

Lean Management Principles

By Prof. Rene T. Domingo
rtd@aim.edu www.rtdonline.com

The Toyota Motor Corporation (TMC) of Japan pioneered the development and implementation of the Lean Manufacturing System. Its purpose was to come out with a highly effective and efficient manufacturing process of producing cars and vehicles with high quality, low cost, and fast delivery through the elimination of all forms of wastes. Lean ensures that there are positive synergies among the quality improvement, cost reduction, and time reduction programs of the company, and that no trade-offs and sacrifices are encountered. Based on non-traditional concepts, this system enabled TMC to compete globally in the highly competitive car market while maximizing the use of scarce and expensive resources Japan is known for, like raw materials, labor, fuel, and land. The Lean System and Lean Thinking were extended throughout Toyota's supply chain to achieve the highest operational results. Toyota involved all its affiliates, major suppliers, contractors, distributors, and dealers in TPS training and implementation. TMC also implements the Lean System in its overseas plants and supply chain. The Lean System is also known as follows, each label highlighting a particular principle of Lean Thinking:

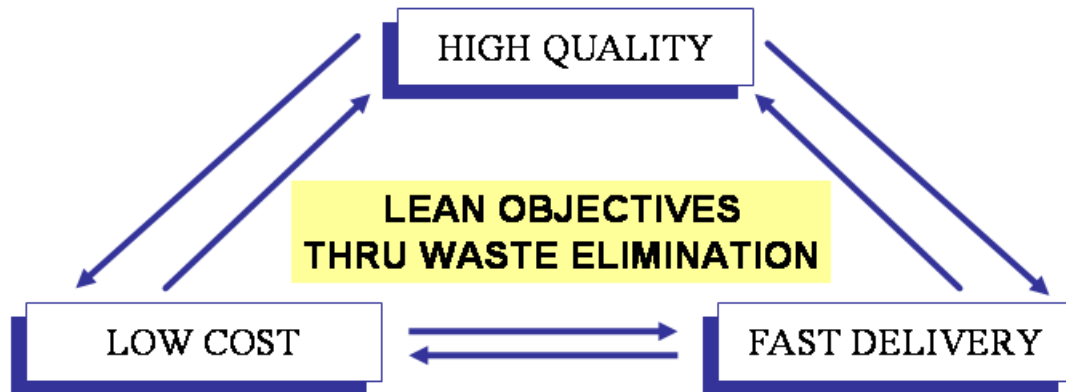
“Just-in-time Production System”

“Kanban System”

“One-piece Flow System”

“Pull Manufacturing System”

Officially, TMC calls it the Toyota Production System (TPS). As TPS is adapted in other manufacturing industries and lately in service industries, this manufacturing philosophy is now commonly and more appropriately called Lean System.



What are the Basic Lean Principles of TPS?

The original and primary principle of the TPS is:

"Produce only what is needed, when it is needed, with the quantity needed."

Excess inventory due to overproduction was considered the biggest waste in a manufacturing process that should be reduced continuously by imposing strict discipline and rules in production flow and scheduling. Anything in excess of what was needed to satisfy the customer was considered wasteful – be it raw material, work-in-process, and finished goods. Later on, this principle would be extended to unnecessary processing, man-hours, manpower, supplies, storage, utilities, and equipment due to the production of excess inventories. TPS was patterned after the US supermarket system wherein goods are continuously replenished or restocked on the shelves with exactly the same amount taken by customers. The shelves are always full, but not overstocked. Supermarkets, having limited space, lots of product variety with fast turnover, and products with short shelf lives, have to apply these strict “lean” principles of “just-in-time” in order to survive and avoid huge losses due to overstocking (spoiled goods) and under stocking (lost sales).

TPS adopts this “just-in-time” principle wherein a work station (factory, process, or equipment) produces only what is needed by the next process which could either be the external customer or buyer itself or another work station

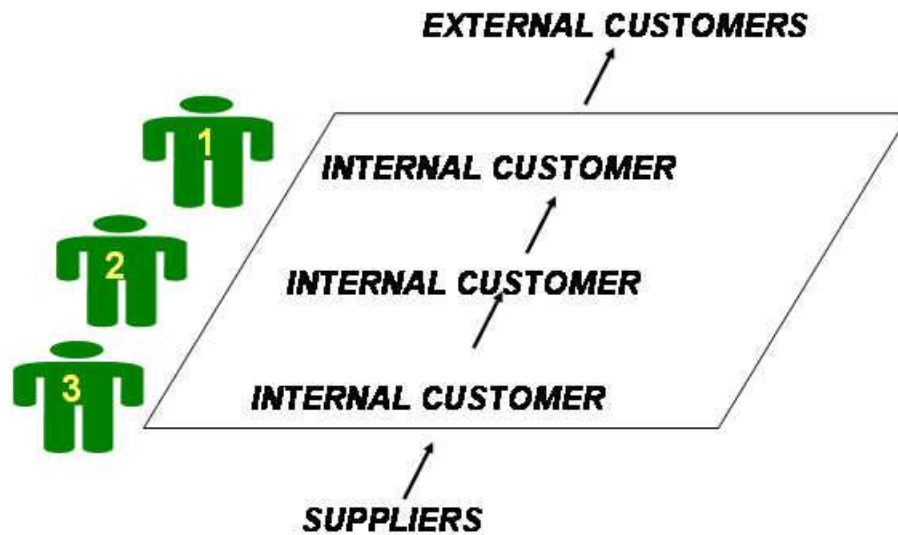
known as an “internal customer.” The quantity produced and delivered ideally is the exact amount, no more no less, not early nor late at the place needed by the next station. This principle is in contrast to the conventional manufacturing concept of “Just-in-case” which allows early delivery, production and delivery in excess of demand, and the carrying of safety stocks at all stations and storage areas to cope with contingencies and variability.

The three basic production rules of TPS are

- 1) Never send defects to the next process.
- 2) The next process gets only what it needs from the prior process.
- 3) Produce only the quantity taken by the next process.

The first rule dictates that each station delivers only quality goods to the next station, since the latter does not have spares nor the time to replace or rework defects. The second rule means that the producer cannot push its output to the next station; it should wait for the next station or “customer” to pull its required quantity. Thus TPS is sometimes called the “Pull” system in contrast with conventional system or “Push” system. The “Pull” system is similar to a train in which the front engine, representing the customer, pulls everything behind it and sets the pace and speed. The “Push” system is like a tractor that pushes everything in front of it. “Pull” is customer driven, based on demand, while “Push” is supplier driven, based on capacity. In a way, TPS is like a “make to order” system while the traditional system is “make to stock”. The third rule means that the producer can only replace what was taken by and delivered to the next process. It cannot produce more than this amount, in contrast to conventional systems in which production volume is based on capacity utilization, economic order quantity, and batch size rules unrelated to actual demand. By applying the three rules mentioned, the entire manufacturing chain or supply chain in the full application of TPS, is expected to be inventory free or “lean”, with inventory being considered “fat” that weighs down and slows down the process.

SERVING EXTERNAL AND INTERNAL CUSTOMERS



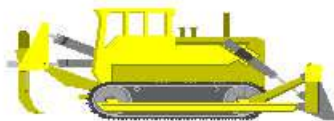
Just-in-time (JIT)

“pull system” – produce according to demand



Just-in-case (JIC)

“push system” – produce according to capacity



Why is Excess Inventory considered Waste?

Inventory in whatever form for whatever reason is always associated with three costs: carrying costs, management costs, obsolescence costs. Dramatic reduction of inventory would therefore result in significant cost reduction and savings for the company. Carrying costs include cost of money or working capital to build up the stocks, insurance costs, and storage costs. Management costs include supervision costs to manage inventory and its holding facilities, information costs to track and record stock movements, quality costs to inspect and audit the condition of the stocks, security costs to safeguard the inventory from pilferage, fires, damage, and other contingencies. Obsolescence cost, which can perhaps be the biggest of the three in these modern times, is essentially the depreciation, diminution, total loss of the value of the inventory because of lack of demand due to tough competition, unforeseen change in consumer preference, rapid change in technology, or shortening of product life. The most vulnerable to obsolescence risk is finished goods, followed by work-in-process, and lastly by raw materials. Should demand change, the last two types of inventory, to some extent, may still be saved from obsolescence and be converted to the required finished goods. In this regard, TPS gives priority to the just-in-time production of finished goods. Any excess would be the most wasteful inventory because of their high value and inflexibility. Losses would usually come from heavy discounting or eventually scrapping or write-offs of slowing or non-moving finished goods stocks.

What is “One piece flow”?

