

Summary PPQC

Igor Konstantinov
Menno Vellinga

Planning

“Allocating a firm’s resources to the tasks or activities to be executed.” Basically, in manufacturing, the balance between efficiency and speed/flexibility is expressed.

Why should we plan?

Because we can influence Machine Idle time, product Waiting time, and machine Changeover time with the sequence of production. To do so, we can combine similar products (**batching**): less setups, more efficient. But: longer waiting time for product. Or **plan an earliest due date**: no batching, less waiting time, but: more setups, less efficient

Examples of changeover:

- Light after dark paint
- Thick after thin steel bending
- Regain concentration after a disturbance

What makes planning difficult?

>Planning is transcomputational

>Setup time is sequence dependent

>In general, the number of sequence possibilities equals the factorial number of the number of products. Therefore, one cannot compare all possible schedules to choose the best

Build a solution stepwise by:

- Hierarchical planning
- Heuristics

Scheduling

First come – first serve

SPT: Shortest Processing Time

Advantage: many customers served

Disadvantage: long jobs keep waiting

EDD: Earliest Due Date

Advantage: less due date violations

Disadvantage: perhaps many small due date violations instead of a single large one

Scheduling - practice

Those were simple priority rules. Many advanced scheduling algorithms exist.

Most scheduling performance criteria look at the effects of execution of the schedule.

- › Problem 1: the schedule is never executed as envisioned. Departments determine their own sequence based on setup time
- › Problem 2: Theory separates scheduling from rescheduling. Most companies don't know scheduling, only rescheduling (although they say they are scheduling)
- › Problem 3: Constraints do not exist. Usually we have the goal: 'violate as few constraints as possible'
- › Problem 4: Theory treats scheduling as a puzzle. In practice, it is a process with much negotiation, communication, hidden agenda's, parallel schedules, etc.

Lean manufacturing tools

The Lean Toolbox

> Investigate	> Design	> Control
<ul style="list-style-type: none">• Time/motion studies• Spaghetti diagrams• 5 Why• Value Stream Map• ...	<ul style="list-style-type: none">• Design for flows• Design for manufacture• SMED• 5S• Poka Yoke / Jidoka / Andon• Continuous improvement• ...	<ul style="list-style-type: none">• JIT• Pull Production• Line balancing• ...

Four General Components of Lean Thinking:

1. Methods to understand processes in order to **identify and analyse problems**
2. Methods to organize **more effective and / or efficient processes**
3. Methods to **improve error detection, relay** information to problem solvers, and **prevent** errors from causing harm
4. Methods to **manage** change and solve problems with a scientific approach

Six Sigma

Six sigma (quality improvement program) is an organized, parallel-meso structure to reduce variation in organizational processes (>gives possibility to get rid of buffers) by using improvement specialists, a structured method, and performance matrix with the aim of achieving strategic objectives.

Lean thinking should go further than direct waste reduction by addressing the reduction of variability and buffers in order to improve performance substantially.

Bottom-up lean interventions should be combined with lean (six sigma) projects.

Statistical Process Control (SPC)

In a manufacturing context, the less consistent and predictable a process is, the higher its costs are. SPC is used to reduce variation and lower costs. SPC uses histograms, control charts

5S

5S is a simple tool for organizing your workplace in a clean, efficient and safe manner to enhance your productivity, visual management and to ensure the introduction of standardized working.

5S goal is to introduce standard operational practices to ensure efficient, repeatable, safe ways of working. In addition to standardised working which provides you with a stable foundation to build all of your other improvements through implementing Lean Tools, you also provide a highly visual workplace. One of the most important factors of 5S is that it makes problems immediately obvious.

› **Housekeeping**

› Seiri	Sort	Remove unnecessary items
› Seiton	Set in order	Every item has a (fixed) place
› Seiso	Shine	Keep the workplace clean
› Seiketsu	Standardize	Standardize on best practices
› Shitsuke	Sustain	Continuous improvement

Jidoka

Jidoka is about quality at source, or built in quality; no company can survive without excellent quality of product and service and jidoka is the route through which this is achieved

The principle of Jidoka can be broken down into a few simple steps;

1. Discover an abnormality
2. STOP
3. Fix the immediate problem
4. Investigate and correct root cause

It is about building Quality into a process rather than inspecting for it at the end of the process, inspection still has a place even in Toyota, and despite what people think can still be a powerful way of preventing defects reaching the customer.

Poka yoke

“Poka yoke” is the Japanese name that indicates any type of system which prevents production defects to happen. Poka yokes were introduced firstly by the Toyota Just-In-Time production system to, depending on the system type, individuate, signal and stop the production in case of an unexpected situation. Because of such a broad defining concept, these control system can

be applied anywhere an error might happen, to prevent successive production steps to add value on a mistaken component and create a demand for wasteful rework. Along with other innovative quality focused techniques, Mr. Shingo, ideator of the Toyota system, managed to achieve the so called “6-sigma” quality standard for every Toyota product, where just 1 out of one million product is defective.

Value Stream Mapping (VSM)

Value Stream Mapping (VSM) or simple Flowcharting or spaghetti diagrams are very powerful ways to identify and highlight the wasteful steps in your processes. This allows you to create future state maps and create action plans to simplify your work and drive improvements.

Kaizen

Kaizen as seen by the Japanese is a method of involving the workforce to come up with many ideas for improvement, each employee is expected to come up with (and implement) 3 to 5 improvement ideas each and every month. The power of this method is not in the individual small improvement but in the combined power of many hundreds of small improvements moving the business forward constantly. Kaizen seeks to eliminate problems associated with the wastes inherent within our processes, not just the tradition seven wastes or Muda, but also Mura (unevenness) and Muri (Overburden.) The view of any process should be that it is wasteful unless you cannot find a way to eliminate it or do it in a more economical way, everything should be continually challenged and tested.

