



CHAPTER 14

Lean Operations and Supply Chains

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- 14.1 Define lean operations.
- 14.2 Describe the philosophy of lean systems.
- 14.3 Outline the elements of lean operations systems.
- 14.4 Apply lean ideas to service operations.
- 14.5 Identify the characteristics of a lean supply chain.
- 14.6 Explain why it is so difficult to make global supply chains lean.
- 14.7 Discuss how sustainability initiatives can be considered an extension of the lean philosophy.

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OPERATIONS PROFILE: *Lean Operations at Rolls-Royce Indianapolis*

Rolls-Royce Holdings plc, headquartered in London, England, is one of the world's leading manufacturers of jet engines for commercial and military uses. The jet engine business has always been highly competitive, especially in periods when fuel costs rise. At such times, airlines are under pressure to reduce costs, and one way they do so is to require suppliers like Rolls-Royce to produce more energy-efficient engines. To maintain its profitability, Rolls-Royce needs to continue to innovate. One critical decision the company made during such a period was to aggressively move to lean manufacturing.

Since 2000, Rolls-Royce has invested nearly US\$100 million in modernizing its manufacturing site, including implementing a series of lean manufacturing initiatives. The initiatives included establishing production levels based on actual customer demand rather than on sales forecasts. A smaller number of parts are warehoused, and engines are produced to order.

To accomplish this change, the company drastically redesigned the plant's operations to improve its flow. The plant adopted a process that involved first gathering from the stockroom all the parts needed to assemble an engine into a kit prior to sending them to the manufacturing line. This practice minimizes unnecessary employee movement and traffic around the plant floor while keeping inventory levels low. The company also improved the lighting and working conditions in the plant and invested in new equipment to accommodate its manufacturing innovations. The overall impact was dramatic: By 2008, the lean plant redesign had enabled Rolls-Royce to demolish more than 850,000 square feet of the facility. As a result of the leaner practices, the space was no longer needed.

The decision by Rolls-Royce to adopt lean operations has paid off handsomely. The company has surpassed Pratt & Whitney (East Hartford, CT) and is now the second-largest supplier of jet engines in the world, behind General Electric (aka GE, Fairfield, CT). "Rolls-Royce has come from a distant number three to a strong number two," said Nick Cunningham, who covers Rolls-Royce for Citigroup Global Markets in London (division of Citigroup Inc., New York, NY).¹



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Rolls-Royce's success story illustrates some of the clear advantages that lean operations provide to organizations. In this chapter, we explore the concept of lean to understand better the philosophy behind lean practices, the steps a firm can take to introduce lean into its operations, as well as the methods to expand lean to supply chains.

14.1 Introduction to Lean Operations

According to the **lean philosophy**, which we introduced in Chapter 1, any activity or process that does not add value to the product or service wastes resources and, therefore, should be eliminated. Henry Ford used lean concepts in the assembly lines for his cars in the early

Define lean operations.

14.1

Lean philosophy: the belief that any activity or process that does not add value to a product or service wastes resources and, therefore, should be eliminated

Just-in-time (JIT): a system in which customer demand, rather than sales forecasts, dictates production levels



Implementing the Toyota Production System

Lean concepts can also be applied in service industries; companies like FedEx utilize lean practices for their delivery management and performance processes.

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1900s. **Just-in-time (JIT)** strategies, which we discussed earlier as well, are often a part of lean production. When a company uses a just-in-time strategy, it delays receiving raw materials or inventory from its suppliers until right before it is needed for production. By adopting a just-in-time strategy, the firm reduces its investment in inventory and minimizes the space needed to store raw materials. Products are produced and services are performed only when they are needed.

Lean production and just-in-time concepts became important in the early 1970s, after Tai-ichi Ohno, a longtime employee and executive of Toyota (Toyota Motor Corporation, Toyota City, Japan), used them to propel the automaker to the forefront of its industry. Since then, thousands of companies all over the world have adopted lean production methods to manage both their operations and their supply chains. The German automobile manufacturer Porsche AG (Stuttgart, Baden-Württemberg, Germany) is an example. After nearly going bankrupt in the 1990s, lean methods enabled Porsche to move from US\$300 million in losses to profitability in just 4 years. During the last global downturn in 2008, the firm remained one of the most profitable companies in the automobile industry.²

Lean operations, however, are just one part of an integrated supply chain. Many individual companies that adopt lean concepts quickly find that whatever gains they can achieve will be limited unless their immediate suppliers and other partners in the supply chain also become lean. The Boeing Company's (Chicago, IL) introduction of the 787 Dreamliner in 2009 was marred by a complicated supply chain of over 300 global suppliers. Boeing's decision to outsource most of the aircraft components required them to verify that each of their principal suppliers was capable of meeting aggressive production schedules. Boeing discovered that, in fact, not every supplier had been lean qualified, and the challenge of managing part quality and delivery speed led to a huge backlog for 787s. In fact, until Boeing revamped its supply chain and improved the capabilities of some of its suppliers, it was predicting that it would take 10 years just to eliminate the order backlog.³

Global sourcing makes it considerably more difficult to achieve the key components of lean systems, such as the rapid and smooth flow of goods and information as well as the reduction of waste. There are several reasons for this. First, longer lead times and higher inventory levels are needed for global supply chains compared with domestic supply chains. Second, because global supply chains are longer, sales forecasts are rarely accurate, and managers sometimes have to contend with significant delays. Nevertheless, applying some lean concepts such as reducing defects and minimizing the orders for changes in parts, assemblies, specifications, engineering drawings, and documents can stabilize these global supply chains and improve the flow of goods. Delta Galil Industries, a private-label clothing manufacturer in Tel Aviv, Israel, has adopted lean supply chain operations to connect its more than 1,000 suppliers, reducing lead times and transaction costs. By contrast, Nissan (Nissan Motor Company Ltd., Yokohama, Japan), in 2010, halted production

for 3 days at four of its Japanese facilities and two American plants because its lean supply chain was mismanaged specifically because Nissan failed to coordinate shipments from its suppliers. Nissan estimated these stoppages reduced the company's output for 2010 by 15,000 vehicles.⁴ Implementing lean systems within a global supply chain may be more expensive and challenging. Yet, it has the potential to produce long-term benefits, making it worth the effort.

The success the manufacturing industry has experienced by adopting lean concepts has also occurred in the service sector. FedEx (FedEx Corporation, Memphis, TN) has employed lean transportation systems in its operations, adopting four "laws of lean" as they apply to delivery management and



performance. In 2009, three medical facilities in the Comarca del Garraf, near Barcelona, merged into one organization, the Consorci Sanitari del Garraf. As a result of the financial crisis, the health care organization faced a 17% budget cut and had to find a way to improve its processes and become more efficient. Introducing a wide range of lean methods, it took the Consorci Sanitari del Garraf just 1 year to improve its processes and develop its human resources to achieve the goals of lean health care: (a) improving the quality of care and patient experience, (b) simplifying tasks for providers, and (c) making better use of resources to treat an expanding patient population without adding more doctors and nurses, beds, or equipment.⁵ Toyota's lean production system has become the gold standard for U.S. hospitals looking to simplify their processes.⁶ In this chapter, we discuss lean systems, including lean supply chains and lean services.

14.2 The Philosophy of Lean Systems

Lean production is not only a methodology but also a philosophy intended to promote respect for people and eliminate waste and inefficiency. In a lean system, assembly-line workers and supervisors take on additional responsibilities. In fact, because they are the firm's best source for spotting problems and ensuring quality, the success or failure of a lean system depends on these workers. Quality at the source is based squarely on the willingness of managers to empower workers to identify quality problems and stop the production line. Consequently, an organization that wants to implement a lean system should create an environment that fosters cooperation, trust, and respect between its workforce and managers. In addition, empowering workers to identify problems during production and make decisions, soliciting their advice for improvements, and having multiskilled employees who can work in different jobs and on different machines can facilitate the implementation of lean systems.

As an example, when Rolls-Royce restructured its jet engine operations into a lean system, the local chapter of the United Auto Workers (UAW)—the principal labor union at the plant—agreed to the proposed changes. In fact, the union not only embraced the lean principles but also did so with so much enthusiasm that the Indianapolis facility is now Rolls-Royce's most productive. This result wouldn't have been possible without the workers and the union committing to the lean philosophy.

The second principle of lean manufacturing is the elimination of waste and inefficiency. Toyota's past president Fujio Cho defined waste as "anything other than the minimum amount of equipment, materials, parts and workers (working time) which are absolutely essential to production." In the original Toyota model, three types of waste were identified by their Japanese names:

1. **Muri** means waste and decreased productivity resulting from the unreasonable work managers impose on people and machines because of the poor design of systems. Examples are assignments that require employees to carry excessively heavy weights or engage in dangerous tasks.
2. **Mura** refers to unevenness in the production process, out-of-balance workflows, and uneven workloads. The essence of lean production is to strike a balance between supply and demand, customers and suppliers, workloads and capacity, and so forth. Fluctuations in supply, bottlenecks that result from poor scheduling, or resources that are unavailable may occur if a poor system design leads to a production imbalance. This imbalance can lead to excessive wear and tear on equipment, facilities, and people (*muri*), which in turn can create wasteful non-value-adding (*muda*) activities, such as excess inventories and waiting time.
3. **Muda** is any wasteful activity that does not add value or is unproductive. It also refers to waste that occurs from any variation in output as a result of poorly planned and designed systems. For example, any activity or process that consumes more resources than necessary to produce or deliver the product or service customers actually want is *muda*. Lean approaches are primarily designed to eliminate *muda* from operations.

14.2

Describe the philosophy of lean systems.

Muri: waste and decreased productivity resulting from the unreasonable work managers impose on people and machines because of the poor design of systems

Mura: unevenness in the production process, out-of-balance workflows, and uneven workloads

Muda: any wasteful activity that does not add value or is unproductive

Why Lean Operations Matters

"Lean" is a philosophy focusing on eliminating waste by identifying and eliminating non-value-adding activities, which speaks to many firms' sustainability initiatives. Firms that have applied lean principles have experienced significant improvements in productivity, efficiency, quality, and reductions in inventory levels.

The ultimate goal of a lean system is to achieve a smooth and rapid flow of materials and work by eliminating non-value-adding activities and to improve operations continuously so products and services have value-added benefits. The extent to which this goal is achieved depends on three factors: eliminating disruptions, keeping the system flexible, and eliminating waste. Table 14.1 identifies eight common sources of waste in a company.

Another element in the philosophy of lean operations is commitment to the **Five S (5S)** practices that guide worker behavior and management objectives. The 5S framework is a model for showing how to implement lean practices in any business operation. (Think of the model as a checklist for assessing the quality of a firm's approach to lean.) The 5S framework contains the following elements:

1. **Sort and separate.** Sort out and retain everything that is needed for the work area. Separate and remove all unnecessary items (parts, tools, and equipment) or procedures (paperwork, unnecessary checks) from the work area. Doing so will remove clutter, simplify the work space, and make flows more open and orderly.
2. **Simplify and straighten.** Organize and arrange what is left into a logical pattern of work operations or a simplified set of motions for the worker.
3. **Shine.** Clean the area daily. Eliminate all forms of contamination, dirt, refuse, or discarded materials.
4. **Standardize.** Make all activities standard and uniform. Eliminate variation from the workflow by establishing operating procedures. Standardize the use of equipment and employee training so any variations or deviations will be obvious.
5. **Sustain.** Avoid deviating from the first four Ss, and embed these practices throughout the company's operations. That is, make sure all employees remain motivated to sustain the effort, and reward them for their adherence to it.



TABLE 14.1: Eight Common Sources of Waste⁷

Sources of Waste	Examples
1. Waste from overproduction and excess inventory (<i>mura</i>)	Producing a product or service before it is actually needed. Overproduction contributes to unnecessary inventory and longer lead times.
2. Waste from waiting time (<i>muda</i>)	Production delays that waste the time of personnel. When a product is not moving or being processed, downstream resources are idle.
3. Waste from unnecessary transportation (<i>muda</i>)	The excessive movement and handling of a product between processes, which can damage or degrade it without adding value to it. For example, having to deliver inputs to storage facilities prior to their use leads to wasted time and effort, and it increases the likelihood they will sustain damage.
4. Waste from defective products (<i>muda</i>)	Defects in product quality that lead to rework and scrap. Rework leads to additional inspection costs, yield losses, and the loss of goodwill on the part of customers.
5. Waste from inappropriate processing (<i>muda</i>)	Using the wrong equipment, tools, or procedures. Using unnecessarily complicated or expensive equipment instead of simpler and flexible machinery will waste money, as do processes that are not streamlined.
6. Waste from the underutilization of workers (<i>mura</i>)	The failure to use workers' knowledge and creativity and realize their full potential.
7. Waste from unnecessary motion (<i>muri</i>)	Unnecessary efforts, including bending, stretching, lifting, walking, or other movements. Poor machinery placement or the need to move equipment wastes time and leads to injuries.
8. Misguided effort (<i>muda</i>)	Manufacturing poorly conceived goods or services that do not meet the demands of customers.

Five S (5S): a model for showing how to implement lean practices in any business operation; it contains the following elements: (a) sort and separate, (b) simplify and straighten, (c) shine, (d) standardize, and (e) sustain

14.3 Elements of Lean Systems

If the critical goal for any operation is to remove waste, the key question is, “How?” The first point to remember is that the move to a lean process is ongoing. It is not a onetime activity. The Japanese term for continuous improvement is *kaizen* (see Chapter 5). *Kaizen* is a perspective that can best be understood if contrasted to the Western saying “If it ain’t broke, don’t fix it.” In fact, under *kaizen*, the system can *always* be fixed or improved. The goal of a firm should be to take a critical look at its operations on an ongoing basis and determine what improvements can be made and how they can be accomplished. Improvement may not come from any one big fix but from a steady stream of small adjustments. This is the idea of **incrementalism**.

