Chapter 18 Lean Manufacturing

Objective:
In this chapter, we introduce the fundamentals of Lean Manufacturing. Concepts of waste elimination are discussed. Components for Lean including: Waste identification and elimination (value stream analysis), set-up reduction, part families, cell formation, cell design, batches of one and pull systems are also discussed.

"Perfection is not attainable. But if we chase perfection, we can catch excellence." Vince Lombardi

18.1 Introduction to Lean Manufacturing

Lean manufacturing or **lean production** are reasonably new terms that can be traced to Jim Womack, Daniel Jones and Daniel Roos' book, ***The Machine that changed the world*** [1991]. In the book, the authors examined the manufacturing activities exemplified by the Toyota Production System. **Lean manufacturing** *is the systematic elimination of waste*. As the name implies, lean is focused at cutting "fat" from production activities. It has also been successfully applied to administrative and engineering activities as well. Although lean manufacturing is a relatively new term, many of the tools used in lean can be traced back to Fredrick Taylor and the Gilbreaths at the turn of the 20th century. What Lean has done is to package some well-respected industrial/manufacturing engineering practices into a system that can work in virtually any environment.

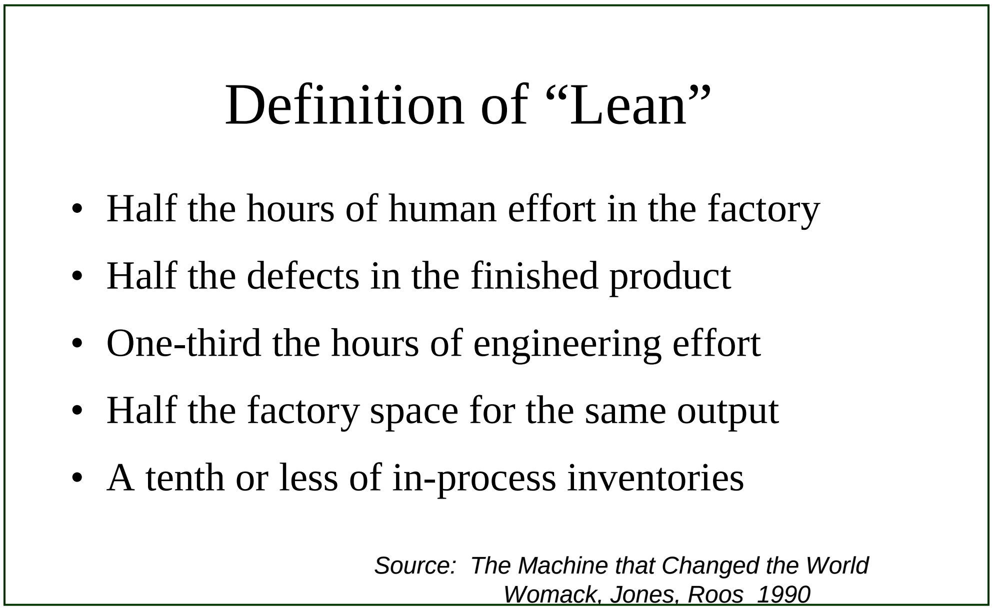
Figure 18.1 provides a definition of lean as a function of the outcomes that one realizes. The definition comes from Womack and it identifies the results rather than the method of lean. In the following sections, the procedures and specifics of lean will be introduced.

18.1.1 The 3 M's of Lean

Lean manufacturing is a Japanese method focused on 3M's. These Ms are: **muda,** *the Japanese word for waste***, mura,** *the Japanese word for inconsistency***,** and **muri,** *the Japanese word for unreasonableness***.** Muda specifically focuses on activities to be eliminated. Within manufacturing, there are categories of waste. **Waste** *is broadly defined as anything that adds cost to the product without adding value to it*. Generally, **muda** (or waste) can be grouped into the following categories:

1. Excess production and early production
2. Delays

3.Movement and transport



Definition of "Lean"

- Half the hours of human effort in the factory
- Half the defects in the finished product
- One-third the hours of engineering effort
- Half the factory space for the same output
- A tenth or less of in-process inventories

Source: The Machine that Changed the World
Womack, Jones, Roos 1990

Figure 18.1 An early definition of Lean.

4.Poor process design
5.Inventory
6.Inefficient performance of a process
7.Making defective items

These wastes are illustrated in Figure 18.2

Excess production results in waste because it captures resources too early and retains the value that is added until the product can be used (sold). In today's highly changing society, many items produced before they can are sold to a specific customer often go obsolete before demand is realized. This means that a perfectly good product is often scrapped because it is obsolete. Producing a product simply to keep a production resource busy (either machine, operator or both) is a practice that should be avoided.

Delays, such as waiting for raw material, also result in the poor use of capacity and increased delivery time. Raw materials and component parts should be completed at approximately the time that they will be required by downstream resources. Too early is not good, but late is even worse.

Movement and transportation should always be kept to a minimum. Material handling is a non-value added process that can result in three outcomes: 1) the product ends up at the right place at the right time and in good condition, 2) the part ends up in the wrong place, and 3) the part is damaged in transit and requires rework or scrap. Two of the three outcomes are no desirable, which further leads to minimizing handling. Because material handling occurs between all operations, when possible, the handling should be integrated into the process, and the transport distances minimized.

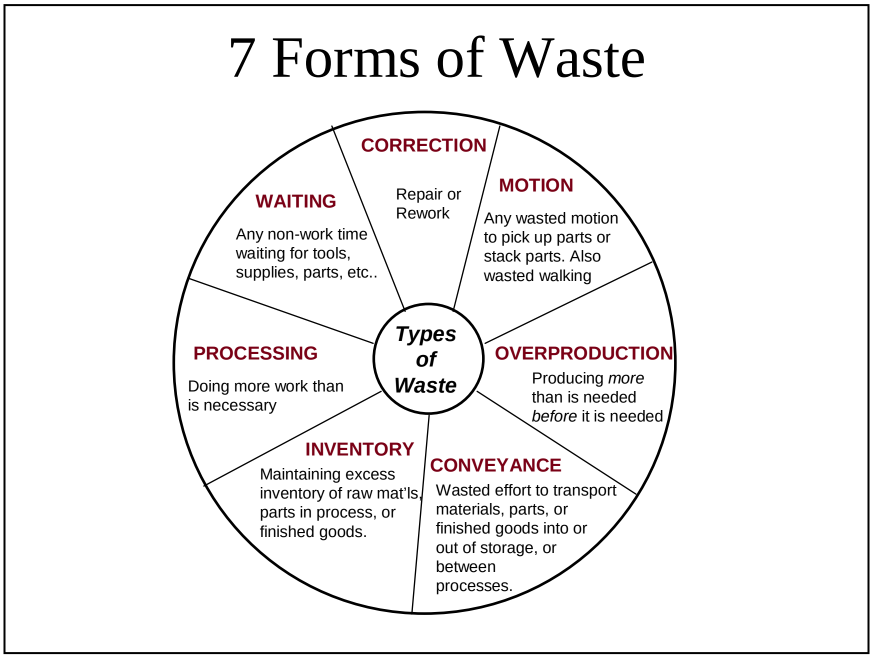


Figure 18.2 The seven Forms of waste.

