

# Summary PPQC

June 2017  
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## Hoofdstuk 2, continuous improvement

### 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.

### 5 why's ( to see what the cause are for the problems)

### Value Stream Mapping (VSM)

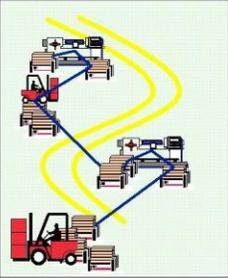
Value Stream Mapping (VSM) or simple Flowcharting or spaghetti diagrams are very powerful ways to identify and highlight the wasteful steps in your processes. This allows you to create future state maps and create action plans to simplify your work and drive improvements.

## Hoofdstuk 3, Value added + waste elimination

### 7 Wastes of Lean Manufacturing (TIMWOOD)

### Transportation

Poor layout exacerbates transportation wastes



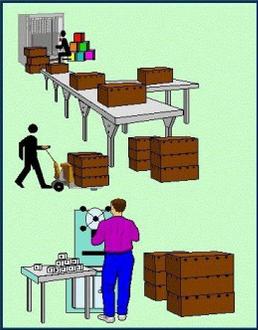
- Transport waste is material movement that is not directly associated with a value adding process
- Processes should be as close together as possible and material flow directly from process to process without any significant delays in between
- Excess transportation may be caused by :
  - Poor layouts
    - Large distance between operations
  - Lengthy, or complex material handling systems
  - Large batch sizes
  - Working to faster rate than customer demand (overproduction)
  - Multiple storage locations

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*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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**Solution:** The simplest and most powerful lean manufacturing tool at disposal to eliminate the waste of within your work cells is that of 5S; 5S challenges your team to review each every step of their operation and eliminate the symptoms of the seven wastes. These changes will on the cost you nothing other than the time team but will result in more efficiency, as making your work area safer preventing accidents. The lean tool of minute exchange of Die (SMED) will remove many wasteful motions from 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.

**Solution:** 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



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- 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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## Overproduction

Avoid overproduction by balancing supply to demand



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- 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

**Solution:** implement the principles of lean manufacturing, identify the value stream using tools such a value stream mapping, process mapping. 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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**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 nonstandard 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.

**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

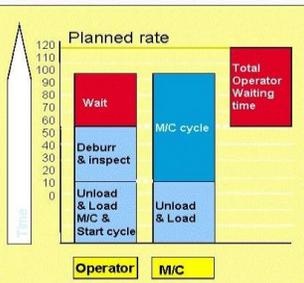


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- Waste of correction includes additional work performed on a product or service
- Caused by or unclear operating procedure / specifications
- Defects are caused by
  - Inadequate training
  - Skills shortage
  - Incapable processes
  - Incapable suppliers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

## 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:** 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.

Waste in service: waste in planning, human resources and indirect labour.

## Lean principles:

### 1.Simplification

Product/process/procedure simplification reduce waste.

### 2.Cleanness and organization (use 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

### 3.Visibility

Knowing what has been, must be, or should be done by seeing it. (schedule on work place who is in schedule and who not)

### 4. Variation reduction

Variation leads to higher average cycle times, WIP levels and costs. To handle variation we need buffers. (lead times, capability and inventory), but buffers impede our stable, predictable and efficient flow. Reduction of variability and buffers (lead times, capability and inventory) in order to improve performance substantially. no idle time of machines / people ♣ No Time buffers: customer orders never have to wait ♣ No Product buffers: no holding cost

### 5. Agile

Ability to produce any product, in any quantity, quickly in response to unplanned changes in demand.

### 6. Cycle timing

Cycle timing should be regular, regularity stimulates standardization and simplification.

### 7. measurement

Its fundamental for improvement that data is collected to assess the extent of progress.

## Lean Production

Two cornerstones

1. Basic design of production system: as much as possible

- Unidirectional flows
- Process based management
- Flow based layout

2. Reduce waste through continuous improvement (Kaizen) using flow enhancing techniques

- Pull production
- Setup time reduction
- Maintenance
- Line balancing

## Hoofdstuk 4, customer focused quality

### Customer-focused quality(perspective, dimension):

- 1.Performance
- 2.Features
- 3.Reliability: likelihood that will perform as expected for specific time.
- 4.Conformance: degree to which satisfied the standards.
- 5.Durability
- 6.Serviceability
- 7.Aesthetics
- 8.Perceived value

### Total quality control (TQM)

Management approach to focus all functions and levels of an organization on quality and continuous improvement. TQM has not a specific static goal.