Finally, the processes are usually linked together in some way, which means adjustments to one element in a process (improving one step) will have implications for other steps in the chain. This is the idea of **dependence**. For example, suppose you work bussing tables in a restaurant, and its managers want to increase the usage rate of those tables. That is, the managers want a great turnover of customers per hour. You may discover a faster way to clear tables (one step in the chain), but unless the next employee in the process (the waiter) can also increase the speed at which he or she takes orders and delivers food, the new clearing approach will not improve the overall speed of the system. In the following sections, we discuss several different ways to design a lean system. Keep in mind that underlying them all is the principle of *kaizen*.

Workflow and Throughput

Workflow simply describes any process that consists of a sequence of connected steps or operations necessary to complete a task. For example, the workflow to treating a patient at a hospital emergency room might consist of (a) registering the patient; (b) performing a preliminary evaluation of the person, including taking his or her blood pressure and temperature; (c) having a physician consult with the patient; (d) conducting x-rays and running blood tests; and (e) diagnosing and treating the patient. The more logically and simply we can sequence the workflow, the more repeatable the operations are and the more likely the system can run efficiently.

Looking at a system’s throughput is one way to measure efficiency. **Throughput** is a measure (usually in terms of time or units) of how an order moves from receipt to delivery. Organizations constantly evaluate their throughput to detect inefficiencies or errors that cause delays and add costs. In the case of an emergency room, the hospital strives to eliminate unnecessary delays at any stage that force patients to wait to complete the necessary steps in their treatment. The longer the delays, the more inefficient the process is, and the greater the overall costs to the hospital are. The costs can result from bottlenecks and the dissatisfaction of customers. In other organizations, such as manufacturing firms, delays in throughput can lead to inventory accumulation and storage costs.

Pull Systems Versus Push Systems

Push and pull systems describe different types of throughput in organizations. **Push systems** are systems in which services or products are produced based on forecasts. That is, a certain amount of the good is produced before customers actually demand it. In **pull systems**, by contrast, the product or service is only produced after it is ordered, not in advance. Pull systems characterize the lean philosophy.

To demonstrate, suppose you owned two fast-food restaurants; we’ll call them “Instant Burger” and “Custom Burger.” Instant Burger prides itself on filling customer orders instantly, with no delays or errors. Instant Burger is located directly across the street from a large plant employing more than 500 people who each have a 30-minute lunch break. Obviously, these people value fast service. You know from experience that you can expect anywhere between 100 and 150 workers to arrive within a 10-minute window of time. The smartest production system in this case would be to cook many hamburgers in advance and have the food prepared and ready for the lunch rush—in other words, to implement a push system. A push system would also help you minimize any variation across the burgers as you prepare them. Timing is also critical: If the burgers are made too early, they will get cold or soggy.

Push systems depend on good planning and stocking the product in advance. Too much food prepared too early leads to waste and will cut into your profit margins. Consequently, you must create a balance between making sure enough burgers are available to your customers when they want them and not producing so many that they must be thrown out if they are not purchased.

14.3

Outline the elements of lean operations systems.

Incrementalism: the idea that improvements may not come from any one big fix but from a steady stream of small adjustments

Dependence: the idea that an adjustment to one element in a process will have implications for other elements in the same process

Workflow: any process that consists of a sequence of connected steps or operations necessary to complete a task

Throughput: a measure (usually in terms of time or units) of how an order moves from receipt to delivery

Push systems: systems in which services or products are produced based on forecasts

Pull systems: systems in which the product or service is only produced after it is ordered

At your other restaurant, Custom Burger, your goal is to provide gourmet hamburgers to customers on an as-ordered basis. Each order is unique and will be filled after it has been placed. This is a pull system. Materials are pulled from inventory, and the burgers are produced only when they are needed. This eliminates a great deal of waste. With a pull system, you purposely sacrifice some delivery speed to minimize waste. A critical issue with pull systems is to pay particular attention to demand and inventory levels. As orders are pulled through the system and produced, inventory levels will dip and must be replenished. Moreover, the use of pull systems ultimately leads to far smaller initial inventory levels, which can make a shortage all the more acute.

Deciding whether to use a push or pull system depends on an organization's operating philosophy or type of industry in which it competes. Consider the hair salon industry. In this industry, it is impossible to stockpile hairdos. They are produced and delivered only when they have been ordered. For other businesses, push systems make perfect sense.

Focused Factories

One useful option for eliminating waste and making operations more efficient is the creation of focused factories or specialized plants that are built and operated for a single purpose. For example, a focused factory for Samsung (Ridgefield Park, NJ) might make only LCD televisions rather than the full range of Samsung's electronic products. The narrower focus of these factories can lead to greater efficiencies. Focused factories also do not require as many workers with multiple skills. Toyota, for example, has 12 plants located in the vicinity of Toyota City in Japan. Each one concentrates on building specific models of cars instead of trying to manufacture the full range of Toyota products. By focusing on just a few models, each plant can dramatically improve its throughput.

Value Stream Mapping (VSM)

A company's **value stream** is best understood as the sequence of activities required to design, produce, and provide a good or service, along with information, materials, and workflow.⁸ Value stream mapping (VSM), which is a prerequisite to converting to a lean system, can enable managers, production workers, and suppliers to identify waste and pinpoint the causes of it. The method involves creating a visual map of the production process that shows its cycle time, downtime, work-in-process inventory, movement of materials, and information flow. The map will help a manager visualize both individual activities and the overall state of the system—at the single process level, at the entire plant level, and even across the entire supply chain. The map, in turn, can guide managers toward a future desired state and a possible implementation plan. VSM is essentially a communication tool, a business-planning tool, and a mechanism for managing your process change in an efficient manner.

Manufacturing processes that are reasonably routine and standardized are most likely to benefit from value stream mapping. Unlike a typical process flow chart, a VSM is much broader. It shows the big picture of how value is added, not just processes. Consequently, managers can identify sources of wasteful, non-value-adding activities and eliminate them.

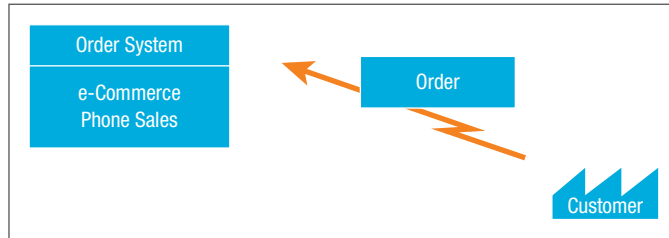
The first step in VSM is to select the product or service to map. Choose a process that would benefit from implementing leaner, more efficient practices. It's important to define the scope of your map. Identify the start and end points, and make sure you map from one end of the process to the other so you can find the location of the blockages and nonvalue activities. You also need to identify which part of the overall process you need to look at. As an example, if the amount of profit you're generating from each order is falling, then you may want to look at how an entire order is fulfilled. If the volume of orders is falling, then you may want to look at the sales process in more detail. If equipment and resources are used to make multiple products, instead of looking at the manufacturing of one product, you might want to perceive manufacturing as a whole system.

Let's now look at the value stream for an order processing and delivery system. We will create a map of the process of transforming an Internet order into a shipped product. The tasks involved in order processing and delivery are order entry and processing, supplier liaison, inventory management, order picking, packaging, and shipping.

- **Phase 1.** The customer places an order that is received through the firm's order processing system. The order could have been placed by phone, through the Internet, or by some other method. Figure 14.1 shows this portion of the map.

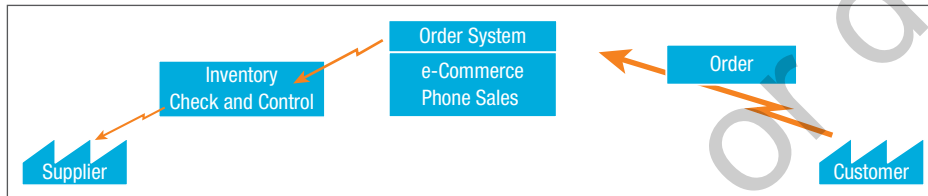
Value stream: the sequence of activities required to design, produce, and provide a good or service, along with information, materials, and workflow

FIGURE 14.1: Phase 1 of the Value Stream Mapping Process



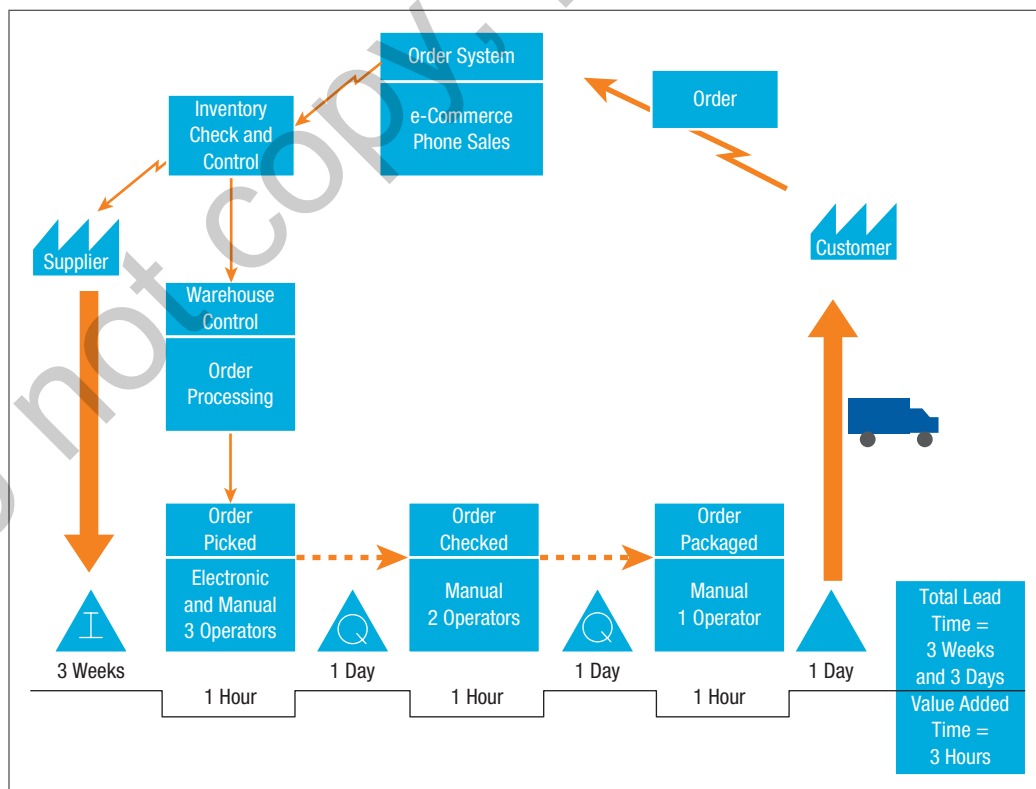
- **Phase 2.** In the second phase, the order processing system relays the order information to the inventory control system. Assuming there is no available inventory in stock for that item, an order for it is then sent to the supplier. Figure 14.2 shows this portion of the value stream added onto the previous map.

FIGURE 14.2: Phase 2 of the Value Stream Mapping Process



- **Phase 3.** The inventory control system relays the order information to the warehouse for processing. The supplier delivers the order in 3 weeks, which is stored as inventory (triangle labeled I, for inventory) in the warehouse. The order placed by the customer is then picked, checked for accuracy, packaged, and shipped to the customer. Figure 14.3 shows the fully completed VSM for this operation.

FIGURE 14.3: Completed Value Stream Map⁹



The completion of a value stream map allows you to examine the flow of order placement and processing critically. For example, the full VSM allows you to examine the amount of value-added time as a proportion of the total lead time for order placement and fulfillment. In this example, 24 days (a full 3 weeks and 3 days) are needed from the order placement to the receipt of the good. One way of reducing the end lead times of 3 weeks could be to arrange more frequent orders from the supplier. This would move orders more rapidly through the order processing system and lead to much quicker shipments to customers. The steps that can be used to construct a VSM are presented in Appendix 14.2 to this chapter.

Quality and Lean Systems

Total quality management or TQM, which we discussed in Chapter 5, includes several elements, such as worker responsibility for quality, statistical quality control, the use of fail-safe methods, and systematic or automatic inspection of the manufacturing process. Built-in quality and defective-free processes are absolute prerequisites for lean operations. The use of Six Sigma methodology, improved product design, standard product configurations, and fewer parts reduces the variability in both the product and the process and improves quality.

Lean Six Sigma

Although distinct and separate, the lean manufacturing philosophy and Six Sigma are both vital concepts. Each is required to reduce waste and add value to the end customer. Many leading companies that have used both lean and Six Sigma methods in the past for operational improvements have combined the lean methods and Six Sigma approaches, now referred to as **Lean Six Sigma**, to realize innovations throughout the enterprise that extend beyond operational improvement. The use of Lean Six Sigma in these companies has produced breakthrough innovations resulting in profound impacts on their business performance. More important, the use of Lean Six Sigma has eliminated the biggest innovation obstacle in these companies—complacency and unsupportive organizational cultures—by creating an organizational climate in which innovation has become instinctive.¹⁰

The Lean Six Sigma approach draws on the knowledge, methods, and tools of both the lean and Six Sigma approaches derived from decades of operational improvement, research, and implementation. Although lean approaches focus on reducing cost through optimization of the manufacturing process, Six Sigma focuses on meeting customer requirements and stakeholder expectations and on improving quality by measuring and eliminating defects. Nevertheless, the goal of Lean Six Sigma extends beyond cost cutting and efficiency to growth and effectiveness. The dynamic changes in the competitive global marketplace force companies to change on a massive scale from improvement to *innovation*. Despite its past use for operational improvements, Lean Six Sigma is ideally suited for this step change in target and scope. Many leading companies in the world have demonstrated that the Lean Six Sigma approach can go far beyond the applications for process improvement. These companies have used Lean Six Sigma to innovate in all areas of their businesses, including their operations, products and services, and even their business models.¹¹

Lean Six Sigma: an approach that draws on the knowledge, methods, and tools of both the lean and Six Sigma approaches; is derived from decades of operational improvement, research, and implementation; extends beyond cost cutting and efficiency to growth and effectiveness; and is ideally suited for this step change in target and scope

The Six Sigma approach has served as a catalyst for broad-scale innovation in almost every industry, and all firms that have adopted Six Sigma have realized substantial benefits. At Amazon.com (aka Amazon, Seattle, WA), for example, Six Sigma is widely used by an organization employing thousands of people in its order fulfillment and customer service centers. They need the commitment of all workers at these centers for the program to succeed because they are the ones who are receiving, stowing, picking, packing, and sending packages or responding to customers by phone, chat, or e-mail. Amazon has worked to reinvent the lean idea of “autonomation” by keeping humans for high-value, complex work while using machines to support those tasks. Autonomation helps human beings perform tasks in a defect-free and safe way by only automating the basic, repetitive, low-value steps in their processes. So enthusiastic is Amazon’s management regarding Six Sigma that they are exploring ways to move into creating actual products on demand. Today, in some fulfillment centers, Amazon uses printing equipment to print and ship a book to customers within 4 hours of receiving the order. The technology of three-dimensional printing may soon allow Amazon to create its own products for customers—the ultimate in lean just-in-time production!¹²

Quality at the Source

The Japanese word *jidoka*, or quality at the source, means doing it right the first time and stopping production should something go wrong. Workers are personally responsible for the quality of their own work. If someone finds a quality-related problem, he or she is empowered to stop the process by turning on a visual signal. The purpose of stopping the process is to prevent the defective parts from moving forward in a manufacturing facility. Production will not resume until the quality problem is fixed.

