. JIT/Lean, by highlighting problems, is quick to dispel the quick-fix mentality, demanding instead that problems be eliminated for today and tomorrow and forever.

The analogy of a lake better illustrates JIT/Lean’s ability to reveal real problems (see Figure 21.8). You look out over the lake and see the calm, flat surface of the water and perhaps an island or two. From this observation, you conclude that the lake is navigable, so you put your boat in and cast off. You avoid running into the islands because they can be seen plainly and there is plenty of room to steer around them. However, a rock just below the surface is not evident until you crash into it. It turns out there are lots of rocks at various depths, but you can’t see them until it is too late. This is like a traditional factory. The rocks represent problems that will wreak havoc on production (the boat). The water represents all the inventory maintained: raw materials and parts, WIP, and even finished goods. Now if you make the change

**FIGURE 21.8** JIT/Lean Exposes Hidden Problems.
to just-in-time/Lean, you start reducing those inventories. Every time you remove some, the level of the water in the lake is lowered, revealing problems that had been there all along but that were not eliminated because they couldn't be seen. You just kept running your boat into them, making repairs, and sailing on to the next encounter. But with the lower water level, the problems become visible and can be eliminated. Clear sailing? Probably not. Other rocks are no doubt just below the new lower surface level, so you have to take some more water out of the lake (remove more inventory), enabling you to identify and eliminate them. Like most analogies, our lake doesn't hold all the way to the logical conclusion of zero inventory because the lake would be dry by then. But remember, true zero inventory doesn't hold either. As was said before, it is a target to aim at but never to be fully reached.

JIT/Lean is by nature a visible process, making problems and opportunities for improvement obvious. Moreover, when problems do occur in a JIT/Lean setting, they must be solved and not merely patched up, or they will immediately reappear. Visibility to all levels, from the workers to the top executive, means that the power to make necessary changes to eliminate problems and improve processes is available.

Elimination of Waste

In the preceding three sections, it was shown how just-in-time/Lean facilitates reduction of inventories and cycle time and promotes continual improvement. This section will show that JIT/Lean is also a powerful eliminator of waste. Common types of waste include waste arising from: (1) overproducing, (2) waiting (time), (3) transport, (4) processing, (5) unnecessary stock on hand, (6) unnecessary motion, and (7) producing defective goods. These types of waste are explained in the remainder of this section.

1. Mass production pushes materials into the front of the factory in response to market forecasts. These raw materials are converted to finished goods and pushed through the distribution system. The first real customer input into the process is at the retail level. If customers don't want the goods, they will eventually be sold at prices much lower than anticipated, often below their actual cost. That is waste to the producer. In addition, producing goods for which there is not a matching demand is a waste to society by using resources to no purpose. In a JIT/Lean environment, the customers enter the system at the beginning, pulling goods from the distribution system and, in turn, from the manufacturer. The JIT/Lean factory produces nothing without a kanban, which, in effect, originates with a customer.

The same is true within the two kinds of factories. A fender-stamping press in a mass production factory will continue to stamp out fenders even though the final assembly line, which uses the fenders, is stopped. The overproduction must then be handled by people who contribute nothing to the value of the product, stored in buildings that would otherwise be unnecessary, and tracked by people and systems that add no value to the product, but cost a lot of money. In a JIT/Lean factory, the fender-stamping press will shut down unless it receives kanbans requesting more fenders, and there will be no overproduction. Of all the wastes, overproduction is the most insidious because it gives rise to all the other types of waste.

2. Wait time can come from many causes: waiting for parts to be retrieved from a storage location, waiting for a tool to be replaced, waiting for a machine to be repaired or to be set up for a different product, or waiting for the next unit to move down the line. JIT/Lean sets aside time for tool and machine maintenance, so replacement or repair during a production period is rare. Whereas setup times for machines in mass production plants tend to take hours (or even longer), JIT/Lean factories devote a great deal of attention to setup time, typically reducing it to a very few minutes. In a traditional factory, an operator is assigned to each machine. While the machine is running under automatic control, the operator has nothing to do but wait. In a JIT/Lean factory, the same operator may run five machines, arranged so that he or she can easily see and control all five without much movement. As three machines are running automatically, the operator may set up the fourth and unload the fifth, for example. In this way, the operator's day is no longer mostly wait time.

Perhaps the biggest waste associated with waiting involves not human waiting but inventory waiting. In the traditional setting, raw materials and parts can sit idle for weeks and months before they are needed. Work-in-process may wait weeks to have a few hours of value-adding work done. Finished goods may wait very long periods for customers. JIT/Lean does not allow any of these waits to occur, and the carrying expense is eliminated.

3. Mass production factories tend to buy their materials and parts in very large quantities from the lowest price (as opposed to lowest cost or best value) source, regardless of the distance from the source to the factory. JIT/Lean factories of necessity must buy in small quantities (no warehousing) with frequent deliveries, often several times a day. That means that the suppliers should be relatively close to the factory, cutting transportation time and costs.

Transportation within plants can be a very high-cost item, too. Moving things costs money and time and increases exposure to damage. Moving materials in and out of storage areas, to and from the floor, or back and forth across the factory from process to process is waste. None of that happens with JIT/Lean. Production materials are delivered to the point of use in a JIT/Lean factory, so they are not shuttled in and out of storage or put in temporary storage to be moved again before use. Factories are arranged to minimize distances between adjacent processes, whereas the
same product manufactured in the traditional factory could log thousands of feet, or even miles, of movement before completion.

4. Any process that does not operate smoothly as intended but instead requires extra work or attention by the operator is wasteful. An example is the necessity for the operator to override an automatic machine function to prevent defective products. Because one of the basic tenets of JIT/Lean is continual improvement of processes, wasteful processes are soon identified and improved to eliminate the waste. That is far more difficult in the traditional production environment because of its emphasis on output, not process improvement.

5. Any stock on hand has storage costs associated with it. When that stock is unnecessary, the costs are pure waste. Included in these costs are real estate, buildings, employees not otherwise needed, and tracking and administration. Because JIT/Lean attempts to eliminate stock, unnecessary stock is just not tolerated.

6. JIT/Lean plants are laid out to minimize motion of both workers and product. Motion takes time, adds no value, makes necessary additional workers, and hides waste. The contrast between a JIT/Lean plant laid out with product orientation and the traditional plant laid out with process orientation is profound (see Figure 21.9).

In the traditional plant, there is much motion, with people and product shuttling all over the place. In a JIT/Lean plant, motion is almost undetectable to a casual observer.

7. Defective goods will surely cost money in one of three ways: (a) the product may be reworked to correct the deficiency, in which case the rework labor and material costs represent waste; (b) it may be scrapped, in which case the cost of the materials and the value added by labor has been wasted; or (c) it may be sold to customers who, on discovering that the product is defective, return it for repair under warranty and may be dissatisfied to the extent they will never buy this manufacturer's products again. Warranty costs represent a waste, and the potential for a lost customer is great, portending a future loss of sales.

In a traditional factory, it is possible to produce large quantities of products before defects are discovered and the line corrected. It is not uncommon in mass production for a company to keep the line running, intentionally producing defective products, while trying to figure out what has happened and devising a solution. It is considered less troublesome to fix the defective products later than to shut down the line. In JIT/Lean, however, because line stops are anticipated and because the preferred lot size is one unit, it is improbable that more than one defective unit could be produced before shutting down the line.