A poorly designed process results in overuse of manufacturing resources (men and machines). There are no perfect processes in manufacturing. Generally, process improvements are made regularly with new efficiencies embedded within the process. Continuous process improvement is a critical part of Lean Manufacturing.

Excess inventory reduces profitability. Today, it is not uncommon for a manufacturer to store a supplier's product at the production site. The supplier, right up until the time that they are drawn from inventory, owns the materials. In many ways this is advantageous to both the user and supplier. The supplier warehouses his material offsite, and the user does need to commit capital to a large “safety stock” of material.

Insufficient (or poor) process performance always results in the over utilization of manufacturing resources and a more costly product. There is no optimal process in that improvements can always be made; however, many processes operate far below the desired efficiency. Continuous process improvement is necessary for a manufacturing firm to remain competitive. Excess movement or unnecessary part handling should be the first targets of waste elimination.

Poor quality (making defects) is never desirable. Labor and material waste results from producing any defect. Furthermore, the cost of mitigating poor quality (rework) can often exceed the price of the product. A critical balance between processing speed and quality exists. A process should be run as fast as possible without sacrificing acceptable quality.

From the above discussion, it should be obvious that waste is a constant enemy of manufacturing. Waste elimination should be an on-going process that focuses on improving a process regularly. Regular reviews and worker input should be conducted as often as allowable.

The second “M” is for **mura,** or inconsistency. Inconsistency is a problem that increases the variability of manufacturing. **Mura** is evidenced in all manufacturing activities ranging from processing to material handling to engineering to management. Figures 18.3 and 18.4 illustrate some characterization of **mura**.

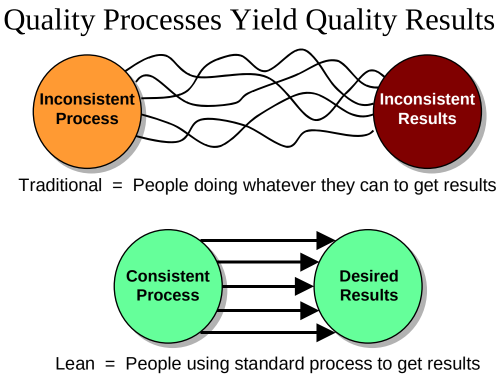


Figure 18.3 Inconsistency is a problem in manufacturing.

Henry Ford - Standards

"To standardize a method is to choose out of the many methods the best one, and use it. Standardization means nothing unless it means standardizing upward.

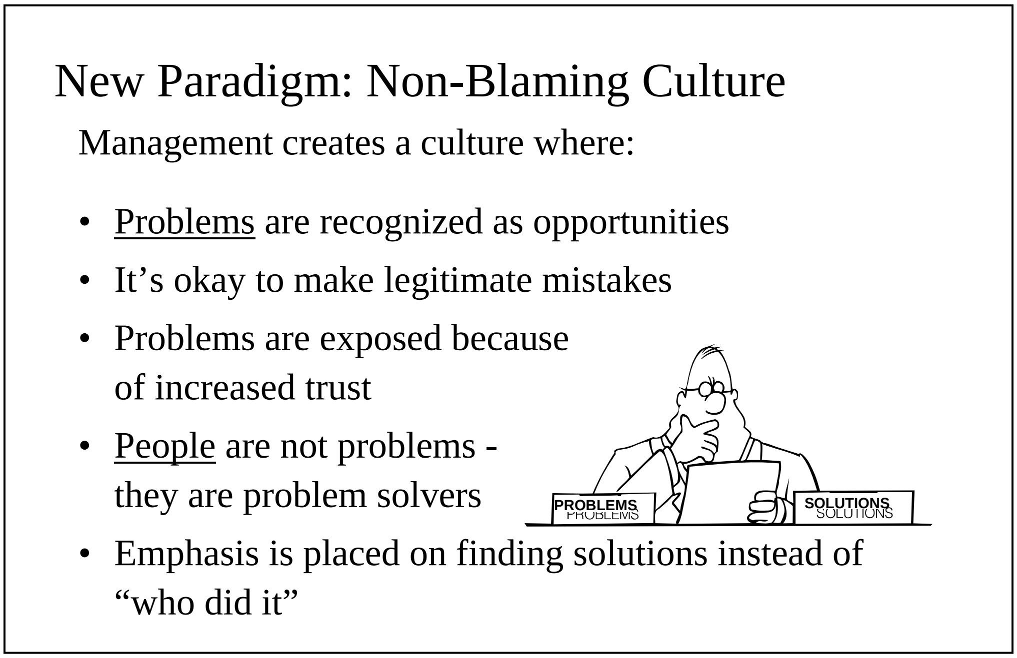
Today's standardization, instead of being a barricade against improvement, is the necessary foundation on which tomorrow's improvement will be based.

If you think of "standardization" as the best that you know today, but which is to be improved tomorrow - you get somewhere. But if you think of standards as confining, then progress stops."

Henry Ford, 1926
Today & Tomorrow

Figure 18.4 Henry Ford on standards (or against inconsistency).

The final "M" is for muri or unreasonableness. Muri applies to a variety of manufacturing and management activities. For instance, Figure 18.5 shows an example of being unreasonable by blaming someone for problems rather than looking at resolution of problems. It is unreasonable to blame rather than mitigate issues. This is true for all manufacturing activities -- do what is reasonable. Don't be emotional!



New Paradigm: Non-Blaming Culture

Management creates a culture where:

- Problems are recognized as opportunities
- It's okay to make legitimate mistakes
- Problems are exposed because of increased trust
- People are not problems - they are problem solvers
- Emphasis is placed on finding solutions instead of "who did it"

Figure 18.5 Be reasonable -- muri.

18.1.2 The 5 S's of Lean

Much of Lean manufacturing is applying "common sense" to manufacturing environments. In implementing Lean, 5 S's are frequently used to assist in the organization of manufacturing. The 5 S's are from Japanesse and are:

- Seiri (sort, necessary items)
- Seiton (set-in-order, efficient placement)
- Seison (sweep, cleanliness)
- Seiketsu (standardize, cont. improvement)
- Shitsuke (sustain, discipline)

These concepts are illustrated in Figure 18.6.

Figure 18.6. The 5 S's of Lean.

18.2 Laying out a Lean Production Facility

Another critical aspect of Lean is the organization of the production facility. Since one of the keys to lean is waste elimination, the layout of any system should be arranged in such manners that waste of motion (material handling and material transport) and elimination of inventory is part of the object for the layout. You may recall that there are two traditional forms of layout in manufacturing: process and product. In a **process layout (or job shop as it is informally called)**, *machines are organized and clustered by type*, where typically all mills are in one department, all lathes in another, etc. In a **product layout (or flow shop)**, *machines are located so that sequential operations are performed at adjacent machines*. These types of layout are illustrated in Figures 18.7 and 18.8 respectively.