To demonstrate how *jidoka* works, assume a product moves through a sequence of seven manufacturing steps. Also assume you have found a defective part after completion of all activities in the third step. Unless you stop the assembly line, the defective product will move all the way through the system. Additional work will be done on the product in the fourth, fifth, and sixth steps before finally coming to the seventh and final manufacturing step. Clearly, the final product that will come off of the assembly line will be defective.

At this point, you have a choice of either discarding the bad product or sending it back through the system for rework. In either case, you incur productivity losses. The time, money, and effort expended by workers after the third manufacturing step are now wasted. Yet, if you stop the assembly line and fix the quality at the source, you solve the problem immediately with little waste, and you send a strong signal to your staff members that they are critical not just to the production process but also to your firm's overall commitment to quality.

Plant Layouts That Balance Workflow

The goal of a plant layout in lean operations is to design it to achieve a balanced workflow. The plant layout design should also link the internal and external logistics systems to the layout. **Internal logistics systems** are all the management and movement of materials within a manufacturing facility, such as raw materials and parts, work-in-process inventory, and finished goods. **External logistics systems** refer to the collection, transportation, and distribution of goods between suppliers and the plant, as well as between the plant and consumers. This includes managing the external movement of goods through various transportation modes (rail, motor, air, water, or pipeline), their storage in warehouses or distribution centers, and their subsequent distribution.

Stable Schedules

Variations in production volumes are caused by such factors as late deliveries, machine breakdowns, quality problems, and poor worker performance. As a hedge against these problems, companies tend to carry inventory, which can be expensive and is considered a form of waste. Lean production requires that daily production schedules in a repetitive flow environment should be stable for extended time horizons. Schedule stability is accomplished through level schedules, frozen windows, and underutilization of capacity. In a **level schedule**, materials are pulled through the assembly line at a steady rate to allow production activities to respond efficiently to the pull signals. To minimize inventory levels, lean operations tend to underutilize capacity. **Frozen windows** are specific periods in which production levels cannot be changed. Leveling out the workload or smoothing production to achieve stable schedules, achieve a steady flow of work, and eliminate waste is called **uniform plant loading** (or *heijunka*, in Japanese).

Suppose a manufacturing plant produces three types of shoes. The plant's production cycles for each, which are shown in Table 14.2, are referred to as **takt time**. (*Takt* is the German term for rhythm.) The essence of lean manufacturing systems is that they operate at a pace, or rhythm, determined by the customer.

Let's assume that for a shoe company, the proportions of sneakers (S), sandals (Sn), and dress shoes (D) demanded are 50%, 25%, and 25%. The takt times for each of these models are as follows:

Dress shoes: 1.0 unit every 6 minutes

Sandals: 1.0 unit every 3 minutes

Sneakers: 1.0 unit every 6 minutes

Jidoka: a Japanese term meaning quality at the source; a production philosophy of doing it right the first time and stopping production should something go wrong

Internal logistics system: all the management and movement of materials within a manufacturing facility, such as raw materials and parts, work-in-process inventory, and finished goods

External logistics system: the collection, transportation, and distribution of goods between suppliers and the plant, as well as between the plant and consumers

Level schedule: a schedule stability method where materials are pulled through the assembly line at a steady rate to allow production activities to respond efficiently to the pull signals

Frozen windows: specific periods in which production levels cannot be changed

Uniform plant loading: leveling out the workload or smoothing production to achieve stable schedules, achieve a steady flow of work, and eliminate waste

Takt time: the cycle time needed to match our production rate to demand for the product

Suppose the firm knew it needed to produce footwear in the following quantities every month: sandals (4,000), dress shoes (2,000), and sneakers (2,000). Under a more conventional mass production system, we would most likely order production first to produce all 4,000 sandals, then retool the assembly line to make all the required dress shoes, and finally retool again to make the 2,000 sneakers. Unfortunately, there are problems with this “unleveled” schedule. First, customers do not always buy predictably. The plant will manufacture a certain number of each type of shoe based on forecasted demand. But, as you know, forecasts aren’t always accurate. Suppose, for example, the purchases of sneakers unexpectedly jump in one month. Obviously, we don’t want to run out of sneakers for customers to buy because it will result in lost sales. If we have not scheduled to handle this increase in orders, we will be forced to produce a larger number of the sneakers and hold them in inventory until they are sold. This increased production of sneakers and the resulting inventory will increase our costs and leave us less time and money to produce sandals and dress shoes. One approach that companies use to handle this predicament is to use safety stock. **Safety stock** is the minimal level of inventory a company seeks to have on hand at all times to act as a buffer against the mismatch between forecasted and actual demand.

A second problem is the risk of unsold goods. If we cannot sell all the sneakers we produce, we must continue to maintain them in inventory. Third, the use of resources becomes unbalanced. There are different work requirements to make sneakers as compared with sandals (perhaps sneakers take more labor time and materials to produce). So, the plant may need more workers and materials shipments. Our suppliers now must carry larger inventories as well to accommodate our uneven orders. As you can see, even a small change in the demand for sneakers by consumers has a *bullwhip effect* on the entire system. That is, the last-minute change in consumer demand affects so many processes that it gets magnified throughout the production line and the supply chain.

The way to resolve this problem is to have set monthly output rates for all three types of footwear and then make small adjustments to them at the end of the process based on updated demand numbers. Toyota pioneered this practice of a **mixed-model production cycle**. The same mixture of products is produced every day in small quantities. The advantage of a mixed-model production cycle is that several models can be produced initially without a changeover of equipment. The mixed-model production cycle helps smooth out the demand that upstream suppliers face too. An example of a mixed-model production cycle is shown in Table 14.2.¹³

A mixed-model production system may complicate line operations to some extent. Nevertheless, stabilizing the labor requirements for the production process, and streamlining and simplifying upstream operations—as well as the inventory, scheduling, and transportation that connect the line with these upstream operations—far outweigh this minor inconvenience.

Faster Setup Times

The changeover of equipment, tools, fixtures, and cleaning—all of which must be done to produce one product or service versus another—reduces a firm’s throughput. One way to shorten setup times is to differentiate between **internal setups** and **external setups**. Internal setups are activities requiring machinery to be stopped or the process to be shut down for the setup work to be completed. External setups refer to work that can be completed outside of the process and does not require machinery to be stopped or the process to be shut down.

Converting internal setup activities into external setup activities can significantly reduce the amount of downtime. This conversion requires some preparation, however. For example, for an injection molding process, workers could preheat the dies and set the controls for the plastic

TABLE 14.2: Production Cycles and Quantities for Three Types of Footwear Produced at the Same Plant

Model	Monthly Quantity (in units)	Daily Quantity (in units)	Model Cycle Time (in minutes)
Sandals	4,000	200	3
Dress shoes	2,000	100	6
Sneakers	2,000	100	6

Safety stock: the minimal level of inventory a company seeks to have on hand at all times to act as a buffer against the mismatch between forecasted and actual demand

Mixed-model production cycle: a production method where the same mixture of products is produced every day in small quantities

Internal setups: activities requiring machinery to be stopped or the process to be shut down for the setup work to be completed

External setups: work that can be completed outside of the process and does not require machinery to be stopped or the process to be shut down



CONSIDER THIS 14.1:

Calculating Takt Time

Takt time is simply the cycle time needed to match our production rate to demand for the product.

There is a simple formula for calculating takt time:

$$\text{Takt time} = t \times \frac{n}{D}$$

where

t = Productive operating time per shift

n = Number of shifts

D = Desired production quantity to meet customers' requirements

Example: Suppose a manufacturing plant that produces widgets needs to produce 900 widgets in 5 days to meet the demands of customers. The plant runs three shifts. What is the takt time? Assume productive operating time per shift is 420 minutes.

Because the customer needs 900 widgets in 5 days, the number of widgets that needs to be produced per day is $900 \div 5 = 180$ widgets per day. This is the desired production capacity per day. Therefore, the takt time is

$$\frac{420 \text{ minutes} \times 3 \text{ shifts}}{180 \text{ widgets}} = 7 \text{ minutes per widget}$$

injection molding machines as an external setup activity. This will reduce the internal setup time. A rule of thumb for setup times is to aim for a change that takes less than 10 minutes. As an example, it takes a race team at the Indianapolis 500 less than 1 minute to change all four tires and fill a car's fuel tank. This kind of efficiency can only occur after hours of practice. Yet, it also requires a logical flow of all equipment. All tools and materials must be laid out in an orderly way and be sequenced correctly and within reach when needed. In a factory, the same rules apply: To get setup times to take 10 minutes or less takes time, training, and a careful plan.



Group Technology

Group technology (GT), which we discussed in the context of cellular manufacturing layouts in Chapter 9, is effective in achieving lean production because it addresses the need for this product variety demanded by customers by facilitating customization while reducing costs by standardizing processes.

Kanban Systems

The Japanese term *kanban* means “sign” or “designated place.” **Kanban systems** are manual control systems using containers and cards. Kanbans are visual signals used to tell workers when it is time to get or make more of something. The production of goods and the delivery of parts are triggered by the demand from a firm's downstream operations. This simple example will demonstrate how a single-card Kanban system works: Your firm, Fly-Rite Golf, manufactures premium golf balls. A container with a Kanban card attached holds the amount of rubber compound needed to produce a day's worth of balls. When a downstream user of the rubber compound empties the container, he removes the card and places it on a receiving post. The empty container is then taken to the storage area, refilled, and the card is reattached to the container. The cycle then continues.

Racing pit crews illustrate how fast setup times can make or break an operation.

William West/AFP/Getty Images

Kanban system: a manual control system using visual signals (cards or Kanbans) to tell workers when it is time to get or make more of something



OPERATIONS PROFILE: *Kanban Systems at Dell*

Michael Dell founded Dell Computer Corporation (now Dell Inc., Round Rock, TX) in 1984 with only US\$1,000 in start-up capital. Since these modest beginnings, the company has grown to be the second largest computer manufacturer in the world, with daily sales of more than US\$5 million. Dell factories in the United States, Ireland, Malaysia, China, and Brazil support sales in more than 170 countries.

Customizing Dell's computer products—hardware, software, and networking—to meet the specific needs of each consumer has been one key to the company's success. Dell uses a basic platform for its computers, to which are added the various components each order specifies. Building computers to suit individual consumer orders means that Dell operates with extremely lean inventory levels. Most of the firms' plants carry just 8 days of inventory.

Dell uses a pull method for its JIT process, including Kanban systems, to make the assembly process as orderly and efficient as possible. Suppliers and upstream workstations only deliver components when they receive a card (such as an e-mail or an empty order form) informing them of the parts that will be needed for assembly. Dell also employs an integrated Kanban that uses both transport and production Kanban signaling techniques. The transport Kanban works on a daily schedule: Components are produced by suppliers

and delivered for each order for that day. The production Kanban outlines when work is to be completed by a particular workstation or cell. Based on that schedule, suppliers can determine at which point in the assembly line the particular components will be needed.

The highly complex nature of Dell's JIT pull system requires that Dell and its suppliers coordinate closely with one another. Although Dell's inventories are lean, they can leave the company's operations vulnerable to supply chain disruptions.¹⁴

Kanban systems also allow firms to control the flow of resources in a production process by replacing only the parts that have been consumed. When there is schedule stability, it is easy to account for parts and components that are pulled through the assembly line. This is accomplished through an inventory management process known as backflush. During the **backflush** process, parts that go into each unit of the product are removed from inventory and continually tallied along with the finished units produced. The backflush process ensures supplies remain consistent in the production pipeline. So, instead of ordering supplies in advance by guessing how many of them will be needed in a given period, they can be made available just in time.