Single Minute Exchange of Dies (SMED)

Setup time: The time between the last good item and the first good item

The Big Idea

Changeover times can be dramatically reduced – in many cases to less than 10 minutes. Each element of the changeover is analyzed to see if it can be eliminated, moved, simplified, or streamlined.

Step One – Identify Pilot Area

Step Two – Identify Elements

Step Three – Separate External Elements

Step Four – Convert Internal Elements to External

Step Five – Streamline Remaining Elements

A successful SMED program will have the following benefits:

- Less hours spent in setup
- Similar batch size, higher productivity or similar productivity, smaller batches (=flexibility)
- No dedicated staff
- Scheduling setups not needed anymore
- Lower manufacturing cost (faster changeovers mean less equipment down time)
- Smaller lot sizes (faster changeovers enable more frequent product changes)
- Improved responsiveness to customer demand (smaller lot sizes enable more flexible scheduling)
- Lower inventory levels (smaller lot sizes result in lower inventory levels)
- Smoother startups (standardized changeover processes improve consistency and quality)

If we decrease changeover time (SMED), then we need less batching (Small lots and transfer batches) which reduces waiting time, and we probably need to synchronize parallel and sequential processes. Thus, transport time might even become a bottleneck

Pull Production

Traditional control: schedule on the basis of predictions.

Pull: authorize based on system status.

Basic Principle: Never run out of stock at any workstation, but do not have too much inventory.
Only final stage needs to be scheduled, the rest is automatic

Pull Production with buffers

>Never run out of stock at any workstation

- the buffer should not be depleted before it is restocked
- if either depletion rate or lead time are variable, then we need some safety stock

Reorder point = $D(LT) + SS$ (similar to EOQ)

D = Demand Rate; LT = Lead Time; SS = Safety Stock

In a pull system, if I reach my reorder point, the workstation upstream is authorized and can start producing immediately

In a pull system, lead time (LT) is: Waiting + Setup time + Processing + Transport

Rules for Pull Production

1. Downstream only orders what is needed for upstream
2. Only produce what is indicated on the card
3. No production or transport without card
4. Defective items are not sent downstream
5. Demand variations are limited
6. Start with too many cards, but slowly reduce them

Requirements for Pull Production

1. Final schedule needs to be uniform (stable demand)
2. Produce only the demand
3. Local planning & control
4. Low setup time, performed by operators
5. Everyone must have a focus on WIP reduction
6. It is a team effort
7. Preventive maintenance
8. Prevent defects (Andon, Poka Yoke etc.)

9. Facility layout must facilitate transport etc.

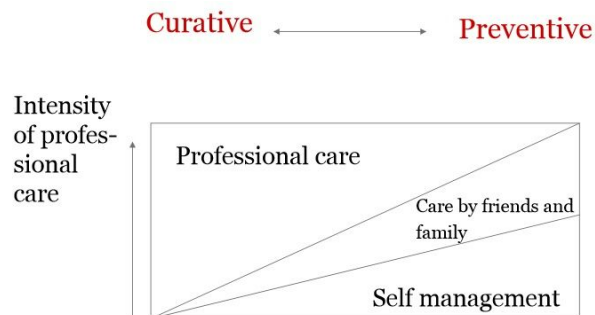
Lean in Healthcare

Actors in a Healthcare system

- Patient / Insured Person
- Provider / Business
- Third party / Insurer
- Government

Wastes and healthcare examples

1. Transportation	Poor layout
2. Inventory	Excess stock; expired supplies
3. Motion	Unnecessary staff movement
4. Waiting	Workloads that do not level
5. Over Production	Unnecessary diagnostic tests
6. Over Processing	Duplication of information
7. Defects	Any work not done right the first time
8. Talent	Employees quit giving suggestions for improvement



Two types of variability in Healthcare:

(1) Natural

- Clinical variability
- Flow variability
- Professional variability

(2) Artificial

- Generally flow or professional variability caused by a dysfunctional process within the healthcare delivery system

Coping with variability by buffers

- Inventory buffers
- Capacity buffers
- Time buffers

Two pillars of lean thinking

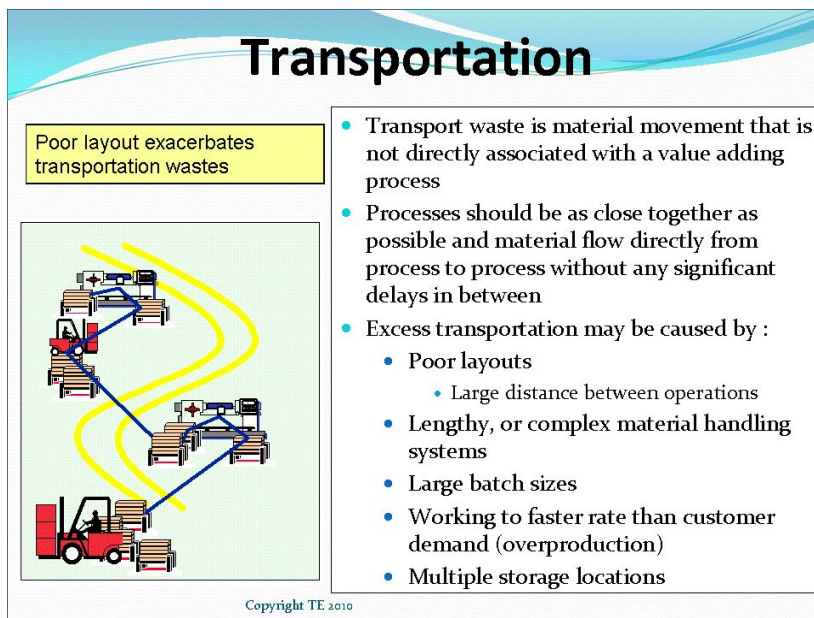
1. Total elimination of waste
2. Respect for people