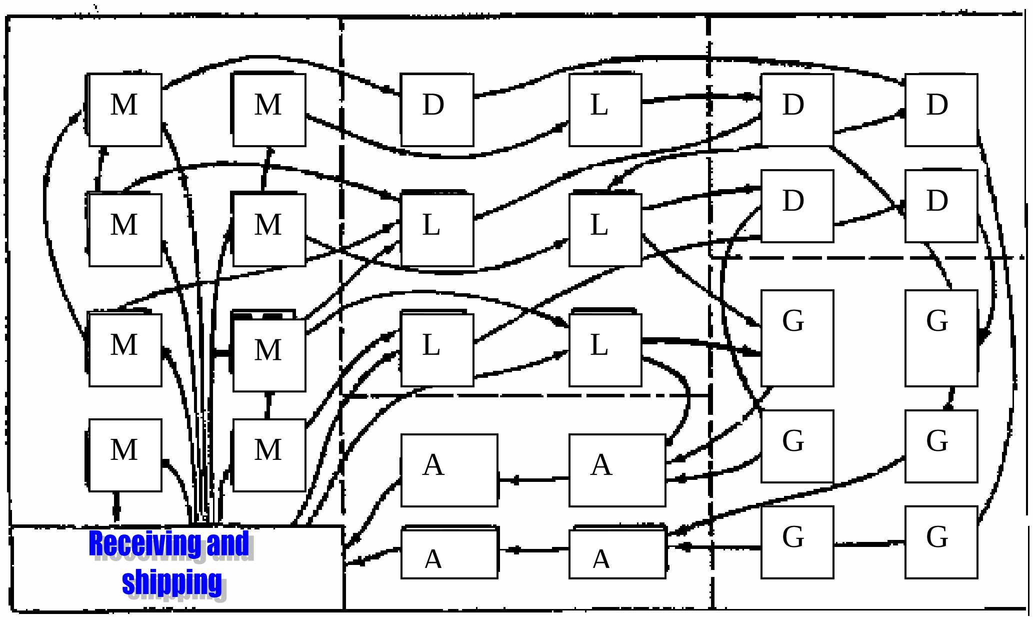


Figure 18.7 A typical process or job shop layout.

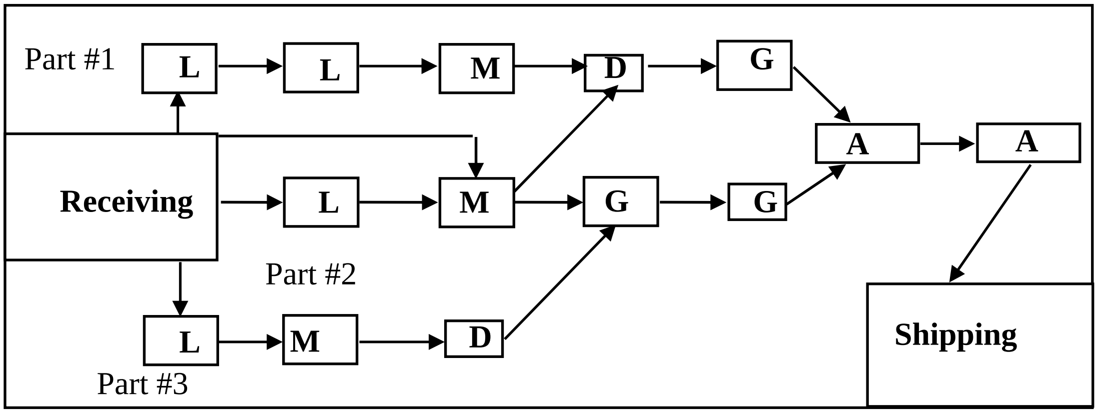


Figure 18. 8 A typical product or flow shop layout.

Process layout is typically employed for a large variety of products that are made in very small batches (ones or twos). The advantages of Process Layout are: 1) the flexibility of the system to product almost any part that fits within the volumemetric boundaries of the machines, 2) an in depth understanding of a specific process can be obtained, and 3) some tooling and fixtures can be shared. The disadvantages of process layout are: 1) the spaghetti flow is difficult to manage and control, 2) there is usually a lot of inventory in front of each machine, 3) set up is usually expensive, 4) material handling times are large, and 5) it is difficult to automate these types of systems.

Product layout systems are used effectively for the economic production of high volume goods. The advantages of these systems are: 1) large batches can be produced inexpensively, 2) material handling is minimal, 3) in-process materials are minimized, 4) it is easy to control these systems, and 5) automation is more achievable and justifiable. The disadvantages of these systems are: 1) they are inflexible, in that only one or very few products can be produced on them, 2) set up time for these systems is very large, and 3) duplicate tooling is required to replace worn tooling so that maintenance can be minimized.

Process systems work effectively on “one of a kind” type of production. As batches get larger, these systems fail to produce the required “economies of scale”, and that production time and cost remains relatively constant. Product systems work very effectively on single item production. For instance, high volume products like soda, beer, canned foods, and cigarettes are effectively produced on these flow systems. The reason that these items are so inexpensive is in part because of the way they are produced. Unfortunately, the high capital cost and long set-up for these systems mandates large volumes to offset these initial cost and then the changeover costs for the system.

In general, very low volume items should be produced on process type systems, and very high volume items should be produced on product type systems. A problem facing most manufacturers is that the general trend today is for medium volume batches that change regularly. This means that process and product layout fails to meet the requirements for much of what is demanded today. The result is that a hybrid of the two systems has been developed. It is called a manufacturing cell. See Figure 18.9 and 18.10. Cells are used to make families of parts, rather than just one-of-a-kinds or high volume items. Cells are logical clusters of machines organized to produce a variety of parts requiring the same equipment type, tooling and fixtures. Cells are intended to provide as many of the benefits of process and product layouts as possible.

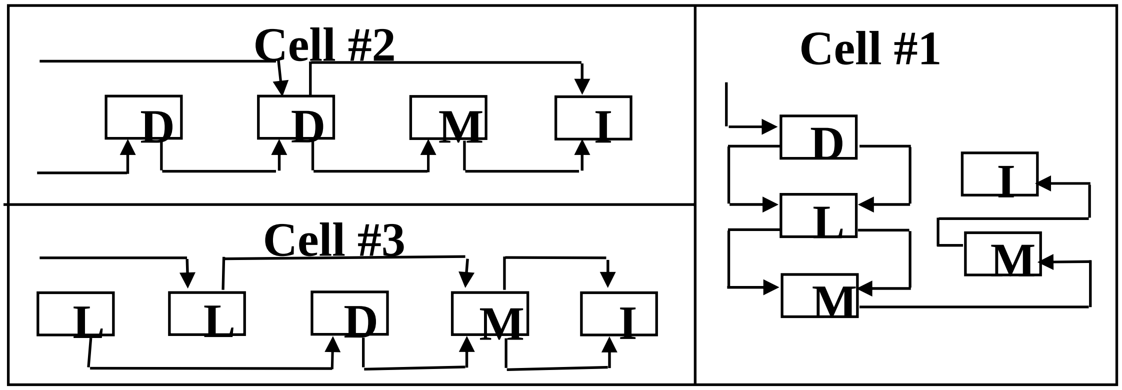


Figure 18.9 A manufacturing cellular layout.