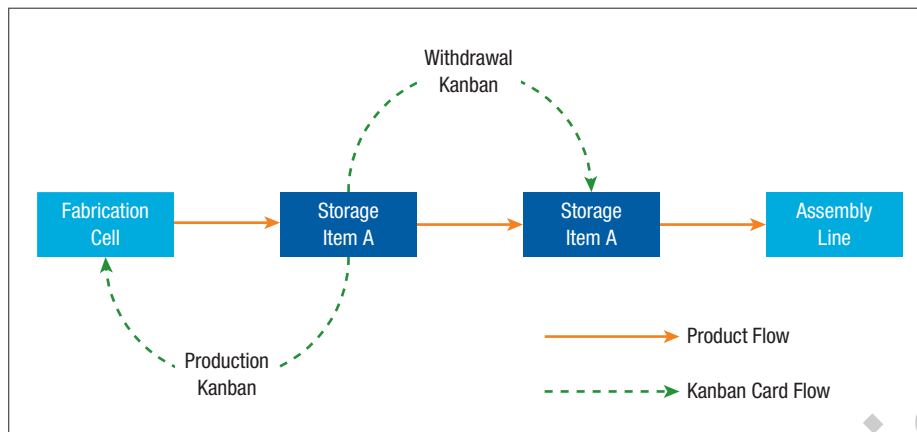
Instead of a single card, many companies use a two-card Kanban system. Figure 14.4 shows how a two-card system works. Both production and withdrawal Kanban cards are used. The plant in this example has both a fabrication cell and an assembly line:

1. The container next to the fabrication cell has a production Kanban card, whereas the one near the assembly line has the withdrawal Kanban card.
2. When the last piece of Item A is removed from the container near the assembly line, the withdrawal Kanban card from the container is also removed and placed in the fabrication cell storage area.
3. Next, a worker from the fabrication cell area finds another full container of Item A. She then removes the production Kanban card from that container and attaches the withdrawal Kanban card in its place. The withdrawal Kanban card sends a signal to the assembly cell that the items are ready for use, whereas the production Kanban card that was removed signals the fabrication cell to produce another batch of Item A.

Backflush: an inventory management process in which parts that go into each unit of a product are removed from inventory and continually tallied along with the finished units produced

Other visual devices can be used instead of cards, such as flags or bright lights. It is also important to note that use of the Kanban system is not restricted to just a manufacturing facility. It can also be used to coordinate suppliers and manufacturing plants.

FIGURE 14.4: Two-Card Kanban System



EXAMPLE 14.1: Orion Manufacturing, Inc., is a fictional producer of a wide assortment of temperature-sensing devices. Although the company's business has been growing at the rate of 15% per year, its operations have been hampered by long lead times and poor on-time delivery. The manager responsible for this product line identified the 10 top-selling products that make up nearly 80% of sensing devices produced in one manufacturing cell. Based on demand history and forecasts, the manager estimated the monthly demand for each of the 10 sensing devices. In addition, he decided to carry 2 weeks of safety stock in the shipping area for each product.

Consequently, each product was assigned a finished goods Kanban that would hold 2 weeks' inventory of sensing devices. The number of each sensing device to be produced daily along with the takt time was determined. Next, the number of devices to be produced was multiplied by the production time per product per worker, and the resulting number was further divided by the number of workers in the cell to ensure that enough capacity was available to make the required number of products per day.

The manager also decided that at least 25 units of each product should be produced at a time in the manufacturing cell. A set of Kanban cards with instructions to produce 25 units of a sensing device totaling approximately the number needed for a 2-week supply was attached to all of the finished goods Kanbans. As orders to be shipped were filled, the cards were detached and sent to production as a signal to produce sensor devices to replace those that were just shipped.

Solution

Determining the number of Kanban cards and containers is a prerequisite for setting up a Kanban control system. In a finished goods Kanban system, for example, these cards represent the number of containers of finished goods that flow back and forth between the production and shipping areas. Because each container represents the production lot size, the containers directly determine the amount of finished goods inventory in the system. **Lot size** refers to the predetermined quantity of an item that is either manufactured or purchased from a supplier.

To determine the correct number of Kanban containers, you need an accurate estimate of the lead time for producing the finished units. The lead time for production consists of the processing time for the container, the waiting time during production, and the transportation time to the shipping area. The number of Kanbans should be sufficient to meet the expected demand during the lead time *plus* any required safety stock. The formula used to calculate the number of Kanbans (K) is

$$K = \frac{\text{Expected or average demand during the lead time} + \text{Safety stock}}{\text{Container quantity size}}$$

$$= \frac{d \times LT + SS}{C}$$

Lot size: the predetermined quantity of an item that is either manufactured or purchased from a supplier

➤ Example 14.1

where

K = the number of kanban card/container sets

d = average number of units demanded per period

LT = Lead time needed for order replenishment

SS = Safety stock expressed in units

C = Quantity size of container

Note: Both lead time and demand must be expressed in the same time units

Example 14.2

EXAMPLE 14.2: Let's return to the Orion Manufacturing example. Remember that Orion makes temperature-sensing equipment and uses a Kanban system to pull material through its manufacturing cells. The temperature sensors are made in batches (lot sizes) of 15 units, and the cell that manufactures these devices can replenish an order for a batch of sensors in approximately 5 hours. The average demand for the sensors is approximately 10 per hour. Orion's managers decided to carry a safety stock of 10% of the average demand during the lead time. How many Kanban sets are needed to manage the replenishment of the temperature sensors?

Solution

d = Average number of units demanded per period = 10

LT = Lead time needed for order replenishment = 5 hours

SS = Safety stock expressed in units = 10% of $(d \times LT) = 0.10 \times 10 \times 5$

C = Container quantity size = 15

K = the number of Kanban card/container sets

$$K = \frac{\text{Expected or average demand during the lead time} + \text{Safety stock}}{\text{Container quantity size}}$$

$$K = \frac{(10 \times 5) + 5}{15}$$

$$K = 3.67, \text{ or } 4 \text{ (rounded up)}$$

Orion Manufacturing needs four Kanban card sets and four containers of sensors.

Reduced Inventory

An objective of lean operations is the reduction of inventory to the lowest possible levels: the continuous commitment to finding ways to reduce inventory, not just in the obvious places such as warehouses, but also in other places where inventory can "hide," such as on a firm's plant floor, on carousels, on conveyors, or in transit. Remember that each time you reduce inventory and its locations, you are reducing waste, streamlining operations, and simplifying the steps workers need to take. For example, a Kansas City publisher recently upgraded its sorting operations to include a horizontal carousel system arranged with four carousels per workstation. This setup streamlined the company's order fulfillment processes and minimized its inventory. The system ultimately saved the company 66% in labor costs because employees didn't have to move from shelf to shelf to fulfill orders. Instead they could stand in one place and process them.¹⁵

Large inventory savings cannot be realized without small and frequent shipments of purchased materials and components from a firm's suppliers. For small and frequent shipments to occur, the firm needs to develop quality standards with its suppliers and demand forecasts so it will have a

good sense of the long-run demands that will be placed on its production and distribution systems. This process can be complicated. For example, Target Corporation (aka Target, Minneapolis, MN), a leading retailer, had a partially manual process for tracking inbound shipments. Employees had to input shipments manually into the company's vendor management system, which led them to make transportation decisions with limited information. Target has since implemented a fully automated order entry system that has made the inbound shipment tracking process much more streamlined and efficient.

Improved Product Designs

Upgrading and improving the design and configuration of products is another element of lean systems. One reason Dell is so successful in shipping personalized orders is its commitment to individualization *and* standardization. That is, although all orders have customized components that are put together for individual customers, the "box" into which they are installed is a standardized unit. In this way, Dell has adopted a standard product configuration with specialized component parts and can therefore reduce the total number of parts it must order from vendors and store them at its assembly sites.

Although the application of lean techniques is used most typically in assembly-line flow processes, it can also be adapted to job-shop production processes. Settings of this type, such as factory machining centers or paint shops, produce a large variety of products in low volumes. The demand for products produced in a job shop isn't as stable as it is for flow operations because the products are customized and depend on different buyers' tastes. Nonetheless, lean techniques can be used in these situations by creating internal demand stability. For example, if demand from downstream production activities can be stabilized by reducing variations in the workflow, then a relatively smoother, just-in-time, and level production schedule can be implemented, and the benefits of lean can be realized.

14.4 Lean Services

Lean principles can be used in service industries as well as in manufacturing companies. The more service delivery systems can be standardized, the easier it is to analyze the process and to identify ways to improve it. McDonald's (Oak Brook, IL), which has long been a leader in standardizing its operations, has adopted lean methods for supplying outlets, training employees, and delivering food to customers.

There are some important principles a service operation should follow to create a lean system:¹⁶

- **Pinpoint the Value the Service Offers.** To implement lean operations, the service firm must understand the customers' wants and needs. How do customers perceive value in the service exchange? What is it they seek? In lean approaches, the customer determines what value is. For example, a hospital may *assume* it knows what the patient wants during treatment, but it cannot be sure. Value exists only in the eyes of the customer. Taco Bell (subsidiary of Yum! Brands, Inc., Irvine, CA), a fast-food chain, has found that customers want fast delivery, accurate orders, cleanliness, and food served at appropriate temperatures.
- **Identify the Service's Value Stream.** What is a firm's process for designing, developing, providing, and assessing the needs of its customers? How does the supply chain function? Where are the inefficiencies in the system? These critical questions are necessary for understanding the service's value stream. In a lean operation, a company must constantly monitor all the activities required to provide the service and to determine how to streamline and improve the process from the customer's point of view. Customers can identify a company's activities that add value, those that do not affect value, and those that may reduce value. For example, a cable television provider may institute an automated call service to answer technical questions, thinking it is responding to the needs of its customers. Suppose in reality, however, the firm's technical support personnel simply can't handle the load of calls they are receiving. Perhaps they aren't trained well enough to help frustrated customers quickly. The cable provider may think it is adding value to its product. Nevertheless, it may actually be reducing value because most customers would rather talk to a human being than to an automated call.

14.4

Apply lean ideas to service operations.



OPERATIONS PROFILE:

WIPRO Limited and Lean Software Development

WIPRO Limited (Bangalore, India), the world's largest software development and technology services provider, employs more than 95,000 people. WIPRO relies on lean principles. Lean processes have made it possible to avoid the bottlenecks that were slowing the company's thousand-plus software development projects it has going on at any point in time.

As part of its lean effort, WIPRO follows these four rules, which are part of Toyota's production system:

- **Rule 1:** All work shall be highly specified as to content, sequence, timing, and outcome.
- **Rule 2:** Every customer–supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses.
- **Rule 3:** The sequence for producing every product and service must be simple and direct.
- **Rule 4:** Any improvement must be made in accordance with carefully established methods, under the guidance of a teacher or supervisor, at the lowest possible level in the organization.

To implement its lean system, a team of WIPRO's managers visited some lean manufacturing operations to understand how the firm could apply lean principles to its operations. Shortly thereafter, more than half the company's projects were being developed with lean approaches that involved a simple set of practices. Some of these practices are as follows:

- **Using a Simplified Organizational Structure.** WIPRO's project teams are flat. Fewer levels of hierarchy result in fewer delays.

- **Striving for Continuous Improvement.** New ideas and procedures are tested. When they are successful, they are implemented across the organization.
- **Sharing Mistakes.** When mistakes are made on a project, the results are widely shared in a nonthreatening way so they aren't repeated.
- **Specialized Tools.** Project tools and scheduling methods are tested and modified to make them as useful as possible for the types of projects WIPRO undertakes.

The results of WIPRO's lean approach have been very encouraging. Lean principles provide WIPRO with a standard way to tackle new projects, while creating significant savings across its development cycle. WIPRO started slowly, launching 10 pilot projects to see whether the lean approach was a viable option. After receiving encouraging results, the company is now fully committed to lean; in fact, of the 4,000 to 5,000 projects undertaken yearly by WIPRO, more than 1,600 are lean projects. The average efficiencies and time and cost savings on new projects are now 20% better than what they used to be and are steadily improving.¹⁷



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- **Improve the Flow of the Service.** Service flow is the manner in which services are delivered to the end user. Lean service firms analyze the flow of their services to find the flaws or delivery delays that prevent the service from proceeding smoothly from the provider to the customer. To speed up its service delivery, Taco Bell remodeled its supply chain, using frequent just-in-time deliveries of preprocessed food products to decrease the firm's inventory and costs and to save space in its restaurants.
- **Be Prepared to Respond to the Pull From Customers.** Service firms have to respond to the needs of the customer at the time of the customer's choosing. Consequently, developing accurate demand forecasts for its services is critical.

- **Pursue Perfection.** The better the first four principles in service delivery are pursued, the greater the probability of satisfying the end user's desire for the highest value at the lowest cost. Although perfection can never be achieved, a company can never allow itself to be satisfied with its current state. The idea behind lean systems is that there is always room for improving them.



Lean Services

Southwest Airlines (SWA; Southwest Airlines Co., Dallas, TX) holds the unique distinction of being one of only a handful of steadily profitable airlines during the past decade. In addition, SWA has routinely held the “triple crown awards” of fewest customer complaints, fewest late arrivals, and fewest lost bags. A close look at the airline's approach to operations shows the company is committed to resolving common problems within the airline industry by using innovative techniques some firms might even consider radical. SWA has eliminated services customers don't value. For example, after surveying fliers, the company eliminated in-flight meals. Instead, the company worked harder to provide the services that customers do expect, such as courtesy, on-time departures, and trouble-free travel. Southwest Airlines has been adept at practicing lean service delivery, and the results can clearly be seen in its steady profitability in an extremely difficult industry.

Lean philosophy has helped service providers like SWA develop processes and methods to improve their operations; streamline and cut their costs; and most importantly, satisfy their customers better at the same time. Yet, successful service operations will always be closely linked to how well a firm listens to and satisfies its customers. That is, the continuous improvement strategies that lean methods offer must always be filtered first through the lens of customer needs. Once those needs are understood, they form the goals that will shape the ability of a company to provide effective services in the most efficient way possible.

14.5 Lean Supply Chains

A lean supply chain is one in which the members work collaboratively to reduce cost and waste by efficiently pulling what is needed to meet the needs of the individual customer. A lean supply chain is a network of integrated organizations in which all of the supply chain partners collectively align their capabilities to meet customer demand effectively. As the Operations Profile box about Walmart (Walmart Inc., Bentonville, AR) demonstrates, expanding lean concepts to the entire supply chain can help its members achieve higher levels of competitiveness as well.

14.5

Identify the characteristics of a lean supply chain.