Five principles of lean thinking

1. Provide the value customers actually desire
2. Identify the value stream and eliminate waste
3. Line up the remaining steps to create continuous flow
4. Pull productions based on customers consumption
5. Start over in a pursuit of perfection (Kaizen, continuous (incremental) improvement)

7 Wastes of Lean Manufacturing (TIMWOOD)

- Transport
- Inventory
- Motion
- Waiting
- Over-Processing
- Overproduction
- Defects



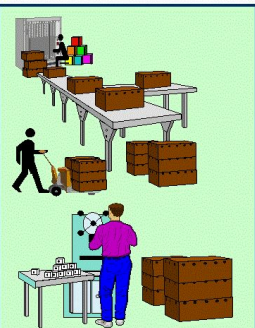
Transport is the movement of materials from one location to another, this is a waste as it adds zero value to the product. If you look at Toyota where the tools and techniques behind Lean Manufacturing have been refined as part of the Toyota Production System (TPS) you will see that many of their suppliers are located close to their plants. Products are not shipped huge distances at great cost with the potential for delay and damage. There are many causes that contribute to the waste of transport, the main one being the

waste of overproduction which in turn leads to the waste of inventory; inventory that then has to be transported throughout your facility or between factories and even continents.

Solution: Layout should be changed as per the principles of lean manufacturing, create value streams and make that value flow at the pull of the customer. This requires you to have production lines or cells that contain all of the value adding processes rather than a functional layout. It also means reducing the spaces between those operations and avoiding the use of “super machines” by using small dedicated (often cheaper) machines instead. Improving factory layout through the use of value stream mapping and process mapping can give huge savings in time and money, often with little cost involved relative to the savings to be made.

Inventory

Stock wastes space and effort



- Inventory waste is stock and work in process in excess of the requirements necessary to produce goods or services 'just in time'
- Unnecessary inventory that accumulates before or after a process is an indication that continuous flow is not being achieved
- Excess inventory be caused by
- Lack of balance in work flow, forcing inventory build-up between processes
- Large batch sizes
- Failure to observe first in first out - stagnant materials
- Incapable processes
- Long changeover time
- Not adhering to procedures

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Inventory is the raw materials, work in progress (WIP) and finished goods stock that is held, we often hold far more than is required to produce goods and services when the customer wants them using Just in Time (JIT) principles.

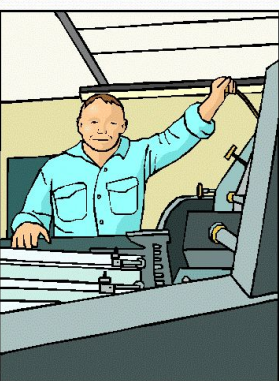
The main causes of the waste of inventory is that of the waste of overproduction, making more than the customer wants or in advance of customer demand, these two wastes are heavily interlinked and you should read up on the waste of overproduction. It can also be caused by poor layout and lack of balance in

your workflow causing inventory to build up before or after different processes. This is a good indication of poor flow within your processes and one that a good lean practitioner will look for when observing your organization.

Solution: The first thing is to work to the main principles of lean manufacturing, making value flow at the pull of the customer, the idea of Just in Time (JIT) production. This will cause us to remove the main cause of inventory that of overproduction. Look at factory and cell layout and balance your production processes to ensure that work in progress does not build up between processes, it is not important to run every machine as fast as it can be run, at the end of the day we only need to make things as quickly as the customer wants them, no faster; takt time (the time interval between customer call off) and Kanban can be used to help ensure that we balance our processes and prevent the build up of inventory.

Motion

Work smarter not harder



- Waste of motion is any motion of man and / or Equipment that does not add value to the product or service
- Wasteful motion is caused by:
 - Poor workstation layout - excessive walking, bending reaching
 - Poor method design - transferring parts from one hand to another
 - Poor workplace organisation
 - Large batch sizes
 - Reorientation of materials

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The waste of **motion** in your process gives rise to a number of problems that are either immediately obvious or hidden beneath the surface waiting to rise up and bite you in the future. The first and most obvious is a lowering of your work efficiency, if your workers are spending their times lifting, retrieving, and searching rather than actually assembling then your work efficiency will be very low.

Solution: The simplest and most powerful lean manufacturing tool at your disposal to eliminate the waste of motion within your work cells is that of


5S; 5S challenges your team to review each and every step of their operation and eliminate the

symptoms of the seven wastes. These changes will on the whole cost you nothing other than the time of your team but will result in efficiency gains in the order of 10% to 30% in most cases as well as making your work area safer preventing accidents.

The lean tool of single minute exchange of Die (SMED) will also remove many wasteful motions from your setup process, using similar principles to 5S, they are applied to the setup process of your work and will often reduce setups from hours to single minutes.

Overproduction

Avoid overproduction by balancing supply to demand



- Overproduction is the worst kind of waste because it causes other wastes and obscures the need for improvement
- Overproduction waste results from producing more (or faster) than required
- Overproduction is caused by
 - Large batch sizes
 - Unreliable processes
 - Unstable schedules
 - Unbalanced cells or departments
 - Working to forecast / inaccurate information not actual demand

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Overproduction is making products in too great a quantity or before it is actually needed leading to excessive inventory.