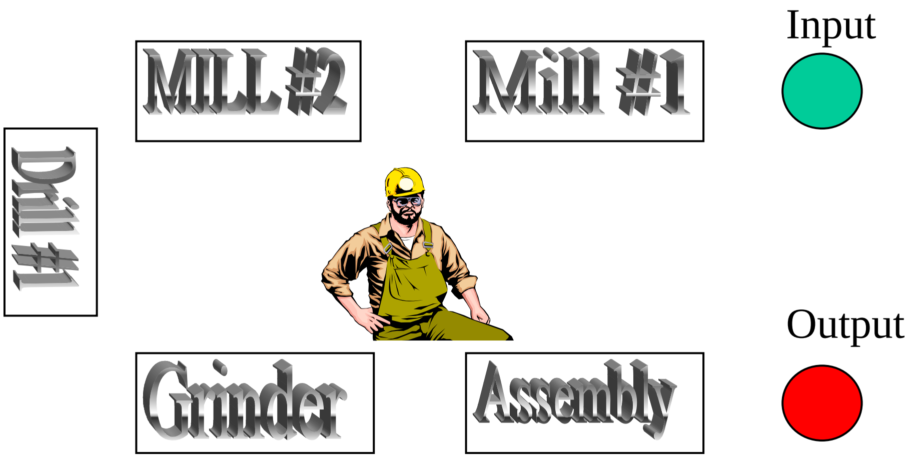


Figure 18.10 A "U – shaped" manufacturing cell.

In many ways, cellular layout separates and groups products within a manufacturing system into smaller units. The strategy here is to identify parts that belong to the same "product families". A **product family** *is a group of products that normally look similar and require the same (or similar) processing steps to produce*. Traditionally, designers have formed product families by grouping products that provide similar functions into a common product family. Examples might be: springs, clips, brackets, etc. The problem however becomes one where functional names may create very large families (for instance, brackets typically form a large portion of products the automotive industries make) or function may require different processes as the size scales**. Group technology (GT)** was introduced as a method to characterize products into code-able families. A descriptive code was used to characterize the product geometry, function and/or method used to make the part. As database systems have become more powerful, the code has been replaced with descriptive fields in a database. Today, more formal techniques are used to identify cells. In the following section, a methodology to organize factories, machines, tooling will be presented.

18.3 Setup reduction

One of the methods employed in cutting fat from a lean production system is to reduce the time required to setup production equipment. Perhaps the best know method for setup reduction is SMED or the Single Minute Exchange of Dies system developed by [Shingeo Shingo]. The system has been widely applied in automotive and other industries. It received its name because when used effectively, setup times of a day or more for manufacturing presses can be lowered to minutes. The system is far more complicated then the brief discussion below would indicate. This section is only intended to provide an overview of SMED.

SMED is a process that begins with detailing what happens to a machine between batches of parts. For example, NC machines have become popular in part because setup between lots **can** be very small. If the adjacent lots use the same tooling and fixturing, the only requirement is to download a part program corresponding to the new part lot. Using a network and/or serial communication, this can be done in a fraction of a second. For a conventional machine, fixed stops might have to be remounted and adjusted, and the setup process might take hours or days. For the same NC machines, the tooling required for the new lot may change completely requiring that all new tool holders and tools be reloaded onto the machine, and then requalified with respect to a new or existing fixture. If new tooling is necessary, it may take several hours to load and install the tooling. In order to begin setup reduction activities, the first step of the process is to document all of the requirements and specifics for adjacent lots or parts.

Once setup is documented, each setup element is analyzed in order to determine if the element is an ***internal*** or ***external*** element. An ***internal element*** *is one that requires the equipment resource*. An ***external element*** *is one that can be done without the equipment or external to the equipment*. For instance in the NC example, qualifying the tooling with respect to the part or fixture would be an ***internal element***. That is, the machine resource is necessary in order to set the location of the tool with respect to the part. On the other hand, new tools could be loaded into tool holders or collects ***external*** to the operation of the machine. Loading the tools into tool holders would be an ***external element.***

The key here is to keep critical resources operating as long as possible. In order to accomplish this, ***external elements*** should be conducted in parallel with machining. For our NC example, the operator would load tools into tool holders while the NC machine was producing parts from a previous lot. This eliminates non-productive machine time. Please note here that the time for change-over is not idle time, but rather non-productive time. This process is illustrated in Figure 18.11.

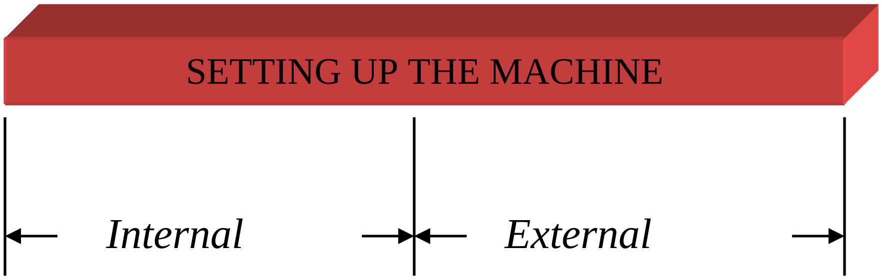


Figure 18.11 Setup elements used in SMED.

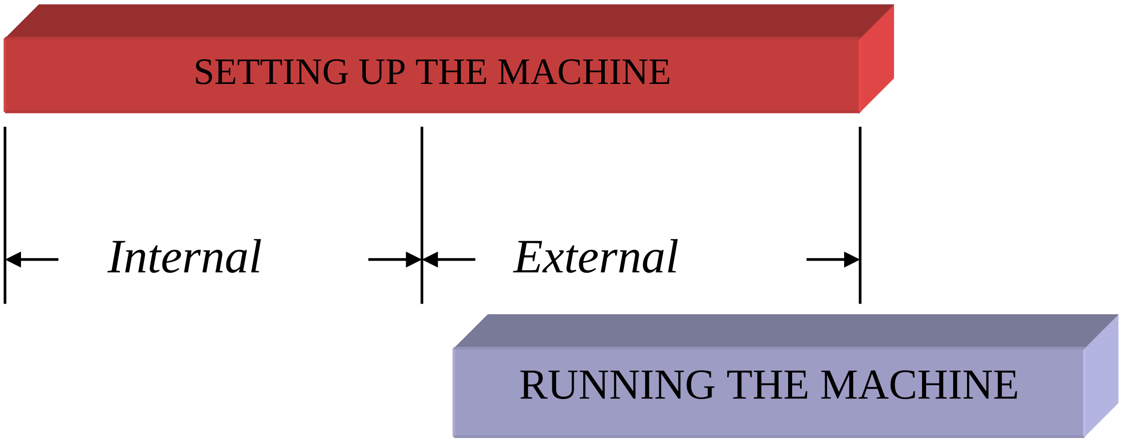


Figure 18.12 Running a machine while external elements are complete.