TPS is also sometimes called “One piece flow” production system. Lot and batch sizes are continuously minimized and reduced as close as possible to one piece. Conventional manufacturing systems which practice big batch production to attain efficiency and justify long set-ups, will tend to overproduce and push unneeded stocks to the next station. To make smaller batches and lots economical, TPS practices set-up time reduction. As a result, a TPS line can operate as a mixed-model line, meaning it can produce or assemble different models at the same time or same run without practically no lost time between set-ups. A mixed-model line can operate with a much smaller lot size for each product model, and can therefore be synchronized more easily with the actual demand patterns than a batch based system. It can mass customize rather than just mass produce. The work stations in a line operating with one piece flow or minimum work-in-process between them are said to be coupled or synchronized with a high degree of dependency. To operate, such a line must have very reliable work stations and strong teamwork. In conventional manufacturing lines, on the other hand, there are high levels of WIP between and inside work stations. The stations are de-coupled, unsynchronized, and virtually act independent of each other. Less teamwork

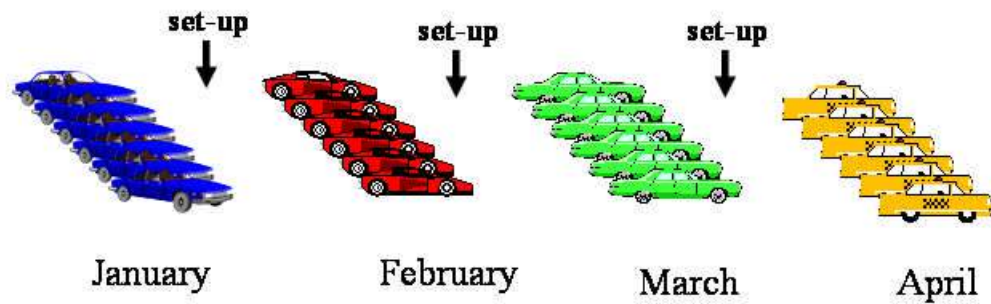
and communication, poor feedback and slow corrective response action are observed. One-piece flow lines are highly productive and in general produce better quality because every station or worker takes good care of every piece it produces before sending it the next station or worker one at a time. The receiving station, receiving only one piece at a time, also become very sensitive to quality and would not want to accept a defect.



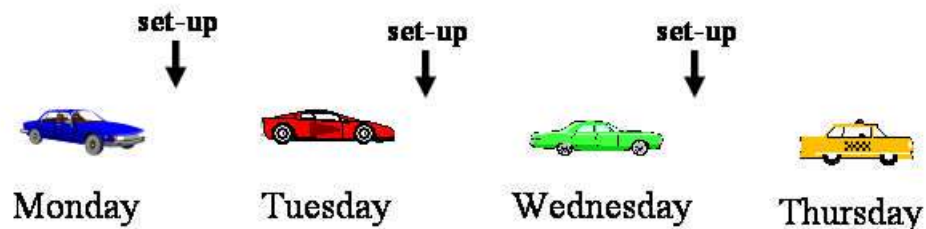
TRADITIONAL BATCH SYSTEM



ONE-PIECE FLOW SYSTEM



Conventional Production



Just-in-time Production

What is SMED (Single Minute Exchange of Die)?

To produce high variety of products at low cost in one line or to produce with smaller lots economically as dictated by lean principles, it is necessary to cut set-up time and consequently set-up costs. This set-up time reduction program is called SMED or Single-Minute-Exchange-Of-Die. The press die or mold usually takes hours to change or replace and this long set-up encourages the production or pressing of big batches and long production runs that go against the principle of lean and one-piece-flow. In order to achieve economical small lot production, the set-up time is ideally reduced to minutes or one minute from hours. The set-up process is shortened using the principles of kaizen and process simplification. SMED is now a generic lean concept that is applied not only to press operations, but to any equipment or process that have long set-ups. A typical tire change may take 30 minutes or more, but the Formula One pit-stop maintenance crew can replace 4 tires in 6 seconds while doing other tasks like refueling using principles very similar to SMED.

SET-UP TIME REDUCTION

SMED - “SINGLE MINUTE EXCHANGE OF DIE”



Formula One 7-second Pit Stop

What is Heijunka?

For a lean one-piece flow system to work, the production must be smooth. Heijunka means production or workload leveling to create a stable process. Without heijunka, a lean line will be erratic and costly to operate because of peaks and valleys in demand pattern. The TPS applies heijunka to production volume and product mix. To level volume, customer orders are usually pooled together and production schedules are leveled. To level product mix, TPS uses mixed-model lines with short set-ups to produce smaller lots of every model.

What is Kanban?

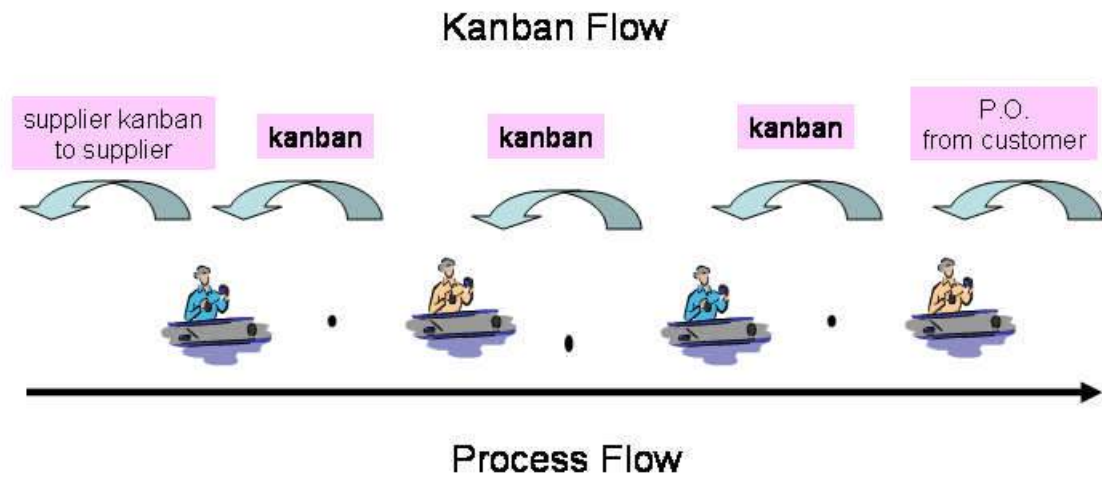
To ensure the “pull” production flow, TPS employs a control mechanism across the manufacturing process called “kanban” which means signboard in Japanese. The kanban system serves as an effective and visual production control mechanism of the TPS at the shop floor level and ensures timely and synchronized production and delivery of the right quantity across the entire manufacturing chain and supply chain.

In practice, kanban serves as an internal purchase order or PO between work stations. When a customer orders, he issues a PO to the supplier which then processes that order. In a way, the PO triggers the production or withdrawal

from warehouse, and delivery of the exact amount ordered. Without the PO, the supplier cannot deliver anything; and with the PO, the supplier cannot deliver more than the quantity specified in the PO. Needless to say, the supplier cannot deliver later than the specified date in the PO or risk being penalized. This basic supplier-customer relationship is implemented in the manufacturing process between work stations using the kanban as the trigger rather than a PO. In order to comply with the TPS rule no. 2 “The next process gets only what it needs from the prior process”, each station will issue a kanban to the prior station which then produces and delivers the exact item, with the right amount, at the right time and place specified in the kanban. Without a kanban from its internal customer(s), no station can produce nor deliver to anyone - thus behaving like a typical supplier. A kanban, is similar to a PO in that contains the names or part number needed, quantity required, date and time required, and place or delivery. What it does not have is price, since work stations do not pay each other. Also unlike the PO, the kanban does not allow earlier delivery.

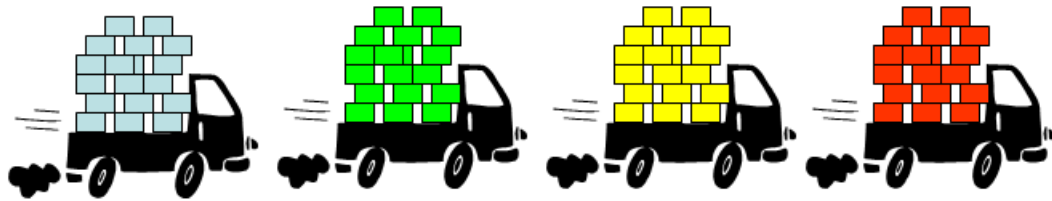
The kanban is typically made of cardboard or plastic and attached to the part or its container or bin. A work station receives the kanban, typically attached to empty bins from the next process, refills them with the required parts and quantity, and sends the filled up bins back to the next process for its usage. Once the bins are used and emptied, these are sent back to the prior process with the kanbans for replenishment, and the cycle repeats itself. The delivered parts may be delivered and unloaded at the factory temporary storage site or more typically directly at the point of use, e.g. assembly point where the parts are used immediately. In some cases, the containers or bins, serve as the kanban itself.

Under TPS, the factory, instead of issuing and sending PO's to its suppliers, sends supplier kanbans which are similar to the internal kanbans. The supplier must then comply strictly as to the exact part number, quantity, timing, and delivery points indicated in the kanbans it receives. Suppliers under the kanban system, must deliver more frequently than traditional suppliers, sometimes as often as thrice daily instead of once a month. They are not allowed to deliver early nor late. They have to deliver mixed parts and smaller lots if the kanbans demand so. Just-in-time suppliers are carefully selected and trained thoroughly by Toyota on lean principles and practices so that they can cope with the strict system flawlessly. Toyota forms strong and reliable supply chain partnerships with these key suppliers rather than just buy or purchase parts from them.



E-kanbans or electronic kanban is an improvement over the physical kanban which can be lost, damaged, error-prone because of the need for manual data entry. Instead of written or printed kanbans, kanban data are sent electronically by a station to the prior station to trigger production and delivery. The control of e-kanbans can be integrated into the factory's information system or manufacturing resource planning (MRP) systems.

