

Introduction to Lean Manufacturing

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This publication introduces the reader to a process called *lean manufacturing*, sometimes called the Toyota Production System. The intended audience is manufacturers of forest products, although manufacturers of other types of products will also find this publication useful.

Global Competitiveness

Today, competition in the forest products sector is global. U.S. firms are finding it difficult to compete with those outside the United States that use cheaper labor, cheaper materials, and face fewer regulations while manufacturing similar products. For example, China is highly competitive in forest products manufacturing. Christianson (2004) states that China's share of U.S. furniture imports rose from 8 percent in 1993 to 40 percent in 2003. This trend has continued as the value of Chinese furniture imports to the United States in 2009 increased to \$16 billion (U.S.-China Business Council, 2010). Buehlmann et al. (2003) reported that the U.S. wood furniture industry lost 34,700 workers from 2000 to 2003. The U.S. wood household furniture industry employment fell from 130,000 employees in 1999 to 42,000 employees in 2009 (Bureau of Labor Statistics). The U.S. economy was forecast to lose 900,000 jobs to Chinese imports by 2010 (Kiplinger, 2002). Scott (2010) reported that between 1997 and 2001, growing trade deficits displaced an average of 101,000 jobs per year; and since China entered the World Trade Organization in 2001, the number of jobs displaced increased to an average of 353,000 per year. In 2002 imports of Chinese wood flooring were valued at \$100 million and in 2007 they were valued at more than \$1 billion (FPInnovations, 2010).

To remain competitive, some U.S. companies have begun partnerships consisting of overseas manufacturing with domestic sales and distribution. Typically, companies' products that can be produced in large quantities, and those that have a relatively long lead time between customer order and delivery can be manufactured overseas, while high-margin specialty items made in smaller quantities or those needing shorter lead times are manufactured in the United States.

Lean Manufacturing

Some U.S. companies are embracing a business philosophy known as lean manufacturing to compete successfully in the global market. In the forest products industry, the approach offers firms a management philosophy and business tools that help them become more efficient and, therefore, more competitive. While common in industries such as automotive and aerospace, lean manufacturing is not widespread in the forest products industry, perhaps because the sector traditionally has been conservative in adapting new technologies and methods.

Traditional Manufacturing

Traditional manufacturing segregates different functional operations. Value-added manufacturing facilities, for example, typically arrange engineering, customer service, scheduling, and marketing as separate departments. Processing steps are separated in sequential operations such as rough-cut milling, surfacing (planing/sanding), cut-up operations, finishing operations, and others. In some companies, these various operations take place in different buildings, requiring materials to be transported

over long distances. The final product becomes part of the finished inventory, which takes up space and may need to be moved several times before eventually being loaded onto trucks or railcars and shipped to customers. In addition, work in process (WIP) inventories accumulate anywhere along the manufacturing process chain. These batches of WIP inventory are also often moved before being sent downstream for further processing. It is not unusual to find thousands of components stored in bins. In many cases, no one knows exactly what products and components are in inventory or even if they will ever be used.

Downstream operations frequently find defects that were not detected during upstream manufacturing processes. In many companies, there is little communication between the different operations, and the communication often occurs late. If quality problems occur, upstream operations have already produced large quantities of defective pieces before feedback can be received and the problem corrected. If components are assembled with one or more defective part, then much time and effort have been wasted and costs have greatly increased.

Push versus Pull

This traditional “batch-and-queue” manufacturing method is referred to as a *push system*. Push systems emphasize manufacturing as much product in as little time as possible and “push” the product to the next operation. This type of production manufactures and distributes products based on market forecasts that often are outdated or wrong by the time the product is delivered.

Lead time is defined as the time it takes to deliver a product to the customer after receiving the customer’s order. Lead times increase when setup times are long. Long setup times encourage manufacturers to produce in large batches, producing products that may or may not sell. Parts and finished products are inventoried and moved time and again. The inventory of unwanted products is pushed onto the customer through sales and special incentives.