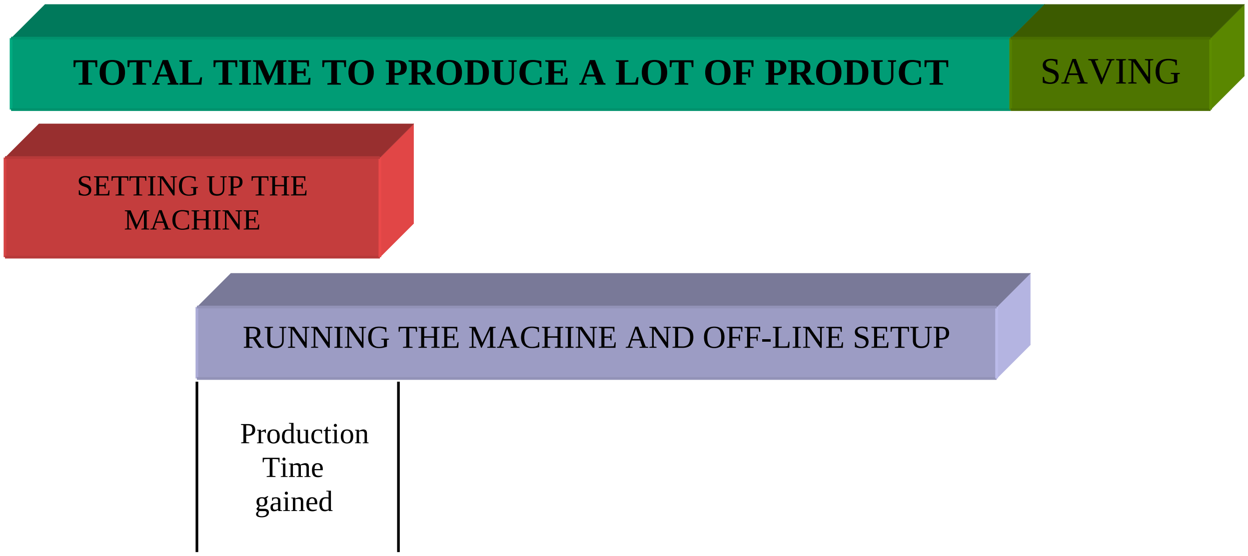


Figure 18.13 Saving time using external element reduction

Using internal and external elements is one part of setup reduction. In addition to using external elements in parallel, applying good methods engineering practice is also critical to reduce setup time. For instance, screw connectors can require a long time to remove, fasten and torque to the proper set point.

In a recent industry activity, a set of presses was found to be idle more frequently than they were producing good product. After investigating the situation, it was discovered that a much greater variety of products were being produced on the presses. This meant that the batch sizes were smaller, and the setups were more frequent. The net result was that average production runs were 1-2 days, which was about the same time required to setup the presses. This resulted in expensive equipment that was producing good product less than 50% of the time. In analyzing the situation, standard punch and die sets were being used. They were kitted and assembled using standard threaded nuts and bolts. Because there had been a problem with tools being taken, the company had standardized on two head sizes and physically chained two open-end wrenches to the presses for use in setup. The type of wrench used is shown in Figure 18.14.

Figure 18.14 Common wrenches used for setup.

Several recommendations were made to the company. The first was that **if** screw fasteners had to be used, sockets sets and power tools would lessen setup time significantly. In a quick economic analysis, it was determined that both sockets and power drivers would pay for themselves in a single setup. This tooling was purchased and setup time was reduced by about 10%. The screw fasteners were then replaced with “quick-lock” mechanisms like those shown in Figure 18.15. These simple changes (external elements done in parallel and methods improvements) brought setup time down from 1-2 days to 4-6 hours within weeks. With continued work on setup reduction, the year-end target was set to reducing setup time to less than one hour. This would increase the actual production time by just about 100%

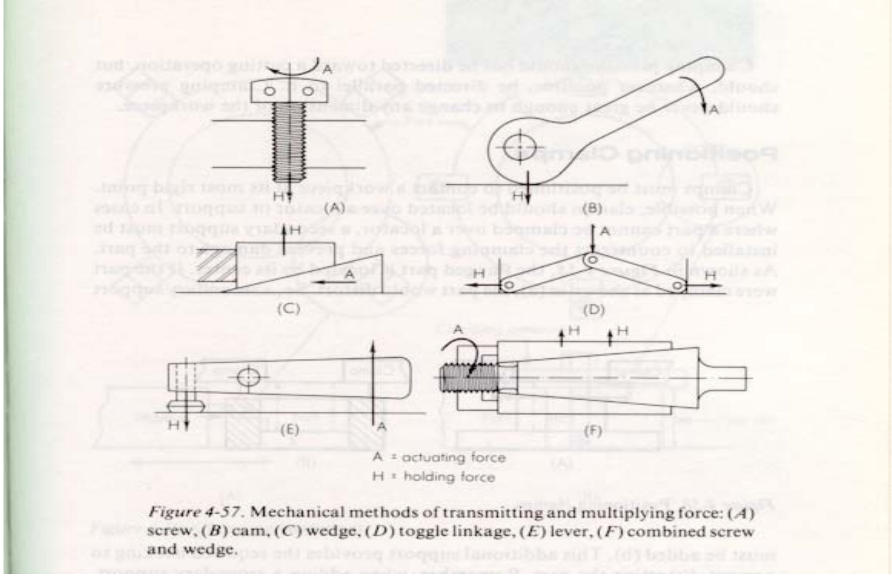


Figure 4-57. Mechanical methods of transmitting and multiplying force: (*A*) screw, (*B*) cam, (*C*) wedge, (*D*) toggle linkage, (*E*) lever, (*F*) combined screw and wedge.

Figure 18.15 Devices that can be used to replace screw fasteners.

18.4 Controlling a Lean Production Facility

The foundation of Lean manufacturing is to create efficient methods for producing goods. Eliminating waste, minimizing inconsistencies and taking a reasonable approach to producing products and managing facilities is the key to lean manufacturing. The largest portion of time a part spends in a manufacturing facility is spent waiting rather than having value added. The result is that Lean Manufacturing has become more than just eliminating waste. A new key has become reducing lot sizes and applying better production control methods. In this section, we will introduce several production control techniques that have been used as part of lean developments.

In traditional factory control, “push” control was the strategy used to regulate parts in a production environment. That is, when an operation was complete at a machine, the product or part was pushed to the next machine. If one machine works slower than the other machines in the system then product accumulates in front of the machine until no more room exists and the machine begins to physically “block” the flow of parts from the feeding machine(s). Many of the Materials Requirements Planning (MRP) software systems use this type of strategy. This type of control is easy to use, but produces lots of inventory and imbalance in the production operations. Figure 18.16 illustrates how a Push system works. In this type of control, both information and materials are pushed forward.

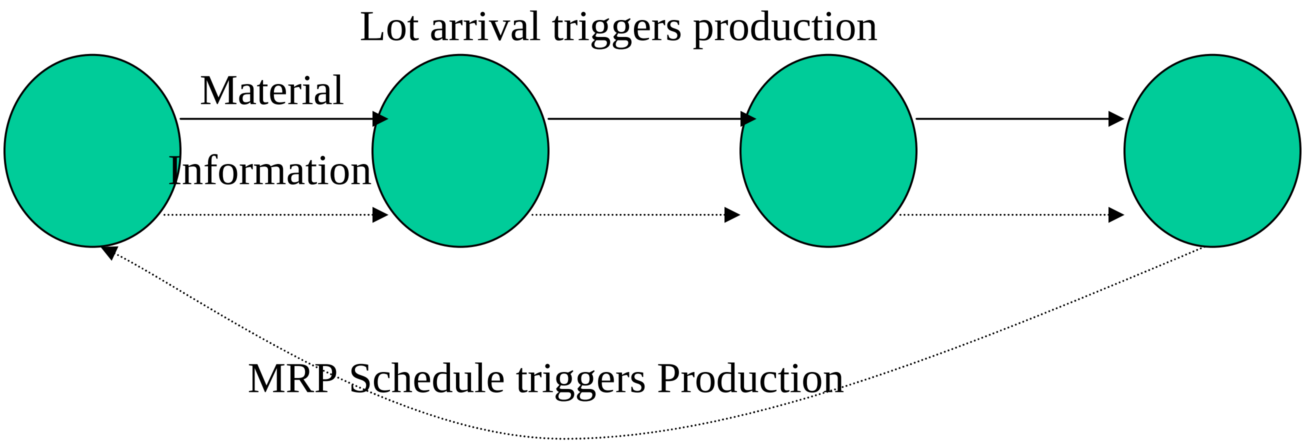


Figure 18.16. A typical “Push” control system.