Characteristics of a Lean Supply Chain

There are three types of flows common to all supply chains: product and service flows, information flows, and financial flows. To build a lean supply chain, the wastes associated with each flow should be identified and eliminated, and the fluctuations smoothed out. As the Walmart box demonstrates, information technologies can successfully link all entities in the network and facilitate the fast and accurate financial flows and information flows. Furthermore, performance metrics and measurement systems should be developed to sustain the efficiency and effectiveness of these flows and for continuous improvement.



A Lean Supply Chain

Full Collaboration Among the Supply Chain's Partners

The strength and competitive advantages of a lean supply chain result from the synergy and unity of purpose of its partners. Nevertheless, this collective power cannot be achieved without close relationships based on trust and collaboration. These relationships are necessary not only to ensure that the supply chain members can satisfy the customer but also to make each company in the supply chain profitable. These are features of lean relationships:¹⁸

- **Fewer Suppliers.** Fewer suppliers lead to improved communication and cooperation, better control of the process, and more trusting relationships.
- **Interdependency.** In lean supply chains, there is a high degree of interdependence among the members. The result of this interdependence is stability over fixed time with a higher degree of mutually beneficial collaboration. Note that the more complex and critical the final product is, the more serious and permanent the relationships within the supply chain should be. Pfizer, Inc. (New York, NY), for example, will only work with long-term suppliers that have passed its own quality checks and adhere to the company's strategic sourcing processes.



OPERATIONS PROFILE:

Lean Operations at Exempla Lutheran Medical Center

To create and maintain a sterile environment, most hospitals use positive-pressure airflow systems in their surgical rooms. The systems frequently exchange air in the rooms to keep them cool and remove microscopic sources of bacteria. Nonetheless, the sterility of the operating room is compromised when people go in and out during surgical procedures.

Employees of the Exempla Lutheran Medical Center of Denver, Colorado, examined this problem and determined that it often resulted from poor planning prior to the start of surgery. In particular, supplies, instruments, and equipment needed for a procedure were not properly identified in advance and located and placed in the rooms. Instead, as surgeons realized that an instrument was needed, they would ask an assistant to leave the room and locate it.

Exempla solved the problem by applying lean principles to the delivery of surgical health care. The medical center developed a streamlined flow process. For example, prior to the start of a surgery, a doctor is now required to supply a list of all instruments, equipment, and other supplies that will likely be needed. These supplies are located in advance and placed in a case cart that is assigned to the surgical room. Missing-item

tags attached to the front of the case carts identify which items need to be located and replaced or added prior to the start of a procedure.

The process is especially useful when doctors perform multiple procedures as they are not required to leave the room between operations. Furthermore, the hospital periodically evaluates the doctor's preference list requests as compared with actual usage and eliminates unused or unnecessary items. In this way, doctors and staff constantly review and update their requests. To promote continuous improvement, post-case briefings help to identify problems related to missing equipment or supplies.

Together, these process improvements have led to a 32% reduction in foot traffic in and out of surgical rooms during procedures, and they have dramatically cut down the incidence of surgical-site infections. By employing a lean services philosophy, Exempla Lutheran Medical Center has reduced waste, simplified and improved the flow of its surgical procedures, and adopted continuous improvement practices. These changes have had a positive impact on the hospital staff, but most important, they have improved the health care treatment delivered to patients.¹⁹

Also, in a lean supply chain, the boundaries of the organizations become blurred, and the entire chain acts as one extended enterprise that works toward common goals.

Transparent Information

As much information as possible, including actual and forecasted customer demand, market opportunities, and responsibilities, should be transparent and *shared* among a supply chain's members. Technology that can facilitate a seamless flow of information contributes to the success of lean supply chains. Many information technology (IT) systems used to facilitate information flows within supply chains use **electronic data interchange (EDI)**. EDI improves the exchange of standardized documents such as customer orders, shipment information, and bill payments between computer systems. Electronic Kanbans can be used to generate computerized documents sent to the supply chain members to signal that products and materials need to be pulled.

Companies linked with warehouse management and *radio frequency identification (RFID)* systems can track and trace electronically the materials and products that move among the supply chain members. The IT systems should also provide supply chain partners with real-time information about inventory levels and the status of orders, which are crucial to pull systems. This information helps managers examine historical sales and order information to discover demand patterns and, eventually, to develop accurate forecasts. Last, the information systems in lean supply chains have to play the dual role of maintaining transparency while guarding security. That is, the systems need to provide all the necessary information to be shared among supply chain partners while securing information that is proprietary, such as patents or other confidential and valuable company information.

Electronic data interchange (EDI): technology that facilitates a seamless flow of information to improve the exchange of standardized documents such as customer orders, shipment information, and bill payments between computer systems



OPERATIONS PROFILE:

Walmart's Lean Supply Chain Operations

Walmart is a leader in global supply chain operations, and some of the company's innovations serve as industry standards for organizing and maintaining a lean supply chain.

In the millions of retail firms that still use manual inventory counting and reorder systems, workers must physically walk the aisles of the stores and make an actual count of items on the shelves, compare these numbers to the inventory level, and, only then, determine whether to reorder the individual items. From there, the worker fills out a purchase order and telephones the company's central warehouse, where the order is placed.

All these steps cost the company money in terms of labor, paper supplies, lost sales when customers don't wait for the out-of-stock items to arrive, and excessive inventory holding costs when too much of a good is stocked. Kmart's (subsidiary of Sears Holding Corporation, Hoffman Estates, IL) order entry systems, for example, have been so poor that in the past, the company's stores were forced to rent truck container units and place them in their parking lots to store excess inventory. There was no room inside the stores! In fact, manual reorder

systems have historically been so bad that they have led to a whole new retail store category—stores that sell products that were overstocked at other stores. T.J. Maxx (subsidiary of TJX Companies, Framingham, MA), Marshalls (subsidiary of TJX Companies, Framingham, MA), and Big Lots (Big Lots, Inc., Columbus, OH) are examples of stores that take advantage of such overstocked merchandise and resell it at a discount.

Compare this approach with that pioneered by Walmart. When you purchase a new broom from your local Walmart store, the cash register reads the broom's barcode. Within 14 seconds, Walmart's central warehouse is notified that the broom was sold and needs to be replenished. The same system notifies the broom manufacturer that new stock is needed. Even the firms that supply the wood and brush materials (the raw materials for the broom) are notified; and so it goes, right up the supply chain. As a result, Walmart can replenish items on its shelves in less than 3 days—not from central warehouses to the shelf but directly from the manufacturer to the shelf, which eliminates the need for warehousing space.²⁰

The Internet has made developing lean supply chain systems information somewhat easier. Instead of linking all of their separate IT systems, the firms in a supply chain can exchange information over the Internet. Using a joint website that all the firms can easily access, the companies can coordinate their activities. For example, Walmart requires all their suppliers to use their online Retail Link system to coordinate their activities relative to Walmart's needs. The system offers real-time information to vendors on various issues, such as determining which stores are out of stock of particular items or the percentage of Walmart shoppers that buy their product. Often a key supply chain partner (usually the leader) manages and maintains the site.

Lean Logistics

Lean thinking should be implemented in the logistical flows of a supply chain—from raw materials to the delivery of end products or services. Several lean logistical approaches are the following:

- **Just-in-Time (JIT) Delivery.** JIT can facilitate a smooth physical flow of goods and materials throughout the entire supply chain. To facilitate JIT delivery, the milk run approach is frequently used. This approach involves routing a supply or delivery vehicle to make multiple pickups or drop-offs at different locations.²¹ Supply chain partners in close proximity can easily adopt this approach as long as the demand fluctuations and quantities transported are not too large. The approach has the advantages of minimizing inventory and predictable lead times and of improving inventory visibility and communication among supply chain members.²²
- **Cross-Docking.** Invented by Walmart, cross-docking is a logistical approach in which goods in incoming shipments are packaged in a way that they can be easily sorted for outgoing shipments. Goods in a warehouse or distribution center that are cross-docked are directly transferred from receiving docks to shipping docks without intermediate storage. Cross-docking can reduce the handling and storage costs of the firms as well as speed up order cycle times and inventory turnover, which can improve the cash flows of the supply chain members.²³

Supplier park: the location of multiple suppliers in close proximity to a producer to create a leaner supply chain

Time metrics: an assessment of the amount of time to process an order, transportation time, and similar variables

Cost metrics: an assessment of material and labor costs, the costs associated with returns and repairs, interest, rent, facilities, transportation, and storage

Efficiency metrics: the evaluation of inventory turnover or days of inventory on hand, as well as capacity and capital usage (ROI or cash flow)

- **Vendor Managed Inventory (VMI).** In a vendor managed inventory (VMI) system, the management of an item at the customer's site or retail location is entirely the responsibility of the supplier of that item. For example, P&G (Procter & Gamble Co., Cincinnati, OH) manages the inventory of the items it supplies to Walmart in all of its retail locations. VMI incorporates the pull concept, which is used in lean systems, and provides the benefits of improved communication between the supply chain partners and more efficient demand and inventory management in the chain.
- **Third-Party Logistics (3PL).** With increasing globalization, it is almost impossible for individual supply chain members to have their own transportation systems—their own trucks, planes, and so forth—to transport everything they need. Consequently, they rely on third-party logistics (3PL) companies such as FedEx (introduced earlier in the chapter); United Parcel Service, Inc. (aka UPS, Sandy Springs, GA); and DHL Express (division of Deutsche Post DHL, Bonn, Germany). The members in a supply chain can contract with these 3PL companies to handle many of their logistical needs, which in turn enables them to focus on their core competencies. From a lean perspective, the key advantage of using 3PL providers is the improved and efficient product flows that can be achieved from the point of origin to the point of consumption.
- **Supplier Parks.** The extent to which companies can improve the cost and time associated with logistics is often constrained by the widely separated global locations of the supply chain members. To create a leaner supply chain, one possible option is have suppliers locate near a producer in a **supplier park**. The physical proximity can improve the efficiency of production and delivery of goods. For example, Nissan announced its intention to spend US\$160 million on a 1.5-million-square-foot supplier park to locate many of its suppliers close to its Smyrna, Tennessee, plant.²⁴ Yet, a supplier park is only feasible in situations where there is a high density and concentration of population and manufacturing facilities, and it is more common in countries such as Japan, China, and Taiwan. In geographically large countries such as the United States and Canada, persuading suppliers to relocate near you isn't always feasible.

Approaches to lean logistics will continue to evolve as more and more companies embrace the concept of lean supply chains. Note that lean logistics approaches will work *only* if the supply chain members mutually reinforce and cooperate with each other.



Nissan decided to open a supplier park near its plant in Smyrna, Tennessee, to cut down on production and delivery costs and increase efficiency in its supply chain.

Bloomberg/Bloomberg

faction metrics, such as number of customer complaints and percentage of returned items.²⁵

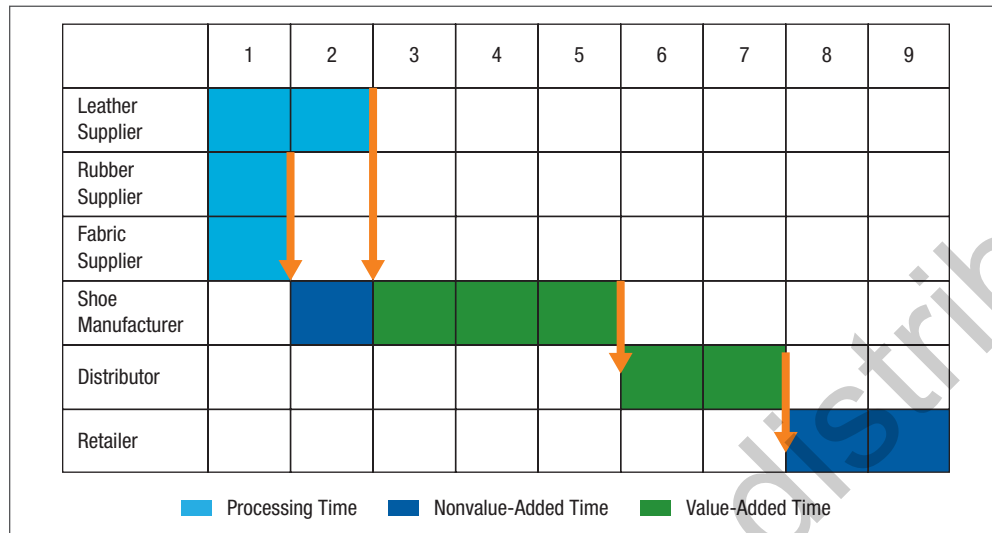
The metrics often used to monitor the performance of lean supply chains are inventory turnover and days of inventory on hand. Nonetheless, several other performance metrics have been developed. An ideal starting point for determining the appropriate performance measurements to use is a value stream map. The value stream map provides a comprehensive view of the entire supply chain, including product and information flows. Using the value stream map, you can identify problem areas and then select relevant performance metrics to improve each.

In addition, a **timeline chart**, such as the one shown in Figure 14.5, can be used to track both the value-added and non-value-added time a T-shirt spends in various production stages. For example,

Performance Measurement and Continuous Improvement

Performance metrics can be used to gauge quantitatively how well a supply chain is performing. **Time metrics** assess the amount of time to process an order, transportation time, and similar variables. **Cost metrics** assess material and labor costs, the costs associated with returns and repairs, interest, rent, and facilities, transportation, and storage costs. **Efficiency metrics** evaluate inventory turnover or days of inventory on hand, as well as capacity and capital usage (ROI or cash flow). **Effectiveness metrics** evaluate the percentage of orders delivered on time and customer satisfaction.

FIGURE 14.5: A Simplified Example of a Timeline Chart



the figure shows there are two cells where no value-added work is being done on the t-shirt. These cells are indicated in red. The chart shows that the distributor’s cycle could be shortened as well as the time the product spends with the contractor before being shipped to the customer. Using the value stream map and the timeline chart in tandem can reveal wastes in the supply chain, identify problem areas, and help pinpoint potential opportunities for improvement.