Solution: Once we understand the issues we need to implement the principles of lean manufacturing, identify the value stream using tools such as value stream mapping, process mapping, spaghetti diagrams and a host of analytical tools that are available to us. Then we need to make that value flow by rearranging our work place, creating production cells that contain all of the required processes and

moving away from functional layouts. Using smaller, simpler, dedicated machines rather than “super machines” that have to handle every product in the factory. We need to tackle set up times on our equipment to enable the production of smaller batches using the technique of SMED, Single Minute Exchange of Die.

Once we have done this we can use the ideas of just in time manufacturing to enable the production of product only when it is ordered, using techniques such as Kanban to enable the Pull of production through our processes.

Over-processing

Clear, standardised instructions avoid over-processing



- Over processing is putting more into the product than is valued by the customer,
 - painting of unseen areas
 - unnecessarily tight tolerances
 - cleaning and polishing beyond the level required
- The goal is to do only the level of processing to match that which is useful and necessary
- Over-processing is caused by:
 - No standardisation of best techniques
 - Unclear specification / quality acceptance standards

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Overprocessing is adding more value to a product than the customer actually requires such as painting areas that will never be seen or be exposed to corrosion. *Solution:* SOPs will ensure the standardization of methods across shifts and personnel. Moreover, Balancing of your production processes using Takt time and Yamazumi boards will help ensure that the processes are better matched with regards to cycle times. Improving machine reliability and quality using Total Productive Maintenance (TPM) and quality tools.

Defects

Right first time avoids scrap & rework



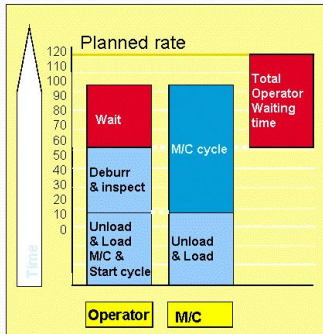
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- Waste of correction includes additional work performed on a product or service
- Caused by or unclear operating procedure / specifications
- Defects are caused by
 - Inadequate training
 - Skills shortage
 - Incapable processes
 - Incapable suppliers
 - Operator error
 - Excessive stock
 - Transportation

Solution: Reducing overproduction and inventory to minimize transport and movement between and within cells. Implement Standard Operating Procedures (SOP) to ensure that standards and methods are clear. Use visual methods of planning combined with daily cell meetings to ensure that everyone is clear what is required for the day.

Waiting

Waiting time results from failure to synchronise activities

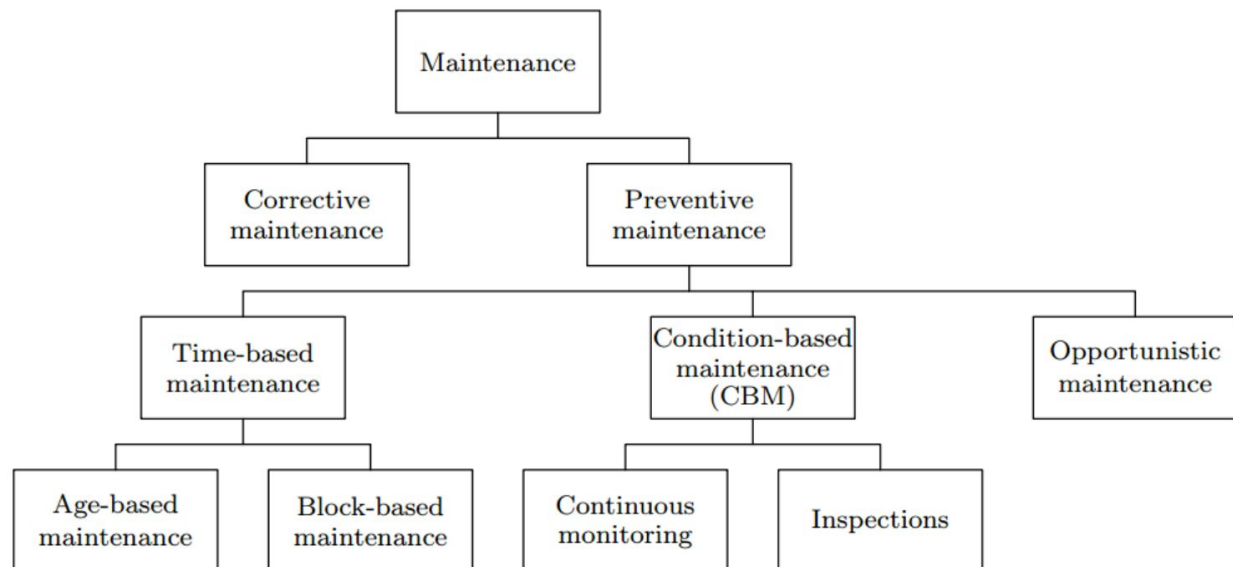


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- Waste of waiting is any idle time produced when two interdependent processes are not completely synchronised
- Operators are kept waiting, or simply work slowly whilst the machining cycles
- Waiting results from:
 - Poor man / machine coordination
 - Long changeovers
 - Unreliable processes / quality
 - Batch completion, not single piece transfer between operations
 - Time required to perform rework

Solution: The prevention of defects is achieved by a number of different techniques from automation / Jidoka (Machines with “human” intelligence that are able to detect when a non standard event has occurred) through to Poka yoke devices that detect if a product is defective, either preventing the process from running or highlighting the defect for action. We also implement standard operations procedures (SOP) and training to ensure that the correct methods are undertaken and standards achieved.