CONVENTIONAL PARTS DELIVERY

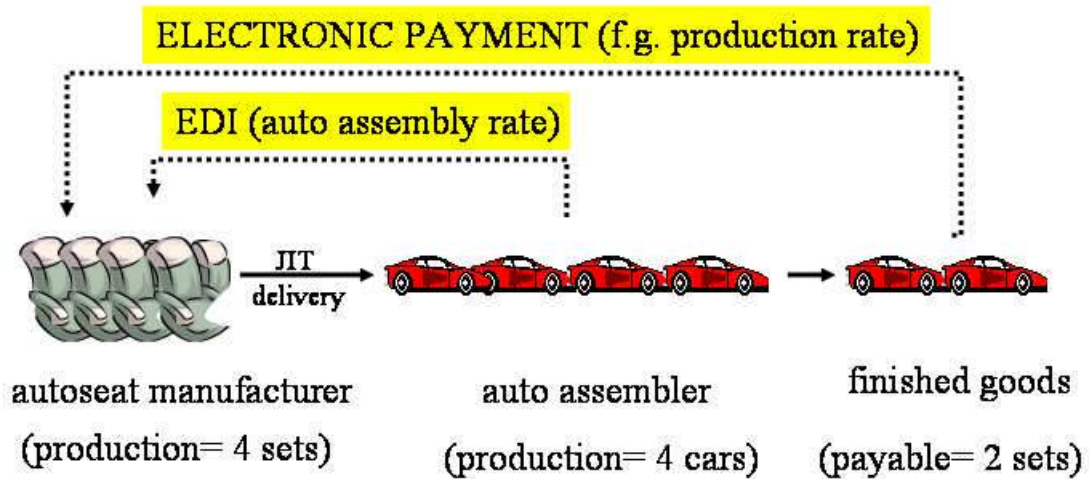


1X/MONTH

3X/DAY



JIT MIXED-MODEL PARTS DELIVERY



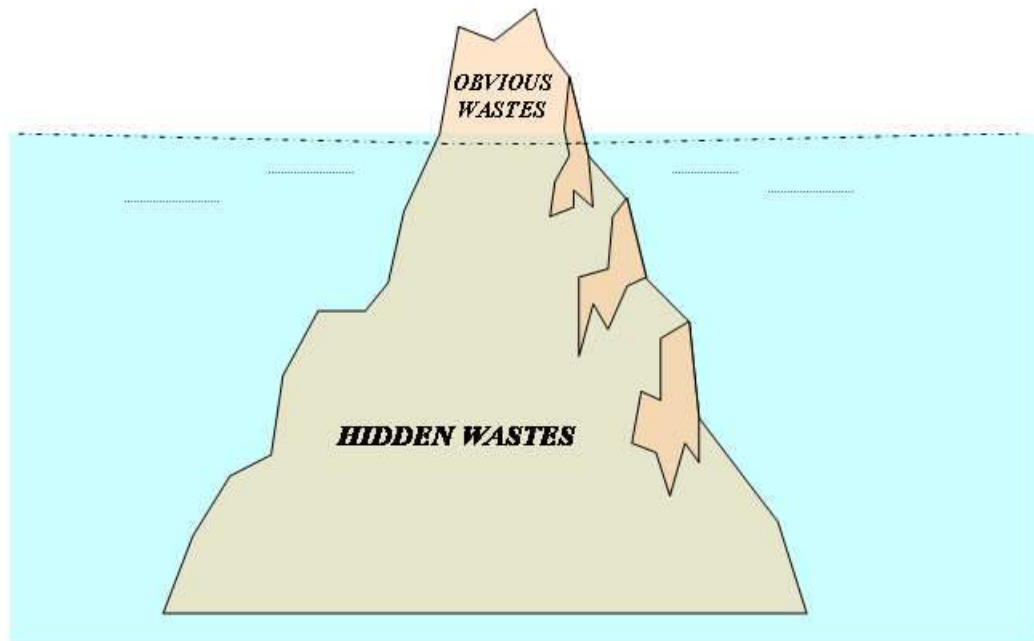
SYNCHRONIZED PRODUCTION/DELIVERY WITH PAPERLESS PAYMENT

What is Waste?

The elimination of waste is the primary goal of any lean system. In effect, lean declares war on waste – any waste. Waste or muda is anything that does not have value or does not add value. Waste is something the customer will not pay for. When the great Italian sculptor Michelangelo was asked what he was sculpting, he responded he was not sculpting but releasing the figure (value) inside by removing the unnecessary rocks (wastes). Like Michelangelo, we should eliminate all forms of wastes in any process or product until only what is valuable remains. The key is to spot waste and then stop waste.



There are two types of wastes: obvious wastes and hidden wastes. It is important to uncover and eliminate the latter since they are usually bigger. Wastes take the shape of an iceberg, the tip consists of the obvious wastes while the unseen bulk under the water contain the hidden wastes. Wastes are not necessarily ugly, and most are outside the waste can! Waste can be in the form of unnecessary output, input, or processing. It can be in the form of materials, stocks, equipment, facilities, manhours, utilities, documents, expenses, motion, and other activities that do not add value.



The steps to effective waste elimination are:

1. Make waste visible.
2. Be conscious of the waste.
3. Be accountable for the waste.
4. Measure the waste.
5. Eliminate or reduce the waste

In other words, before one can stop waste, he should be able to see it, recognize it as waste, identify who is responsible, and finally appreciate its size and magnitude. Waste that is not seen cannot be eliminated. When something is denied as waste, it also cannot be stopped. When one refuses to accept responsibility for the waste, then he will not eliminate it. Finally, when the waste is not measured, people may think it is small or trivial and therefore will not be motivated to stop it. As the saying goes “What is not measured, is not improved”.



Muda, Mura, Muri

Aside from “muda” or wastes, the lean system also attacks and avoids “mura” or overload or overburden and “muri” or unevenness. Mura refers more specifically to overloading an equipment, facility, or human resource beyond its capacity. This undue stress may cause downtime, defects, delays, and even disasters. Muri refers to unevenness in production volume. The wild fluctuations due to extreme highs (peaks) and lows (valleys) in production scheduling cause periods of overload and long idle time. One way to reduce muri is to implement heijunka or production leveling. In a way, mura and muri also cause wastes but in a particular way. Muda, mura, and muri cause inefficiencies and high costs in any operation.

What are the seven types of wastes or “muda”?

A lean system declares war on wastes or “muda”. These wastes are classified into 7 types:

Over-production waste

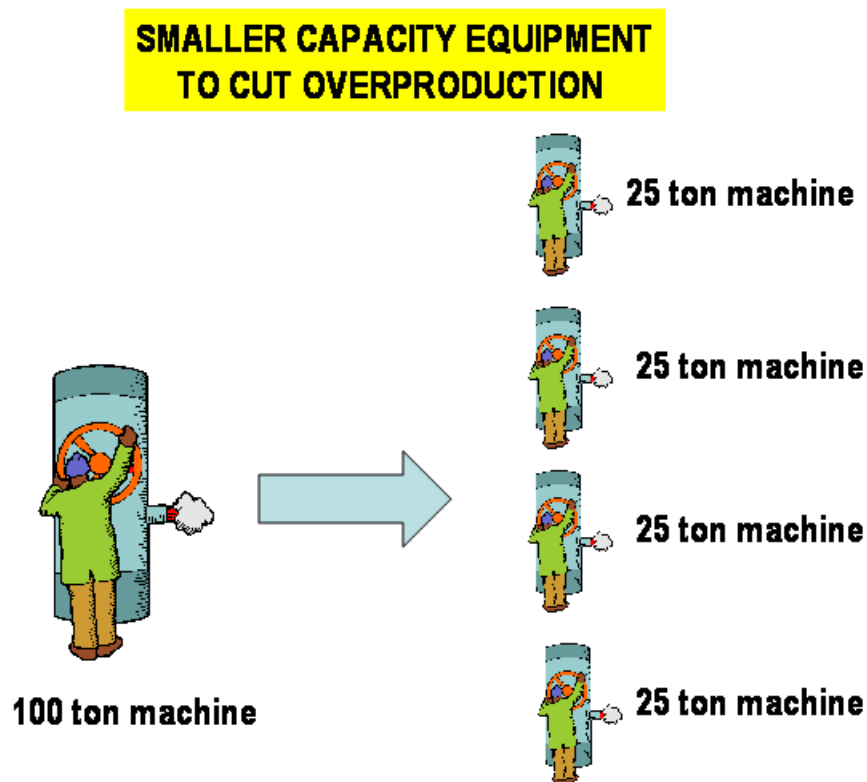
Definition

- producing more than what is needed
- producing faster than what is needed

Causes

- volume incentives (sales, pay, purchasing)
- high capacity equipment
- line imbalance; poor scheduling/shifting
- poor production planning
- cost accounting practices that encourage build up of inventory

Over-production waste occurs when more goods are produced than can be sold, resulting in idle finished goods inventory. Over-produced goods are often hidden wastes since many think they are assets with value, when in fact most of them may be obsolete or costing the company unnecessary expenses just to keep them until they can be sold if ever. The just-in-time, pull system, and kanban rules prevent over-production wastes. Also, lean systems favor smaller equipment over large ones to avoid overproduction due to high but unnecessary capacity utilization.