Today, many flow systems use “Pull” control rather than “push”. In a “Pull” system, parts or product is held at a manufacturing station until approval is issued from a downstream machine. This type of control is illustrated in Figure 18.17. This type of control is frequently referred to as a kanban system. Kanban is Japanesse word that refers to the “paper authorization or approval” to continue to move a part. Traditional kanban systems use physical cards or paper records as authorization to move a product. Today, paperless approval is more typically given to upstream machines in the form of “ANDON” lights or electronic messages, but some systems still use tradition kanban as shown in Figure 18.18.

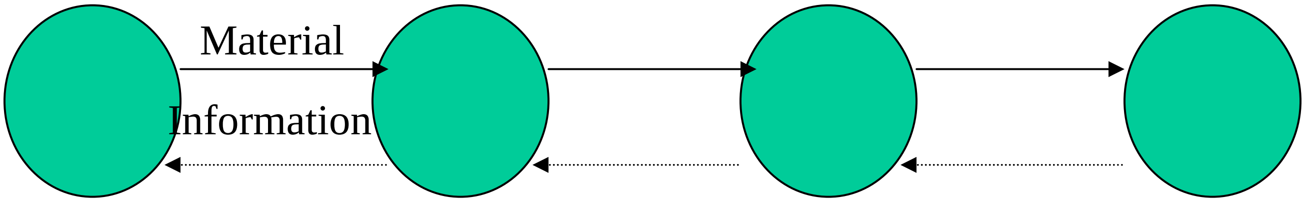


Figure 18.17. A typical “Pull” system.

Store sheet No. TR215 Item Back No. S2 F6 Item No. 3278784 Item Name Securing Bracket Handling type 4Ert5	Proceeding Process CNC Turning CNC - 6
Box capacity Box type Issue No. 12 A1 4/7/03	Subsequent Process CNC Machining CNC M-7

Figure 18.18 A typical production kanban.

Kanbans typically come in two varieties – production and transport (or material handling). Production kanbans are used to authorize the start of a production activity, like machining or heat-treating while transportation kanbans authorize moving a part from one location to another. In the following sections, we will describe the motivation for controlling manufacturing systems.

18.4.1 An analogy: Marching soldiers

In Eliyahu Goldratt's book ``The Goal''[Goldratt, 1996], the importance of a bottleneck in a factory is described through an analogy to a troop of boy scouts out for a march. One of the boy scouts has an extra-heavy backpack. The result is that he walks more slowly than the rest of the troop, so a gap keeps opening between him and the scouts in front. This is then connected to how inventory masses up in front of a slow machine in the factory.

But this is less than half the story. In a column of marching soldiers, the problem is not a slow marcher falling behind. Each soldier carries the same weight, so the line is balanced, and there is no pronounced bottleneck. The problem is variability amplification: If the first soldier for some reason speeds up a little bit, the second soldier will see a gap open in front of him, and take this as a signal to speed up, as well. But he will have to speed up more than the first soldier did, in order to catch up with him. When he has caught up, he then needs to slow down again to avoid bumping into the one in front.

Now the third soldier sees a gap opening up even faster than the second one did, so he has to speed up by even more, and has to slow down more abruptly when he has closed the gap. This way, the small change in speed amplifies down the line like a whiplash, and the poor guy at the end of the line will alternate between running flat out and marching in place.

This is the same process that occurs in a manufacturing line. The last machine in the line tries to track the demand process, but adds some noise to it due to process variability. The second last machine tries to track the input process of the last machine, but adds some more noise. This amplifies the noise upstream, so the first machine in the line will alternate between working at capacity and waiting for something to be taken out of its output buffer. To get rid of the problem, one has to eliminate all process variability, such as machine failures and operation time variability. This can be time-consuming and expensive.

How do soldiers counteract this age-old problem? If the soldiers are recruits, they get the attention of a very loud drill sergeant that yells out the cadence. More seasoned soldiers will be singing a marching song as they go along, and any infantry outfit has a large supply of these songs. Both of these techniques have the effect of distributing the proper cadence to every soldier in the line, simultaneously.

This is what an integrated control system does. It passes the status and demand information, without any noise, to the first machine in the line. All downstream machines know that any part arriving in their input buffer can be worked on, so they hear the signal, too.

Marching soldiers do not close their eyes and march blindly. Even if they receive the proper cadence, they will still be watching the distance to the marcher in front. If the gap widens, they will take longer strides, and if it narrows, they will shorten their steps. In this way, the marchers act on two types of information at once: The global information flow that determines the overall speed, and the local information that is used for minor adjustments.

This is also the way our hybrid policy works: CONWIP or Constant Work In Process sets a target inventory level, where a small buffer is used to help offset some production variability. The CONWIP control gives a global information flow (like the drill sergeant), and the kanban control gives a local flow of information (like watching the distance to the guy in front). In our hybrid policy, the global information flow from the demand process is supplemented by the local information from the buffer levels. This attains the advantages of CONWIP control, while using the strengths of kanban control to cancel its disadvantages.

18.4.2 Balancing and timing production

Pull-based production control systems tend to balance activities. These systems however only work on flow systems so it is important that part families are created so that the product in a manufacturing facility moves in a common direction. When the control of these systems is implemented correctly, these systems are called Just-in time (JIT) manufacturing systems, because the product arrives as it is needed. This helps to reduce the inventory and highlight trouble spots in manufacturing. These systems work well when the flow is uniform and the product mix is stable. Wild variations in product mix and production times create problems for any control system, and JIT systems are no different than others. These systems may perform even worse than traditional systems because little or no buffer is available to offset variability.

Kanban and JIT are also based on several other system requirements. These are:

1. Stability of preceding process
2. Leveled production
3. Takt time and production requirement
4. Maintaining good quality
5. Team member education and training

Most of these requirements are somewhat intuitive. For instance, without a stable process, the production variability will be too high for JIT-based control.

Similarly, if the operation times are the different machines are significantly different then the machine utilization will be very low. Takt is a German word for rhythm and refers to how often the part or product is required or the rate at which the product is required (typically by the customer). Takt time (time/piece), t_k , is computed as

$$t_k = \frac{\text{Available Operating time (sec/day)}}{\text{Daily Demand (pieces/day)}}$$

Cycle time is a measure of how much time it takes for a particular operation, which is also expressed in similar units (time/piece). Takt and cycle times are illustrated in Figure 18.19. In the figure, the upper figure shows an incorrect