Maintenance management



Corrective maintenance

Maintenance after the occurrence of a breakdown/failure. In general, the cost of corrective maintenance is therefore high.

Potential consequences of a breakdown include:

- I Safety issues
- I Machine damage
- I Quality issues
- I Machine unavailability (unplanned downtime)
- I Long repair times
- I Unplanned maintenance action

Preventive maintenance

Aim of preventive maintenance is to postpone the moment that a machine/unit fails.

Characteristics:

- I The cost of a preventive maintenance action is lower than the cost of a failure (and its consequences).
- I Typically still failures to be expected (but they become less likely).
- I A fully functional machine is 'repaired'.
- I A planning should be decided upon (it becomes a decision/optimization problem).

Condition-based maintenance (Predictive maintenance)

The aim of predictive maintenance is two-fold. Firstly, to predict when equipment failure might occur, and secondly, to prevent occurrence of the failure by performing any required maintenance.

Main advantages:

- It's just-in-time nature: maintenance can be performed just before failure.
- More effective planned maintenance actions, because the condition of the unit is taken into account

However:

- Condition information should be available.
- CBM is more difficult to plan than TBM.
- Condition monitoring should be technically possible.
- Condition monitoring (and required equipment) should not be too expensive.

Examples of condition parameters that might be suitable:

- vibration
- temperature
- lubricating oil
- contaminants
- sound

Methods to monitor conditions:

1. Continuous monitoring (in general the most expensive one, creates most noise)
 - continuous degradation information
 - signals are received at certain degradation levels
2. Performing inspections (at a certain cost)
 - periodic inspections (how often?)
 - aperiodic inspections (when?)

Condition-based maintenance should only be implemented if its benefits over TBM outweigh the cost that are required to apply CMB

Time based maintenance (Preventive maintenance)

Time-based maintenance is maintenance performed on equipment based on a calendar schedule. An example is the maintenance that is done on an air-conditioner every year before summer. With the maintenance plan in place, the maintenance is performed each time the calendar rolls over the specified number of days.

- Easy to implement, only time has to be recorded.
- Useful remaining life may be wasted, we may be too late

Opportunistic maintenance

When preventive maintenance is performed on a component, also perform maintenance on components that are used for at least 10 days.

Total productive maintenance (TPM)

Total productive maintenance (TPM) is one of the foundation blocks of any lean manufacturing implementation; Also similar to TQM in that many of the responsibilities for day to day activities are placed into the hands of the operators and they became more involved in the actual maintenance of the machine freeing the experts to do more preventative works. TQM and TPM also focus very much on the prevention of problems rather than firefighting after the event.

Steps of TPM:

- Put routine maintenance, such as cleaning, lubricating, and inspection, in the hands of operators.
- Training and education of operators. Fill in knowledge gaps necessary to achieve TPM goals.
- Design error detection and prevention into production processes.
- Apply root cause analysis to eliminate recurring sources of quality defects.
- Have small groups of employees work together proactively to achieve regular, incremental improvements in equipment operation.
- Maintain a safe and healthy working environment.

OEE (Overall Equipment Effectiveness) is a metric that identifies the percentage of planned production time that is truly productive. In the table below you can find Six Big Losses of OEE.

Six Big Losses	OEE Category	Examples	Comments
Breakdowns	Down Time Loss	<ul style="list-style-type: none"> ■ Tooling Failure ■ Unplanned Maintenance ■ Overheated Bearing ■ Motor Failure 	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	<ul style="list-style-type: none"> ■ Setup/Changeover ■ Material Shortage ■ Operator Shortage ■ Major Adjustment ■ Warm-Up Time 	This loss is often addressed through setup time reduction programs such as <u>SMED (Single-Minute Exchange of Die)</u> .
Small Stops	Speed Loss	<ul style="list-style-type: none"> ■ Component Jam ■ Minor Adjustment ■ Sensor Blocked ■ Delivery Blocked ■ Cleaning/Checking 	Typically only includes stops that are less than five minutes and that do not require maintenance personnel.
Slow Running	Speed Loss	<ul style="list-style-type: none"> ■ Incorrect Setting ■ Equipment Wear ■ Alignment Problem 	Anything that keeps the equipment from running at its theoretical maximum speed.
Startup Defects	Quality Loss	<ul style="list-style-type: none"> ■ Scrap ■ Rework 	Rejects during warm-up, startup or other early production.
Production Defects	Quality Loss	<ul style="list-style-type: none"> ■ Scrap ■ Rework 	Rejects during steady-state production.

Cellular manufacturing

Group layout

“Group production” arranges factory floor in labor into semi-autonomous and multi-skilled teams, or work cells, able to manufacture family of parts. Consequently such a way of arranging labor is labeled “cellular manufacturing”. The general goal when proceeding with work cell formation is to maximize the degree of independence of each work cell, although a total independence is often very difficult to achieve for matters as close location of cells and required communication.

Cellular manufacturing is a system that links the advantages of a job shop with the product layout of the continuous flow line. The cell design provides fast and efficient flow, and the high productivity which is common for assembly lines. In addition, it also provides the flexibility of the job shop, allowing both similar and varied products to be added to the line without affecting the process.

By breaking the factory into small, homogeneous and cohesive productive units, production and quality control is made easier. Cells that are not performing according to volume and quality targets can be easily isolated, since the parts/products affected can be traced to a single cell. Also, because the productive units are small, the search for the root of problems is made easier.