Dr. M. Scott Myers, author of the landmark book *Every Employee Is a Manager*, made the case for an eighth waste: the waste arising from the underutilization of talent. Myers believed that the most damaging of the eight wastes is the waste of talent. If all the talents of all employees were brought to bear on the problems and issues of production, the other wastes would probably disappear. This is the rationale for both employee involvement and teamwork. JIT/Lean is designed to make use of the ideas and talents of all employees through team activities and employee involvement, in an environment that fosters the open and free interchange of ideas, all of which are foreign to the traditional production systems. Elimination of waste is an integral focus of just-in-time/Lean by design. No other production system looks at waste except after the fact.

** REQUIREMENTS OF JIT/LEAN **

For a factory to operate as a just-in-time/Lean production facility, a number of steps must be taken. It is very important that JIT/Lean implementation be a part of a larger total quality program; otherwise, many interdepartmental roadblocks will crop up as time passes. Like total quality, JIT/Lean requires an unwavering commitment from the top because production is more than just the manufacturing department. If these two elements (a total quality program and a commitment from the top) are in place, JIT/Lean implementation should be within reach. The following discussion touches on the issues that must be addressed as the implementation progresses.

** Factory Organization **

The JIT/Lean plant is laid out quite differently from that to which most people are accustomed. Most traditional factories are set up according to the processes that are used. For example, there may be a welding shop, a machine shop, a cable assembly area, a printed circuit board assembly area, a soldering area, and so on. Each of these discrete processes may be set up in separate parts of the factory (all machining operations done in the machine shop, all cable assembly done in the common cable and harness area, etc.), no matter which of many processes it might be for (refer to Figure 21.9). The JIT/Lean plant attempts to set up the factory by product rather than process. All the necessary processes for a given product should be located together in a single area and laid out in as compact a manner as possible.

The chart at the top of Figure 21.9 represents the old process-oriented traditional factory. Each of the processes has its own territory within the plant. Additionally, an area dedicated to warehousing is used for storage of production materials, work-in-process that is waiting for the next process, and perhaps finished goods awaiting orders. There is also an area set aside for shipping and receiving. Materials are received, inspected, processed, and sent to the warehouse area. Finished goods are taken from the warehouse or from final assembly, packed, and shipped. The upper illustration in Figure 21.9 maps the movement from the warehouse through the processes and finally to shipping in a traditional factory.
Chapter Twenty One

Just-in-Time/Lean Manufacturing (JIT/Lean)

implementation and the nature of the product and its anticipated production life. Mapped out in the upper illustration of Figure 21.9 is a typical work-flow diagram for one product. Parts and materials are pulled from several locations in the warehousing area and moved to a process A workstation. These materials may be in kit form (all the parts needed to make one lot of a product). The work instructions call for process A first, followed by process D. If process D is busy when the lot is finished by process A, the lot, now WIP, may be stacked up in a queue at process D or taken back to the warehouse for storage. The lower illustration in Figure 21.9 represents a JIT/Lean factory that is set up to manufacture four different products. The warehousing area is gone. This cannot happen overnight, but an objective of JIT/Lean is to eliminate all inventories. The second thing to notice is that the factory is divided into discrete areas dedicated to the different products rather than to the different processes. Each product area is equipped with the processes required for that product. Parts bins are located right in the work area. These bins may have enough to last from a few hours to a few days or more, depending on the degree of maturity of the JIT/Lean implementation and the nature of the product and its anticipated production life.

Figure 21.9 Comparison of Factory Floor Layouts: Traditional Versus JIT/Lean.
that require other adjustment. Work cells are coarsely tuned at first, with fine-tuning taking place during the initial runs. Excess capacity should be removed, just as required added capacity must be brought into the work cell. Bottlenecks will be quickly discovered and corrected. From there on, it is a matter of continual improvement to increase efficiency forever.

Training, Teams, and Skills

Assuming an existing factory is converted to just-in-time/Lean, one would assume that the people who had been operating it would be capable of doing it under JIT/Lean. Naturally, many of the skills and much of the training necessary for the traditional factory are required under JIT/Lean, but JIT/Lean does require additional training. First, the transition from the traditional way of doing things in a factory to JIT/Lean involves profound changes. It will seem that everything has been turned upside down for a while. People should not be exposed to that kind of change without preparation. It is advisable to provide employees with training about why the change is being made, how JIT/Lean works, what to expect, and how JIT/Lean will affect them. Initial training should be aimed at orientation and familiarization. Detailed training on subjects such as kanban, process improvement, and statistical tools should be provided when they are needed—a sort of just-in-time approach to training.

Most factory workers are accustomed to working individually. That will change under JIT/Lean, which is designed around teams. A JIT/Lean work cell forms a natural team. The team is responsible for the total product, from the first production process to the shipping dock. Perhaps for the first time the workers will be able to identify with a product, something that they create, and the processes they own. This doesn't happen in a traditional factory. But with JIT/Lean, it is important to understand that workers must function as a team. Each will have his or her special tasks, but they work together, supporting each other, solving problems, checking work, helping out wherever they can. This may require some coaching and facilitating.

It was enough in the old way of production that workers had the skills for their individual processes. They did not need additional skills because they were locked into one process. This is not the case with JIT/Lean. Specialists are of far less value than generalists. Cross-training is required to develop new skills. As a minimum, work cell members should develop skills in all the processes required by their product. Naturally, there are limits to this. We do not propose that all the members of a work cell become electronics technicians if their cell employs one for testing the product, but the cross-training should broaden their skills as far as is reasonable. Even on the issue of technical skills, it is beneficial to move in that direction. For example, if an operator's task is to assemble an electronic assembly that will be part of an end-item device, there is no reason that operators couldn't test it when they complete the assembly. Go/no-go testers can be built to facilitate testing any electronic assembly, and they can be simple enough to operate that the assembler can...
easily perform the test. This frees the technician for the more complicated tests downstream and ensures that the assembly is working before it is passed on to the next higher level. It also gives operators a sense of ownership and accomplishment. Over time, they may even be able to troubleshoot an assembly that fails the test.

Requiring multiple skills in JIT/Lean teams is important for several reasons. First, when a team member is absent, the work cell can still function. Second, problem solving and continual improvement are enhanced by having more than one expert on whatever process is in question. New people will have fresh new ideas. Third, if one of the cell’s processes starts falling behind, another member can augment the process until it is back on track.

Establishing the Flow and Simplifying

Ideally, a new line could be set up as a test case to get the flow established, balance the flow, and generally work out initial problems. In the real world, this may not be feasible. Normally, the new line is set up to produce deliverable goods. What typically happens is a line is set up and then operated with just a few pieces flowing through to verify the line’s parameters. It is very important to maintain strict discipline on the line during pilot runs. Everyone must strictly adhere to procedures. Each operator must stay in his or her assigned work area, with no helping in another process. Only if pilot runs are conducted this way will the information gained be meaningful and valid. This will allow process times to be checked, wait times to be assessed, bottlenecks to be identified, and workers to become synchronized. It is not necessary to have a pull system in place for these preliminary runs because only a few pieces will be involved. In fact, until the flows have been established, kanban is not possible.

The second thing to look for in these pilot runs is how well the line accommodates the work. Are the workstations positioned for the least motion? Is there sufficient space but not too much? Can the operators communicate easily with each other? Is the setup logical and simple? Can any changes be made to make it better, simpler? Don’t overlook the processes themselves. Ultimately, that is where most of the simplification will occur.