Marketing and Sales are contact point with the customer, defining customer quality characteristics and requirements and what they are willing to pay. Purchasing from supplier should always be high quality parts.

### 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.

### 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. For this we need a stable process and capability of the process should be good enough.

### Employee involvement quality

Frontline responsibility and quality training and education.

## Hoofdstuk 5, Small lot production

### Lot size reduction

- Will lead to a reduction of the production lead time.
- Will lead to a reduction of WIP levels, so cost will also reduce.
- Will lead to higher setup and handling costs.
- Will lead to quicker detection of defects.
- Will lead to increasing flexibility, because of lower WIP inventory.

## Hoofdstuk 6, setup-time reduction

### Simplifying setups procedures and reducing setup times benefits:

1. Quality, easier, so no mistakes
2. Costs, reduce labour hours
3. Flexibility
4. Worker utilization
5. Capacity and lead times, shorter setup times increases capacity
6. Process variability, reduced setup variability

### SMED: Single-minute exchange of dies

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

Step One – Identify internal and external steps

Step Two – Convert internal steps to external

Step Three – Improve all aspects of the setup operation (simplification/standardization)

Step Four – Abolish setup (reduce variability, fewer differences, so less changeovers and setups)

Internal step: step that must be performed while machine is stopped

External steps: step can be performed while machine is running

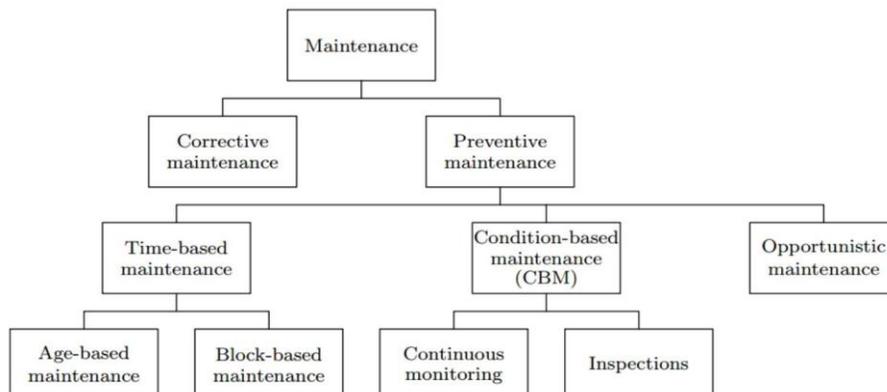
Improve internal setup: using multiple workers to reduce internal setup or standardization

Improve external steps: everything needed should be stored close

### 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 demand (smaller lot sizes -> more flexible scheduling)
- Lower inventory levels (smaller lot sizes result in lower inventory levels)
- Smoother startups (standardized changeover processes improve consistency and quality)

## Hoofdstuk 7, Maintaining and improving equipment



### **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:

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

### **Preventive maintenance**

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

#### Characteristics:

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

## Hoofdstuk 8, pull production systems

*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 zero 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

- Downstream only orders what is needed for upstream
- Only produce what is indicated on the card
- No production or transport without card(Kanban)
- Defective items are not sent downstream
- Demand variations are limited
- Start with too many cards, but slowly reduce them

### Requirements for Pull Production

- Produce only the demand
- Everyone must have a focus on WIP reduction
- Preventive maintenance
- Prevent defects (Andon, Poka Yoke etc.)
- Facility layout must facilitate transport etc.
- Final schedule needs to be uniform (stable demand)
- planning & control must be in hands of frontline supervisor and workers
- Low setup time, performed by operators
- Team effort, everybody should develop and expand their skills

Amount of cards =  $K = D(P+C)/Q$

D= demand per day, P= % capacity container of daily demand, Q= capacity container, C= 0 because buffer is around 0

### Want to:

A product layout  
With single piece / small lot production  
Short setups  
No intermediate stock  
Synchronized production

### Achieved by:

Group technology  
Transfer batches  
SMED  
Pull production  
Line balancing

## Hoofdstuk 9, Focused factories and Group technology

### 3 Layouts: fixed-position, product and process (functional)

#### Fixed-position

The end item remains in a stationary position, while equipment and people are moved to it. (ship)

#### Functional (process)

Process layouts, similar types of operations (similar equipment and similar workers with same expertise) clustered in functional work areas.

Process layouts are found primarily in job shops (multidirectional), or firms that produce customized, low-volume products that may require different processing requirements and sequences of operations.