In contrast, lean manufacturing emphasizes *pulling* the products through the manufacturing process. Pull starts with the customer; that is, nothing is manufactured until the customer orders it. Even within the manufacturing process, the next processing center can be thought of as an internal customer.

Parts are not passed on from one processing station until the next internal customer “pulls” them.

The Seven Wastes

The *lean* in lean manufacturing refers to the elimination of all waste. Waste is defined as any activity that creates no value (Morton and Pentico, 1993; Womack and Jones, 1996)—and value is defined by the customer.

Lean manufacturing derives much of its direction from the methods used by the Japanese automobile manufacturer Toyota. These methods became internationally recognized as a result of Womack, Jones, and Roos book, *The Machine That Changed the World* (1990). They studied the practices of 90 automobile assembly plants in 17 countries to learn about Japanese successes in manufacturing. They reported that the hallmarks of lean production are teamwork, communication, and efficient use of resources. The lean approach for manufacturers is to improve their organizations by focusing on the elimination of any and all *muda*—the Japanese word for waste. The approach focuses on continuous systemwide improvement, not only in the manufacturing division but businesswide, and advocates methods to control the flow of material on the shop floor (Moore and Scheinkopf, 1998).

A few years before *The Machine That Changed the World* was published, Taiichi Ohno, considered by many to be the father of lean manufacturing, published his book, *Toyota Production System* (1988). Ohno explained the main foundations of lean manufacturing. These principles guided the Japanese companies that were described as “world class” by Womack and Jones (1996). Ohno identified seven categories of muda which cover virtually all of the means by which organizations waste or lose money. As described by Ohno (1988), the seven wastes are as follows:

1. Overproduction/early production—producing what the customer does not want.
2. Waiting—idle time when no value is being added to the product or service.
3. Transportation—unnecessary moving or handling, delays in moving material.
4. Inventory—unnecessary stored materials, WIP, finished products.

5. Motion—movement of equipment, inventory, or people that adds no value.
6. Overprocessing—unnecessary processing and procedures that add no value.
7. Defects—producing defective products.

Ray et al. (2006) identified *energy consumption* as an additional area of significant waste in wood-processing operations—or any other industry in which a primary raw material is converted with energy-intensive processes. In such cases, a lean manufacturing approach should include a focus on efficient energy consumption and/or product conversion. A muda-free process is a process that is working correctly. A firm's focus must be on work that creates value for the ultimate customer. Providing the wrong product or service, even with high efficiency and of high quality, is muda. As with every product, the customer is the final judge as to whether the company has created value (Womack and Jones, 1996).

Overall, lean companies work to define value by having dialogues with specific customers about specific products with specific capabilities offered at specific prices. They work at identifying and delivering a quality product that the customer wants. Companies will often restructure their product lines and their management and employees into product teams to make this happen (Womack and Jones, 1996).

The Current State Map

The first step in a companywide lean transformation effort is often to identify the value stream. A value stream map is the tool typically used to show the flow of all of the materials and information as well as the cycle times and wait times involved in making a product. A *current state* (as compared to the *ideal* or desired future state) value stream map is created by visiting each process involved in making a given product in a business. When creating your map, use consistent icons to represent processes, inventories, information, and flows. Although you can create your value-stream map on a computer, many experts state that the best method is to draw it on a sheet of paper that can be rolled out and affixed to the wall. The paper map makes it easy for everyone in a room to visualize the processes, inventories, information, and flows, and allows room to add information to the map. Rother and Shook (1999) suggest the following when creating a current state value stream map:

- Begin with a quick walkthrough. Walk the entire process of material and information flow to get a sense of the flow and sequences.
- Collect current-state information while walking along the actual pathways of material and information flows.
- Begin at the end (shipping) and walk upstream. The downstream processes are most closely related to the customer and will set the pace for the other processes upstream.
- Bring a stopwatch. You will need to collect process and flow times to calculate value-added and non-value-added times (defined below) and record them on the current state map.
- Map the entire value stream yourself; that is, if different people map different segments of the value stream, then no one will understand the whole.
- Use a pencil. Start your rough sketch as you walk through the process. Plan to clean it up and transfer to a larger paper, also using a pencil. Resist the temptation to use a computer program.