Neither the value stream map for a product nor its timeline map explicitly provides cost information about the supply chain. To overcome this shortcoming, a **cost-time-profile map (CTP)**, such as the one shown in Figure 14.6, can be constructed. A CTP map tracks the money invested over time in a production process.²⁶ The advantage is that it provides supply chain managers with insight into the time value of the money invested as working capital, and it enables them to identify problem areas in the supply chain, in terms of both time and costs. For example, activities that provide no value increase the overall production cost. Likewise, the longer a product spends time as inventory represents money that could have been profitably used elsewhere.

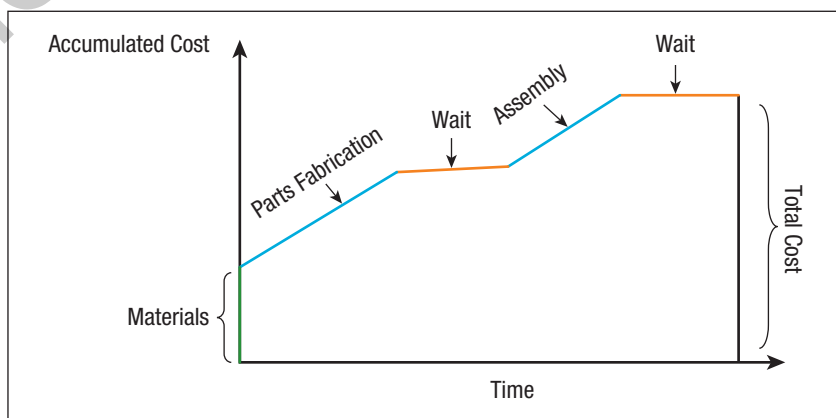
The continuous improvement of supply chain performance is an ongoing process. One possible way to improve the performance of a lean supply chain is to develop a future-state value stream map for the chain that is similar to the map for a single firm. To create a future value stream map for a supply chain, begin selecting critical supply chain members that have the greatest impact on

Effectiveness metrics: the evaluation of the percentage of orders delivered on time and customer satisfaction metrics, such as number of customer complaints and percentage of returned items

Timeline chart: a tool used to track both the value-added and non-value-added time a product spends in various production stages

Cost-time-profile map (CTP): a map that tracks the money invested over time in a production process

FIGURE 14.6: A Simplified Example of a Cost-Time Profile



the flow of products as well as costs and times. Then construct a value stream map and a timeline map that reflect the desired future state of the lean supply chain, just as you would for a single operation. Implement projects to improve the performance of the lean supply chain, and then repeat the process.²⁷

14.6

Explain why it is so difficult to make global supply chains lean.

14.6 Lean Global Supply Chains

Global supply chains have many stages and components, and each can increase costs and create risks (or offer opportunities) for every partner. Global supply chains have at least one firm that locates portions of its supply chain in a foreign country. Firms in a global supply chain outsource some of their activities to third-party companies located elsewhere and forge partnerships with firms in other countries through strategic alliances and joint ventures.

Although lean concepts can offer benefits to supply chains, it is often difficult to make global supply chains lean. Why is that so? First, it requires coordination to establish the rapid flow of goods and information in a global supply chain. Achieving this degree of coordination across countries is expensive and difficult. Second, the frequent and often daily deliveries required for JIT inventory management are nearly impossible in a global setting because of long shipping times, infrequent freight connections, unpredictable weather delays, the bureaucracy associated with customs, and labor strikes common in some foreign countries. Third, longer lead times are required, making low inventories hard to achieve, so firms need to carry a greater amount of safety stock to avoid running short on goods. In addition, shipping numerous small quantities of products is less cost effective over long distances. Finally, the lack of face-to-face contact, time zone differences, and cultural and language barriers can make global communication regarding the design, quality, and scheduling more expensive and less effective.²⁸

Despite these obstacles, it is still possible to incorporate certain elements of lean systems in global supply chains. Some trade-offs need to be considered—for example, although JIT production and low inventories may not be feasible, it is possible to incorporate certain other features of lean systems such as design-for-manufacturing principles, the reduction of defects, and reduction of engineering change orders. Also, note that not all activities in a global supply chain are of equal importance in the value they add. Supply chain managers need to identify the most critical activities and evaluate the trade-offs of each.



A Global Supply Chain

14.7

Discuss how sustainability initiatives can be considered an extension of the lean philosophy.

14.7 Sustainability Issues

Environmentally sustainable practices are a natural extension of lean because the pursuit of lean strategies leads companies toward sustainability initiatives. For example, the lean concept of eliminating waste is also a key objective of sustainability initiatives. Furthermore, lean tools can also be used to solve environmental problems and to reduce a firm's carbon footprint. Thus, sustainability is very much similar to lean practices, in both concept and practice; hence, they can be thought of as an extension of lean to achieve a much broader objective.³⁰ Both sustainability and lean systems not only share many similarities but also have a synergistic relationship. In fact, many companies now believe that lean processes and sustainability initiatives work hand in hand, achieving the same goal of increasing profits. For example, the following lean initiatives that companies adopt will also improve sustainability:³¹

- **Fewer Product Defects.** The lean practice of attempting to minimize product defects means the use of fewer raw materials, less plant space, fewer systems, and less equipment to rework or repair, which leads to less energy consumption.
- **Eliminating Overproduction.** This practice is a major focus of lean manufacturing with an emphasis on producing what you need and when you need it. Eliminating overproduction consumes fewer raw materials, uses less energy for production, and eliminates the risk of waste from the accumulation and disposal of excess inventory.
- **Minimizing Wasted Movement.** The lean principle of minimizing wasted movement among workers through more efficient facility layouts increases worker safety and reduces energy needed for heating, cooling, and lighting.



OPERATIONS PROFILE:

LESSONS LEARNED: *Learning to be Lean at Amazon*

Learning the Toyota way of lean in manufacturing organizations is a challenge. Trying to implement lean operations in an e-commerce company as large as Amazon represents a whole new way of thinking and addressing the lean principles. Since the beginning of Amazon, its founder and CEO, Jeff Bezos, has been customer-focused. He tried to create a site that was customer-friendly, intuitive, and pleasing to use, linking information technology to online shopping and purchasing.

As Marc Onetto, former head of Amazon's Global Operations, noted, becoming lean was harder than Amazon originally thought because, "as a technology company, Amazon believed that most issues of operations could be resolved with technology"—bigger challenges required better technology. In fact, the more Bezos and his executives examined Amazon's operations, the more they came to understand they were failing to engage their workers in the process of continuous improvement. That is, when problems emerged with customer orders and fulfillment, initial reactions were always to fine-tune the technology, to improve the IT, and trust to the process. In reality, Amazon learned it was their people, not their technology, that led to the company's success. Amazon now has more people working in the fulfillment centers and customer service centers than it does computer science engineers. They are dedicated to pursuing the engagement of their people to succeed, since they are the ones who are actually receiving, stowing, picking, packing, and sending packages or responding to customers by phone, chat, or e-mail.

For example, earlier in Amazon's development, the company had been trying to automate almost everything in a fulfillment center. The automation was designed for books but did not work for new types of goods, such as shoes, as Amazon expanded its selection. When the shoebox reached the flip mechanism in the automated machine that was supposed to collect the shoes and bring them to the packing line, they went flying out of the box. The same thing was happening with other merchandise lines. Amazon wanted to expand, but its systems were interfering with progress. As a consequence, they were limited to certain types of goods in the automated warehouses.

In order to evolve from a bookstore to the store for everything, Amazon had to reinvent automation, following the lean principle of "autonomation": keeping the humans for high-value, complex work and using machines to support those tasks. Humans are extremely creative and flexible. Autonomation helps human beings perform tasks in a defect-free and safe way by only automating the basic, repetitive, low-value steps

in a process. The result is the best of both worlds: a very flexible human being assisted by a machine that brings the process up to Six Sigma.

There were several other ways that Amazon has adopted the principles of lean for its e-commerce operations, including the following:

1. *Enforcing the idea of "standard work."* The problem at many companies, including Amazon, is that workers' assigned tasks are very vague; it's up to the worker to figure things out. Amazon began to consider ways of improving workers' performance by taking a detailed look at their assigned tasks. It discovered that what was happening in reality was quite different from what was written down—and it was riddled with abnormalities. So it set a very well-defined standard process, tracked all abnormalities, developed root cause analysis for these problems, and assigned *kaizen* teams to eliminate them.
2. *Pursuing kaizen methods at each stage of the order process.* Making small, incremental improvements to the ordering and fulfillment system by following kaizen principles leads to large, accumulated improvements. No one improvement by itself may be significant, but the process of building up steady improvements leads to a much improved operation.
3. *Creating an andon-cord system.* *Andon* systems empower employees to "stop the line" when they spot a defect, especially if it is a recurring problem. The process begins when a service agent receives a complaint from a customer. If it is a repetitive problem, the agent can stop the line, which means taking the product off the website until the defect gets fixed. Onetto estimates that the *andon* cord has eliminated tens of thousands of defects per year since its introduction while empowering workers. Just the ability to respond to irate customers by pulling a product for defect testing has been highly motivating to all employees.

Applying lean to an e-commerce organization may seem like a stretch, but the underlying principles that guide lean, including kaizen, applying "autonomation," an emphasis on customer service, and empowering employees, have been some of the most important reasons why Amazon has become one of the top five most valuable companies by market capitalization and suggest that even bigger things are in store for the organization in years to come.²⁹

- **Reducing Transportation.** The lean concept of minimizing unnecessary internal or external movement of materials that add no real value to the product can lead to meaningful sustainability results by decreasing energy use and the costs associated with the product.
- **Less Excess Inventory.** The lean practice of minimizing excess inventory means more efficient use of plant space leading to less energy use, consumption of fewer packaging and raw materials, and reduction in the risk of waste from obsolescence and undiscovered defects.
- **Reduced Waiting.** One of the key concepts of lean manufacturing is to reduce waiting time for equipment, information, or materials. The lean practice of synchronizing production processes to reduce waiting can reduce production downtime, thereby leading to less wasted energy.
- **Less Overprocessing.** The lean practice that every step of a production process adds value to the customer leads to more efficient production processes. As a result, reduced waste lowers a company's environmental and carbon footprint.

Companies that apply lean thinking to their sustainability efforts contribute to the long-term staying power of sustainability initiatives as they add value to the company and its customers.

Application of lean principles minimizes waste and continuously improves operational efficiency. As a result, lean implementation enables a company to reduce operational costs and enhance the value provided to customers. Thus, lean implementation does support a company's desire to act in an ethically responsible manner. Yet, because lean systems force waste elimination and continuous improvement, lean implementation also has ethical implications within the organization as it can cause discomfort and stress among employees dealing with streamlined or modified jobs. Furthermore, applying lean principles may even lead to layoffs of workers with lesser skills or of those working in now redundant roles. One possible way by which a company can overcome this ethical dilemma is to guarantee the jobs of those employees who are dedicated and willing to go through additional training to support lean implementation. A company can also shift employees who lack the necessary skill levels to another position within the company where they can be productive. At a minimum, before implementing lean, a company should give its employees an honest account of the possible consequences of lean implementation.



Sustainability and
Lean Systems



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CHAPTER SUMMARY

14.1 Define lean operations.

Lean operations, including just-in-time (JIT) practices, are philosophies of continuous improvement. The goal of lean operations is to eliminate waste of any kind, a problem that affects both manufacturing and service organizations.

14.2 Describe the philosophy of lean systems.

The first feature of the philosophy of lean systems is to promote respect for people. Consequently, one prerequisite for implementing a lean system is to create an environment that empowers workers and fosters cooperation, trust, and respect between a firm's workforce and managers. Second, to achieve

a smooth and rapid flow of materials and work, waste and inefficiency should be eliminated. Finally, the philosophy of lean systems requires commitment to the 5S model that shows how to implement lean practices in any business operation.

14.3 Outline the elements of lean operations systems.

Lean systems are based on a pull system of throughput and can include such features as focused factories, value stream mapping, TQM, quality at the source, level scheduling, faster setup times, group technology, plant layouts that balance the workflow, stable scheduling, Kanban systems, reduced inventory, and improved product designs.

14.4 Apply lean ideas to service operations.

Lean systems aren't limited to manufacturing operations. A service operation can create a lean system as well by pinpointing the value the service offers, improving the flow of the service, being prepared to respond to the pull from customers, and pursuing perfection.

14.5 Identify the characteristics of a lean supply chain.

The lean philosophy is equally critical to enhancing an organization's supply chain and requires four key elements: (a) the full collaboration of all supply chain partners; (b) the use of transparent information; (c) lean logistics, including third party logistics, vendor managed inventory, cross-docking, and supplier parks; and (d) performance monitoring.

14.6 Explain why it is so difficult to make global supply chains lean.

Difficulties in creating lean global supply chains include the need for high levels of coordination, just-in-time (JIT) delivery, and low inventories, as well as the need for frequent and rapid deliveries from suppliers, coordination and information flow, and effective communication. JIT practices are nearly impossible in a global setting because of long shipping times, infrequent freight connections, unpredictable weather delays, the bureaucracy associated with customs, and labor strikes that are common in some foreign countries. The lack of face-to-face contact, time zone differences, and cultural and language barriers can make coordinating global supply chains even more difficult. Once these obstacles are overcome, however, the lean supply chain's advantages can be significant.

14.7 Discuss how sustainability initiatives can be considered an extension of the lean philosophy.

Both sustainability and lean systems share many similarities, and they have a synergistic relationship. Many of the lean initiatives that companies adopt, such as reducing product defects and inventory reduction, will also improve sustainability. In addition, both lean and sustainability initiatives also have the same goal of increasing profits.

