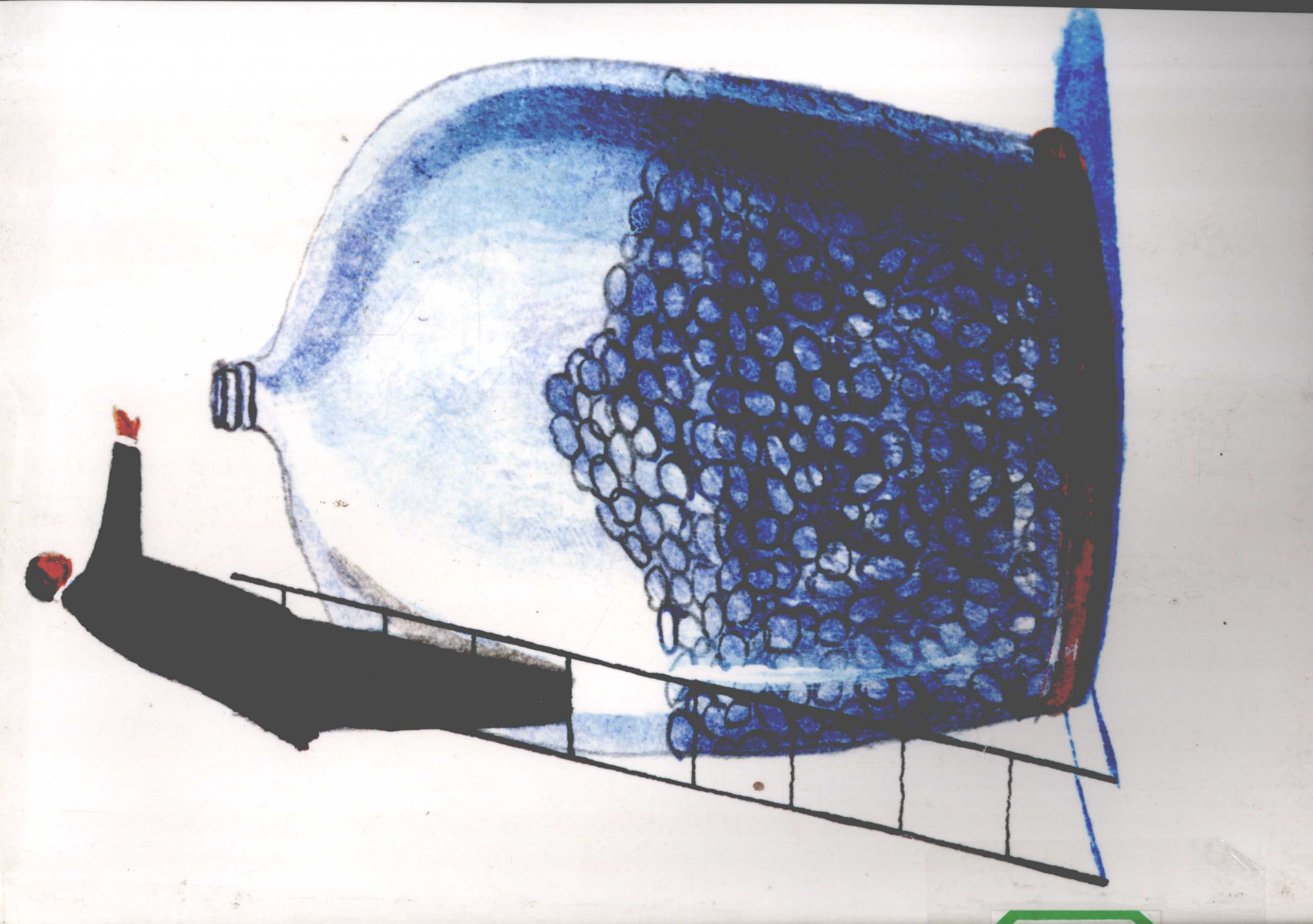

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Just-in-Time and Lean Production Systems

Chapter Outline

Learning Objectives

When you complete this chapter you should be able to

IDENTIFY OR DEFINE:

- Variability
- Kanban
- 5S System
- Seven Wastes

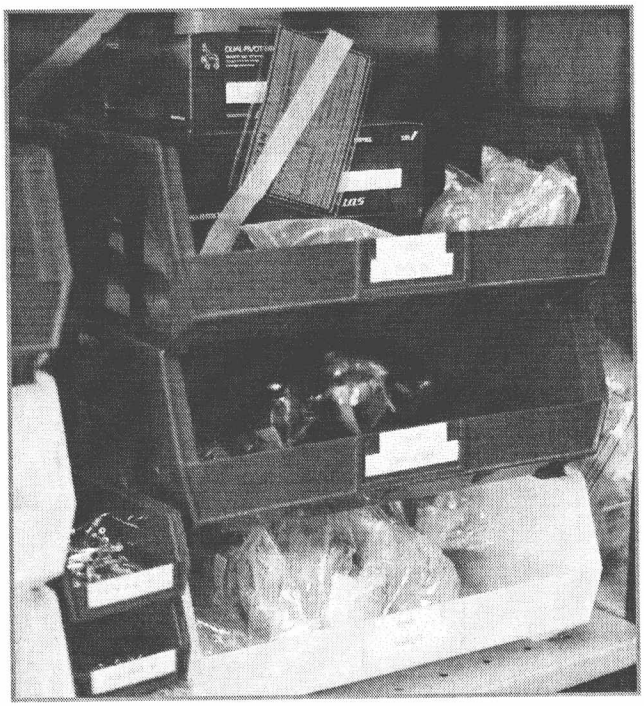
DESCRIBE OR EXPLAIN:

- Just-in-time philosophy
- Pull systems
- Push systems
- The goals of JIT partnerships
- Lean production
- Principles of Toyota Production System