Kanban Pull System

Having established the flow and simplified it to the extent possible, the company can now introduce the kanban pull system. As the work cell is being designed, the kanban scheme should be developed. For example, will a single or double kanban card system be used? Or, will kanban squares or bins be used? Or, will some combination or a different variation be used?

You may want to use an electronic kanban system, although it might be best to use one of the manual systems initially. After the kinks are worked out the electronic system will be easier to implement. Any kanban plan must be tailored to the application; there is no single, best, universally applicable kanban system.

Readers who are familiar with manufacturing may know that cards have been used in the manufacturing process as long as anyone can remember. They take the form of traveler tags, job orders, route sheets, and so on, but they are not at all the same as kanbans. These cards push materials and parts into a production process, such as PC-board stuffing. When the boards controlled by the card are all stuffed (the electronic components have been inserted into the boards), the entire batch is pushed to the next process—ready or not, here they come. The next process didn’t ask for them and may not be ready for them—in which case, they will stack up in front of the process or be removed from the production floor and stored with other waiting WIP. By contrast, in a JIT/Lean line, the succeeding process signals the preceding process by kanban that it needs its output. Be sure to understand the distinction; with kanban, the succeeding process pulls from the preceding (supplying) process. The kanban always tells the supplying process exactly what it wants and how many. The supplying process is not authorized to make more product until the kanban tells it to do so—nothing waiting, no stored WIP.

Ohno’s double card system uses two types of kanbans: the withdrawal kanban and the production kanban.

The withdrawal kanban, also called the move kanban, is used to authorize the movement of materials or WIP from one process to another (see Figure 21.10). This

![FIGURE 21.10 Withdrawal (Move) Kanban (MK).](image-url)
Just-in-Time/Lean Manufacturing (JIT/Lean)

The grinding process has been taken back to the preceding process in order to obtain the parts it needs to grind six new pieces.

Segment 5 shows the finishing workstation halfway through its six pieces, with the grinding process started on its next six pieces. This cycle will repeat itself until there is no more demand pull from the right side (from the customers and the final processes).

The finishing workstation had its Out parts pulled by the next process in segment 2, triggering finishing’s pull demand on grinding in segment 3. That, in turn, resulted in grinding’s pull from its previous process in segment 4. The pulls flow from the right (customer side), all the way through the production processes to the left (supplier side). When demand stops at the customer side, pulling stops throughout the system and production ceases. Similarly, increase or decrease in demand at the customer side is reflected by automatically adjusted pulls throughout the system.

As suggested earlier, it is not always necessary to use actual kanban cards. In many applications, it is necessary only to use kanban squares, kanban shelves, or kanban containers. In Figure 21.12, for example, the two processes could have used any of these devices. The Out side of the grinding workstation could have the right side of its tabletop marked out in six kanban squares. One part ready for finishing would be placed on each square, like checkers on a checkerboard. The signal to grind six more parts would be the finishing workstation’s taking of the parts, leaving the kanban squares empty. In this case, the empty kanban square is the signal to produce more. Marked-off shelf areas, empty containers designated for so many parts, and various other devices can be used. Combinations are the rule.

Consider the operation of two processes in a manufacturing sequence to see how this works in practice. Figure 21.12 shows a preceding process that does grinding on metal parts. This is the supplier for the parts finishing workstation, the succeeding process. Figure 21.12 shows five segments, described in the following paragraphs:

Segment 1 reveals that the finishing workstation has containers at both its In and Out areas. The container at the In area carries a move kanban (MK) and has one part left to be used. The container at the Out area has five finished parts in it and is waiting for the sixth. Back at the grinding workstation, the Out container is filled with the six parts authorized by the production kanban (PK) attached. The container at the In area is empty, and work is stopped until another production kanban appears.

Segment 2 shows that the finishing workstation has completed work on the six parts, emptying the container at its In area. The empty container with its attached MK for six parts is taken back to the grinding workstation, which is ready to supply the parts.

Segment 3 shows that when the empty container is received at the grinding workstation, the move kanban is removed from the empty container and attached to the full container, which is sitting at the process’s Out area. This authorizes movement of the six parts to the finishing workstation. At the same time, the production kanban is removed from the full container and attached to the empty one, which is placed at the grinding workstation’s Out area. This authorizes the grinding process to grind six more pieces.

Segment 4 shows that the finishing process has now processed two parts. The empty container at the In area of the grinding process has been taken back to the preceding process in order to obtain the parts it needs to grind six new pieces.

Segment 5 shows the finishing workstation halfway through its six pieces, with the grinding process started on its next six pieces. This cycle will repeat itself until there is no more demand pull from the right side (from the customers and the final processes).

The finishing workstation had its Out parts pulled by the next process in segment 2, triggering finishing’s pull demand on grinding in segment 3. That, in turn, resulted in grinding’s pull from its previous process in segment 4. The pulls flow from the right (customer side), all the way through the production processes to the left (supplier side). When demand stops at the customer side, pulling stops throughout the system and production ceases. Similarly, increase or decrease in demand at the customer side is reflected by automatically adjusted pulls throughout the system.

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Kanban is a shop floor control or management system. As such, it has some rules that must be observed: (1) never send forward a defective product, (2) withdraw only what is needed when needed, (3) produce only the exact quantity, (4) smooth production load, (5) adhere to kanban while fine tuning, and (6) stabilize and rationalize. These rules are explained in the remainder of this section.

Instead, stop the process, find out why it was made defective, and eliminate the cause. It will be much easier to find the cause immediately after it happened than it will be after

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**Figure 21.11** Production Kanban (PK).
Production flow should be such that subsequent processes subtract from preceding processes in regular intervals and quantities. If production has not been equalized (smoothed), the preceding process will have to have excess capacity (equipment and people) to satisfy the subsequent process. The earlier in the production process, the greater the need for excess capacity. Because excess capacity is waste, it is undesirable. The alternative would be for the processes to “build ahead” in anticipation of demand. This is not allowed by rule 3. Load smoothing will make or break the system because it is the only way to avoid these two intolerable alternatives.

Time has elapsed and conditions have changed. Attention to the problem will escalate rapidly as subsequent processes come to a halt, forcing resolution. Only after the problem has been eliminated and the defective part replaced with a good one should the subsequent process be supplied.

There can be no withdrawal without a kanban (of some sort). The number of items withdrawn must match the number authorized by the kanban. A kanban must accompany each item.

Never produce more than authorized by the kanban. Produce in the sequence the kanbans are received (first in, first out).

**Figure 21.12** Dual-Card Kanban System.
In the previous section, we said that for a kanban system to work, the flow must first be established. Kanban cannot respond to major change, but it is a valuable tool for the fine-tuning process. All the production and transportation instructions dealing with when, how many, where, and so on are designated on the kanban. If the manufacturing process has not been smoothed, one cannot, for example, tell a preceding process to do something early to compensate. Instructions on the kanban must be observed. Adhering to the kanban's instructions while making small, fine-tuning adjustments will help bring about optimum load smoothing.

The processes need to be made capable and stable. Work instructions and methods must be simplified and standardized. All confusion and unreasonableness must be removed from the manufacturing system, or subsequent processes can never be assured of the availability of defect-free material when needed, in the quantity needed.

Observing the six rules of kanban all the time is difficult, but it is necessary if the production flow in a JIT/Lean system is to mature and costs are to be reduced.