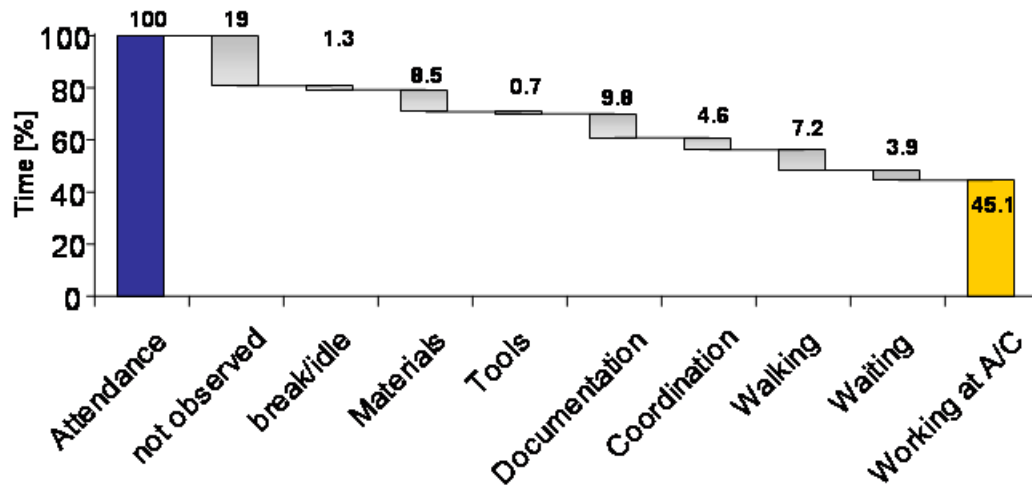


Processing waste

Definition

- non-value added man processing

Waterfall Diagram of Time Spent by Aircraft Maintenance Mechanic



OBVIOUS AND HIDDEN WASTES



Somebody who sits whole day doing nothing



Somebody who writes something unnecessary the whole day

Transport waste

Definition

- unnecessary material movement
- unnecessary tools or equipment movement

Causes

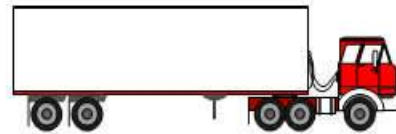
- poor route planning
- distant suppliers
- complex material flows
- poor layout
- disorganized workplace
- line imbalance

When anything – people, equipment, supplies, tools, documents, or materials – is moved or transported unnecessarily from one location to another, transport waste is generated. Examples are transporting the wrong parts, sending materials to the wrong location or at the wrong time, transporting defects, and sending documents that should not be sent at all. One way to cut transport waste is co-location, wherein customers are served by nearby suppliers, usually less than one-hour driving distance away. Departments working with each other or serving each other are also put near each other to cut transport waste. For example, materials and tools departments may be moved, relocated, or repositioned beside or nearer the user departments or their internal customers.

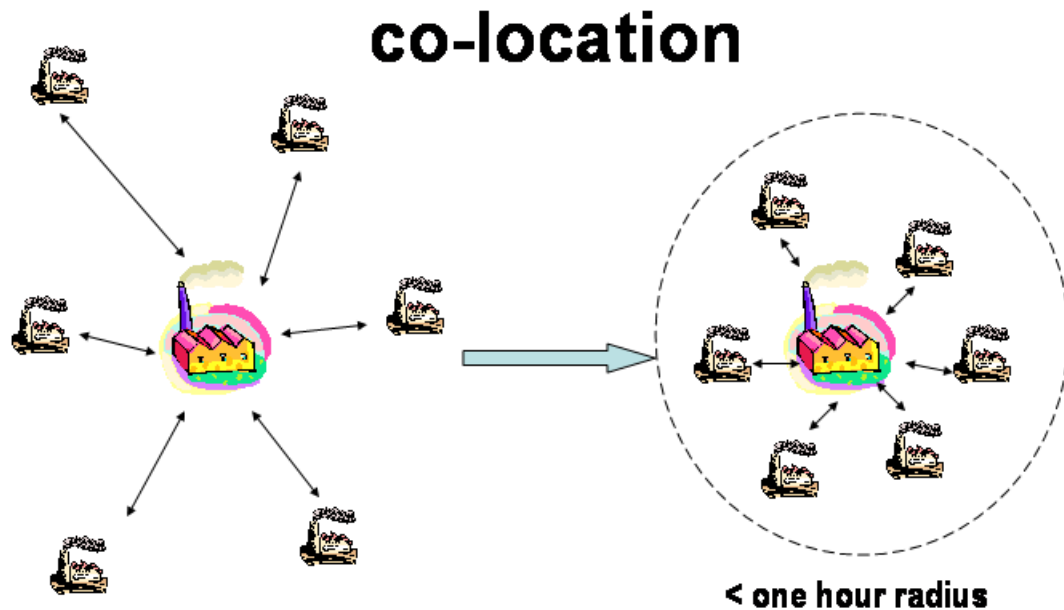
OBVIOUS AND HIDDEN WASTES



An empty truck running



A truck transporting
something unnecessary



Waiting time waste

Definition

- man idle or waiting time
- machine idle or waiting time

Causes

- unsynchronized processes; line imbalance
- inflexible work force
- over-staffing
- unscheduled machine downtime
- long set-up
- material shortage or delay
- manpower shortage or delay

When resources like people and equipment are forced to wait unnecessarily because of delays in the arrival or availability of other resources including information, there is waiting time waste. Waiting for late attendees in a meeting, waiting for tools to start work, waiting for a signature for a process to continue, waiting for a late vehicle to transport workers to a project site are examples of this waste.

OBVIOUS AND HIDDEN WASTES



Somebody who stands up
the whole day in the office



Somebody who watches
over an equipment the
whole day in the office

Inventory Waste

Definition

- excessive process (WIP) inventories
- excessive raw material inventories and supplies

Causes

- over-production
- imbalanced line
- big batch sizes
- long lead times
- local optimization (turf mentality)
- large minimum order quantities
- high rework rate
- JIT-incapable suppliers
- lack of material requisition and issuance standards

Inventory wastes come from the purchasing, issuance, storage of excess or excessive supplies, materials, and other resources. This waste can also be caused by overproduction as excess materials and work-in-process are accumulated. Inventory waste is often due to lack of planning and failure to match purchases with the actual consumption or usage rate of a particular

resource. Another example is the storing of slow-moving and obsolete stocks like tools and materials.

OBVIOUS AND HIDDEN WASTES



A heap of expired items



A mountain of good stocks

Motion Waste

Definition

- unnecessary movement and motions of worker

Causes

- poor lay-out
- disorganized work place and storage locations
- unclear, non-standardized work instructions
- unclear process and materials flow

Motion waste happens when unnecessary body movements are made when performing a task. Examples are searching, reaching, walking, bending, lifting, and other unnecessary bodily movements. Workers commit this form of waste by searching for tools or documents when their workplace is cluttered or disorganized.

Defects

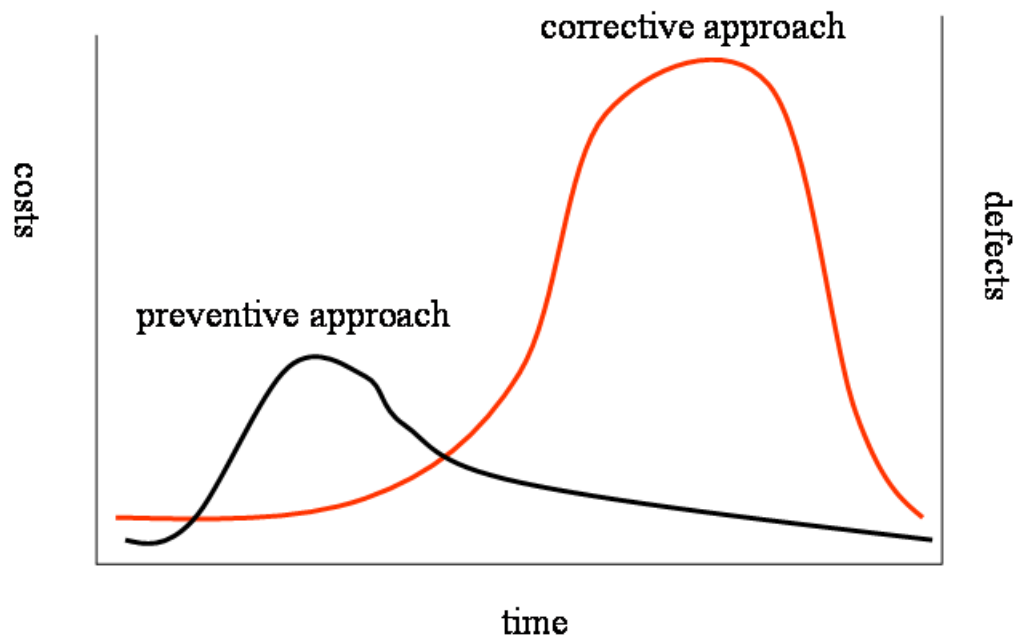
Definition

- processing due to the production of defects
- processing due to rework or repair of defects
- materials used due to defect and rework

Causes

- unclear customer specifications
- incapable processes
- lack of process control
- unskilled personnel
- departmental rather than total quality
- incapable suppliers

Quality is doing the right thing right the first time. It is about prevention and planning, not correction and inspection. Bad quality or defects do not only result in customer dissatisfaction and damage to company image, but also in wastes due to additional costs and time to recall, rework, repair, and replace the defective items. Continuous quality improvement and preventive measures are the most effective means to cut defect wastes.