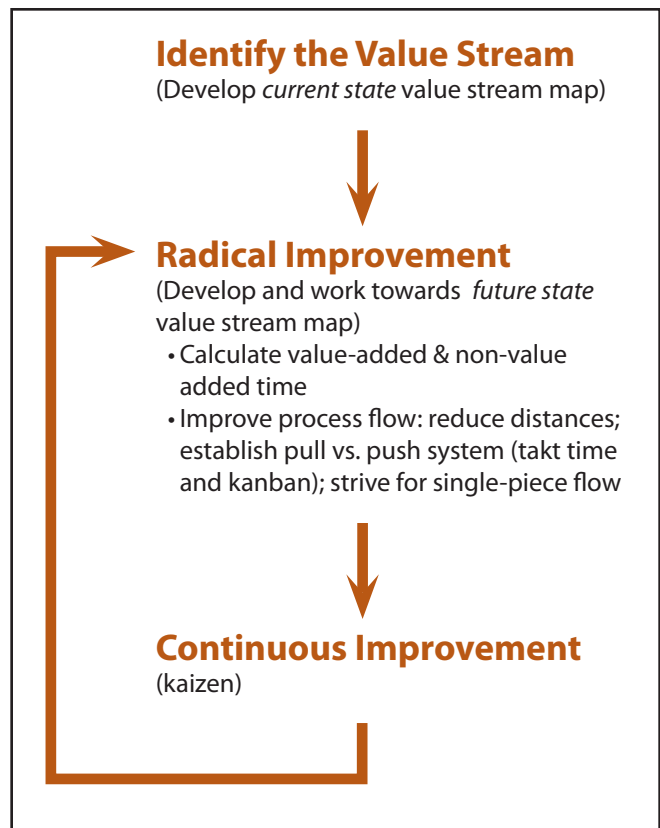


Figure 1. Value stream flowchart.

Kaikaku: Radical Improvement

While creating the current state map, you should be thinking about creating a future state map. Three categories of activities will help you decide how the future state value stream map will look.

For each process you have identified, three categories of activities become apparent:

1. Steps that create value. For manufacturing, these are the processes that change the raw material closer to the form for which customers will pay you; that is, steps that bring the material closer to the final product.
2. Steps that create no value but are necessary because of the current state of the system. For manufacturing, these might include quality inspections, waiting for processing, and some transportation.
3. Steps that create no value and can be immediately eliminated. If the activity does not fall into one of the two preceding categories, then it needs to immediately be stopped.

For each step in the manufacturing process, value-added and non-value-added times are calculated. Value-added time, meaning the time it takes to accomplish activities defined by (1) above, is divided by the total time and multiplied by 100 to calculate the percentage of value-added time. Non-value-added time, which is time spent on activities defined by (2) and (3) above, is divided by the total time and multiplied by 100 to calculate the percentage of non-value-added time (or, more simply, just subtract percentage of value-added time from 100 for the percentage of non-value-added time).

As an example: A sheet of medium-density fiberboard (MDF) was sanded and placed in a stack of MDF sheets. It sat in the stack for 60 minutes (3,600 seconds). It took 5 minutes (300 seconds) to move the stack of sanded sheets by forklift to the router. The sheet sat for 3 hours or 10,800 seconds before it was loaded onto the router. It took 25 seconds to load the sheet onto the router, 1 minute (or 60 seconds) to rout it, and 25 seconds to unload the material from the router. For this series of steps, the percent of value-added and non-value-added time are calculated as follows:

Value-added time as a percent of total time:

$$\frac{60 \text{ seconds}^1}{14,810 \text{ seconds}^2} = 0.00405 \times 100 = 0.41\%$$

¹The time something of value to the customer was being accomplished.