Kanban is often used by itself for shop floor control very effectively, but it can also be used in conjunction with automation, such as bar code and computer augmentation. Computer-based kanban systems exist that permit the fundamental kanban system in a paperless environment. As with automation in general, such a computerized system must be designed, or tailored, to suit the application. Applying technology simply for technology's sake is never a good idea. Whatever you do, it is best to have the system working in its basic manual form before automating; otherwise, you are likely to automate your problems.

The demand pull system has proven itself far more efficient than the traditional push system. If the advantages of just-in-time/Lean are wanted, there is no alternative but to use a pull system, and kanban, in one form or another, is what is needed.

Visibility and Visual Control

One of JIT/Lean's great strengths is that it's a visual system. It can be difficult to keep track of what is going on in a traditional factory, with people hustling to and fro storing excess WIP and bringing stored WIP back to the floor for the next stage of processing, caches of buffer WIP all over the place, and the many crisscrossing production routes. The JIT/Lean factory is set up in such a way that confusion is removed from the system. In a JIT/Lean factory, it is easy to tell whether a line is working normally or having a problem. A quick visual scan reveals the presence of bottlenecks or excess capacity. In addition to the obvious signals, such as an idle workstation, JIT/Lean encourages the use of information boards to keep all the workers informed of status, problems, quality, and so on.

Each product work cell or team should have one or more boards, perhaps on easels, perhaps on computer screens, on which they post information. For example, if the schedule anticipates the production of 300 subassemblies for the day, the workers will check off the appropriate number each time a succeeding process pulls subassemblies from its output. This keeps the team apprised of how it is doing and presents the information to managers, who only have to glance at the chart to gauge the work cell activity and its kanbans to develop a clear picture of how well the line is doing. Another board charts statistical process control data as the samples are taken in the work cell. Anyone can spot developing trends or confirm the well-being of the process with a quick look at the charts. Every time a problem beyond the control of the work cell or an issue with which the work cell needs help comes up, it is jotted down on a board. It stays there until resolved. If it repeats before it is resolved, annotations are made in the form of four marks and a slash for a count of five (see Figure 21.13). This keeps the concerns of the work cell in front of the managers and engineers who have the responsibility for resolution. The mark tally also establishes a priority for resolution. The longest mark "bar"
gets the highest priority. Maintenance schedules for tools and machines are also posted in plain view, usually right at or on the machine, and normal maintenance activity, such as lubrication, cleaning, and cutter replacement, is assigned to the work cell.

Consider what happens when these charts are used. Information is immediately available to the work cell. The team is empowered to perform maintenance and solve all problems for which it has the capability. With the information presented to the team in real time, the team solves the problems at once and performs maintenance at appropriate times. This approach minimizes waste, keeps the machines in top shape, and produces a flow of ideas for improvement. The shop floor control loop is as tight as it can get. The operator detects and posts the information. The operator reacts to the information to solve problems or take action.

If a problem is beyond the work cell team’s capability, all the people who can bring skills or authority to bear are immediately brought in and presented with the data, and the problem gets solved—quickly. The control loop goes from information to action in one or two steps. In the traditional factory, the operator may not even be aware of a quality problem. It is usually detected by a quality assurance inspector hours or even days after the defect was created. The inspector writes it up. The form may go to the management information system (MIS) department, where, after a period of time, the data are entered into the computer. Sometime later the computer prints a summary report including an analysis of quality defects. The report is sent to management through the company mail or via an intranet system. The report may rest in queue for a length of time before being examined. Managers in traditional plants are kept so busy with meetings and firefighting they hardly have time to read their mail, but eventually they will get around to looking at the report. They will see that the line is (or was) having a quality problem and pass the report to the floor supervisor for action. The floor supervisor will attempt to see whether the problem still exists. If it does not, case closed. It happened days or weeks ago, and the operator, who up until now was unaware of the defect(s), can’t remember anything that would confirm the problem, let alone suggest a root cause. If the floor supervisor is lucky, the problem may still be there, and the cause may be found. But in the meantime, weeks of production may have been defective.

In this control loop, at least six functions are involved before the loop is closed. That is bad enough, but when the time delay factor is added, finding root causes of problems that come and go is unlikely. Process improvement is much more difficult in this kind of traditional production system. Having had personal experience with both, the authors can attest that the most expensive, most sophisticated computer-based defect analysis system, such as might be employed in the above example, is infinitely inferior to the simple one- or two-step, person-to-person, no-computers-involved control loop of JIT/Lean when it comes to presenting useful information on a timely basis for the purpose of problem solving and process improvement.

Before our plants changed over to JIT/Lean, a mainframe-based defect analysis system was used. The U.S. Navy designated it as a best practice in the industry. Other companies came to see it, and many of them used it as a model for their own new systems. It could analyze data and present it in many different forms. But it had one flaw: time delay. From the time a process produced a defective part until the loop was closed with the operator of the process, several days (at best) had passed. We are not suggesting that the system was unable to make improvements, because it did. But the real revelation came with implementing JIT/Lean and finding what could happen right inside the work cell when workers had the information they needed while it was fresh and vital and were empowered to do something with it. Immediately, defects dropped dramatically, and they continued to drop as continual improvement was established. Before JIT/Lean, these plants were never able to achieve results remotely comparable, even with their megadollar computer-based system.

Every JIT/Lean line develops its own versions of information display techniques. But whatever the variation, everyone has valuable, useful information available at all times. That kind of information is extremely difficult to find in a traditional line and most often comes to light in the periodic (weekly or monthly) computer analysis reports. By then, the trail to the root cause may have been obliterated by the passage of time, other problems, or events. In the JIT/Lean factory, real-time visibility lets people know of the problem right then and there, while the cause is obvious. Coupled with the JIT/Lean philosophy that says that the problem must be solved before going any further, this visibility becomes a driver for elimination of problems and for process improvement.

Eliminating Bottlenecks

Richard Schonberger makes the interesting point that only the bottlenecks in a traditional factory forward work to the next process just-in-time. He explains that in a conventional manufacturing plant, the bottleneck process is one that goes as fast as it can all the time, barely keeping up with demand. If it breaks down, there is real trouble. To keep it running and to attempt to find ways to increase its output, the bottleneck receives attention out of proportion to the rest of the plant, monopolizing the efforts of engineering and management.

In a JIT/Lean plant, all processes are potential bottlenecks in the sense just discussed because there is little excess capacity and there are no buffer stocks to fall back on when a process or machine shuts down. The upside of this is that all processes are constantly under scrutiny—none is ignored. As Schonberger also points out, the fact that all the processes must be watched carefully makes it imperative that the process operators play a major role in the care and monitoring and improving of the processes because there cannot be enough engineers to go around when every process is a potential bottleneck.

For this discussion, though, the bottleneck is put into a slightly different frame of reference. We are talking primarily
about the setup stage of a JIT/Lean operation when trying to establish a balanced, rational flow through the production system. In this early stage, it is not uncommon to have some real functional bottlenecks. For example, if the new JIT/Lean line is being established to produce as many as 1,000 parts per day, but the manual assembly process can turn out only 800, there is a bottleneck. One way or the other, the process must be brought up to 1,000 or more. If the process employs two people using hand tools, then the answer is simple: add a third person and the appropriate tools. Then the capacity for that process should be 1,200 per day. The extra capacity will have to be accepted until the process can be improved to bring the daily single-operator output up to 500 each, making it possible to go back to two operators.