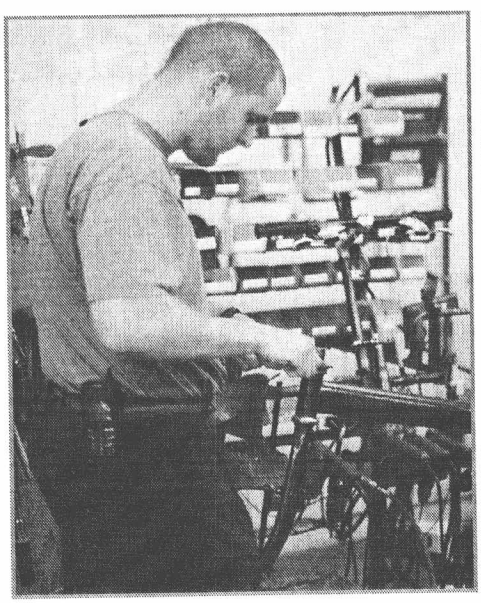
GLOBAL COMPANY PROFILE:

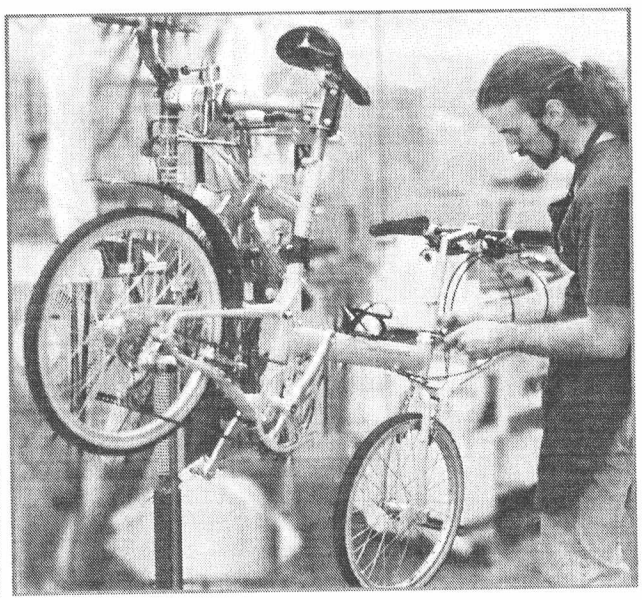
Just-in-Time (JIT) Provides Competitive Advantage at Green Gear

Green Gear Cycling, Inc., of Eugene, Oregon, designs and manufactures a high-performance travel bicycle, known as Bike Friday. The name is a take-off on Robinson Crusoe's "man Friday," who was always there when needed. Bike Friday is a bike in a suitcase—always there when you need it. This unique line of folding suitcase travel bicycles is built-to-order. Green Gear's goal, from its inception in 1992, has been to produce a high-quality custom bike rapidly and economically. This goal suggested a mass customization strategy requiring fast throughput, low inventory, work cells, and elimination of machine setups. It also meant adopting the best practices in operations management with a major focus on just-in-time (JIT) and supply-chain management.



Green Gear has carefully integrated just-in-time manufacturing and continuous improvement into its culture and processes. Inventory resides in individual containers at their point of use. Each container is labeled and includes a kanban card to trigger reordering. PHOTO CREDIT: Green Gear Cycling, Inc.



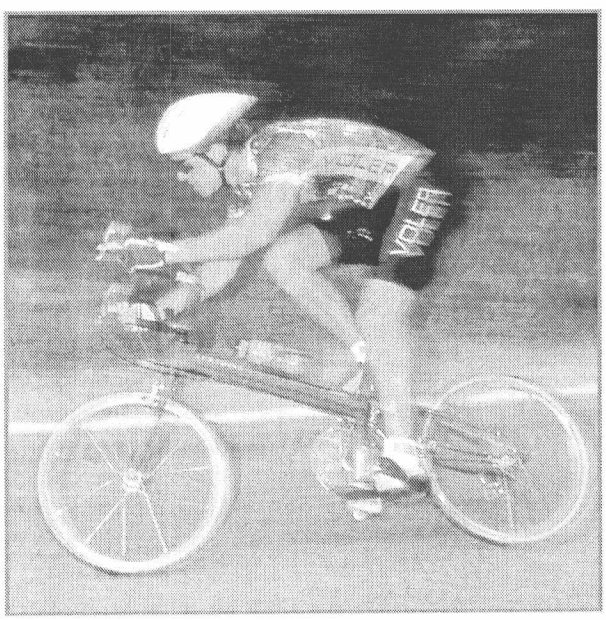


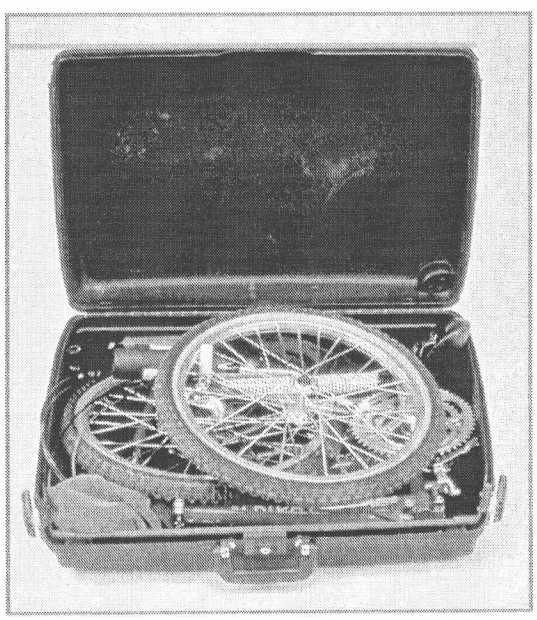
Work cells make extensive use of visual signaling and explicit labeling of all inventory, tooling, and equipment. Each item is kept in a specific location, which facilitates cross training and assignment of employees to various cells. Effective work cell design translates to low inventory with work-in-process inventory of one bike per cell.