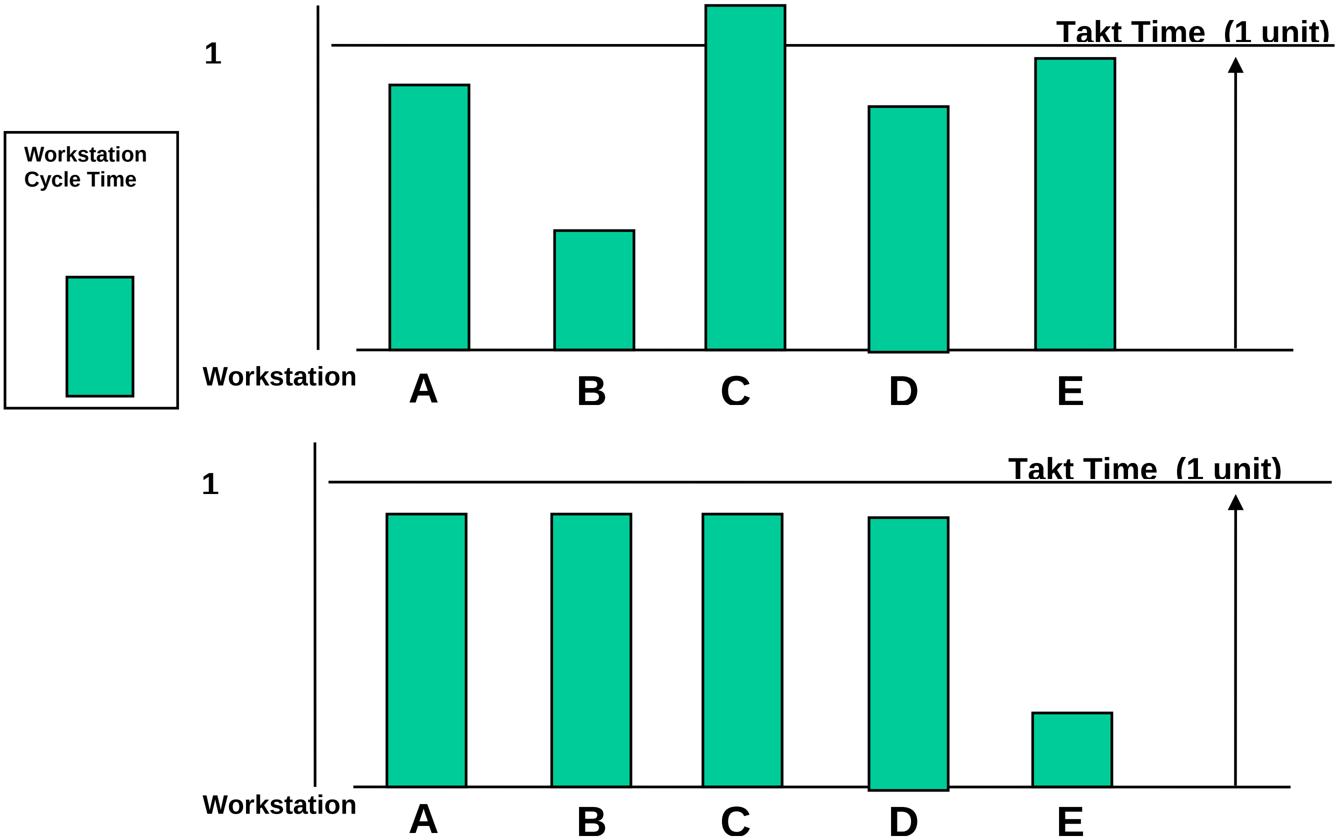


Figure 18.19 Takt and cycle time comparisons.

implementation of takt time where an average cycle time (or just below average cycle time is used as takt time). In this senerio, Operator C will not be able to keep pace with the rhythm of the system; thereby creating a “bottleneck”. In the lower figure, all of the Operators will be able to keep pace with the system rhythm or takt time.

The above production control discussion is a much-abbreviated discussion of control of a Lean system. It is intended as an overview of how an effective Lean Control system works. More detail will be provided in later chapters.

18.5 The Five Steps of Lean Implementation

The process used to implement lean manufacturing is a straightforward one. However it is critical that lean is implemented in a logical manner. The steps associated in implementing lean follow:

Step 1: Specify Value

Define value from the perspective of the final customer. Express value in terms of a specific product, which meets the customer's needs at a specific price and at a specific time.

Step 2: Map

Identify the value stream, the set of all specific actions required to bring a specific product through the three critical management tasks of any business: the problem-solving task, the information management task, and the physical transformation task. Create a map of the Current State and the Future State of the value stream. Identify and categorize waste in the Current State, and eliminate it!

Step 3: Flow

Make the remaining steps in the value stream flow. Eliminate functional barriers and develop a product-focused organization that dramatically improves lead-time.

Step 4: Pull

Let the customer pull products as needed, eliminating the need for a sales forecast.

Step 5: Perfection

There is no end to the process of reducing effort, time, space, cost, and mistakes. Return to the first step and begin the next lean transformation, offering a product that is ever more nearly what the customer wants.

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18.7 Key Words and definitions

Andon lights/boards - a system of flashing lights used to indicate production status in one or more work centers; the number of lights and their possible colors can vary, even by work center within a plant; however, the traditional colors and their meanings are:

green - no problems
yellow - situation requires attention
red - production stopped; attention urgently needed

autonomation - in Toyota parlance, automation with a human touch. Autonomation normally referes to semi-automatic processes where a machine and human work as a well planned system. Literally, the English translation of jidoka.

baka-yoke - a manufacturing technique of preventing mistakes (error-proofing) by designing the manufacturing process, equipment, and tools so that an operation literally cannot be performed incorrectly; an attempt to perform incorrectly, as well as being prevented, is usually met with a warning signal of some sort; the term poka-yoke is sometimes referred to as a system where only a warning is provided.

Balanced production – a system where the operations for various machines are approximately the same. A well-balanced system has a takt time only slightly larger than the operation time.

cellular manufacturing - an approach in which manufacturing work centers [cells] have the total capabilities needed to produce an item or group of similar items; contrasts to setting up work centers on the basis of similar equipment or capabilities, in which case items must move among multiple work centers before they are completed; the term group technology is sometimes used to distinguish cells that produce a relatively large family [group] of similar items.

cycle time - the normal time to complete an operation on a product. This in NOT the same as takt time, which is the allowable time to produce one product at the rate customers are demanding it.

error-proofing - a manufacturing technique of preventing mistakes (baka-yoke) by designing the manufacturing process, equipment, and tools so that an operation literally cannot be performed incorrectly; an attempt to perform incorrectly, as well as being prevented, is usually met with a warning signal of some sort; the term poka-yoke is sometimes referred to as a system where only a warning is provided.

flexible manufacturing system - an integrated manufacturing capability to produce small numbers of a great variety of items at low unit cost; an FMS is also characterized by low changeover time and rapid response time.

flow manufacturing – a manufacturing methodology that pulls items from suppliers through a synchronized manufacturing process to the end product. The principle goal is a faster response to customer demand.

heijunka - A production scheduling/leveling tool, essentially to distribute kanban cards in an efficient manner.

Hoshin Kanri – a strategic planning approach that integrates the practices of leadership with those of management.

jidoka - a Japanese word which translates as autonomation; a form of automation in which machinery automatically inspects each item after producing it, ceasing production and notifying humans if a defect is detected; Toyota expands the meaning of jidoka to include the responsibility of all workers to function similarly, i.e. to check every item produced and to make no more if a defect is detected, until the cause of the defect has been identified and corrected.

jishu kanri - self-management, or voluntary participation.

just-in-time - a production scheduling concept that calls for any item needed at a production operation - whether raw material, finished item, or anything in between, to be produced and available precisely when needed, neither a moment earlier nor a moment later.

jutsu - to talk, or ‘the art of’ (i.e., 'leanjutsu: the art of lean production').

kaikaku - A rapid and radical change process, sometimes used as a precursor to kaizen activities.

kaizen - the philosophy of continual improvement, that every process can and should be continually evaluated and improved in terms of time required, resources used, resultant quality, and other aspects relevant to the process.

kanban - a card or sheet used to authorize production or movement of an item; when fully implemented, kanban (the plural is the same as the singular) operates according to the following rules:

1. All production and movement of parts and material take place only as required by a downstream operation, i.e. all manufacturing and procurement are ultimately driven by the requirements of final assembly or the equivalent.