Perhaps a machine can produce only 75% of the projected demand. Here the options are a little different. This may be a very expensive machine, too expensive to replicate. Is it possible to put that machine to work somewhere else and put two lower-capacity, less expensive machines in the line, or maybe a single new, higher capacity machine? Can the old machine be modified to increase its output? If setup time is a part of the machine's normal day, there is a potential for improvement. Another possibility may be adding a second, smaller machine to augment the existing machine's capacity, although two different machines on the same line making the same part or product is not a desirable solution.

Another kind of bottleneck can exist when a single physical process is shared by two or more JIT/Lean lines. It is preferable to make each JIT/Lean product line independent and self-sufficient, but this is not always possible. An example might be a single-wave solder machine servicing two or more JIT/Lean lines. Because of the cost, size, and maintenance requirements of such a machine, it may not be feasible to put one in each JIT/Lean product line. Rather, all the JIT/Lean lines take their PC boards to a single-wave solder service cell for soldering. The JIT/Lean lines operate independently of each other. Therefore, it is difficult to predict when conflicts might develop. If they all need servicing at the same time, there is a bottleneck. If soldering delays cannot be accommodated, then one or more of the lines must have its own soldering capability.

Technology can often provide solutions to such problems. For example, 20 high-quality drag soldering machines could be purchased for the price of one wave soldering machine. Production rates of drag solder machines are much lower than those of wave machines, but in many applications, they are ideal for placement right in the JIT/Lean line, dedicated to the line's product and controlled by the line. Such solutions are feasible with many other types of machines.

Whether your bottlenecks appear during the setup phase or during production, the best approach is to assign a cross-functional team to solve the problem. The team should have representation from engineering, manufacturing, finance, and any other relevant functional areas. Its job is to list all possibilities for eliminating the bottleneck. This can be done by brainstorming, setting aside those ideas that don't make sense, and finding the most satisfactory solution in terms of quality, expense, efficiency, and timing.

Frequently, the solution to a bottleneck results in some degree of excess capacity in the process, as occurred earlier when the third operator was added. This is not always bad. Although JIT/Lean always works to achieve more and more efficiency—and, taken to the extreme, would have just exactly enough capacity to produce the demanded level and no more—in a practical sense, some excess capacity is desirable. If a line is running at top speed every day, the operators will have no time for problem solving or improvement activities. Some time should be set aside each week for those two items as well as for maintenance and housekeeping. For most applications, 10 to 15% excess capacity is acceptable.

### Small Lot Sizes and Reduced Setup Times

For a century, industrial engineers have been taught that the larger the production lot size, the greater the benefit from economy of scale. If one wanted to hold down cost of production, bigger lot sizes were the answer. This was the conventional thinking until the JIT/Lean manufacturing bombshell landed on our shores from Japan in the early 1980s. Under the leadership of Toyota and Taiichi Ohno, Japanese manufacturers concluded that the ideal lot size is not the largest but the smallest. Is it possible that both the manufacturers and the universities could have been wrong all those years? Our conclusion is that the big lot was appropriate as long as mass production systems were used, although they certainly had major problems even then. But once the Toyota

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**Control Loop Effectiveness**

The effectiveness of any control loop is inversely proportional to the number of functions in the loop and the time required to close the loop.

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**Financial Data on the Factory Floor**

Work cells develop many kinds of charts for display in their work areas. In a San Antonio plant where employee empowerment was in full bloom, we encountered financial charts in the production areas. The cells determine their contribution per unit produced to several financial factors, including waste, labor cost per unit, and so on, and post a running record of the numbers on a chart in each work cell for all to see. The workers in the cells were obviously tuned in to this and were eager to explain both the data and the methodology used for collecting it. We found this interesting because workers in most factories do not have a clue as to their impact on cost or profit. Seldom do line workers take an interest because management doesn't give them financial information. As a result, a connection between their work and the financial well-being of the company is seldom made. In this San Antonio company, however, with management's encouragement, the production workers themselves proudly keep track of how their cells contribute to the company's financial results. The benefits of this approach can be enormous. With the information constantly in front of the cells' workers, they always have an internal urge to improve. On the other hand, if something goes wrong, the cell is the first to know and react.
Production System came into being, the big lot was not only out of step but impossible to justify.

It stands to reason that if a machine is used to produce different parts that are used in the subsequent processes of production and if the time it takes to change the machine over from one part type to another is six to eight hours, then once the machine is set up for a particular part type, one should make the most of it. It seems to make more sense to run the machine with the same setup for four days, setting up for the next part on the fifth day, than to run one day, spend the next on setup, and so on. The one-day runs result in about 50% utilization time for the machine, assuming a single shift for simplicity. The four-day run yields about 80% utilization.

So what is the problem? If there are four different parts to make on the machine, simply make 20 days’ supply in four days and then go to the next part. By the time production has used all the 20-day supply of the first part, the machine will have cycled back to make that part again. Perhaps a 30-day supply should be made, just in case the machine breaks down. Would a 40-day supply be better? Where does this stop? If we are willing to risk an occasional breakdown, the 20-day cycle is acceptable. A place to store a 20-day supply of not just one part type but four part types will be needed.

Then the capability to inventory, retrieve, and transport these parts will also be needed. That represents land, facilities, and labor that would not otherwise be needed. None of it adds value to the product, so it is pure waste. It is likely that these costs add up to more than the supposed inefficiency of running the machine with a 50% utilization factor, but these costs are more acceptable to accountants. Land, buildings, and people in motion are not as apparent as examples of waste as machines that are not making product. Traditional thinking says, “Because the machine is busy, people are busy, floor space is full, it can’t be waste.” But it is.

In addition, suppose that a production flaw is found in one of the parts, caused by the machine. Every part made in that lot is suspect. Samples will be tested, and maybe the whole lot will have to be scrapped. This could be 20 days’ supply, representing significant cost. The line will be down until new parts can be made—a major disruption.

Suppose the engineering department corrects a design weakness in one of the parts. Is the entire inventory of parts already made scrapped, or do we use them up in production, knowing that they are not as good as the newly designed part? Either is a bad proposition.

Now assume that the one-day 50% utilization cycle on the machine was employed. The greatest loss we could take would be eight days’ inventory for any of these cases. The eight-day supply can be stored easier than a 20-day supply. This would reduce the cost of warehousing, control, and transportation. Any design changes can be cut-in in eight days. Everything seems positive except the 50% machine utilization.

Ideally, setup time might be reduced to 30 minutes, producing 1 day’s supply of each part every day. Utilization will be 75% and need for any warehousing may be eliminated. This may seem to be out of reach, but manufacturers using JIT/Lean have done far better, often taking setups from many hours to a few minutes. For example, by 1973 Toyota had reduced the setup time for a 1,000-ton press from four hours to three minutes. Over a five-year period, Yanmar Diesel reduced the setup time for a machining line from over nine hours to just nine minutes. These are not isolated examples.

The general rule seems to be that organizing properly for the setup, making sure the tools and parts that will be needed are in place, and having the right people there at the appointed time will yield an immediate 50% reduction. Then, by analyzing the setup process step by step, a company can usually streamline the process to cut time by half again. Ultimately, the machine itself may be modified to make setup faster and less difficult (e.g., by eliminating the need for adjustment). In any mature JIT/Lean factory, it would be a rare setup that took more than a few minutes, whereas the same setups were previously measured in hours.

The previously supposed advantage of manufacturing in big lots completely disappears when setup times are brought down to the kinds of times being discussed here. Machine utilization can be high to satisfy accounting criteria, and lots can be small to prevent waste and to enable kanban pulling straight from the machine to the next process. Short setup times coupled with kanban have the advantage of flexibility of production. For example, Harley-Davidson used to run its motorcycle line in long production runs of the same model. If a dealer placed an order for a model that had just finished its run, it might have been several weeks before that model could be run again, allowing the order to be filled. Harley was one of the first North American companies to adopt the total quality methods—as a means of survival.