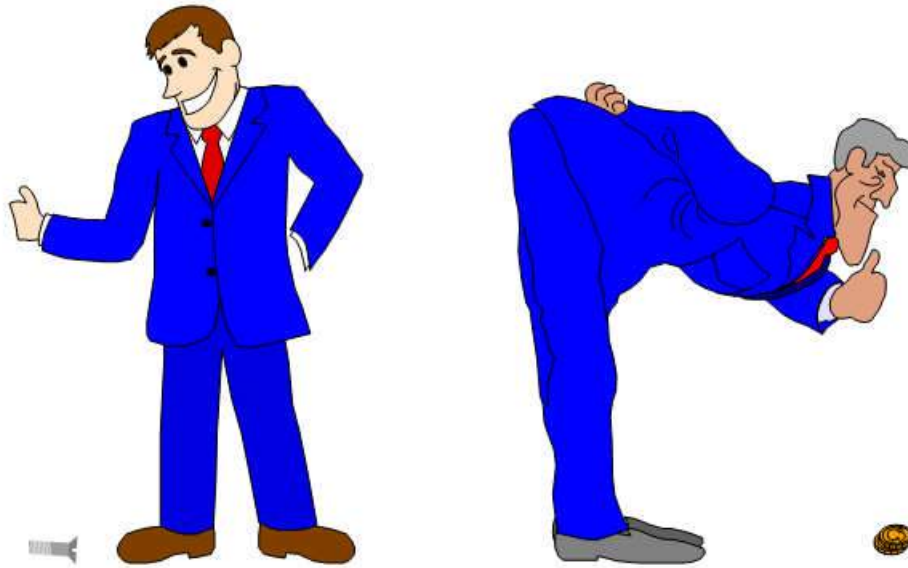
How does one distinguish obvious from hidden wastes?

It is important in lean thinking that one can distinguish hidden from obvious wastes, otherwise only the trivial obvious wastes will be reduced. Imagine a

factory producing 10,000 pieces of bottle caps a day. If one cap accidentally falls on the shop floor from the production line, the worker may not pay attention to it nor pick it up, being too busy in meeting his daily goal. If we replace the cap with a 25 cent coin, he would most like pick it up however. The difference is he does not see the value (or conversely the waste) of the cap on the floor while he sees the coin's value or its waste if he does not pick it up and pocket it. Most hidden wastes are not actually "hiding" or unseen. They are visible but not recognized as waste because we do not normally attach value or cost to these. We may see waste in defects or scrapped items, but not in good products called inventory neatly arranged in shelves which in reality may be more wasteful in terms of carrying costs. Somebody walking or loitering aimlessly in the office or factory may be considered wasting time, but once he carries something, like an empty envelope, his loitering will be unnoticed. In the same vein, a loaded vehicle moving may be more wasteful than an empty one, if the former is carrying the wrong item or going to the wrong place. Somebody pushing a wheelchair with a patient on it may be more wasteful than one pushing an empty wheelchair if the patient can walk! A clerk who sits in front of his desk doing nothing the whole day may be less wasteful than one writing a report the whole day if nobody reads the report in the first place. The first clerk is just wasting time, the second is wasting time and paper. Consider a worker standing in the middle of the factory the whole day – an obvious waste easily recognizable and stoppable. But suppose he stands in front an equipment (press, printer, or fax machine) the whole day just watching it operate, surely most would think he is working when in fact he is just as wasteful as the first worker.

Often waste can be made visible if the measurements are clear and easily understood. A taxi meter is a good example. When riding a taxi, we always can see how much the trips costs at anytime. On the other hand, the household electric utility meter is hard to understand and will not help us cut wasteful electric consumption until it is too late, i.e., when the monthly bill arrives.

MAKE COSTS VISIBLE



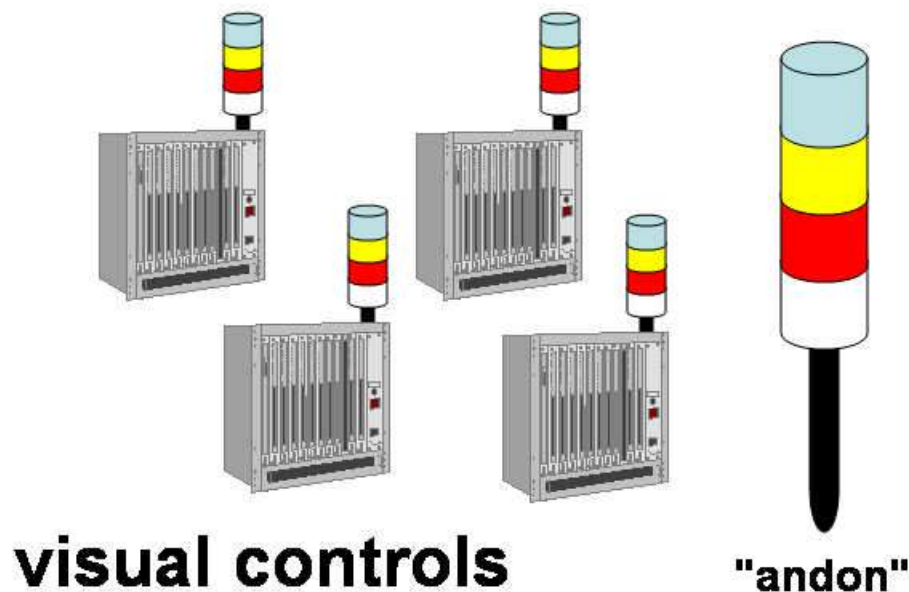
What is takt time?

Suppose a line has to produce 960 units a day to meet market demand. If it operates 8 hours daily, then it must produce one unit every 30 seconds. This target cycle time is called takt time which serves like a metronome that the process must achieve in order to meet the demand without overproduction. Takt time is the basis of the lean principles of one-piece-flow, just-in-time, and pull production. It assures the continuous and perfect match of capacity with demand and avoids overproduction and inventory wastes. A process cycle greater or less than the takt time results in two kinds of wastes – overproduction or waiting time for the next process or customer. In process, we should identify, remove, or improve the bottleneck operations, the slowest in the process, that may cause this mismatch or imbalance. A lean line is a balanced line running and producing with the takt time as its rhythm.

What is visual control?

When a problem like defects, downtime, or wastes occurs, it must be known and corrected immediately. In order to improve and reduce response time to problems, lean systems adopt visual control – the principle of using conspicuous and recognizable signals and signs in the shop floor that will immediately alert those concerned about the location, source, and nature of the

problem. Visual signals can take the form of sounds, lights, dials, labels and other indicators which can be electronic or non-electronic. The other use of visual controls is to clearly indicate the status of any process or equipment, whether it is normally or abnormally operating or being used. When a line encounters a problem, a worker pulls an andon cord which triggers a sound alarm or stops the line to alert his supervisor or seek help. An electronic andon board may also light up in the factory, indicating the location or number of the problem line. The kanban card, another visual control example, indicates the number of pieces to be produced or delivered to the next station. If the kanban is a bin, the bin serves as the visual control for overproduction once it is overfilled. Colors lights attached to equipment called andon lights, similar to traffic lights, indicate its operating status – green for normal operations, red for breakdown, yellow for set-up, and white for waiting for parts. Tool boards which painted outline of tools, like hammers or pliers, immediately show which tools are missing and where to place or hung returned tools. Document markers similarly indicate which documents were borrowed and where to return them.



What is jidoka?

The jidoka principle means that a lean process, even running at high speed, will automatically stop or be stopped by an empowered operator when a problem like defects or wastes is detected, thus preventing the problem from going

downstream. Operators need not guard or watch over jidoka-enabled equipment. Jidoka is like smart automation or “autonomation” compared to dumb automation which characterizes many equipment and processes. For instance, many copiers and printers will continue to produce unclear output for lack of ink until the operator turns them off. In the factory, many automated usually high speed machines without jidoka can produce mountains of defects when left unattended. By incorporating smart sensors in equipment and processes, we can prevent and reduce wastes through jidoka. The jidoka principle is exemplified by the andon cord that a line operator can pull to shut down a line when he experiences a problem, like delays or defects. Jidoka is an application of the lean principle of built-in quality or quality at the source.

What is poka-yoke?

Another built-in quality principle, similar to jidoka, is poka-yoke or mistake-proofing the process. While jidoka will stop the production of more defects or wastes, poka-yoke, a step higher, will prevent their production. In other words, poka-yoke can enable a process to achieve zero defect. Pokayoke are inexpensive devices or modifications of process and equipment that stop it when it senses that a defect is to be made or wrong task is about to be executed. The work stoppage may trigger also an andon alarm to alert the operator. Examples are sensors that check if the right part or raw materials are fed to the equipment before it is worked on. The pokayoke will automatically stop the equipment and operator from working on the wrong or incomplete part. It will also prevent processing a part wrongly loaded or set-up. A pokayoke may also check if the prior process has been done on a part before the next process is initiated, thus preventing the further processing of a defect. A sensor pokayoke can also stop work if a tool such as a drill bit is broken or worn out. A pokayoke can turn off a machine that does not have the correct air pressure or is operating outside standards parameters.



auto focus
auto flash
auto exposure

MISTAKE-PROOFING EXAMPLES

What is root-cause analysis?