KEY TERMS

Backflush	572	Internal logistics system	569	<i>Muri</i>	563
Cost metrics	580	Internal setups	570	Pull systems	565
Cost-time-profile map (CTP)	581	<i>Jidoka</i>	569	Push systems	565
Dependence	565	Just-in-time (JIT)	562	Safety stock	570
Effectiveness metrics	580	Kanban system	571	Supplier park	580
Efficiency metrics	580	Lean philosophy	561	Takt time	569
Electronic data interchange (EDI)	578	Lean Six Sigma	568	Throughput	565
External logistics system	569	Level schedule	569	Time metrics	580
External setups	570	Lot size	573	Timeline chart	580
Five S (5S)	564	Mixed-model production cycle	570	Uniform plant loading	569
Frozen windows	569	<i>Muda</i>	563	Value stream	566
Incrementalism	565	<i>Mura</i>	563	Workflow	565

DISCUSSION AND REVIEW QUESTIONS

1. Explain the three types of waste (*muri*, *mura*, and *muda*) in your own words. Can you think of situations where you have seen each of these types of waste in jobs you have performed?
2. Compare the ideas of lean with the 5S framework. How do they complement each other? How do you see them as distinct approaches?

3. What are the main differences between push and pull systems? Which seems more difficult to manage? Why?
4. Why is production in small lot sizes essential to achieving lean?
5. Why is value stream mapping such a critical first step in a company's move toward a lean approach to operations?
6. What types of production processes are most conducive to developing a value stream map?
7. Lean production requires that seven steps be taken. Why, in your opinion, should the first step be designing the process flow?
8. Why is uniform production an important element of lean, and how is it achieved?
9. How are lean thinking and Six Sigma related?
10. What are the advantages of lean services?
11. Which lean approaches work in both lean manufacturing and lean service operations?
12. What are the elements in a lean supply chain? Why are transparent information and full collaboration two critical components of lean supply chains?
13. Discuss briefly the key elements of lean logistics.
14. You are the shift manager of a medium-sized restaurant. You would like to begin taking a lean production approach. Identify three changes you could make to institute a lean approach at the restaurant.
15. Suggest ways in which lean principles can be applied to a hospital.

SOLVED PROBLEM

A hospital is planning to set up a Kanban control system to manage its supply of blood with the regional blood bank. Blood delivery from the regional blood bank to the hospital occurs every day with an order lead time of 1 day. An order placed at 8:00 a.m. each day will be delivered the next morning. The hospital uses an average of 20 pints a day for each blood type. The hospital maintains a safety stock of 20% over and above its forecasted amount of blood demanded. The regional blood bank delivers blood in five-pint containers. Calculate the number of Kanban sets the hospital should have.

Solution

d = average pints of blood demanded per period = 20

LT = lead time needed for order replenishment = 1 day

SS = safety stock expressed in units = 20% of $(d \times LT) = .20 \times 20 \times 1 = 4$

C = quantity of pints per container = 5

K = number of Kanban card/container sets = ?

$$\begin{aligned}
 K &= \frac{\text{Expected or average demand during the lead time} + \text{Safety stock}}{\text{Container quantity size}} \\
 &= \frac{d \times LT + SS}{C} \\
 &= \frac{(20 \times 1) + 4}{5} \\
 &= 4.80, \text{ or } 5 \text{ (rounded up)}
 \end{aligned}$$

Note: Both lead time and demand must be expressed in the same time units

The hospital requires five Kanban card sets. Whenever a new container of blood (five-pint size) is opened, the Kanban card is sent to purchasing and an order for a five-pint container of blood will be placed. When the new container of blood is received, the Kanban card will be attached to that container and sent to the blood storage area.

PROBLEMS

1. Sprinkman Inc., a fictional supplier of instrument gauge cluster housings, is planning to use a Kanban control system to control material flow. The first step in this process is to calculate the takt time—the time it takes to produce an item (in this case, housing). Given the following information, compute the takt time per house (Hint: Compute in seconds the net production time available per day).
 - Working shifts per day = 2
 - Hours per shift = 8
 - Break time per shift = 30 minutes
 - Lunch break = 30 minutes
 - Demand for housings per day = 1,200 units
2. An autoglass company located in Detroit produces mirrors for automobiles. The company supplies auto mirrors to a nearby Ford (The Ford Motor Company, Dearborn, MI) plant. The demand for mirrors from the Ford plant is 800 mirrors per day. The autoglass company's productive time is 480 minutes.
 - a. What is the takt time?
 - b. If the total standard operating time required to produce a mirror is 144 seconds, how many workers are needed?
3. What is the takt time for a production system that operates one shift given the following information?
 - Total time per shift = 480 minutes
 - Coffee breaks = two 20-minute breaks per shift
 - Lunch break = 1 hour
 - Daily demand = 360 units
4. Given the following information, determine the number of Kanban cards required.
 - Demand rate = 800 units per hour
 - Lead time = 30 hours
 - Container capacity = 1,200 units
 - Safety stock = 15%
5. You have the following information:
 - Demand rate = 250 units per hour
 - Lead time = 15 hours
 - Container capacity = 300 units
 - Safety stock = 20%
 - a. Determine the number of Kanban cards required.
 - b. Convert these Kanban cards into the number of hours of demand they represent.
 - c. If the container size is reduced from 300 to 150 units, what impact, if any, will it have on inventory levels?
6. You have the following information:
 - Demand rate = 500 units per hour
 - Lead time = 5 hours
 - Container capacity = 60 units
 - Safety stock = 15%
 - a. Determine the number of Kanban cards required.
 - b. Convert these Kanban cards into the number of hours of demand they represent.
 - c. If the lead time is reduced from 5 to 3 hours, what impact, if any, will it have on inventory levels?
7. A local automotive company delivers five transmissions to the fabrication line every hour. On average, five vehicles are produced every hour, and management has decided on a safety stock that equals 40% of the expected demand. Calculate the number of Kanban sets needed.
8. Megatech Inc. is a fictional producer of airwave scanners for the defense industry. The company is planning to implement a Kanban control system to eliminate waste in the form of unnecessary inventory. After several days of analysis, Jean Costa, the firm's production manager, developed the following data for the manufacturing cell that produces the connectors for the scanners:
 - Expected daily demand = 1,500 connectors
 - Lead time = 3 days
 - Safety stock = 20% of daily demand
 - Size of a Kanban container = 450

How many Kanban containers of connectors are needed for this cell?
9. A U.S. Postal Service office is planning to adopt a pull system. With the current push system, a machine cancels the stamped letters, which are loaded into tubs with 400 letters in each tub. The tubs are then sent to the postal clerks for sorting. The clerks, with the help of an automatic sorting machine, read and key in the zip codes at the rate of 1 tub per 400 seconds. Nevertheless, every now and then, the stamp canceling machine outpaces the sorting operation, causing considerable stress on the clerks. Under the proposed pull system, employees will

pull a tub of letters with canceled stamps only when the clerks are ready to sort another tub. Given a safety stock of 20% for the tubs and an average waiting and materials handling time of 20 minutes per tub, calculate the number of tubs that should be circulating between the sorting clerks and the machine canceling area if 100,000 letters are to be sorted during a 10-hour shift.

10. A bank in New Delhi, India, uses a Kanban system in its check-processing facility. Each Kanban container holds 60 checks, requires 25 minutes to be processed, and spends 2.5 hours waiting to be handled. The facility operates 24 hours per day. A safety stock of 25% of the expected daily demand is maintained.
 - a. If 25 Kanban containers are currently in use, what is the expected daily demand of the check-processing facility?
 - b. How many containers are needed if the intention is to eliminate all waste in the system completely?
11. Refer to Table 8.2 as a basis for this problem. This month's master production schedule calls for the production of 180 sandals, 120 dress shoes, and 80 sneakers per 8-hour shift.
 - a. What is the average cycle time for each model to achieve the production quota in 8 hours? (Hint: Cycle Time = Operating Time/Desired Production.)
 - b. If a mixed-model production schedule is used, how many of each model will be produced before the production cycle is repeated?
12. Dolphin Motors (not a real company) recently installed a mixed-model production line at its plant in Bangalore, India. The sales of its minivans and SUVs have declined in recent months as a result of rising gas prices. The Bangalore plant has the capacity to produce 250 vehicles per day. Dolphin Motors has estimated that monthly demand for its cars is 2,200; for minivans, 1,100 per month; and for SUVs, 600 per month.
 - a. If a mixed-model production schedule is used, how many of each model will be produced to meet demand?
 - b. How many times per day will the production cycle be repeated?
13. The Standard Herald Motor Company is a fictional producer of three types of vehicles/cars in a single assembly line: the sedan (S), the hatchback (H), and the SUV (V). The plant manager at Standard Herald wants to implement uniform production and mixed-model scheduling. The company has orders for 800 sedans, 500 hatchbacks, and 300 SUVs next month. The plant operates 25 days per month and has the capacity to produce 200 vehicles per day.
 - a. If a mixed-model production schedule is used, what assembly sequence would the plant manager use?
 - b. How many times per day would the assembly sequence be repeated?
14. The fictitious Cool Air Inc. assembles three models (A, B, and C) of air conditioners. The production manager at Cool Air plant wants to implement uniform production and mixed-model scheduling. The company has demand forecasts for 500 units of Model A, 350 for Model B, and 200 units for Model C next month. The plant operates 25 days per month and has the capacity to produce 150 air conditioners per day.
 - a. If a mixed-model production schedule is used, what assembly sequence would the production manager use?
 - b. How many times per day would the assembly sequence be repeated?
15. The same definition of value stream holds true for the office just as it does for the automobile factory, although in an office, it is much harder to see. The easiest value streams to see in an office environment are the ones that are triggered by a piece of paper. Office value streams are by the receipt of a request for a quote, sales order, invoice, job application, benefit claim, procurement request, and so forth. You can then follow the progress of that piece of paper just like you could follow the progress of an automobile being made in a factory. Each activity that occurs in the processing of that piece of paper adds (or subtracts) value just like adding a part to an automobile. For example, processing a job application can have the following activities:
 - Screening the application
 - Scheduling a phone interview with the applicant
 - Conducting a phone interview with the applicant
 - Scheduling a person-to-person interview with the applicant
 - Conducting a person-to-person interview with the applicant
 - Making a hiring decision about the applicant

Each activity occurs in a new-hire value stream that produces value in the form of hired employees. It has a specific order in which it must occur. The application screening and phone interviews add incremental value because they assist in improving the quality of candidates selected for the person-to-person interviews.

Create a value stream map for the applicant example. You can use the value stream mapping symbols provided in Appendix 14.1.

CASE STUDY 14.1 LEAN SUSTAINABLE SUPPLY CHAINS AT UNILEVER

Unilever (London, UK) is one of the world's largest manufacturers of consumer products, with over 400 brands ranging from food products to cleaning and personal hygiene products. In fact, on any given day, 2.5 billion people around the planet are using one of Unilever's products. Seven out of every ten households around the world contain at least one Unilever product, including recognizable brands like Lipton, Knorr, Dove, Axe, Suave, Hellmann's, and Omo. Whether marketing premium-quality ice cream or industrial-strength detergents, Unilever's 2017 market capitalization of \$172 billion makes it one of the most valuable companies in the world.

Unilever has long been committed to corporate social responsibility, including managing a global supply chain that emphasizes sustainability and lean practices. Consider just some of their initiatives:

1. Unilever has sustainability at the very heart of its business model, extending all the way through the supply chain from distribution to procurement. For example, by 2020, Unilever expects to sustainably source 100% of its raw materials, even those used for packaging.
2. Unilever's pursuit of environmental responsibility even reaches out to consumers, by developing products such as washing powders that are effective with minimal quantities of water.
3. Unilever also recognizes the sustainability impacts of its internal supply chain activities. Through initiatives such as sustainable power utilization, 600 tons of carbon was removed from the firm's supply chain over a 3-year period, while also reducing supply chain costs.

Unilever's lean supply chain strategy is centered on five pillars—innovation, sustainability, service, value, and capacity. Unilever identified 200 of its most important suppliers with whom it decided to work “much more closely.” According to the company's vice president of procurement, Biswaranjan Sen, the goal has been to work ever more closely with suppliers in order to gain mutual advantage. “In the past three years, about 70 percent of our innovations have been contributions from our suppliers,” said Sen. This has resulted in over \$1.5 billion in savings to Unilever itself. “So it's been quite a successful journey for us in the way that these collaborations have played out.”

Most recently, Unilever came up with an innovative way to tweak their global supply chain strategy. To develop further innovation, Sen said Unilever is working to encourage its suppliers to work together, instead of in a one-on-one relationship with the company. “Historically we were operating in a model where Unilever sits at the middle of the innovation chain and we have one-to-one relationships with our supplier partners,” he said. “We've just started . . . working with three or four suppliers who are

working on the biggest opportunities we have in our business, and at the same time they are working collaboratively amongst themselves, so Unilever is not the hub in the middle.”

The second development is to “change the value discussion . . . by applying principles of lean to remove value-added costs.” Sen explained Unilever is working with select suppliers to look at whether there are areas where the company can buy better than they can, and what the business can do to help them with manufacturing. This allows an “integrated value chain approach,” which applies the best principles of lean not only to our operations but to the operations of supply chain partners.

Spending time studying Unilever's approach to its sustainable lean global supply chain practices offers some valuable lessons:

1. Adopting sustainable practices is a cost saver. Despite the common assumption that a company can be efficient (cost minded) or it can focus on sustainability but it cannot do both, Unilever shows how to work with suppliers (and get them to work with each other in collaborative relationships) to bring advantages to both the environment and the bottom line.
2. The biggest challenges lie in the parts of the supply chain that a firm may have little control over, but that shouldn't stop them from targeting sustainability in areas such as customer and supplier behavior.

Unilever is convinced that lean sustainability is a critical growth strategy for a fast-moving consumer products company. Their vision is to double in size as a company by 2020, while leaving a smaller carbon footprint and placing less demand on the environment than it does today. To make this happen, they recognize that success with sustainability requires significant change, not only to operations but to the organization's (and supply chain partners') culture and way of thinking. Making this work requires a total alignment with supply chain partners, which has meant that Unilever was forced to part ways with some suppliers unable or unwilling to share their customer's mission and vision. Their no-nonsense approach, along with the appointment of a Chief Sustainability Officer heading a division devoted to sustainable strategy, shows that Unilever's executive team has fully accepted and committed to the need for lean sustainable operations.³²

Questions

1. “A chain is only as strong as its weakest link.” Apply this principle to Unilever's idea of encouraging collaborative partnerships among its supply chain members. How can this approach backfire, particularly if Unilever removes itself from “the hub in the middle”?