Through collaboration with suppliers, Green Gear has developed and implemented JIT deliveries that contribute to minimal inventory levels. And by storing inventory at the point of use and aggressively developing internal systems that support small reorder quantities, the firm has been able to drive inventory down and push quality up. Dedicated machinery and single application jigs also contribute to the small reorder quantities of component items. This success with JIT is instrumental in allowing Green Gear's high-quality, low-inventory system to work. Such systems are known as "kanban" systems and often use a simple signal such as a card, rather than a formal order, to signal the need for more parts.

For competitive as well as efficiency reasons, managers at Green Gear want to maintain a total throughput time, from raw tubing to completed bicycle, of less than 1 day. A manufacturing layout with such a high throughput requires minimizing or eliminating setups. The result is two flow lines, one for tandem bikes and one for single bikes. The seven work cells on these two lines are fed components from three support cells. The three support cells supply subassemblies, powder coating, and wheels. They receive orders via kanban cards. Each work cell's throughput time is balanced to match each of the others. These well-designed work cells contribute to rapid product throughput at Green Gear with little work-in-process.

Each bike is built to size, configured for the customer purchasing it, and shipped immediately on completion. So this build-to-order JIT system requires little raw material and little work-in-process inventory and *no* finished-goods inventory. Supplier collaboration, creative work cells, elimination of setups, and exceptional quality contribute to low inventory and aid Green Gear in its continuing effort to speed bikes through the plant with a lot size of one.





Each Bike Friday is custom built to order from 14 base models, totaling 67 preconfigured bills, multiple paint colors, and additional sizing options. The total number of possible Bike Friday combinations exceeds 211,000. But lot size is one. And it fits in a suitcase. PHOTO CREDIT: Green Gear Cycling, Inc.

Just-in-time (JIT)
A philosophy of continuous and forced problem solving that drives out waste.

As shown in the *Global Company Profile*, just-in-time (JIT) contributes to an efficient operation at Green Gear Cycling. In this chapter we discuss JIT as a philosophy of continuing improvement that drives out waste and supports lean organizations.

JUST-IN-TIME AND LEAN PRODUCTION

Lean production
A way to eliminate waste through a focus on exactly what the customer wants.

Just-in-time is a philosophy of continuous and forced problem solving that supports lean production. **Lean production** supplies the customer with exactly what the customer wants when the customer wants it, without waste, through continuous improvement. Lean production is driven by the "pull" of the customer's order. JIT is a key ingredient of lean production. When implemented as a comprehensive manufacturing strategy, JIT and lean production sustain competitive advantage and result in greater overall returns.[1]

TEN OM STRATEGY DECISIONS

Design of Goods and Services
Managing Quality
Process Strategy
Location Strategies
Layout Strategies
Human Resources
Supply-Chain Management
Inventory Management
Independent Demand
Dependent Demand
JIT & Lean Production
Scheduling
Maintenance

With JIT, supplies and components are "pulled" through a system to arrive *where* they are needed *when* they are needed. When good units do not arrive just as needed, a "problem" has been identified. This makes JIT an excellent tool to help operations managers add value by driving out waste and unwanted variability. Because there is no excess inventory or excess time in a JIT system, costs associated with unneeded inventory are eliminated and throughput improved. Consequently, the benefits of JIT are particularly helpful in supporting strategies of rapid response and low cost.

Because elimination of *waste* and *variability* and the concept of *pulling materials* are fundamental to both JIT and lean production, we briefly discuss them in this section. We then introduce applications of JIT with suppliers, layout, inventory, scheduling, quality, and employee empowerment. Then we review some of the distinguishing features of lean production and look at JIT applied to services.

Waste Reduction Waste is *anything that does not add value*. Products being *stored, inspected,* or *delayed, products waiting in queues,* and *defective products* do not add value; they are 100% waste. Moreover, any activity that does not add value to a product *from the customer's perspective* is waste. JIT provides faster delivery, reduces work-in-process, and speeds throughput, all of which reduce waste. Additionally, because JIT reduces work-in-process, it provides little room for errors, putting added emphasis on quality production. These waste reduction efforts release inventory assets for other, more productive purposes. JIT forces waste out of the system.

Variability
Any deviation from the optimum process that delivers perfect product on time, every time.

Variability Reduction To achieve just-in-time material movement, managers *reduce variability caused by both internal and external factors*. **Variability** is any deviation from the optimum process that delivers perfect product on time, every time. Inventory hides variability—a polite word for problems. The less variability in the system, the less waste in the system. Most variability is caused by tolerating waste or by poor management. Variability occurs because:

1. Employees, machines, and suppliers produce units that do not conform to standards, are late, or are not the proper quantity.
2. Engineering drawings or specifications are inaccurate.
3. Production personnel try to produce before drawings or specifications are complete.
4. Customer demands are unknown.

Variability can often go unseen when inventory exists. This is why JIT is so effective. The JIT philosophy of continuous improvement removes variability. The removal of variability allows us to move good materials just-in-time for use. JIT reduces material throughout the supply chain. It helps us focus on adding value at each stage. Table 1 outlines the contributions of JIT; we discuss each of these concepts in this chapter.

Pull system
A JIT concept that results in material being produced only when requested and moved to where it is needed just as it is needed.

Pull versus Push The concept behind JIT is that of a **pull system**: a system that *pulls* a unit to where it is needed just as it is needed. A pull system uses signals to request production and delivery from stations upstream to the station that has production capacity available. The pull concept is used

[1]Research suggests that the more JIT is comprehensive in breadth and depth, the greater overall returns will be. See Rosemary R. Fullerton and Cheryl S. McWatters, "The Production Performance Benefits from JIT Implementation," *Journal of Operations Management* 19, no. 1 (January 2001): 81–96.