Before a problem, like waste or defect, can be solved and eliminated, its root or real cause must be discovered and stopped. Root cause analysis is a systematic analysis of the problem and goes beyond finding the obvious and superficial causes or symptoms and then treating them. It results in a long term if not permanent solution of the problem.

One powerful technique of root cause analysis is the 5 Why's questioning method. When a problem is defined, a 1st Why is asked to determine the immediate cause. Then a 2nd Why is asked to determine the cause of this immediate cause. After a series of Why's usually not exceeding 5, the root cause is usually arrived at and a countermeasure can be developed. For example a worker produces a defect. Why? He was using a defective tool. Why? The tool room did not check the tools it issued. Why? It does not have a proper tool maintenance program. Solution: Develop and implement and effective tool maintenance to program to reduce tool-related defects.

THE 5 WHY'S QUESTIONING ATTITUDE

WHY?

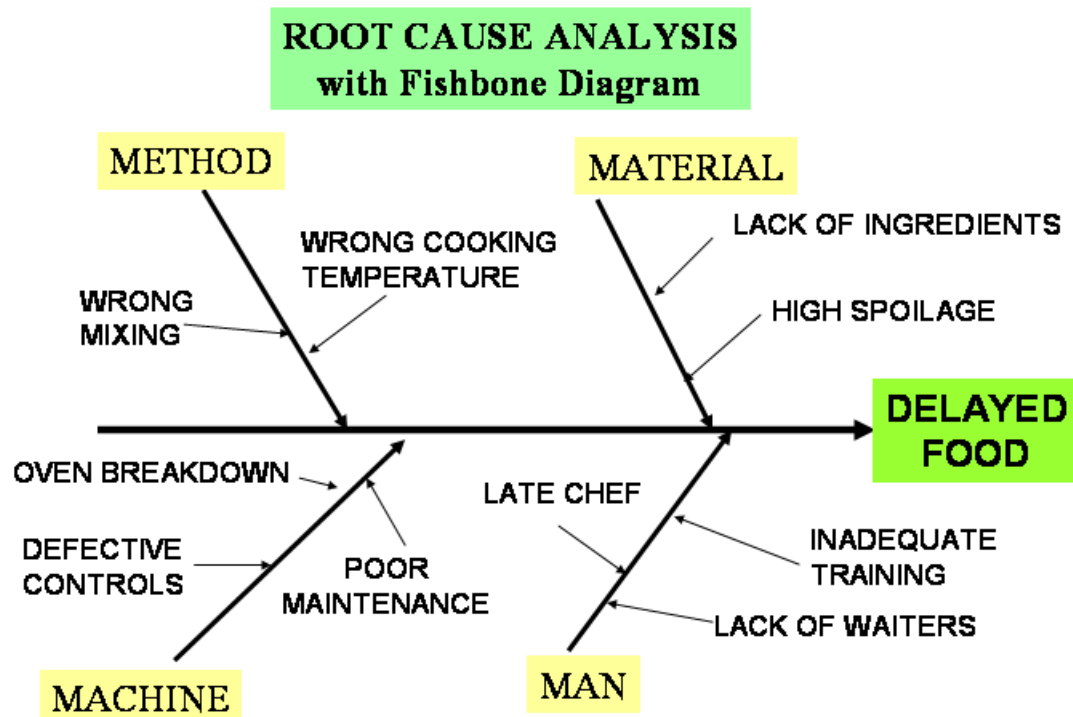
WHY?

WHY?

WHY?

WHY?

Another common root cause analysis technique is the fishbone analysis also called Ishikawa chart, named after its Japanese developer. The problem becomes the head of the fish. A spine is drawn from it and major bones are then drawn from this spine. Each bone represent possible causes of the problem arrived at usually by group brainstorming. The major bones are usually the 4 M's – man, machine, method, and materials. Minor bones are drawn from each of these major bones, indicating specific causes under each category. From the possible causes, the project team selects and determines the probable causes, and from these the actual cause or causes of the problem. It then develops the solution from this analysis.

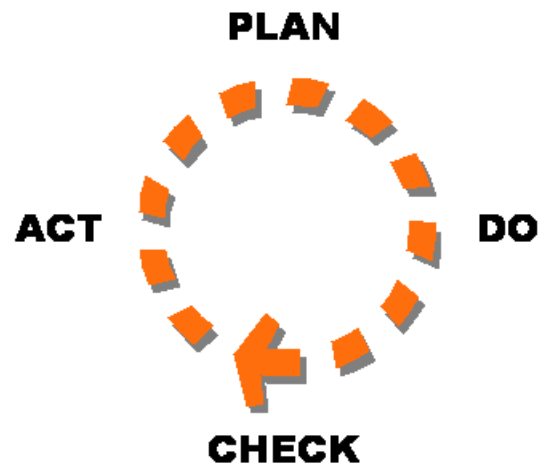


What is Kaizen?

Kaizen means non-stop or continuous process improvement that anyone in the company can do. Kaizen is a Japanese term consisting of two characters- "kai" meaning "change" and "zen" meaning "good", thus together meaning "improvement." Since kaizen is continuous, it does not stop or need a reason to sustain it. The motto of kaizen is "There is always a better way of doing anything." Improvement process starts by correcting the wrong way to make it right or meet standards. Then the right way is improved continuously through kaizen, i.e., higher and higher standards are set and achieved. There is no best way – consequently the process does not stop. Continuous improvement must be done whether the process is delayed or on time, whether the company is profitable or not, or whether the customers are complaining or not. Kaizen can enable a company to achieve higher and higher standards of productivity, quality, and service. Kaizen follows the Plan-Do-Check-Act (PDCA) cycle of improvement. Plan means select the process to improve. The Do or implement the improvement plan. Check means verify the results. If the results are favorable, then Act or make the new process the new standard. Then Plan again the next PDCA cycle of improvement to raise the process standard anew.

Lean processes must be constantly improved with kaizen to reduce waste and inefficiencies. Kaizen does not require big expensive improvements. It favors

incremental, inexpensive, and common sense solutions to process problems like defects and delays. It can be learned and implemented by rank-and-file employees, office staff, as well as managers – in fact any one who does a process or procedure repeatedly at work. Kaizen can be a company-wide program that welcomes both individual as well as small group ideas and suggestions.



KAIZEN'S PDCA CONTINUOUS IMPROVEMENT CYCLE

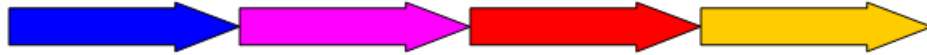
CONTINUOUS PROCESS IMPROVEMENT



One important kaizen principle, expounded by Taiichi Ono of Toyota, one of the pioneers of TPS, is “Use your head, not your money”. Kaizen is not about throwing money and resources at problems. By working smarter, one can do effective kaizen improvements without investments. To simplify a process using kaizen, one can eliminate unnecessary steps, combine related steps (do them in parallel), or change sequence of steps. Using these three simple principles, kaizen can speed up a process, cut its costs without added resources like equipment and manpower.

PROCESS ELIMINATION

BEFORE IMPROVEMENT

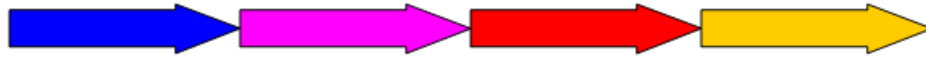


AFTER IMPROVEMENT



COMBINING PROCESSES

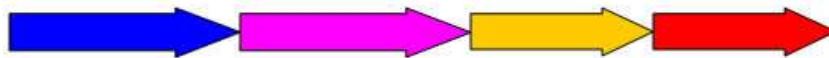
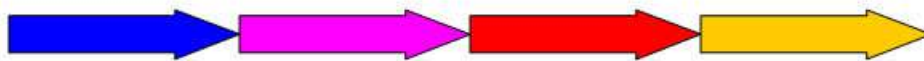
BEFORE IMPROVEMENT



AFTER IMPROVEMENT

CHANGE PROCESS SEQUENCE

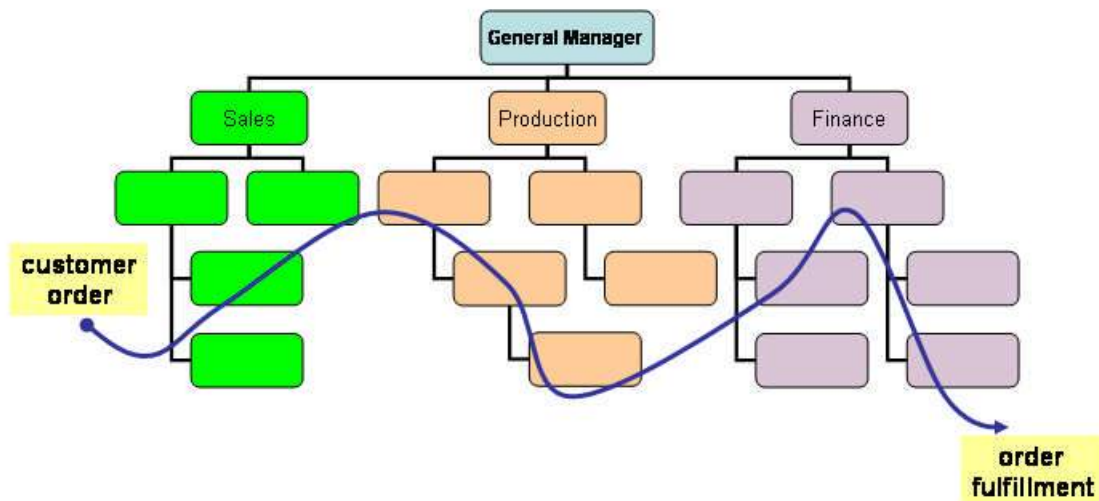
BEFORE IMPROVEMENT



AFTER IMPROVEMENT

Kaizen also applies the process thinking approach. In this approach, one looks at the output and the input, and finds the efficient processes to transform input to output, e.g., converting a customer order to order fulfillment or delivery. On the contrary, the traditional approach is the “silo” system in which the focus is the efficiency of the departments or “silos”.