²3,600 + 300 + 10,800 + 25 + 60 + 25

Non-value-added time as a percent of total time:

$$\frac{14,750 \text{ seconds}^1}{14,810 \text{ seconds}} = 0.99595 \times 100 = 99.6\%$$

¹3,600 + 300 + 10,800 + 25 + 25

In this example, 99.6 percent of the time added no recoupable value to the product.

The 60 seconds of actually adding value (routing) fits into category one, above. The 25 seconds it took to load and the 25 seconds it took to unload fit into category two—necessary, but you should be looking at ways to decrease those times. The rest of the time, 14,700 seconds, is a target for immediate elimination.

Kaikaku, or radical improvement, is an intense questioning and reexamining of every aspect of a process. Any steps that can be eliminated immediately—category three—are stopped. Any steps that fall into category two—those that add no value but are currently necessary—become targets for improvement and, whenever possible, elimination.

The next step is to identify the flow of the process. This includes walking and measuring the distance the product must travel through its entire process. Even small operations can have product flows over hundreds of miles long, and much of this flow (and time) adds no value to the product. Part flows in the aerospace industry have been estimated to be tens of thousands of miles long (Moore and Scheinkopf, 1998). The objective is to concentrate on rapid product flow unencumbered by the distance between departments. According to Womack and Jones (1996), the amount of effort, time, space, tools, and inventories needed to design and provide a given service or good can typically be cut in half very quickly, and steady progress can be maintained from this point onward to cut inputs in half again within a few years.

Once value is defined and the value stream is identified, focus on the actual object—specific design, order processing, and product creation. Next, create lean enterprises by ignoring traditional boundaries of

jobs, careers, functions, and firms. And finally, strive to make every operation work on the pull principle.

Pull means that nothing should be produced upstream until the customer asks for it. Inventory is considered muda. Therefore, any product manufactured but not sold is muda. The final customer should pull the product through the system. This is a difficult concept for managers to grasp. In traditional manufacturing, managers focus on lowering production cost per unit, and on machine up-time and utilization rates. This is a push system. They produce all they can, as fast as they can, and push the product through the system. Each machine center is expected to operate at maximum capacity regardless of actual customer demand. After implementing lean techniques, the process is shortened as wasteful steps, wasteful activity within steps, and the distance parts must travel are reduced or eliminated. By becoming lean, companies greatly increase their capacity to produce, and if they remain in a push system, finished inventory will only build more waste. But in a pull system the tendency to overproduce is controlled and activities are directed toward removing excess capacity or increasing the rate of pull (Moore and Scheinkopf, 1998).

Pull is accomplished using two methods, *takt* time and *kanban*. *Takt* is a German word that refers to the beat of music. You might think of the rhythmic tick-tock of a metronome that music students use to stay in time while practicing their instruments. Similarly, takt time is a cycle or rhythm calculated for your manufacturing process based on the needs of the customer. Takt time is used to balance production rates with customer demand. It is calculated by dividing the available production time by the rate of customer demand. For example, in a plant that operates on a single eight-hour shift (480 minutes) with a demand of 120 units/day, the takt time is four minutes: $480/120 = 4$ (Moore and Scheinkopf, 1998). Takt time needs to be defined during each step and any given point in time in relation to demand.

When orders do not require full utilization of equipment and workers, takt time is increased. Manufacturing (machinery) is slowed down and multi-skilled workers can be used elsewhere in the plant. A lean organization does not cut its labor force but instead ensures that its people are multitalented and can be assigned to many different tasks or to produce new products. Note how this philosophy is in direct

conflict with the traditional manufacturing tendency to continuously work as fast as possible and continue to build inventory using uninformed employees who are often skilled at only one job.