TABLE 1 ■

JIT Contributes to Competitive Advantage

JIT REQUIRES:

Suppliers:	Reduced number of vendors; Supportive supplier relationships; Quality deliveries on time
Layout:	Work-cell layouts with testing at each step of the process; Group technology; Movable, changeable, flexible machinery; High level of workplace organization and neatness; Reduced space for inventory; Delivery directly to work areas
Inventory:	Small lot sizes; Low setup time; Specialized bins for holding set number of parts
Scheduling:	Zero deviation from schedules; Level schedules; Suppliers informed of schedules; Kanban techniques
Preventive maintenance:	Scheduled; Daily routine; Operator involvement
Quality production:	Statistical process control; Quality suppliers; Quality within the firm
Employee empowerment:	Empowered and cross-trained employees; Training support; Few job classifications to ensure flexibility of employees
Commitment:	Support of management, employees, and suppliers

WHICH RESULTS IN:

- Queue and delay reduction speeds throughput, frees assets, and wins orders
- Quality improvement reduces waste and wins orders
- Cost reduction increases margin or reduces selling price
- Variability reduction in the workplace reduces wastes and wins orders
- Rework reduction reduces wastes and wins orders

WHICH YIELDS:

Faster response to the customer at lower cost and higher quality—

A Competitive Advantage

both within the immediate production process and with suppliers. By *pulling* material through the system in very small lots just as it is needed, the cushion of inventory that hides problems is removed, problems become evident, and continuous improvement is emphasized. Removing the cushion of inventory also reduces both investment in inventory and manufacturing cycle time.

Manufacturing cycle time
The time between the arrival of raw materials and the shipping of finished products.

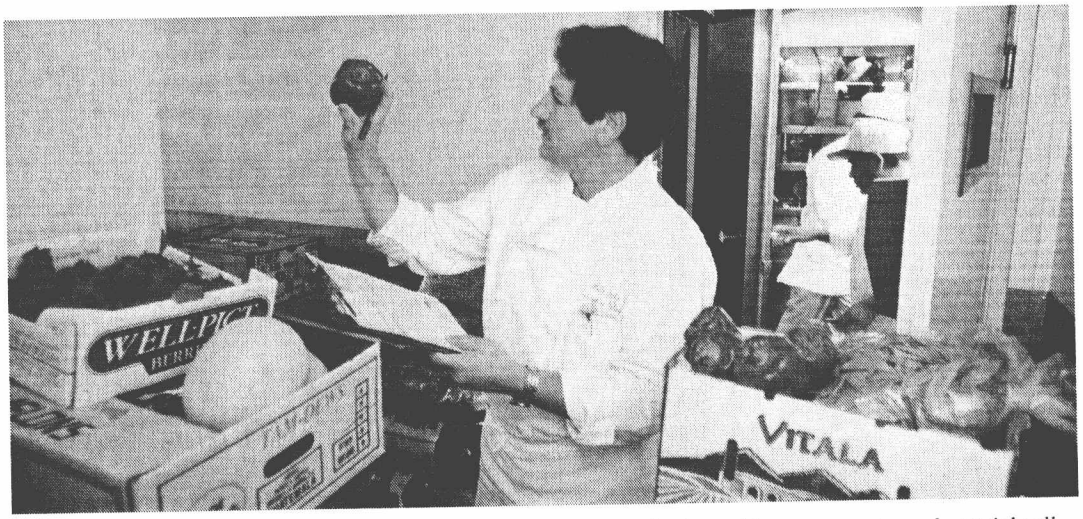
Manufacturing cycle time is the time between the arrival of raw materials and the shipping of finished products. For example, at Northern Telecom, a phone-system manufacturer, materials are pulled directly from qualified suppliers to the assembly line. This effort reduced Northern's receiving segment of manufacturing cycle time from 3 weeks to just 4 hours, the incoming inspection staff from 47 to 24, and problems on the shop floor caused by defective materials by 97%.

Push system
A system that pushes materials into downstream workstations regardless of their timeliness or availability of resources to perform the work.

Many firms still move material through their facilities in a "push" fashion. A **push system** dumps orders on the next downstream workstation regardless of timeliness and resource availability. Push systems are the antithesis of JIT.

SUPPLIERS

Incoming material is often delayed at the shipper, in transit, at receiving departments, and at incoming inspection. Similarly, finished goods are often stored or held at warehouses prior to shipment to distributors or customers. Because holding inventory is wasteful, JIT partnerships are directed toward reducing such waste.



Many services have adopted JIT techniques as a normal part of their business. Most restaurants, and certainly all fine-dining restaurants, expect and receive JIT deliveries. Both buyer and supplier expect fresh, high-quality produce delivered without fail just when it is needed. The system doesn't work any other way. PHOTO CREDIT: Art Montes de Oca & Associates

JIT partnerships
Partnerships of suppliers and purchasers that remove waste and drive down costs for mutual benefits.

JIT partnerships exist when supplier and purchaser work together with a mutual goal of removing waste and driving down costs. Such relationships are critical for successful JIT. Every *moment* material is held, some process that adds value should be occurring. To ensure this is the case, Xerox, like other leading organizations, views the supplier as an extension of its own organization. Because of this view, the Xerox staff expects suppliers to be as fully committed to improvement as Xerox. This relationship requires a high degree of openness by both supplier and purchaser. Table 2 shows the characteristics of JIT partnerships.