PROCESS THINKING



What is 5S?

5S is the company housekeeping program that is implemented in all areas – factory, offices, warehouse, comfort rooms, stairs, canteens, hallways, parking area, etc. Like kaizen, it enjoins all employees to keep their workplace always clean, clutter-free, and well organized. 5S is the acronym of the Japanese terms

1. seiri (sorting)
2. seiton (organizing)
3. seiso (cleaning)
4. seiketsu (standardizing)
5. shitsuke (training and discipline)

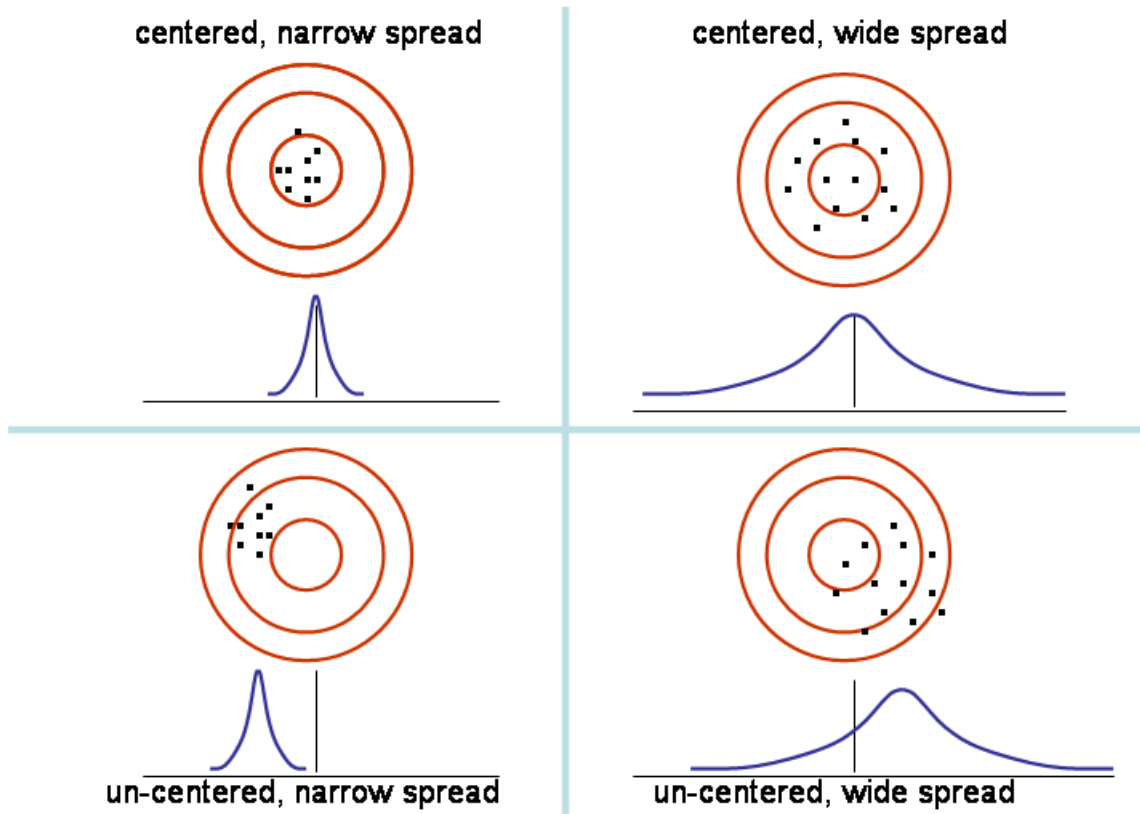
Seiri means to classify items into necessary and unnecessary, and remove the unnecessary called clutter from the workplace, particularly from hidden areas. Removal can mean relocate to a more distant location where it will not obstruct work or outright disposal. Seiton means organizing the necessary items for easy and efficient access and retrieval. This includes proper labeling and storage. Seiso or “sweep” means cleaning the workplace of dust or dirt, including repainting. Seiketsu means setting standards for procedures to implement the first 3 S’s. Examples are standards on when and how to clean, who will clean, how to store and label items, how to distinguish and collect clutter, who is in charge of particular 5S zones which may consist of several workplaces, and how to do 5S audits. Finally shitsuke means implementing and sustaining the program through proper training and instilling discipline in all employees.

The goals of 5S are improve quality, safety, and efficiency in the workplace through proper organization, cleaning, standards, and discipline. 5S creates a visual workplace, visitor-ready all the time like a showroom which one can be proud of. Most 5S activities are done by the workers and employees themselves rather than a dedicated housekeeping staff. A 5S rule is the “30 second rule”, meaning that if a workplace is properly organized and maintained through 5S, one should be able to get any tool, item, or document required or requested within 30 seconds. Thus 5S can reduce wastes due to unnecessary walking, searching and waiting.

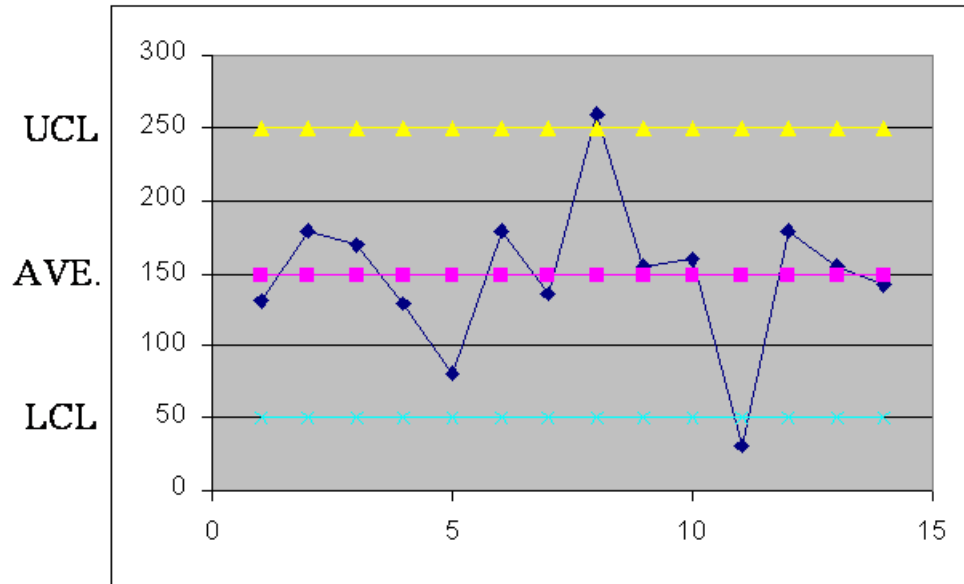
What is control of variation?

Wastes occur when customers’ specifications or process targets are not met, or completely met. It is important therefore to control variation in the process so that its outputs may lie within or close to these targets. Variation control means ensuring process stability through process design and process control. In process design, it is important to have the appropriate process capability that will match the variation or tolerance given by the customer – external or internal. Process control means ensuring that a capable process is always operating within the given upper and lower control limits, using process monitoring techniques such as Statistical Process Control (SPC) and Control Charts. Variation control means good centering and good clustering. Imagine a dart target. The goal is to have all three darts land inside the bulls eye – this is perfect control of variation. A process out of control can mean 1) all three darts are way outside the bulls eye, but clustered together 2) the darts, though far apart from each other or dispersed, surround the bulls eye but lie near yet outside of it and 3) the darts are dispersed and away from the bulls eye. In case 1, we have good clustering, but poor centering. In case 2) there is poor clustering, but good centering. In case 3), both clustering and centering are poor. In this last scenario, if this were a process, wastes, in the form of defects, rejected and reworked items, will be maximum. The measurement of the

centering of an output is its average or mean, while that of its variation or dispersion is the standard deviation or variance.