2. The specific tool which authorizes production or movement is called a kanban. The word literally means card or sign, but it can legitimately refer to a container or other authorizing device. Kanban have various formats and content as appropriate for their usage; for example, a kanban for a vendor is different than a kanban for an internal machining operation.

3. The quantity authorized per individual kanban is minimal, ideally one. The number of circulating or available kanban for an item is determined by the demand rate for the item and the time required to produce or acquire more. This number generally is established and remains unchanged unless demand or other circumstances are altered dramatically; in this way inventory is kept under control while production is forced to keep pace with shipment volume. A routine exception to this rule is that managers and workers are continually exhorted to improve their processes and thereby reduce the number of kanban required.

karoshi - death from overwork.

lean manufacturing or **lean production** - the philosophy of continually reducing waste in all areas and in all forms; an English phrase coined to summarize Japanese manufacturing techniques (specifically, the Toyota Production System).

line balancing - equalizing cycle times [productive capacity, assuming 100% capacity utilization] for relatively small units of the manufacturing process, through proper assignment of workers and machines; ensures smooth production flow.

mixed-model production - capability to produce a variety of models, that in fact differ in labor and material content, on the same production line; allows for efficient utilization of resources while providing rapid response to marketplace demands.

mizusumashi - the classic 'water spider', who performs a wide range of tasks which allow workers to perform 'value-added' tasks.

mokeru - the Japanese term for the industrial engineering, more properly translated as ‘profit-making I.E.’.

muda (waste) - activities and results to be eliminated; within manufacturing, categories of waste, according to Shigeo Shingo, include:

1. Excess production and early production

2.Delays
3.Movement and transport
4.Poor process design
5.Inventory
6.Inefficient performance of a process
7.Making defective items

mura - inconsistency

muri - unreasonablness

nagara - smooth production flow, ideally one piece at a time, characterized by synchronization [balancing] of production processes and maximum utilization of available time, including overlapping of operations where practical.

ninjutsu - the art of invisibility (applies to management)

one piece flow – producing one unit at a time, as opposed to producing large batches.

poka-yoke - a means of providing a visual or other signal as to the location or condition of a part characteristic. Often referred to as 'error-proofing', poke-yoke is actually the first step in truly error-proofing a system (see baka-yoke).

pull system - a manufacturing planning system based on communication of actual real-time needs from downstream operations ultimately final assembly or the equivalent - as opposed to a push system which schedules upstream operations according to theoretical downstream results based on a plan which may not be current.

5S’s - refers to the five Japanese words seiri, seiton, seison, seiketsu, shitsuke. These words are shorthand expressions for principles of maintaining an effective, efficient workplace.

seiri - eliminating everything not required for the work being performed
seiton - efficient placement and arrangement of equipment and material
seison - tidiness and cleanliness
seiketsu - ongoing, standardized, continually improving seiri, seiton, seison
shitsuke - discipline with leadership

6 Sigma – a structured process improvement program for achieving virtually zero defects in manufacturing and business.

seiban - Seiban is the name of a Japanese management practice taken from the Japanese words "sei", which means manufacturing, and "ban", which means number. A Seiban number is assigned to all parts, materials, and purchase orders associated with a particular customer job, or with a project, or anything else. This enables a manufacturer to track everything related with a particular product, project, or customer. It also facilitates setting aside inventory for specific projects or priorities. That makes it great for project and build-to-order manufacturing.

sensei - one who provides information; a teacher, instructor, or rabbi.

setup time - work required to change over a machine or process from one item or operation to the next item or operation; can be divided into two types:

1. internal: setup work that can be done only when the machine or process is not actively engaged in production; OR
2. external: setup work that can be done concurrently with the machine or process performing production duties.

shojinka - continually optimizing the number of workers in a work center to meet the type and volume of demand imposed on the work center; shojinka requires workers trained in multiple disciplines; work center layout, such as U-shaped or circular, that supports a variable number of workers performing the tasks in the layout; the capability to vary the manufacturing process as appropriate to fit the demand profile.

SMED - abbreviation for Single Minute Exchange of Die; literally, changing a die on a forming or stamping machine in a minute or less; broadly, the ability to perform any setup activity in a minute or less of machine or process downtime; the key to doing this is frequently the capability to convert internal setup time to external setup time; variations on SMED include:

1. Single-digit setup: performing a setup activity in a single-digit number of minutes, i.e. fewer than ten.
2. OTED: One touch exchange of die; literally, changing a die with one physical motion such as pushing a button; broadly, an extremely simple procedure for performing a setup activity.

standard operations – clearly defined operations and standardized steps for both workers and machines.

takt time - takt, is a German term for rhythm or pace. Takt time is the allowable time to produce one product at the rate a customer demands it. This is

NOT the same as cycle time, which is the normal time to complete an operation on a product (which should be less than or equal to takt time).

teian - a proposal, proposition, or suggestion. A teian system can be likened to a system that allows and encourages workers to actively propose process and product improvements.

Toyota - changed from the true form, Toyoda, meaning abundant rice field, by the Toyota marketing department. Toyoda is the family name of the founders of the Toyota Motor Company.

Value Stream Mapping (VSM) – a process to determine the value added to a product as it goes through a manufacturing system.

water spider - one who performs a wide range of tasks which allow workers to perform 'value-added' tasks.

WCM - world class manufacturing is the philosophy of being the best, the fastest, and the lowest cost producer of a product or service. It implies the constant improvement of products , processes, and services to remain an industry leader and provide the best choice for customers, regardless of where they are in the process.

18.8 Review Questions

1. Identify how the 3 M’s can be used in some aspect of your personal activities.
2. Identify a service situation where the 3 M’s could be employed.
3. Identify how the 5 S’s can be used in some aspect of your personal activities.
4. Identify a service situation where the 5 S’s could be employed.
5. Find at a grocery store or in your room or kitchen new food products that utilize some Lean principles. As a hint here, think about why microwave dinners have become popular. Another hint would be premix foods that might reduce setup (preparation time).
6. Define what Lean activities are used in CNC machines.
7. Discuss the economics of CNC or some other Lean development.

18.9 Review Problems

1. Layout a kitchen as a “U-shaped cell”. Identify the products that are being produced, and why you choose the organization that you select.
2. Define how Lean principles can be used in developing the “user interface” for a specific software application that you are familiar with.
3. Find an activity that you perform frequently and identify the “set-up” components of that activity. For instance if you play basketball, the set-up for play would be to get to a court, to get dressed, to find a partner, etc. Identify the internal and external elements of the set-up.
4. Identify the set-up requirements for changing a flat tire. How have these set-up components been minimized at a tire outlet?
5. Examine a system like the dinning commons or a cafeteria that you are familiar with. Describe how the control of the system works. Is it pull or push? Is it effective? How can it be changed to make it more effective?