2. Comment on the statement that “adopting sustainable practices is a cost saver.” What are some ways that sustainability can lead to cost savings?
3. How have lean principles improved Unilever’s already world-class supply chain practices?

CASE STUDY 14.2 TAL APPAREL AND JCPENNEY

TAL Apparel Limited, a shirt maker in Hong Kong (P.R. China), brings a unique perspective to its approach to solving operations and supply chain problems. In 1947, the company’s owner, C.C. Lee, started his first spinning mill in Hong Kong. Over the years, he set up several textile mills, including fabric finishing mills, and by the early 1960s had extended his operations into garment making and founded Textile Alliance Limited (TAL). Since the 1980s, when TAL Apparel Limited was formed, it has been among the foremost innovators in the manufacturing and supply of apparel for some of the best-known companies in North America and Europe.

How big is the company? TAL has established relationships with Banana Republic (division of Gap Inc., San Francisco, CA), Brooks Brothers (New York, NY), L.L. Bean (Freeport, ME), Lands’ End (Dodgeville, WI), and Calvin Klein (subsidiary of PVH Corp., New York, NY). TAL’s relationship with the retail giant JCPenney (J. C. Penney Company, Plano, TX) is a particularly interesting partnership. Like all major retailers, JCPenney has been under huge pressure to carry lower quantities of goods in stock. It has done this by outsourcing its warehousing and stock replenishment. TAL offered to work with JCPenney to streamline the retailer’s operations and take pressure off the firm by handling its reorder operations, forecasting, and inventory management. JCPenney agreed to the arrangement. As a result, JCPenney stores carry almost no extra stock of house-brand dress shirts because TAL collects all point-of-sale data directly from the stores and determines how many replacement shirts to make, and in what styles, colors, and sizes. TAL then sends these quantities directly to the individual stores, bypassing the need for JCPenney to operate large central warehouses.

Suppose, for example, that a JCPenney store in Paramus, New Jersey, sells two white shirts and three blue shirts of a different style on a Saturday, leaving no more blue shirts in stock at the store. TAL’s computer system in Hong Kong receives this information instantly and, based on past sales information, calculates the ideal mixture of shirt styles, colors, and sizes for that brand at the Paramus store.

Within 2 days, a factory in Taiwan has received the order to produce and ship the replacement shirts directly to the store.

JCPenney has been willing to maintain this partnership because TAL can instantly do what used to take JCPenney long lead times and extensive warehousing operations to accomplish. Furthermore, because they are linked in real time, any changes in sales generate instant responses. TAL ensures that JCPenney is never without replacement stock.

TAL also removes the guesswork when it comes to forecasting fashion changes and adjusts JCPenney’s stock to meet them. TAL’s design teams in Dallas and New York can design a new style, give their orders directly to the company’s factories in China, and produce 100,000 shirts for a test run in less than 4 weeks. After analyzing the sales data, it is TAL, not JCPenney, that adjusts the retailer’s orders and decides how many of the new shirts to make and ship. With TAL managing the entire process, from design to ordering yarn to manufacturing, the firm can roll out new brands in 4 months, something that would take JCPenney much longer to accomplish.

The TAL/JCPenney relationship is one that illustrates the positive attributes of lean global supply chains: mutual trust, a commitment to innovative practices, instant information processing, and a philosophy of continuous improvement to streamline the resupply cycle.³³

Questions

1. What are the main advantages of letting a company like TAL manage your inventory and reorder systems? What are the major disadvantages?
2. How does TAL achieve integration in its supply chain? What are the critical success factors that make the supply chain work?
3. How does the partnership with TAL help JCPenney achieve a lean service philosophy?

VIDEO CASE

Watch this video case to learn about how SAGE Publishing cultivates lean systems to make processes more efficient.








CRITICAL THINKING EXERCISES

1. Go to Oracle’s (Oracle Corporation, Redwood City, CA) website (<https://www.oracle.com/index.html>) and read about its software applications for retailers. Thousands of retail and wholesale distribution companies around the world rely on Oracle for maximum flexibility and profitability. How does the software use sales and inventory data to help retailers accomplish lean supply chain operations?

- Go to GE's website (<http://www.ge.com/>). How is GE's corporate slogan "Imagination at Work" consistent with its commitment to Six Sigma? What are the key concepts of Six Sigma as defined by GE?
- Imagine you work for a company that provides lean operations and logistical solutions for business around the globe. Watch the video "Kanban Logistics—A Top 3PL Company." What operations management-related job opportunities does the company offer?






APPENDIX 14.1: VALUE STREAM MAPPING SYMBOLS






There are many variations of value stream mapping symbols. The following table shows the most common symbols. You can also create your own symbols for specialized applications.


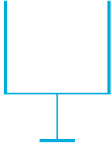


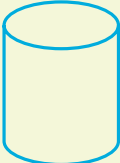


Process Symbols	
 <p>Customer/Supplier</p>	This icon represents the supplier when it appears in the upper left side of the map, which is the usual starting point for material flows. This icon represents a customer when it appears in the upper right side of the map, which is the usual end point for product flows.
 <p>Dedicated Process</p>	This icon represents a process, operation, machine, or department through which material flows. Instead of indicating every process, which could make the map unwieldy, one icon is typically used to indicate the processes in an entire department. In the case of assembly with several connected workstations, even if some WIP inventory accumulates between machines (or stations), the entire line would show as a single box. If there are separate operations, where one is disconnected from the next, inventory between and batch transfers, then use multiple boxes.
 <p>Shared Process</p>	This is a process operation, department, or work center that other value stream families share. Estimate the number of operators required for the value stream being mapped, not for the number of operators required for processing all products.
 <p>Cell</p>	This symbol indicates that multiple processes are integrated in a manufacturing cell. The cells usually process a limited family of similar products or a single product.
Material Symbols	
 <p>Inventory</p>	These icons show the inventory between two processes. The amount of inventory is noted beneath the triangle. The icon also represents storage for raw materials and finished goods. If there is more than one inventory accumulation, use an icon for each.
 <p>Shipments</p>	This icon can represent the movement of raw materials from suppliers to the firm or the movement of finished goods from the firm to customers.
 <p>Push Arrow</p>	This icon represents the pushing of material from one process to the next process.

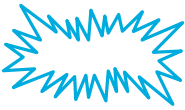

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Material Symbols	
 <p>Supermarket</p>	<p>This is an inventory supermarket (Kanban stockpoint). Like a supermarket, a small amount of inventory is available. One or more downstream workers come to the supermarket to pick out what they need. The upstream work center then replenishes the stock in the supermarket. A supermarket reduces overproduction by limiting the total inventory.</p>
 <p>Material Pull</p>	<p>Supermarkets connect to downstream processes with this pull icon, which indicates the physical removal of inventory.</p>
<p>MAX=XX</p>  <p>FIFO Lane</p>	<p>This icon is used when processes are connected with a first-in–first-out inventory system that limits input. The icon shows the maximum possible inventory.</p>
 <p>Safety Stock</p>	<p>This icon represents safety stock.</p>
 <p>External Shipment</p>	<p>This icon indicates shipments from suppliers or to customers using external transportation.</p>


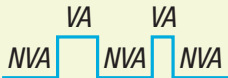
Information Symbols	
 <p>Production Control</p>	<p>This icon represents central production scheduling or control department, person, or operation.</p>
 <p>Manual Info</p>	<p>A straight, thin arrow shows the general flow of information from memos, reports, or conversations. The frequency of the flow and other information sometimes appear on the symbol as well.</p>
 <p>Electronic Info</p>	<p>This wiggly arrow represents an electronic flow of information via an electronic data interchange (EDI), the Internet, intranets, or other electronic medium. It can also indicate the frequency of the information exchange.</p>
 <p>Production Kanban</p>	<p>This icon represents a production Kanban.</p>
 <p>Withdrawal Kanban</p>	<p>This icon represents a withdrawal Kanban.</p>

Information Symbols	
 <p>Signal Kanban</p>	<p>This icon is used whenever the on-hand inventory levels in the supermarket between two processes drops to a trigger, or minimum, point. When a triangle Kanban arrives at a supplying process, it signals a changeover and production of a predetermined batch size of the part noted on the Kanban. It is also referred to as one-per-batch Kanban.</p>
 <p>Kanban Post</p>	<p>This icon represents a location where Kanban signals reside for pickup. The icon is often used with two-card systems to exchange withdrawal and production Kanban cards.</p>
 <p>Sequenced Pull</p>	<p>This icon represents a pull system that gives instruction to subassembly processes to produce a predetermined type and quantity of product, typically one unit, without using a supermarket.</p>
 <p>Load Leveling</p>	<p>This icon is a tool to batch Kanbans to level out the production volume and mixture of products over a period of time</p>
 <p>MRP/ERP</p>	<p>This icon represents an MRP/ERP or other centralized systems.</p>
 <p>Go See</p>	<p>This icon represents the gathering of information through visual means.</p>
 <p>Verbal Information</p>	<p>This icon represents verbal or personal information flow.</p>

General Symbols	
 <p>Kaizen Burst</p>	<p>This icon is used to highlight improvement needs and plan kaizen workshops at specific processes that are critical to achieving a firm's future-state value stream map.</p>
 <p>Operator</p>	<p>This icon represents an operator. It shows the number of operators required to process a part family at a particular workstation.</p>

(Continued)

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General Symbols	
 <p>Other</p>	This icon indicates other information needed for the production process.
 <p>Timeline</p>	This icon represents a timeline. You can use it to calculate the lead time and the total cycle time.

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APPENDIX 14.2: STEPS FOR DEVELOPING A VALUE STREAM MAP

The following steps can be used to develop a VSM.

A. Draw the Current Map

To help you draw the map, gather a team of people who both manage and support the various parts of the value stream. Be sure to include people who actually do the work and not just the managers or team leaders; otherwise, you risk creating a VSM that shows what *should* happen rather than what actually *does* happen.

- Brainstorm with people who are involved, both internally and externally, to determine what is needed to deliver the product or fulfill the customer's needs. Identify the tasks or activities needed to produce the products that meet those needs, and eliminate any tasks that don't need to be done or add value. Some firms video or photograph their systems and then have employees study them to brainstorm ways to eliminate unnecessary activities.
- Put the tasks in order, as much as possible, and include the costs and actual working time required for each task. This will give you a picture of how long it takes and how much it costs to do each task (and, ultimately, the entire, end-to-end process).
- Look at the delays in between stages of the process (for example, the length of time a task sits in someone's inbox), and add in that time.

Depending on your operations, any of these tasks could be the subject of its own value stream map, which is why defining scope is so important.

B. Assess the Current Value Stream

In this step, you analyze whether each activity in the process is adding value. Value-add activities change an item and make it worth

more to the customer. Car assembly is a perfect example: As the car body moves along the production line, more and more pieces or assemblies are added, making it more complete. Eventually, it becomes a fully operational vehicle that people will buy. Each step adds value (although clearly the most value is added when the final component is installed!). This is where you can look for lean improvement opportunities.

- At each point in the map, ask yourself, "Does this activity add value?"
- Identify your value-add points.
- Identify your non-value-add points (for example, places where there are long lead times, material is stored, or redundant or excessive paperwork is slowing a task).
- Determine which non-value-add points are still necessary (for example, for meeting regulatory requirements, addressing other compliance issues, and ensuring worker safety).

C. Create a Future-State Value Stream Map

Map how you want your improved process to look in the future. How will the process work after you've eliminated the waste you identified in the previous step? Follow these tips:

- Ask yourself what your leanest competitor would do.
- Look for similar activities, and see whether there's a way to group them.
- Identify bottlenecks and critical events.
- Look for ways to simplify activities that are complex.
- Confirm that assumptions about adding value align with customers; that is, work to verify that customers actually value each transformation step.

- Look for common forms of waste, such as these:
 - Moving product and materials inefficiently
 - Using equipment and people unnecessarily
 - Keeping too much or too little inventory
 - Performing inefficient quality checks
 - Stockpiling finished goods
 - Adding features or conducting processing the customer does not value

Using these steps, you can critically review current operations with VSM. Here are some opportunities for improvement in the example shown in Figure 14.1:

- Eliminate redundant approvals or move them earlier in the process to prevent unnecessary work.
- Improve the flow of information (paper or electronic). For example, as Figure 14.1 shows, it takes a full day for orders to move from order picking, to checking, to packaging. Through improved communications, it may be possible to streamline this process.
- Restructure warehouse operations for efficiency. The system currently requires 3 weeks and 3 days for lead time. Perhaps through improved efficiency, this lead time figure can be trimmed.

D. Create a Plan to Implement the Desired State

When you have identified your objectives, you can develop a plan for change. At this point, many organizations also begin other lean

initiatives, such as kaizen and just-in-time processes. Remember, though, that the time you invest in VSM will pay off only if you follow through with the implementation plan. To do so,

- Use the VSM to communicate your goals and objectives.
- Include people on your VSM team who will work with the new activities. This helps increase their buy-in for the implementation.
- Talk frequently about lean and efficient operations so that it becomes part of your corporate culture.
- Look for ways to reward efficient work and efficiency suggestions.

E. Implement the Plan

Several techniques can be used, but the one that is most frequently used with VSM is a series of kaizen blitzes, each lasting approximately 1 week. A kaizen blitz is a focused, short-term project in which a cross-functional team makes rapid improvements to a process. The blitz involves observing the existing process, attempting new approaches, and measuring the results. The goal is to move you gradually from the current state to the future state.

F. Review the Results, and Repeat

With the new VSM in place, monitor the new process to see that it is leaner and more efficient than the old process. Choose another process for improvement and repeat the steps listed.