Takt time and each resource's progress relative to it are posted for all to view. This is an example of visual control, another lean technique, in which the status of an activity is displayed so every employee can see, make the appropriate conclusions, and, together with their team, take appropriate action (Womack and Jones, 1996). Manufacturing systems' lack of flexibility to respond to changes in takt time is considered muda and becomes a candidate for improvement teams to eliminate. Takt time provides a sense of the desired pace of an organization's output.

Single-piece Flow

A major objective in lean manufacturing is to implement *single-piece flow*, which involves sequentially aligning processes so that items are manufactured one at a time rather than in batches. Single-piece flow improves productivity and increases throughput while reducing lead time, errors, and inventory costs. In manufacturing, single-piece flow is often difficult to achieve. When single-piece flow is not possible, companies striving to become lean use a method called *kanban* to control the amount of inventory in their system. The literal meaning of the word *kanban* in Japanese is "sign board." Kanban is often described as a card that contains information about the lot size, process, quantity, location, and other data about the material. Kanban are used to signal production and link disconnected processes.

Rother and Shook (1999) define two types of kanban: A *production kanban* triggers processing of parts, while a *withdrawal kanban* is a shopping list that instructs the material handler to retrieve and transfer parts. In either case, a kanban system is made up of a set of rules for calculating kanban quantities, routes for withdrawal from stores and delivery to kanban posts, the cycle of kanban collection and delivery, and the material replenishment lead times to support production at "minimum" but "safe" inventory levels. Only kanban can start production, and the quantity produced is strictly regulated—if cards are used, the quantity is listed on the card.

You can probably visualize that kanban does produce safe amounts of WIP inventory. The goal of lean manufacturing is to connect processes so that WIP

inventories are eliminated and one-piece material flow occurs. Thus, a goal of becoming a lean organization is to eliminate kanban. Jeffrey Liker, author of *The Toyota Way* (2004), states that "...experts get very impatient and even irritated when they hear people rave and focus on kanban as if it is the Toyota Production System. Kanban is a fascinating concept and it is fun to watch.... When is the kanban triggered? How are quantities calculated?... The challenge is to develop a learning organization that will find ways to reduce the number of kanban and thereby reduce and finally eliminate the inventory buffer.... So, kanban is something you strive to get rid of, not to be proud of."

However, kanban is often a way for traditional manufacturers with push processing systems to start down the road toward becoming lean. For instance, sawmill operators who begin to focus their daily production targets on actual customer demand instead of obtaining maximum yield are beginning the struggle to understand the benefit of kanban in a wood products context (Ray et al., 2007). What is unique about kanban is that it is self-synchronizing and self-regulating (Eade, 1995).

The Future State Map

After completing a current-state map, the next step is to create a future-state map of your manufacturing process. Base the flow of your process on takt time. If you have to initially maintain safe WIP inventory, use kanban, remembering that this is a candidate for elimination. Identify ways to eliminate non-value-added processes; link your processes to attain continuous single-piece flow. Obviously, to implement

the future-state map, some significant changes to the process will likely be needed—at first, and into the future. This is where the firm embarks on continuous improvement.

Continuous Improvement

The next step is *kaizen* (the Japanese word for improvement)—that is, continuous improvement. You do not stop striving for perfection after initially completing the steps that resulted in reduced effort, time, space, cost, mistakes, and defects while becoming better at offering products and services that the customer wants. Successful lean organizations share information with their employees and continually do *kaizen* to become more efficient at giving customers what they want, when they want it.

Lean manufacturing is a way of thinking about pulling semi-finished and finished products all the way through the supply chain and delivering a high-quality final product to the customer on time.

Toward Leaner Manufacturing

This publication has given a brief overview of the lean management philosophy. It has not covered all the tools of lean manufacturing, nor was it meant to, but it has given the reader an opportunity to see that lean practices are not difficult to apply to business processes. The authors believe that lean manufacturing techniques are easy to understand but that acceptance and application of them in an organization are often difficult. Future articles will cover other lean tools and will delve deeper into the creation and use of the methods mentioned in this publication.

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