Functional

Process layouts are found primarily in job shops, or firms that produce customized, low-volume products that may require different processing requirements and sequences of operations. Process layouts are facility configurations in which operations of a similar nature or function are grouped together.

Usually firms benefit the most from such a facilities layout when they produce customized, low-volume products that may have different processing requirements and sequences of operations. Moreover, since there are numerous machines available, process layouts are not that vulnerable to equipment failures.

The major downside of “functional layout” is the frequent presence of waiting time; when a job arrives at a workstation it must wait until previous jobs are completed. Because of the structure of the layout, jobs do not move from one workstation to another simultaneously as in “product layout”, resulting in waiting time causing work in progress(WIP). Moreover, the functional areas must be capable of sustaining peaks of production volume; in low-production-volume periods, equipment utilization level is usually low. To modify the functionality of an area, huge setup times and costs are required, which render material handling and production slower and less efficient.

Product layout

Product layouts are found in flow shops (repetitive assembly and process or continuous flow industries). Flow shops produce high-volume, highly standardized products that require highly standardized, repetitive processes. In a product layout, resources are arranged sequentially, based on the routing of the products.

Advantages of product layouts include:

- **Output.** Product layouts can generate a large volume of products in a short time.
- **Cost.** Unit cost is low as a result of the high volume. Labor specialization results in reduced training time and cost. A wider span of supervision also reduces labor costs. Accounting, purchasing, and inventory control are routine. Because routing is fixed, less attention is required.
- **Utilization.** There is a high degree of labor and equipment utilization.

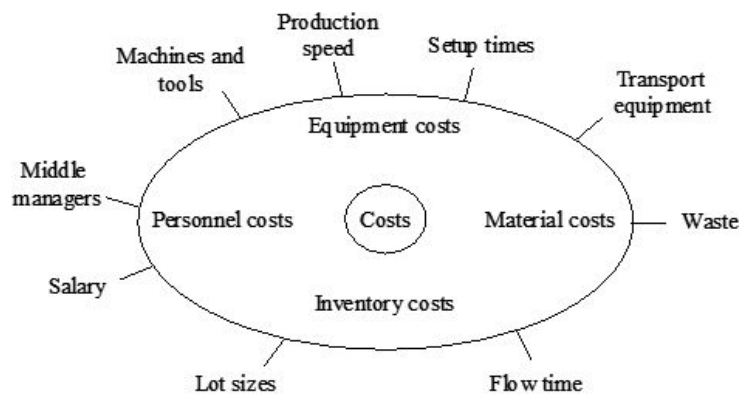
Disadvantages of product layouts include:

- **Motivation.** The system's inherent division of labor can result in dull, repetitive jobs that can prove to be quite stressful. Also, assembly-line layouts make it very hard to administer individual incentive plans.
- **Flexibility.** Product layouts are inflexible and cannot easily respond to required system changes—especially changes in product or process design.
- **System protection.** The system is at risk from equipment breakdown, absenteeism, and downtime due to preventive maintenance.

Five major performance objectives

An essential condition in the selection of a layout is the ability of decision makers to link the strengths and weaknesses of each layout alternative with the market demands, or performance objectives, with which the firm has to deal. Slack *et al.* (2001) distinguish five major performance objectives: *price, quality, speed, flexibility, and dependability*.

1. *Price*: A reduction of the manufacturing costs can be a reason to lower the price of products. Elements of the manufacturing costs are *equipment costs, personnel costs, material costs* and *inventory costs*.



2. *Quality*: another important objective that has to be considered, is the quality of the produced products. As a matter of fact, the layout type has a significant influence on the quality. For example, in a product layout workers are likely to be less specialized than in the process layout, which might lead to a lower product quality than expected. In addition, machinery used in a process layout is usually more advanced, which most of the time has a positive effect on the quality of the products.
3. *Speed*: A measure that can be used to assess speed is the throughput time, which is the time required for product to pass through a manufacturing process. It includes the move, processing, inspection and waiting times. In the throughput time calculation the process time is considered as value-adding time. This is the only step that actually produces a product. The rest of the time is administrative and logistical non-value-added time and manufacturers try to decrease it using lean manufacturing concepts.

4. *Dependability*: The performance objective dependability emphasizes the importance of being dependable with respect to delivery times, the quality of the products and such. Those are likely to be higher in a process layout; Machine breakdowns and unanticipated unattendance of workers may complicate the dependability of a manufacturing system. Interchangeability of machines and the possibility to replace workers or change their working times indicate to what extent a manufacturing system can be reliable in various circumstances.

5. *Flexibility*: Flexibility, in general, can be defined as the ease (time, effort and/or money) by which changes can be realized. For factories producing as many variations of products as the PMC2 plant it is important to maintain a flexible production at a high level to quickly adjust to the changes in demand, adjust the production focus and absorb possible machinery failures.
Product flexibility indicates the ease by which new products can be introduced in a firm. This type of flexibility is higher in a product layout if the new product can be assigned to a single existing product group (quicker response). If a new product has impact on the design of the manufacturing cells, then a process layout is more stable and has more product flexibility (larger range).