Advantages:

- Since there are numerous machines available, process layouts are not that vulnerable to equipment failures.
- Can produce customized products
- High Variation in demand is no problem

Disadvantages:

- Frequent presence of waiting time; when a job arrives at a workstation it must wait until previous jobs are completed.
- Jobs do not move from one workstation to another simultaneously as in "product layout", resulting in waiting time causing work in progress(WIP).
- 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 (unidirectional (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:

- 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. Labour specialization results in reduced training time and cost.
- Utilization. There is a high degree of labour and equipment utilization.

Disadvantage:

- Motivation. The system's labour can result in boring, repetitive jobs that can prove to be quite stressful.
- 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 and downtime due to preventive maintenance.

Product layout	vs	process layout
	Performance criteria	
~	quality	~
+	speed	-
+	dependability	-
-	Flexibility	+
+	Cost	-

Fuctional layout very complex (to schedule), make less complex, switch to cellular manufacturing

- Shorter Lead Time
- More predictable Lead Time
- More efficient (better utilization through balance)
- Less coordination necessary between departments
- Less Flexible
- Less efficient (duplicate machines)

### Group layout

“Group production” arranges factory floor in labour into semi-autonomous and multi-skilled teams, or work cells, able to manufacture family of parts. Consequently such a way of arranging labour is labelled “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.

### Focused factories

Plant within a plant; autonomously creating a product or subassembly.

Three kinds:

♣ Focused flowline: product layout

♣ Focused workcenters: physical process layout, but certain machines are dedicated to families ♣

Workcell: small job/flowshop, able to produce small batches efficiently

Advantages:

- Reductions in lead times and WIP inventories
- Reductions in material handling
- Reduction in required factory floor space
- Reduction of overall machine setup time
- Decrease in quality-related problems
- Simpler shop-floor control procedures and reduced paperwork
- Greater work involvement, productivity and satisfaction
- Reduced overhead costs

Disadvantages:

- Potential for low machine utilization
- Plants shift from process layout to focused factory lose flexibility
- Focused factories, employees need trainings, take a lot of time, to implement it good

**How can we get unidirectional flows?**

Focused factories, group technology and cellular manufacturing.

## **Hoofdstuk 10, work cells and cellular manufacturing**

**A workcells:** is a group of dissimilar operations formed to produce a product family.

**Workcell design: assembly workcells and machining cells**

Assembly workcells: tasks are entirely or mostly manual.

Machining cells: tasks are simpler and more automated by machines.

Takt time/required cycle time= time available/demand

**Implementing Cellular manufacturing**

Requires commitment of the principles of lean production. Setup times must be simplified, machine reliability and commitment to quality must be high. Requires empowering workers.

Cellular manufacturing simplifies product scheduling and control, track only a start and end of the cell.

## **Hoofdstuk 11, standard operations**

**Standard operations** are a group of standard that completely define all aspects of a task, operation, or process.

Responsibility for standards development and implementation result in standard, more accurate, up to date.

Takt time/required cycle time= time available/demand

Standard task time = actual time \* performance rating \* allowance factor

Completion time per unit=average actual time required to process one unit

Production capacity= total operation time/(setup time per unit + completion time per unit)

With standard operations, production plans and master schedules are more realistic and likely to meet production goals.

Standard operations are a prerequisite for pull production, cellular manufacturing, and for more generally, agile, low cost, high-quality manufacturing.

## **Hoofdstuk 12, Quality at the source and mistake-proofing**

**Self-checks:** after worker performance task, he check the result. Defect and he is capable of fixing is, immediately fix it.

**successive checks:** Next person in the process, inspects the work of previous worker. When it is defect the worker pass it back to responsible worker.

Cycle time increase first increases, because time needed to check. Checks becomes standard task, faster defects are spotted and problem are eliminated. With will result in decreasing overall average production lead time, because rework is reduced.

### **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 yoke is a never-ending improvement

Control poka yoke: is a device that shut down an operation whenever it detects an abnormality.

Warning poka yoke: is a device-activated light or buzzer that only signals an abnormality.

## **Hoofdstuk 13, Uniform flow and mixed model 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

### **Priority rules**

- Average tardiness
- No. of tardy jobs
- Maximum tardiness

Disadvantage of priority rules: most are greedy, and don't consider the overall optimum. This could lead to unnecessary gaps (idle time) and due date violations in the schedule.

### **Gantt-chart**

#### **Requirement for leveling production schedules**

- Continuous and stable demand
- Short setup times
- Production = demand

### **Level scheduling in pull production**

#### **Mixed-model schedule**

*Final assembly:* pull production systems utilizes only one schedule, a schedule for the last stage of the process, since orders move upstream, order when downstream the buffer inventory of parts are almost gone.