For many years now, Harley has been able to mix models on the production line. It no longer has to produce its product in big lots because it was able to reduce setup times all along its line. Now when an order comes in, it is placed in the queue without regard for the model. Customers get their new bikes as they want them configured and far sooner.

Led by Nissan in the United States, auto production lines are beginning to be more flexible as well. Several manufacturers have lines that accommodate two or more models of similar vehicles. The Nissan plant in Canton, Mississippi, which came on-line in 2003, has the capability to intermix five dissimilar models in lot sizes of one on the same line. Flexibility like that can happen only when model-to-model setup is eliminated or made insignificant. Who benefits? The customer gets more choice, higher quality, and lower cost, and the manufacturer becomes more competitive.

Small Lot Sizes
Small lot sizes result in improved product quality, production flexibility, and customer responsiveness. Shortened setup times make small lots possible.
Total Productive Maintenance and Housekeeping

This is difficult to comprehend, but many manufacturers spend vast amounts on capital equipment and then ignore the machines until they self-destruct. By contrast, one can find relatively ancient machines in total quality Japanese factories that look like new and run even better. This must become the norm in the United States if U.S. companies are going to compete with the rest of the world. Because a JIT/Lean production line operates very close to capacity in every process, no tolerance exists for machine failure. When the machine is supposed to be running, it had better be, or the whole line will suffer. Companies that have adopted the Japanese philosophy of total productive maintenance have virtually eliminated machine breakdowns. Machines are cleaned and lubricated frequently, most of that work being done by the operators who run the machines. More technical preventive maintenance routines are performed by experts at frequent intervals. The machines are continually upgraded and modified for closer tolerances, faster setup, and fewer adjustments. Not only do the machines last longer, but also during their entire life span they perform as well or better than when new.

The difficulty with TPM is finding the time in which to perform the maintenance, especially in factories in which three shifts are the norm. The third shift is rare in Japan and Europe, so companies there do not share this problem. Regardless of the workday schedule, it is imperative that maintenance time be provided. The operator-performed maintenance is done during the normal shift (one reason to have a bit more than just enough capacity—a half-hour to an hour a day of excess capacity should more than cover operator maintenance needs).

An added benefit of turning some of the maintenance responsibility over to the operators is that the operators develop a sense of ownership for the machines they use and care for. They pay keen attention to the looks, sounds, vibrations, and smells of the machines to spot problems before they develop. For the first time, the operators are in a position to call for maintenance before breakdown occurs. TPM is a must for JIT/Lean production systems.

Housekeeping is another area that is different under JIT/Lean. It is not unusual for the operators themselves to take on the responsibilities formerly associated with janitors. In the better JIT/Lean plants, one will see planned downtime being taken up with cleaning chores—everything spotless, everything in its place. (Remember Five-S from Chapter 15.) It follows that better performance will result from a clean, tidy, and well-organized work area than from one that is dirty and cluttered with tools scattered all over. People like a clean, bright, rational place in which to work. Again, time will have to be made available for this activity.

Process Capability, Statistical Process Control, and Continual Improvement

Process capability, statistical process control (SPC), and continual improvement have already been discussed in detail in this book, but it is important to understand the dependence on them by just-in-time/Lean. Is JIT/Lean a necessary prerequisite for process capability study and improvement, or for SPC, or for continual improvement? The answer is no. At least one of the three is being done in the majority of traditional production plants. Still, there is a connection. The philosophy and discipline of just-in-time/Lean virtually demand that they be used in any JIT/Lean environment. While a traditional manufacturing operation may employ one or more of the three, the JIT/Lean manufacturing operation must, and it must be all three. The reason may be obvious to you by now. The JIT/Lean plant is fragile. Everything must work when it is supposed to, and it must work close to perfection. There are no warehouses of buffer stock to come to the aid of a broken-down process. There is never much excess capacity to help out in tight spots. All the processes with their machines and people must operate in top form all the time.

This is where process capability, SPC, and continual improvement come in. Even before the JIT/Lean line can be certified for full production, the line has to be balanced or rationalized, and a flow has to be established. Unless it is known what the processes are capable of doing in terms of quality and quantity, it will be difficult to achieve the even flow that is a necessary prerequisite of a kanban system. Without that, there is no JIT/Lean. In the traditional factory, not knowing the capability of the processes is not such a problem; normally, gross overcapacity exists, so parts are stored for the day things go wrong, and the bad parts are sorted out because there will still be good ones to use. In JIT/Lean, no extra parts can be made, and all have to be good. Workers must have a handle on the processes.

Because one cannot afford (from the time or cost standpoint) to make defective parts, the processes must be in control at all times. The only way to ensure this is through statistical process control. This is not as necessary in a traditional plant, but it is absolutely essential in JIT/Lean. Perfection is difficult to achieve in any circumstance, so it follows that in a complex manufacturing situation, perfection is next to impossible. This is certainly true. We never quite get to the point where all the parts are perfect, but with solid, stable, in-control processes forming the basis of a relentless continual improvement program, we can come very, very close. (Some of the very best American plants target and achieve Six Sigma, 3.4 defects per million.) The best that can be achieved is the minimum that is acceptable for a JIT/Lean factory. In the process of continual improvement, ways are found to do things better, faster, cheaper, and with constantly improving quality. The process never ends, and the diminishing-return syndrome doesn’t apply.

Suppliers

In the area of suppliers, JIT/Lean has different priorities from the traditional production system. The most obvious difference is the need for frequent, small-lot deliveries of parts, supplies, and materials, rather than the traditional infrequent, huge-volume deliveries. We are finding more and
more JIT/Lean plants in which the suppliers deliver materials directly to the production cells, usually referred to as point-of-use. Several systems have been developed to cue the supplier that it is time to replenish materials. One is the dual-bin kanban system. Two parts bins are used. Bin capacity may range from a few hours’ to a couple of weeks’ supply, depending on value, size, usage rate, and intended frequency of replenishment. When the cell has withdrawn all the parts from one bin, the empty bin itself is the signal that it is time to replenish. The supplier routinely checks the bins on the factory floor, and whenever he or she finds a bin empty, it is refilled with the exact number and kind of part designated on the bin label, usually in bar code. The supplier’s bin checking must be scheduled frequently enough to ensure that the second bin is never exhausted before the first is replenished. In a variation on the dual-bin kanban scheme, the cell’s operators signal the supplier that a bin is empty, either by bar code transmission or by automated electronic purchase order that is triggered by wiping the empty bin’s bar code.

Clearly, for this kind of point-of-use materials delivery system to work, the supplier must be 100% reliable, the materials delivered must be of consistently high quality, and both the supplier and the manufacturing organization must be partners for the long haul. Consequently, choosing the suppliers for a JIT/Lean factory is a much more demanding job than it is for a traditional plant. Traditional factories are not so concerned with the delivery being on the dock at the precise date on the purchase order. It was going to be stored for a while anyway. Before that lot was used up, there would be another shipment in the warehouse. Neither do traditional factories concern themselves as much with quality from suppliers. The bad parts could always be sorted out, leaving enough good material to keep the line moving. The primary interest was price. Low price got the order. It quickly becomes apparent that this style of purchasing is incompatible with JIT/Lean.