Binary Ordering Algorithm (BOA) (For better explanation check appendix)

Step 1: Each *column* is assigned a value 2^{N-k} ,

where N = total number of columns

and k = *column* number

Step 2: Each row (machine) is assigned the sum of the previously assigned column numbers for the columns which the machine is processing parts

Step 3: The row numbers are sorted by descending order (from top to bottom)

Step 4: Each column is assigned a new value as the sum of the previously sorted row numbers for which the column is relevant

Step 5: Repeat step 2, 3 & 4. Keep iterating until no more changes

Step 6: Try to identify dense blocks

BOA does not take into account:

- >Importance of machines/operations;
- >Demand/volume
- >Sequence of production
- >Transport costs
- >Setups

Methods for solving “outliers”:

- Acquire additional machines that are processing the outlier parts/products
- Redesign parts
- Combine groups
- Routing through multiple groups

Quality control

Quality is a term that can be defined in several manners. In fact four principal approaches can be followed to define quality: **customer based, process(or producer) based, value based and product based**. This implies that every organisation has to define what quality means and then carry the message into the activities with their customers.

Four perspectives on Quality

1. Customer perspective: Quality is fulfilling customer's needs and expectations. Difference between expectations and experiences
2. Process / internal perspective: quality is fulfilling specifications
3. Value perspective: value for money
4. Product-based perspective: measurable set of characteristics

Often in practise: combinations of perspectives

Here follows a brief explanation of the four categories used to approach quality. **Customer's** perspective of quality is how well the product or service compares to what the customer expects from it. Once a company has determined customer's expectations, it has to translate them into product design and manufacturing process. The two aspects of producer's or **process** perspective are quality design and quality conformance. No company can achieve the quality levels expected by customers without complying with both quality of design and quality of conformance. **Value-based** quality is defined in terms of costs and prices as well as a number of other attributes. Therefore, the customer's purchase decision is based on quality at the acceptable price. **Product** based quality is viewed as quantifiable and measurable number characteristics; however, as quality is established objectively, the benchmark for measurement may be misleading.

Quality control is a set of procedures intended to ensure that a manufactured product or, as in our case, a performed service complies with a defined set of quality criteria or meets the requirements of the client or customer. For a service organization, quality control of employees' attitude and performance is similar to product quality control for a manufacturer. Services are largely intangible and heterogeneous. The service company counts on positive impressions made on customers as a result of services properly rendered.

Quality in a production system

1. Designing and producing:

- Quality of design: Customer requirements, Producer's ability
- Quality of conformance: Defect detection checking, Defect prevention control

2. Checking

- 100% inspection (ch. 12): Worker dedication, Does not ensure 0% error rate
- Jidoka: built-in mechanisms that prevent proceeding
- Autonomation (line stops) and andons (signs)
- From detection (reactive) to prevention (proactive)

3. Quality control

Making production processes reliable, prevent variability

Before production:

- Poka yoke: once discovered conditions that give rise to defects, eliminate these conditions at the source

After production:

- Six sigma: reducing defect rates through DMAIC
- Statistical process control (SPC): monitoring process stability
- Identify the root-cause of a problem/mistake

4. Quality management

Continuous improvement through Plan Do Check Act

- Plan: set quality requirements and norms
- Do: translate into design of product and process, develop means to secure the process
- Check: measure and compare
- Act: decide on priorities, who can act, what to do

Secure / standardize for continuous improvement (Kaizen)

5. Quality assurance

- Certification and standards
- Importance of involvement of total company

Quality of service

Service Quality: Defined by both output and process

Output (what):

- Core service: reason for existence
- Implicit services: value added to core services as experienced by customer

Process (how):

- Interactions and activities between provider and customer
- Look and feel of supporting facility and facilitating goods

Measuring of service quality: Marketing perspective

Influencing quality in **service design and production:**
Service package

Core service	Essential features of the service Readily observable by the customer
Implicit services	Additional (psychological) benefits, extrinsic features
Information	Information available from customer / from provider
Supportive facility	Where is service being delivered
Facilitating goods	Material consumed, used, purchased by customer or items provided by the customer

How to make sure you provide good quality services?

Checking for quality

- Use your customers: Mystery guests or immediate feedback
- Management control
- Checklists: between service activities / before key activities

Poka-yoke methods:

Preventing *service provider* errors

- Tasks: french fries scoop
- Treatment: eye-contact stimulator

- Tangible: automatic spell check

Preventing *customer* errors

- Preparation: medical survey, tape recording before talking to bank employee
- Delivery: size of carry-on luggage, height bars
- Resolution: tray return stands and trash bins

TQM in services (Silvestro 2001)

Different practices emphasized for different types of services

Mass services: waste elimination, SPC, quality measurements

Customized services: customer orientation, continuous improvement, employee empowerment

Assurance

'Soft' practices: culture, norms and values, training of staff

'Hard' practices: Certification, qualifications (of organization and employees), audits

Cases

Case: Toyoda and Ohno

Toyoda concluded after 3 months of studying the Ford plant that Ford's system of mass production was unworkable in Japan. Since Japan had few auto manufacturers at the time and a small auto market, Toyota wanted to make a variety of cars in just one plant. Because of strong Japanese company unions and the short supply of capital, Toyoda's production engineer Taiichi Ohno concluded he would have to design a system that would be less costly and wasteful, but more efficient and flexible than the system of mass production

Toyota Production System vs. Traditional Mass production system

Reduced setup times (vs. traditional large setup times, large-batch production).

Small lot production (became possible with reduced setup times) and **One-piece flow**:

Once ways were found to make setups short and inexpensive, it then became possible for Toyota to economically produce a variety of things in small quantities. Toyota could produce any sized quantities, whatever demand dictated - even if demand was very small. The smallest size demand is one unit, and Toyota set the goal of being able to produce anything, one unit at a time: One-piece flow.