Goals of JIT Partnerships

The four goals of JIT partnerships are

1. *Elimination of unnecessary activities.* With good suppliers, for instance, receiving activity and incoming-inspection activity are unnecessary under JIT.
2. *Elimination of in-plant inventory.* JIT delivers materials where and when needed. Raw material inventory is necessary only if there is reason to believe that suppliers are undependable. Likewise, parts or components should be delivered in small lots directly to the using department as needed.
3. *Elimination of in-transit inventory.* General Motors once estimated that at any given time, over half its inventory is in transit. Modern purchasing departments are now addressing in-transit inventory reduction by encouraging suppliers and prospective suppliers to locate near manufacturing plants and provide frequent small shipments. The shorter the flow of material in the resource pipeline, the less inventory. Inventory can also be reduced by a technique known as *consignment.* **Consignment inventory** (see the *OM in Action* box "Lean Production at Cessna Aircraft"), a variation of vendor-managed inventory, means the supplier maintains the title to the inventory until it is used. For instance, an assembly plant may find a hardware supplier that is willing to locate its warehouse where the user currently has its stockroom. Thus, when hardware is needed, it is no farther than the stockroom, and the supplier can ship to other, perhaps smaller, purchasers from the "stockroom."
4. *Elimination of poor suppliers.* When a firm reduces the number of suppliers, it increases long-term commitments. To obtain improved quality and reliability, vendors and purchasers have mutual understanding and trust. Achieving deliveries only when needed and in the exact quantities needed also requires *perfect quality*—or as it is also known, *zero defects.* Of course, *both* the supplier and the delivery system must be excellent.

Consignment inventory
An arrangement in which the supplier maintains title to the inventory until it is used.

TABLE 2 ■

Characteristics of JIT Partnerships

SUPPLIERS
Few suppliers
Nearby suppliers
Repeat business with same suppliers
Support suppliers so they become or remain price competitive
Competitive bidding mostly limited to new purchases
Buyer resists vertical integration and subsequent wipeout of supplier business
Suppliers encouraged to extend JIT buying to their second- and third-tier suppliers
QUANTITIES
Share forecasts of demand
Frequent deliveries in small-lot quantities
Long-term contracts
Minimal paperwork to release orders (use EDI or Internet)
Little or no permissible overage or underage
Suppliers package in exact quantities
Suppliers reduce production lot sizes
QUALITY
Minimal product specifications imposed on supplier
Help suppliers meet quality requirements
Close relationships between buyers' and suppliers' quality assurance people
Suppliers use poka-yoke and process control charts
SHIPPING
Scheduling inbound freight
Gain control by use of company-owned or contract shipping and warehousing
Use of advanced shipping notice (ASN)

For JIT to work, the purchasing agent must communicate the goal to the supplier. This includes delivery, packaging, lot sizes, quality, and so on.

OM IN ACTION

Lean Production at Cessna Aircraft

When Cessna Aircraft opened its new plant in Independence, Kansas, it saw the opportunity to switch from a craftwork mentality producing small single-engine planes to a lean manufacturing system. In doing so, Cessna adopted three lean manufacturing practices.

First, Cessna set up consignment- and vendor-managed inventories with several of its suppliers. Honeywell, for example, maintains a 30-day supply of avionic parts on-site. Other vendors were encouraged to use a nearby warehouse to keep parts that could then be delivered daily to the production line.

Second, Cessna managers committed to a philosophy of cross training in which team members learn the duties of other team members and can shift across assembly lines as needed. To develop these technical skills, Cessna brought in retired assembly-line workers to mentor and teach new employees. Employees were taught to work as a team and to assume responsibility for their team's quality.

Third, the company used group technology and manufacturing cellsto move away from a batch process that resulted in large inventories and unsold planes. Now, Cessna pulls product through its plant only when a specific order is placed.

These long-term commitments to manufacturing efficiency are part of the lean production system that has made Cessna an industry leader, with about half the market in general aviation planes.

Sources: Purchasing (September 4, 2003): 25–30 and (June 6, 2002): 31–31; and *Fortune* (May 1, 2000): 1222B–1222Z.

Concerns of Suppliers

To establish JIT partnerships, several supplier concerns must be addressed. The supplier concerns include

1. *Desire for diversification.* Many suppliers do not want to tie themselves to long-term contracts with one customer. The suppliers' perception is that they reduce their risk if they have a variety of customers.
2. *Poor customer scheduling.* Many suppliers have little faith in the purchaser's ability to reduce orders to a smooth, coordinated schedule.
3. *Engineering changes.* Frequent engineering changes, with inadequate lead time for suppliers to carry out tooling and process changes, play havoc with JIT.
4. *Quality assurance.* Production with zero defects is not considered realistic by many suppliers.
5. *Small lot sizes.* Suppliers often have processes designed for large lot sizes and see frequent delivery to the customer in small lots as a way to transfer holding costs to suppliers.
6. *Proximity.* Depending on the customer's location, frequent supplier delivery of small lots may be seen as economically prohibitive.

For those who remain skeptical of JIT partnerships, we would point out that virtually every restaurant in the world practices JIT, and with little staff support. Many restaurants order food for the next day in the middle of the night for delivery the next morning. They are ordering just *what* is needed, for delivery *when* it is needed, from reliable suppliers.

JIT LAYOUT

JIT layouts reduce another kind of waste—movement. The movement of material on a factory floor (or paper in an office) does not add value. Consequently, we want flexible layouts that reduce the movement of both people and material. JIT layouts move material directly to the location where needed. For instance, an assembly line should be designed with delivery points next to the line so material need not be delivered first to a receiving department elsewhere in the plant, then moved again. This is what VF Corporation's Wrangler Division in Greensboro, North Carolina, did. Now, denim is delivered directly to the line. When a layout reduces distance, the firm also saves space and eliminates potential areas for unwanted inventory. Table 3 provides a list of layout tactics.