The JIT/Lean plant must have its materials on the dock exactly on the day specified—in many cases at the hour and minute specified—or production may grind to a halt. Every part delivered must be a good part—there is no inventory cache from which to scrounge more parts to keep things moving. This means that the suppliers’ quality must be consistently at or above specified requirements. Delivery and quality performance requirements of JIT/Lean effectively rule out buying for price. There is an often used phrase in JIT/Lean and TQM purchasing: “cost versus price.” It suggests a holistic approach to the analysis of purchasing on the basis of total cost and value, not simply vendor price. How reliable is a particular vendor in terms of JIT/Lean deliveries? What kind of quality can be expected from the vendor? Does the vendor use JIT/Lean, SPC, and continual improvement? Are its processes stable and in control? A supplier that gives positive responses in these and other areas may not be the lowest price contender but may well be the lowest cost. Value is what the JIT/Lean purchasing manager must look for, not lowest price on a bid sheet, because in JIT/Lean that turns out not to be the whole story.

When a JIT/Lean factory finds a supplier that delivers excellent materials on time, every time, there is every reason to want to continue to do business with it. More and more companies are turning to supplier partnerships to cement these relationships. What this means is that the two companies agree to work together, not only as supplier and customer but also as unstructured partners. The JIT/Lean manufacturer may, for example, provide training and technical assistance to the supplier to get it started in total quality, JIT/Lean, SPC, and other processes. The JIT/Lean firm may certify the supplier’s quality system to the extent that incoming inspections are eliminated, relying on the partner supplier to provide acceptable quality in all its deliveries.

The supplier partner may assign one or more employees to take up residence in the JIT/Lean manufacturer’s plant. Duties will include continually checking the kanban bins mentioned above, having them replenished appropriately, and coordinating on-time deliveries of materials, parts, and other supplies provided under the JIT/Lean partnership agreement between the manufacturer and supplier. In addition, the resident supplier employee is empowered to do whatever is necessary to solve supply problems before they can cause disruption in the JIT/Lean factory. (While this practice has been around for two decades in the United States, and much longer in Japan, it is now sometimes referred to as JIT II. In the authors’ view, it is simply a logical variation of the materials element of just-in-time/Lean that can work very well in numerous situations.)

The supplier may also be called on to assist in the design phase of a new product, bringing its unique expertise to the design team. Such relationships usually carry a multiyear agreement, so the supplier can count on the business as long as its performance remains high.

There may be preferential bidding treatment—say, an advantage of 10% or more over nonpartnership rivals. Effectively what happens is that the JIT/Lean manufacturer extends its factory right back into the supplier’s premises. They operate to each other’s requirements, and both are locked to each other. The results of this kind of arrangement have been excellent.

This kind of relationship is a far cry from the early ill-conceived attempts of some manufacturers to get into JIT/Lean before developing a full understanding of the concept. In those days, some companies would determine that by using JIT delivery of parts and materials, money could be saved. That part had some merit, but the execution was flawed. The companies simply told their suppliers to deliver a week’s supply of materials once a week, rather than their customary 60 days’ supply every two months. The suppliers’ reaction is easy to imagine. They were being told, in effect, to store the materials in their own warehouses (the capacity for which they didn’t have) and to trickle the deliveries from the warehouses in small quantities weekly. This was simply a case of moving the storage facility from the manufacturer’s plant to the suppliers’. A GM or a Ford has the power to do that to a supplier, but the suppliers, being smaller and with less influence, couldn’t force the same back to their own suppliers, so they got caught in an intolerable situation. Only when the suppliers revolted and cried long and loud that this was not JIT—“and by the way, if you want me to store your
goods for you, you’re going to pay the tab anyway”—did the would-be JIT/Lean manufacturers see the error of their ways.

The new approach is working well because both parties benefit enormously. If a company wants JIT/Lean, then it must have the best possible suppliers, and both must want to work together for the long haul.

**AUTOMATION AND JIT/LEAN**

Automation has not been discussed a great deal in this book. We have stuck to the fundamentals. One should not read into this, however, that JIT/Lean and automation are mutually exclusive. Rather, it is more meaningful to discuss the processes that use humans and manual machines than the same processes powered by robots. If the fundamentals where humans apply are understood, the same fundamentals will be useful in an automated plant. All the same rules apply. We are not anti-automation.

We are, however, against “automation for the sake of automation.” Many companies have made the costly mistake of thinking that automation will solve manufacturing problems. During the 1980s, manufacturers in the United States invested billions of dollars in automation. Cadillac built what was at the time the most highly automated auto assembly plant in North America and probably in the world. It turned into a nightmare of high-tech problems that took years to sort through. The plant that was to produce six cars per hour, after a year of operation, could do only half that and the quality of manufacture was, to put it charitably, questionable. Two years later, Toyota opened a new plant in Kentucky. Visitors to that plant, expecting to see a high-tech automated production line, were disappointed to find very little in the way of robotics.19 The difference in the philosophies of the two companies becomes obvious. Executive managers at GM believed that by spending enough money, they could buy their way out of the trouble they were in. Toyota knew what it was capable of in doing in one of its other low-tech plants that was operating successfully in Japan and simply cloned it down to the last detail in Kentucky. No razzle-dazzle; just good common sense.

Automation may be advantageous in many applications, but if you have not solved the problems in the human-operated versions of those same applications, you are not ready to automate them effectively. If you try, you will automate your problems and will find the robots far less adept at working around them than the humans they replaced.

It is frequently found that the need for automation is decreased or eliminated by converting to JIT/Lean. We certainly found that to be the case in two electronics plants. We were well into a program to build a factory of the future. The building was ready, much of the automation was on hand, and the rest—several million dollars’ worth—was on order when we started the conversion to JIT/Lean. Within months, it had become obvious to everyone, including the designers of the new factory, that we were getting more out of JIT/Lean for almost no investment than could be projected for the new automated plant. The outstanding orders for automation equipment were cancelled and penalties were paid, and we walked away from the whole idea. We had learned in those few weeks of exposure to JIT/Lean that world-class manufacturing equates to JIT/Lean in a total quality environment, not to a factory full of robots and automatic guided vehicles. JIT/Lean and automation are compatible, but one should look long and hard at the need, and the company’s readiness for it, before automating processes.

Having said that, automation clearly has its place in harmony with JIT/Lean. There are many examples of very successful automated plants, especially for high-volume manufacturing. Automation and JIT/Lean are completely compatible. Probably the best example of that is in today’s auto industry. Two such plants have recently come on-line in Alabama and Georgia. Hyundai opened its first American plant in Montgomery, Alabama, in May 2005, making 300,000 vehicles per year there. This plant is one of the first designed from the ground up as a highly automated JIT/Lean auto production facility. A tour of the plant will convince the fervent skeptic that it has taken the auto industry into a new era in which JIT/Lean and automation are superbly blended. Where traditional auto plants tended to be dark, noisy, grimy, smelly, hot, and frantic in the hustle and bustle, Hyundai’s Montgomery plant is none of that. No matter where you are in the plant, the atmosphere is almost soothing, and it is certainly one of the most pleasant factories of any type that the authors have ever visited. It is a place where the 2,300 employees genuinely seem to enjoy working. And it doesn’t end there. An hour from Montgomery, up Interstate 85 in West Point, Georgia, Kia Motors opened a sister plant of the same size and capacity, using the same automation technology and, of course, JIT/Lean. The first Kia Sorento rolled off that line in November 2009.