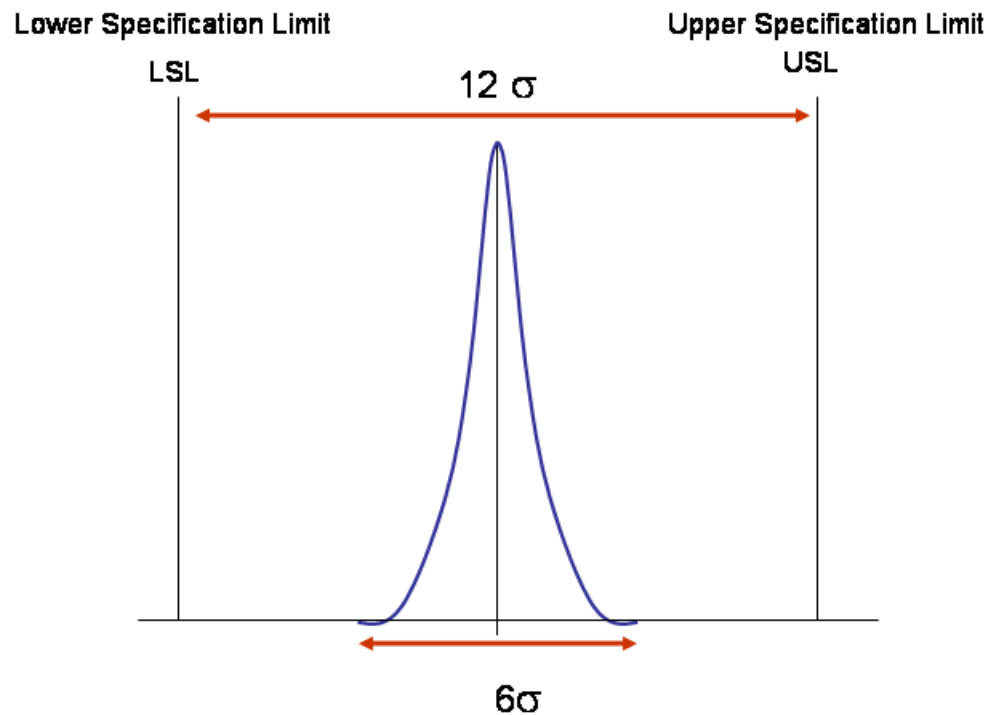
STATISTICAL PROCESS CONTROL



What is Six-sigma?

Six-sigma is a quality improvement method pioneered by Motorola and GE. Projects are implemented following the DMAIC principle (Define, Measure, Analyze, Improve, Control). Six-sigma aims to achieve about 3 defects per million (dpm) by reducing variation and improving process capability. A six-sigma process has a process capability of 2, meaning its output has quality twice that required by the customer. Six-sigma practitioners are classified into Green, Black, and Master Black belt, depending on the skills and project implementation success they have achieved. Lean Six-Sigma is a methodology of cutting wastes using the six-sigma quality improvement principles.

$$\text{SIX SIGMA PROCESS CAPABILITY (Cp)} = (\text{USL} - \text{LSL}) / 6\sigma = 2$$



What is Total Productive Maintenance (TPM)?

Total Productive Maintenance is an integrated maintenance system of improving employee productivity and safety, and equipment and process efficiencies. Lean companies usually have TPM instead of just the traditional preventive or corrective maintenance programs that focus mainly on equipment condition. TPM has three major components: preventive maintenance, autonomous maintenance, and overall equipment efficiency (OEE). Preventive maintenance is the planned maintenance of equipment to prevent unscheduled breakdowns which cause downtime losses. Autonomous maintenance empowers machine operators and other process owners to do routine maintenance to minimize downtime. This requires training and high sense of commitment. OEE is a composite measurement in % of equipment or process efficiency that considers availability, performance rate, and quality of the process. The OEE formula is availability x performance x quality. OEE aims to cut 6 major losses classified into three types of waste: availability loss due to breakdown and long set-ups, performance loss due to idling and slow speeds, and quality loss due to defects and poor yields. OEE also aims to improve the ratio of useful operating time to planned operating time.

Planned operating time (loading time)		
Actual operating time		breakdown & setup losses
Net operating time		idling & speed losses
Useful operating time	defect & yield losses	

What is gemba?

Gemba in Japanese means “actual place”. In practice, it means shop floor management sometimes known as “management by walking around” to get facts instead of staying in the office reading reports. Another term for gemba is “management by facts”, meaning doing thorough analysis and making sound decisions based on actual facts coming from actual operations. Related to gemba is the concept of “genchi-genbutsu” which means going to the actual scene (genchi) to see or verify the actual thing (genbutsu). Both gemba and genchi-genbutsu are powerful and necessary concepts in promoting kaizen and finding hidden wastes or “muda”. Attention to details is very important in process analysis in kaizen.



Getting facts from “Gemba” or workplace

What is hoshin kanri?

Hoshin kanri which means “policy deployment” is the planning system of lean companies. It consists of goal setting based on mission/vision, strategy formulation – both long and short term, performance measures, deployment and communication of strategies and goals down to the lowest level of the organization, milestones for monitoring implementation and progress, and a review process to gauge performance and achievements. The key in hoshin kanri is everyone’s understanding of his or her role in helping achieve the company’s goals and strategies, and his or her involvement and participation in the planning process.

POLICY DEPLOYMENT- HOSHIN KANRI



What is target cost?

Traditionally, a product is priced and sold after determining its manufacturing cost and the desired profit margin is added by management. This common method is known as the cost-plus approach. The formula here is $\text{Price} = \text{Cost} + \text{Profit}$. The sequence in decision making is Cost, Profit, and lastly Price. The problem here is that the selling price may not be affordable to customers when the base costs are high. Most lean companies like Toyota use a different approach known as target costing. First the price the market wants or saleable price is determined, usually by market research. The management sets its profit goal which is then subtracted from the price to get the cost, or target cost, which the company must achieve to be able to sell the product profitably. The formula then becomes $\text{Cost} = \text{Price} - \text{Profit}$. Or more accurately, $\text{Target Cost} = \text{Price} - \text{Profit}$. The sequence in decision making in this case is Price, Profit, and lastly Cost. Target costing is definitely more effective than the traditional approach since it is market-driven, rather than cost driven. It starts with price or the customer in mind, rather than the internal cost of the company. Moreover, target costing encourages kaizen and lean initiatives to cut costs and wastes. If the actual cost is higher than the target cost, the company and all its departments are bound to continuously reduce the difference in order to meet the company's sales and profit goals.

COST PLUS APPROACH

$$\begin{array}{rcc} \text{ESTIMATED COST} + \text{STANDARD MARGIN} = \text{PRICE} \\ \$350 \qquad \qquad \qquad \$88 \qquad \qquad \qquad \$438 \\ \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \uparrow \\ \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{target} \end{array}$$

TARGET COSTING APPROACH

$$\begin{array}{rcc} \text{TARGET PRICE} - \text{TARGET PROFIT} = \text{TARGET COST} \\ \$375 \qquad \qquad \qquad \$75 \qquad \qquad \qquad \$300 \\ \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \uparrow \\ \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{target} \end{array}$$

What is benchmarking?

Benchmarking is finding, and then copying or adapting, the world's best practices in performing particular processes that a company wants to improve usually through kaizen. The model may be a company, organization, institution within the industry or outside the industry. The former is called competitive benchmarking and the latter is non-competitive or functional benchmarking.

What is a lean culture?

The success and sustainability of a lean system depends on the strength of its foundation which lean culture. The elements of lean culture are lean leadership, lean mindsets, employee empowerment, and process ownership. A company has a lean culture when everybody, from the lowest rank-and-file to top management, are working together to cut all forms of wastes continuously as shown by their practices, actions, behavior, and attitudes. In particular, management provides leadership by formulating strategies, policies that support and encourage lean initiatives, and by creating an open working environment conducive to spotting, reporting, and stopping wastes. Everyone under a lean culture has a strong sense of company pride and process

ownership. All are engaged and empowered to do continuous process improvement.

Strong teamwork in a lean culture is not just evident within departments and divisions, but also across all units of the company.

All, whether in production, support, and administration departments, have the same shared goals which are derived from the company's strategies. For example, a tool keeper should not think that his job is just to keep and issue tools. He should think that his real responsibility is to give the right tools at the right time to the production people so that they make the right products at the right time so that the marketing people can sell and deliver them on time to the company's customers. In other words, the tool keeper's job is to support sales, just like the marketing and production people.

Employees show lean attitudes and mindsets when they look beyond their jobs and departments, and think of the rest of the company and its future. For example, imagine 3 aircraft mechanics doing the same work with the same tools on the same aircraft at the same pay. One may be bored, the second indifferent, and the third happy with what they are doing. When asked what they are doing, the bored mechanic may reply: "I'm tightening a bolt". The second may say "I'm installing the engine." The third may reply: "I'm making sure the company will always release an airworthy aircraft to the customer." While all three are tightening bolts, and installing engines, the happy mechanic thinks beyond his actual job assignment, and sees the bigger picture, and his more important role in his company's success. He has more pride with his work, more passion, and clearer sense of purpose. He can do the same work everyday happily with the utmost care and excitement, without ever getting bored or maybe even without feeling tired. His work, compared to those of the other two mechanics, will most likely have much better quality due to the amount of attention he gives. In fact, he will be most motivated to find a better way of doing his work through kaizen or continuous improvement.

Lean success happens through people and processes. Process improvement is not enough. In addition to achieving the "hard" process targets such as delays, defects, backlogs, wastes, inventory, rework, and turnaround time, we also have to achieve the "soft" people goals of empowerment, engagement, ownership, commitment, responsibility, and teamwork. Only by achieving these two hard and soft goals, of right process run by the right people (with the right attitudes) can business results be realized – higher sales, market share, profitability, and competitiveness.