*Heijunka: mixed-model production:* Pull system produce multiple products, requires uniform production schedule for each of them.

*Batch size:* batch must be small to keep the WIP level low, must be produced in advance by upstream operations. Furthermore reducing batch size result in smoother production schedule, which result in smoother flow of orders going upstream and smoother flow of material downstream.

**MMP schedule** is producing different products in repeating sequence, ABCABC.

#### **Requirements for MMP:**

- Flexible workers (work with multiple products)
- Effective quality assurance. Poka yoke, standard operations, source inspection is needed because workers must remember different task and operations, higher chance of defects
- Small-lot material supply. To minimize the WIP levels.

#### **Advantages of MMP:**

- Elimination of losses due to line changeover
- Process improvement, workers are more aware of problems and motivated to eliminated them.
- Balanced workloads
- Fewer losses from material shortages. material shortages for a product -> start to produce other products.

### **Scheduling:**

#### **Assemble to order:**

*Modular bills* show all possible options, modules. It is easier to estimate demand for modules than products. *Planning bills* is used for production schedule, because it greatly simplifies production schedules and improve the ability of forecasting the demand.

#### **Make to order:**

Demand is continuous, but highly variable, only way to level production in that case is to maintain a **backlog** of orders.

## **Hoofdstuk 14, synchronizing and balancing the process**

## **Synchronization**

In make to stock processes and portions of assemble to order processes where products are manufactured on a repetitive basis the production process should be synchronized such that every upstream operation produces at the rate required to satisfy demand. Synchronization meet demand with no delays and no buildup of WIP.

## **Synchronized cycle times**

In a pull system, synchronization is achieved by setting the cycle times at every upstream operation according to the cycle time at final assembly.

## **Bottleneck scheduling**

The goal is to have a bottleneck is the final stage, assembly stage, because then all other process can adjust to the meet capacity, so no WIP is buildup. If last stage is not the bottleneck, but another process and company schedules the entire process based upon the bottleneck constraint is called Bottleneck scheduling.

To increase throughput, effort is needed at the bottleneck, setup times must be reduced or the size of the process batch must be increased. Synchronizing a production process by managing the bottleneck involves the following principles:

- Throughput pace is restricted to whatever the bottleneck process can handle.
- Buffer stock, to ensure that the bottleneck is never without of work, buffer of jobs should be maintained ahead of it.
- Process scheduling, makes no sense to release more jobs into system than can be processed through the bottleneck, otherwise WIP buildup.
- Drum-buffer-rope, products before the bottleneck are pulled to and through the bottleneck. Kanban can be used in processes where the bottleneck is stable and the times through the process routing are constant.

## **Balancing**

Once the CTs in a synchronized process are set, the production capacity to all workcenters must be adjusted to conform to those CTs. Balanced process is one where the actual CTs at all stages are equal, so process is created like a conveyor with materials which moves with a constant speed.

## **Line balancing**

Small buffers between stations can reduce the effects of uncertainty and mixedmodel-task-variety Operators on the non-bottleneck can help the bottleneck.

Multiple tasks in a workstation; as little idle time as possible. (Minimize the number of stations!)  
Equal distribution of idle time over workstations

Step 1: determine the Takt Time

♣ Cycle Time = Time available / Demand

♣ 8 hours per day = 480 minutes

♣ Demand: 200 per day

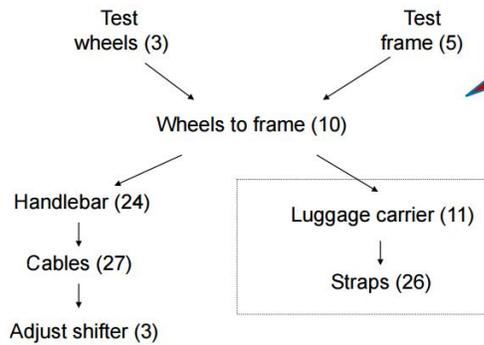
♣ Cycle Time:  $480 / 200 = 2.4$  minutes

♣ Every 2.4 minutes, a product must be finished

Step 2: Find groups of activities that take less than or equal to 2.4 minutes

Step 3: Assign those groups of activities to workstations

## **Precedence diagram**



### Rank Positional Weight

Procedure:

- ♣ Calculate for each task the time of itself and its successors (positional weight)
  - ♣ Order the tasks in decreasing positional weight
  - ♣ Repeatedly assign the tasks to the first feasible station
- feasible: (1) sum of already allocated task times plus time of to-be-assigned task is smaller than cycle time;  
 (2) no violation of zoning restrictions

See example above and suppose CT of 29.