Regardless of factory age, and although employing large numbers of workers, the auto industry is a big user of automation. Whether in North America, Japan, or Korea. And all those plants use JIT/Lean successfully. Remember, JIT/Lean was originally designed for an auto producer, and as automation has been integrated, and as automation capabilities have evolved, JIT/Lean has been there doing its job. In these plants, JIT/Lean is at least as valuable as it is in plants with less automation. Its pull system prevents overproduction of any manufacturing element, and supplies materials at the front end of the process when needed, and does it without the massive inventories of the pre-JIT/Lean era. Whether the processes are operated by humans or robots makes no difference in this regard.

**SUMMARY**

1. JIT/Lean is a management philosophy that seeks to eliminate all forms of waste. As a production system, JIT/Lean produces only what is needed, when it is needed, in the quantity needed.
2. The root justification for JIT/Lean is improved product quality with lower costs.
3. JIT/Lean began as a means of reducing the seven wastes. Over time, the JIT/Lean system came to be a pull system whose small lot production is supported by reduced setup times.
productive maintenance and statistical process control were integrated to provide the necessary production reliability and predictability. Continual improvement provides the vehicle for the relentless attack on all wastes.

4. JIT/Lean is at its best as a part of a total quality system. Results can be severely restricted when JIT/Lean is operated without the total quality umbrella.

5. Inventory reduction, shortened cycle time, continual improvement, and elimination of waste are all inherent benefits of JIT/Lean.

6. JIT/Lean has a different set of requirements from traditional production systems: providing training in new skills; rationalizing production flow for the pull system; empowering operators to take advantage of JIT/Lean’s visibility features; guarding against bottleneck vulnerability through TPM, process capability study, SPC, and continual improvement; producing small lots and shortening setup times; and establishing close working relationships with superior suppliers.

7. JIT/Lean is successfully employed around the world in situations where automation is nonexistent and equally successful in the most highly automated plants on the planet. World-class manufacturing employs JIT/Lean as an integral part of a total quality system, producing the highest quality products at competitive prices. It is not related to the presence or absence of automation.

**FACTUAL REVIEW QUESTIONS**

1. Define JIT/Lean.
2. Explain the difference between the traditional production system and JIT/Lean in terms of placement of production control.
3. Describe the bases for production scheduling for mass production systems and for JIT/Lean.
4. Explain how a JIT/Lean process knows when and how much to produce.
5. What two fundamental advantages are provided by JIT/Lean?
6. List the seven wastes.
7. Identify the two pillars of the Toyota Production System.
8. Explain how traditional mass production contributes to the seven wastes.
9. Explain how JIT/Lean impacts each of the seven wastes.
10. Discuss JIT/Lean’s vulnerability to parts shortages, breakdowns, and bottlenecks from the perspective of the mass production advocate and the JIT/Lean advocate.
11. Explain the push system and what triggers it to start.
12. Explain the pull system and how it is started.
13. Why is superior machine maintenance and improvement critical to JIT/Lean?
14. Describe how kanban supports the pull system.
15. What are the advantages of reduced setup time?
16. Why does this book recommend that JIT/Lean be a part of a total quality system?
17. Describe JIT/Lean’s objectives relative to inventory and WIP.
18. Discuss the relative complexity of the two production systems.
19. Explain cycle time, and list its constituent elements.
20. Why is a JIT/Lean production line-stop considered a positive phenomenon?
21. Explain how inventory can deter problem solving.
22. Describe the difference in plant organization and layout between the two production systems.
23. Explain how JIT/Lean can cause immediate cycle time reduction.
24. To whom is credit given for the development of the JIT/Lean system?
25. Discuss the relative value of JIT/Lean in production environments of little or no automation versus those that are highly automated.

**CRITICAL THINKING ACTIVITIES**

1. Study the operations of an electric utility company, and determine where the production of electricity stands vis-à-vis push or pull systems. Using charts and narrative, explain your finding.
2. Study the operation of a supermarket, and list the JIT/Lean features in use. Look for special JIT/Lean practices such as supplier partnerships, and describe how they operate in a supermarket environment.

3. Develop a chart contrasting the philosophies of mass production and JIT/Lean.

4. Mass production was the most successful production system from the time of Henry Ford’s Model T until the 1960s. There is no question that this system permitted the manufacture of a wide range of goods at much lower prices than had been possible before then. Given this success, how do you explain that JIT/Lean is supplanting mass production?

5. You are the president of a new division of a major auto producer. Your organization has been chartered to design and build a line of cars to compete with intermediate-size Asian and European imports. The division is to be located in a historically agricultural state that has availability of unskilled labor but no experience in auto manufacturing. Your key staff and mid-level managers will be handpicked from among other divisions. The corporate headquarters staff has not been able to come to terms with how the new division should be set up. The options seem to be these: (a) set up as a total quality organization, using JIT/Lean in the factory or (b) because the corporation has little experience with either, set up like the other divisions in a traditional hierarchy and production system, converting to total quality and JIT/Lean little by little as time and experience permit. You believe that in the long run, total quality and JIT/Lean are necessary to compete, especially with the Japanese and Koreans. But you and the people who will make up the division’s management team are experts in mass production. Going the traditional route looks like an easier start-up path. Going directly to total quality or JIT/Lean has unknowns.

The CEO is leaning toward letting you make the call, but he wants you to convince him and the senior staff. You have to prepare a briefing for the corporate staff for that purpose. Which course will you choose? Explain the advantages and possible pitfalls of both, and make the argument that supports your choice.

**DISCUSSION ASSIGNMENT 21.1**

Taiichi Ohno’s JIT/Lean system, with the elimination of practically all inventories, and using demand pull (kanban) to coordinate the flow of materials and assemblies through the production process, has been resisted by some on the basis that if even the smallest part in the system failed to appear or perform when needed, the entire process must come to a halt. Ohno proclaimed that this “weakness” of JIT/Lean was in fact its power since it removed all safety nets, and, with the production line stopped, forced the entire organization to focus on resolving the root cause of the problem so that it never recurs.

CourseKar Industries manufactures golf carts. Their product is reasonably successful, but competing manufacturers sell their carts for less than CourseKar can, and yet have fewer product warranty and reliability problems. As a result, CourseKar’s market share has been slipping, and the Board of Directors is calling for action. Management knows that its competition has been using JIT/Lean production techniques for several years. But while they find JIT/Lean appealing for eliminating waste and improving quality and productivity, they are concerned that conversion to JIT/Lean, with its precariousness of having little or no inventory of materials on hand would be too great a risk. In order to lower production costs and improve quality, management is leaning toward a hybrid JIT/Lean system instead. This system will employ the principles and methodology of JIT/Lean, but will maintain buffer stocks of materials and assemblies to prevent every part delivery problem or malfunction on the line from shutting down the production process.

**Discussion Questions**

Discuss the following questions in class or outside of class with your fellow students:

1. If something as trivial as a missing screw or a broken tool can stop a JIT/Lean production line, how could Ohno consider that to be a power of the concept?
2. Discuss what would likely happen if a needed screw or a working tool is missing from a traditional mass production line.
3. Discuss the implications of a JIT/Lean production system that employs buffer stocks or materials and parts.
4. Discuss the potential for a nonmanufacturing organization to benefit from employment of JIT/Lean.

**ENDNOTES**

5. Ibid., 9.
6. Ibid., 75.
9. Materials and general and accounting expenses are held constant for this example to keep it simple, although both could be expected to decrease under JIT/Lean.