TABLE 3 ■
Layout Tactics

Build work cells for families of products
Include a large number of operations in a small area
Minimize distance
Design little space for inventory
Improve employee communication
Use poka-yoke devices
Build flexible or movable equipment
Cross train workers to add flexibility

Distance Reduction

Reducing distance is a major contribution of work cells, work centers, and focused factories. The days of long production lines and huge economic lots, with goods passing through monumental, single-operation machines, are gone. Now firms use work cells, often arranged in a U shape, containing several machines performing different operations. These work cells are often based on group technology codes. Group technology codes help identify components with similar characteristics so we can group them into families. Once families are identified, work cells are built for them. The result can be thought of as a small product-oriented facility where the "product" is actually a group of similar products—a family of products. The cells produce one good unit at a time, and ideally they produce the units *only* after a customer orders them.

Increased Flexibility

Modern work cells are designed so they can be easily rearranged to adapt to changes in volume, product improvements, or even new designs. Almost nothing in these new departments is bolted down. This same concept of layout flexibility applies to office environments. Not only is most office furniture and equipment movable, but so are office walls, computer connections, and telecommunications. Equipment is modular. Layout flexibility aids the changes that result from product *and* process improvements that are inevitable with a philosophy of continuous improvement.

In a JIT system, each worker inspects the part as it comes to him or her. Each worker knows that the part must be good before it goes on to the next "customer."

Impact on Employees

Employees working together are cross trained so they can bring flexibility and efficiency to the work cell. JIT layouts allow employees to work together so they can tell each other about problems and opportunities for improvement. When layouts provide for sequential operations, feedback can

be immediate. Defects are waste. When workers produce units one at a time, they test each product or component at each subsequent production stage. Machines in work cells with self-testing poka-yoke functions detect defects and stop automatically when they occur. Before JIT, defective products were replaced from inventory. Because surplus inventory is not kept in JIT facilities, there are no such buffers. Getting it right the first time is critical.

Reduced Space and Inventory

Because JIT layouts reduce travel distance, they also reduce inventory by removing space for inventory. When there is little space, inventory must be moved in very small lots or even single units. Units are always moving because there is no storage. For instance, each month Security Pacific Corporation's focused facility sorts 7 million checks, processes 5 million statements, and mails 190,000 customer statements. With a JIT layout, mail processing time has been reduced by 33%, salary costs by tens of thousands of dollars per year, floor space by 50%, and in-process waiting lines by 75% to 90%. Storage, including shelves and drawers, has been removed.

TABLE 4 ■
JIT Inventory Tactics

Use a pull system to move inventory
Reduce lot size
Develop just-in-time delivery systems with suppliers
Deliver directly to point of use
Perform to schedule
Reduce setup time
Use group technology

INVENTORY

Just-in-time inventory
The minimum inventory necessary to keep a perfect system running.

Inventories in production and distribution systems often exist "just in case" something goes wrong. That is, they are used just in case some variation from the production plan occurs. The "extra" inventory is then used to cover variations or problems. Effective inventory tactics require "just in time," not "just in case." **Just-in-time inventory** is the minimum inventory necessary to keep a perfect system running. With just-in-time inventory, the exact amount of goods arrives at the moment it is needed, not a minute before or a minute after. The *OM in Action* box "Let's Try Zero Inventory" suggests it can be done. Some useful JIT inventory tactics are shown in Table 4 and discussed in more detail in the following sections.

Reduce Variability

The idea behind JIT is to eliminate inventory that hides variability in the production system. This concept is illustrated in Figure 1, which shows a lake full of rocks. The water in the lake represents inventory flow, and the rocks represent problems such as late deliveries, machine breakdowns, and poor personnel performance. The water level in the lake hides variability and problems. Because inventory hides problems, they are hard to find.

OM IN ACTION

Let's Try Zero Inventory

Just-in-time tactics are being incorporated in manufacturing to improve quality, drive down inventory investment, and reduce other costs. However, JIT is also established practice in restaurants, where customers expect it, and a necessity in the produce business, where there is little choice. Pacific Pre-Cut Produce, a $14-million fruit and vegetable processing company in Tracy, California, holds inventory to zero. Buyers are in action in the wee hours of the morning. At 6 A.M., produce production crews show up. Orders for very specific cuts and mixtures of fruit and vegetable salads and stir-fry ingredients for supermarkets, restaurants, and institutional kitchens pour in from 8 A.M. until 4 P.M. Shipping begins at 10 P.M. and continues until the last order is filled and loaded at 5 A.M. the next morning. Inventories are once again zero and things are relatively quiet for an hour or so; then the routine starts again. Pacific Pre-Cut Produce has accomplished a complete cycle of purchase, manufacture, and shipping in about 24 hours.

VP Bob Borzone calls the process the ultimate in mass customization. "We buy everything as a bulk commodity, then slice and dice it to fit the exact requirements of the end user. There are 20 different stir-fry mixes. Some customers want the snow peas clipped on both ends, some just on one. Some want only red bell peppers in the mix, some only yellow. You tailor the product to the customer's requirements. You're trying to satisfy the need of a lot of end users, and each restaurant and retailer wants to look different."

Sources: Supermarket News (September 27, 2004): 31; *Inbound Logistics* (August 1997): 26–32; and *Progressive Grocer* (January 1998): 51–56.