Employee Involvement and Empowerment Ohno reasoned that most tasks done by specialists could be done by assembly workers and probably done better because assemblers were more familiar with the workplace. To this end he organized his workers by forming teams, and gave them responsibility and training to do many specialized tasks. He introduced the notion of workers **asking why five times** to get problem root-causes.

Quality at the source Elimination of rework through detecting defects and the source.

>Jidoka, or line stop

Equipment maintenance

> Preventive maintenance

Pull production

>Kanban

Standard work

> 5S

Supplier Partnership

Case : America's fall from Manufacturing Grace

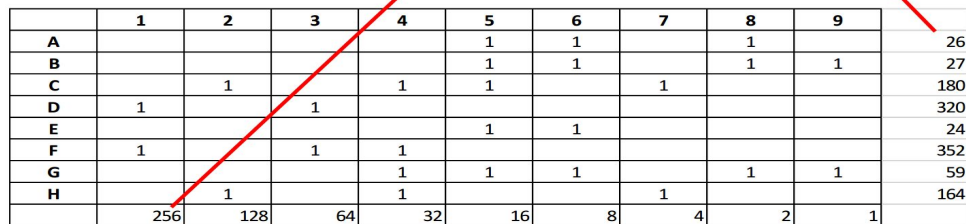
1. While the Japanese were developing improved methods of production, American manufacturers were being distracted. Beginning in the 1950s a new breed of executives came to power. Change was first seen at Ford, starting with hiring a group of young men known as the Whiz Kids, men who during the war had gained a reputation in the Air Corp for prowess in applying analytical techniques to managerial problems. However, the Whiz Kids were not car men, nor even product men. In the Whiz Kids' brand of management, financial controls are allowed to dominate and smother every other component of business - marketing, engineering and manufacturing.
2. At Ford and most other corporations in the U.S., a powerful new bureaucracy was installed. As it assumed power it displaced the manufacturing people who had customarily dominated. The best students went into finance and systems analysis, which had become the fast tracks to senior management. Rarely did good students go into manufacturing, which was viewed as a dead end. As U.S. managers changed their style, they also changed their business agenda. Driving up the price of shares on the stock market became more important than making a good product with a profit. Rather than learn from the Japanese, American managers used the challenge of Japan as a threat to keep wages down. They told workers "You better take the contract we are offering you or see your jobs moved to another country."

Appendix

Binary Ordering Algorithm

Binary Ordering Algorithm

1. Each column is assigned a value 2^{N-k} , where N is the number of columns and $k = 1, 2, 3, 4, 5 \dots$
2. Sum per row



	1	2	3	4	5	6	7	8	9	
A					1	1		1		26
B					1	1		1	1	27
C		1		1	1		1			180
D	1		1							320
E					1	1				24
F	1		1	1						352
G				1	1	1		1	1	59
H		1		1			1			164
	256	128	64	32	16	8	4	2	1	

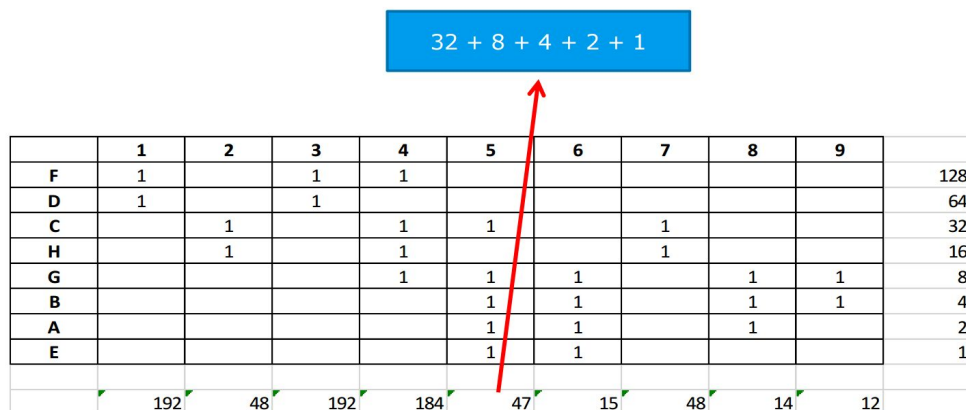
BOA

> Sort by sum

	1	2	3	4	5	6	7	8	9	
F	1		1	1						352
D	1		1							320
C		1		1	1		1			180
H		1		1			1			164
G				1	1	1		1	1	59
B					1	1		1	1	27
A					1	1		1		26
E					1	1				24
	256	128	64	32	16	8	4	2	1	

BOA

> Same trick for the columns



	1	2	3	4	5	6	7	8	9	
F	1		1	1						128
D	1		1							64
C		1		1	1		1			32
H		1		1			1			16
G				1	1	1		1	1	8
B					1	1		1	1	4
A					1	1		1		2
E					1	1				1
	192	48	192	184	47	15	48	14	12	

BOA

› Columns sorted

	1	3	4	7	2	5	6	8	9	
F	1	1	1							128
D	1	1								64
C			1	1	1	1				32
H			1	1	1					16
G			1			1	1	1	1	8
B						1	1	1	1	4
A						1	1	1		2
E						1	1			1
	192	192	184	48	48	47	15	14	12	

BOA

- › Now the rows again
- › They are already ordered, so we can stop
- › If they weren't ordered, we would have to order them and do the columns again; keep iterating until no more changes

	1	3	4	7	2	5	6	8	9	
F	1	1	1							448
D	1	1								384
C			1	1	1	1				120
H			1	1	1					112
G			1			1	1	1	1	79
B						1	1	1	1	15
A						1	1	1		14
E						1	1			12
	256	128	64	32	16	8	4	2	1	