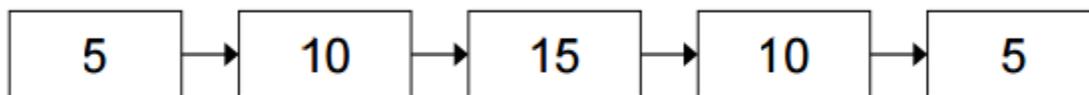
Test frame=5	Station 1: 29- 5=24
Test wheels=3	Station 1: 24- 3=21
Wheels to frame = 10	Station 1: 21- 10=11
Handlebar=24	Station 2: 29- 24=5
Luggage carrier + straps = 11+26=37	Station 3: 29- 26-11=-8
Cables=27	Station 4: 29- 27=2
Adjust shifter= 3	Station 5: 29- 3=26

Station 3 needs a solution, because cycle time of these 2 steps are 37 and should be 29. Station 3 can be double, so 2 stations for Luggage carrier and straps. Other option is : station 5 is underutilized. "Workers will adjust their speed toward the speed of their coworkers, creating a regression-to-the-mean effect among processing times"

### Unpaced line

Work will be given to the next station when it is finished

- ♣ Blocking
- ♣ Starving



What is the cycle time? 15

What is the efficiency?  $45 / 5 \times 15 = 60\%$

What is the throughput time?  $15 + 15 + 15 + 10 + 5 = 60$

## Hoofdstuk 15, planning and control in pull production

## Why should we plan?

Because we can influence Machine Idle time, product Waiting time, and machine Changeover time with the sequence of production.

- ♣ Combine similar products (batching): less setups, more efficient. However: longer waiting time for product.
- ♣ Earliest due date: no batching, less waiting time, however: more setups, less efficient

## 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

## Hoofdstuk 16, lean production in the supply chain

**Supply chain management:** coordinating the activities of suppliers to meet the requirements of the customers above(downstream) them in the supply chain.

### Customer-supplier relationship

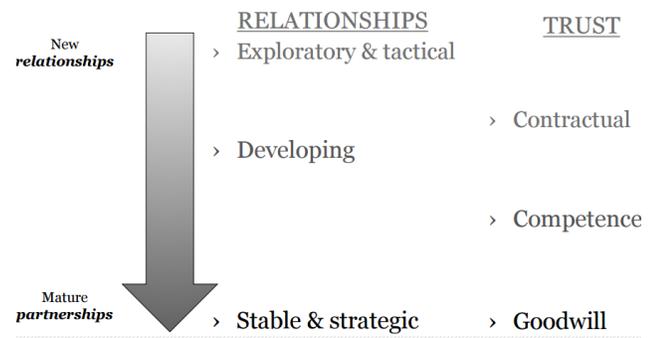
Joint problem solving: customer work with supplier to help supplier resolve cost or quality problems and way requirements can be meet better.

Quality at the source: Supplier should deliver 100% quality of incoming materials

Information sharing

### Making decisions about partnership relationships

- Purchase criteria
- Design source
- Number of suppliers



### What are humanitarian operations?

Humanitarian operations entail short-term material and/ or logistic assistance to victims of natural and man-made disasters with the goals of saving lives, alleviating suffering, and maintaining/ restoring human dignity.

### Characteristics of humanitarian NGOs

- Not driven by profit
- Equity (fairness)
  - Equal acces for all disaster victims (e.g. flood victims in an area)
  - Available for all in need (e.g. right to food and health care access)
  - Equally treated (e.g. assistance offered regardless of gender, religious identity etc.)
- Effectiveness ("doing the right things")
- But also: drive for (increasing) efficiency and quality

### The Kralijc matrix – product classification

Profit impact ↑ high Low	<b>Leverage items</b> Exploitation of purchasing power	<b>Strategic items</b> Performance based collaboration
	<b>Non-critical items</b> Efficient processing	<b>Bottleneck items</b> Secure supply, search alternatives
	Low	high
	Supply risk	

**Note:**  
In humanitarian operations, it is not always about profit!!!

At the y-as:

- Equity
- Cost-budget
- Quality
- Lifesaving impact

### Lean supply chain management

Can be achieved within and between processes:

- Purchasing
- Warehousing (receipt, storage, picking, shipping)
- Inventory management
- Transportation
- Customer-supplier relationships

### 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

# 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	

16 + 8 + 2

### 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

32 + 8 + 4 + 2 + 1

	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	

# Quality control

## 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.

### **Case : America's fall from Manufacturing Grace**

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.

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."