Video 16.1

Sailing through the Problems of Excess Inventory

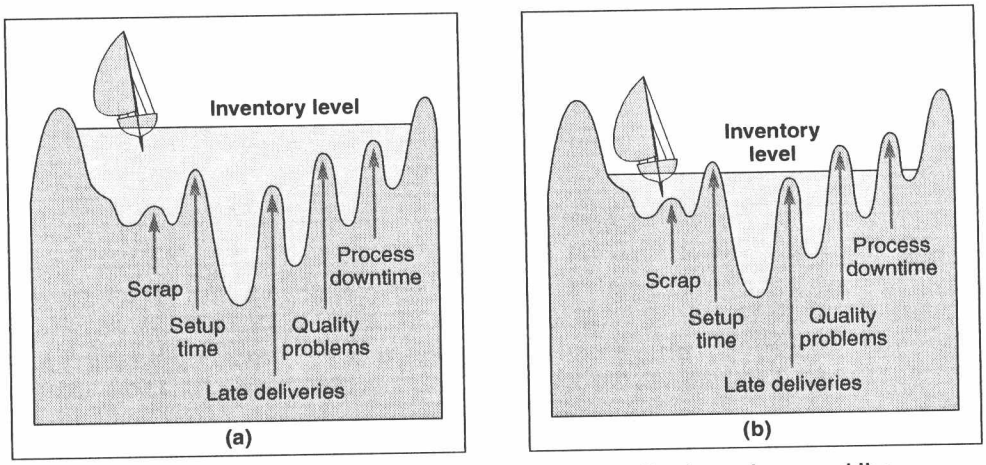


FIGURE 1 ■ Inventory Has Two Costs, One for Holding the Inventory and the Second for the Problems It Hides; Just as Water in a Lake Hides the Rocks

"Inventory is evil."
Shigeo Shingo

Reduce Inventory

Operations managers move toward JIT by first removing inventory. Reducing inventory uncovers the "rocks" in Figure 1(a) that represent the variability and problems currently being tolerated. With reduced inventory, management chips away at the exposed problems until the lake is clear. After the lake is clear, managers make additional cuts in inventory and continue to chip away at the next level of exposed problems (see Figure 1[b]). Ultimately, there will be virtually no inventory and no problems (variability).

Dell estimates that the rapid changes in technology costs $\frac{1}{2}\%$ to 2% of its inventory's value *each week*. Shigeo Shingo, codeveloper of the Toyota JIT system, says, "Inventory is evil." He is not far from the truth. If inventory itself is not evil, it hides evil at great cost.

Reduce Lot Sizes

Just-in-time has also come to mean elimination of waste by reducing investment in inventory. The key to JIT is producing good product in small lot sizes. Reducing the size of batches can be a major help in reducing inventory and inventory costs. When inventory usage is constant, the average inventory level is the sum of the maximum inventory plus the minimum inventory divided by 2. Figure 2 shows that lowering the order size increases the number of orders but drops inventory levels.

Ideally, in a JIT environment, order size is one and single units are being pulled from one adjacent process to another. More realistically, analysis of the process, transportation time, and contain-

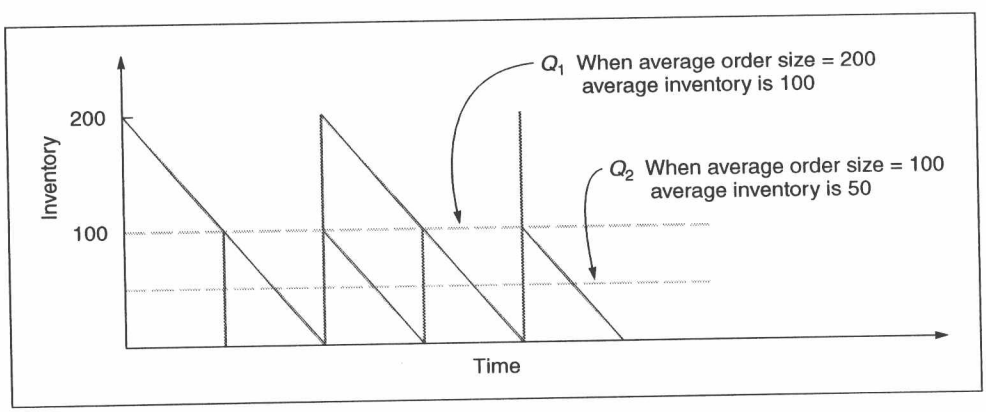


FIGURE 2 ■ Frequent Orders Reduce Average Inventory

A lower order size increases the number of orders and total ordering cost but reduces average inventory and total holding cost.

ers used for transport are considered when determining lot size. Such analysis typically results in a small lot size but a lot size larger than one. Once a lot size has been determined, the EOQ production order quantity model can be modified to determine the desired setup time. The production order quantity model takes the form

$$Q^* = \sqrt{\frac{2DS}{H[1 - (d/p)]}} \quad (1)$$

where D = Annual demand
S = Setup cost
H = Holding cost
d = Daily demand
p = Daily production

Example 1 shows how Crate Furniture, Inc., a firm that produces rustic furniture, moves toward a reduced lot size.

Example 1

Determining optimal setup time

Crate Furniture's production analyst, Aleda Roth, determined that a 2-hour production cycle would be acceptable between two departments. Further, she concluded that a setup time that would accommodate the 2-hour cycle time should be achieved. Roth developed the following data and procedure to determine optimum setup time analytically:

D = Annual demand = 400,000 units
d = Daily demand = 400,000 per 250 days = 1,600 units per day
p = Daily production rate = 4,000 units per day
Q = EOQ desired = 400 (which is the 2-hour demand; that is, 1,600 per day per four 2-hour periods
H = Holding cost = \$20 per unit per year
S = Setup cost (to be determined)

Roth determines that the cost, on an hourly basis, of setting up equipment is \$30. Further, she computes that the setup cost per setup should be

$$Q = \sqrt{\frac{2DS}{H(1 - d/p)}}$$

$$Q^2 = \frac{2DS}{H(1 - d/p)}$$

$$S = \frac{(Q^2)(H)(1 - d/p)}{2D}$$

$$S = \frac{(400)^2(20)(1 - 1{,}600/4{,}000)}{2(400{,}000)}$$

$$= \frac{(3{,}200{,}000)(0.6)}{800{,}000} = \$2.40$$

Setup time = \$2.40/(hourly labor rate)
= \$2.40/(\$30 per hour)
= 0.08 hour, or 4.8 minutes

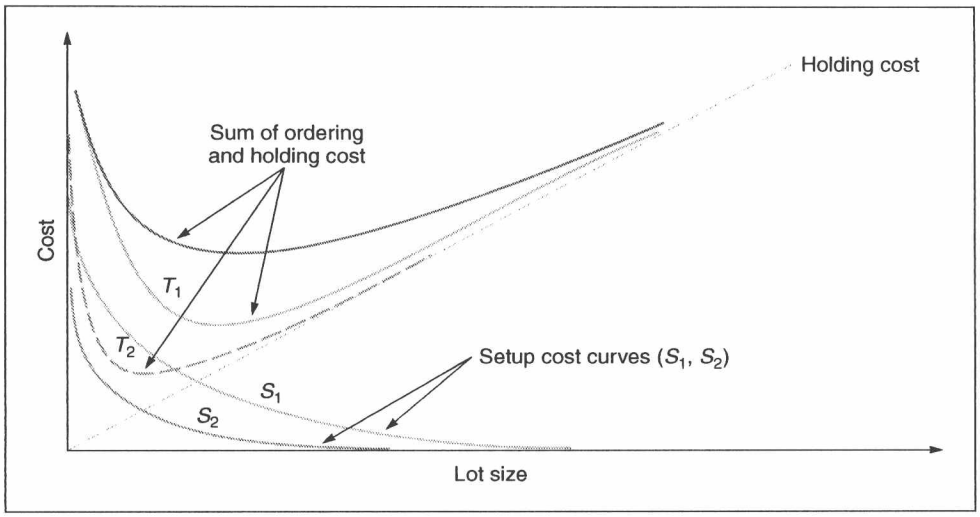
Now, rather than producing components in large lots, Crate Furniture can produce in a 2-hour cycle with the advantage of an inventory turnover of four *per day*.

Only two changes need to be made for small-lot material flow to work. First, material handling and work flow need to be improved. With short production cycles, there can be very little wait time. Improving material handling is usually easy and straightforward. The second change is more challenging, and that is a radical reduction in setup times. We discuss setup reduction next.

FIGURE 3 ■

Lower Setup Costs Will Lower Total Cost

More frequent orders require reducing setup costs; otherwise, inventory costs will rise. As the setup costs are lowered (from S_1 to S_2), inventory costs also fall (from T_1 and T_2).



Reduce Setup Costs

Both inventory and the cost of holding it go down as the inventory-reorder quantity and the maximum inventory level drop. However, because inventory requires incurring an ordering or setup cost that must be applied to the units produced, managers tend to purchase (or produce) large orders. With large orders, each unit purchased or ordered absorbs only a small part of the setup cost. Consequently, the way to drive down lot sizes *and* reduce average inventory is to reduce setup cost, which in turn lowers the optimum order size.

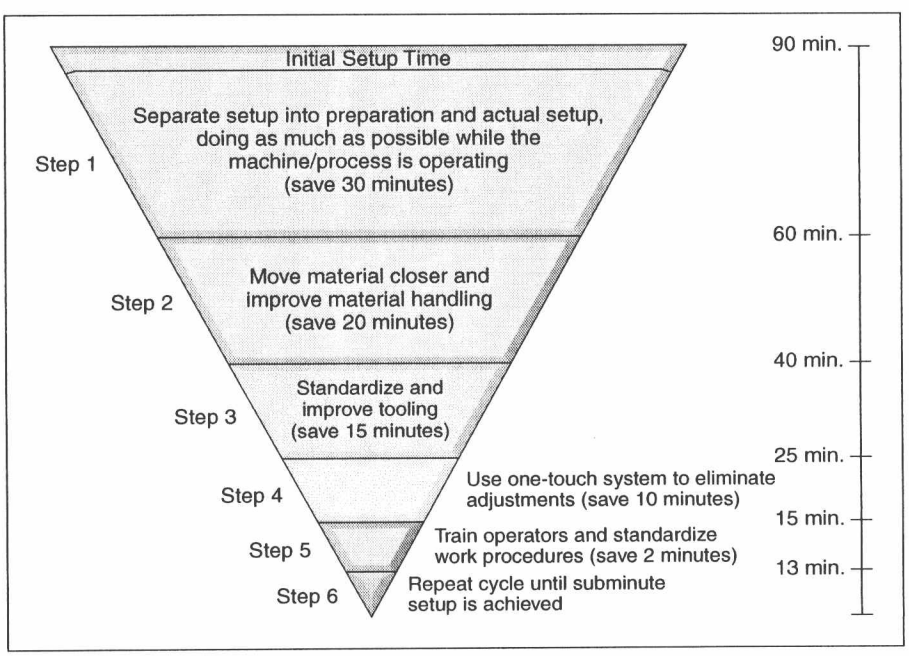
The effect of reduced setup costs on total cost and lot size is shown in Figure 3. Moreover, smaller lot sizes hide fewer problems. In many environments, setup cost is highly correlated with setup time. In a manufacturing facility, setups usually require a substantial amount of preparation. Much of the preparation required by a setup can be done prior to shutting down the machine or process. Setup times can be reduced substantially, as shown in Figure 4. For instance, in Kodak's Guadalajara, Mexico, plant a team reduced the setup time to change a bearing from 12 hours to 6 minutes![2] This is the kind of progress that is typical of world-class manufacturers.

Reduced lot sizes must be accompanied by reduced setup times; otherwise, the setup cost must be assigned to fewer units.

FIGURE 4 ■

Steps for Reducing Setup Times

Reduced setup times are a major JIT component.



[2]Frank Carguello and Marty Levin, "Excellence at Work in Guadalajara, Mexico, Operation," *Target* 15, no. 3 (third quarter 1999): 51–53.