# Lean Production

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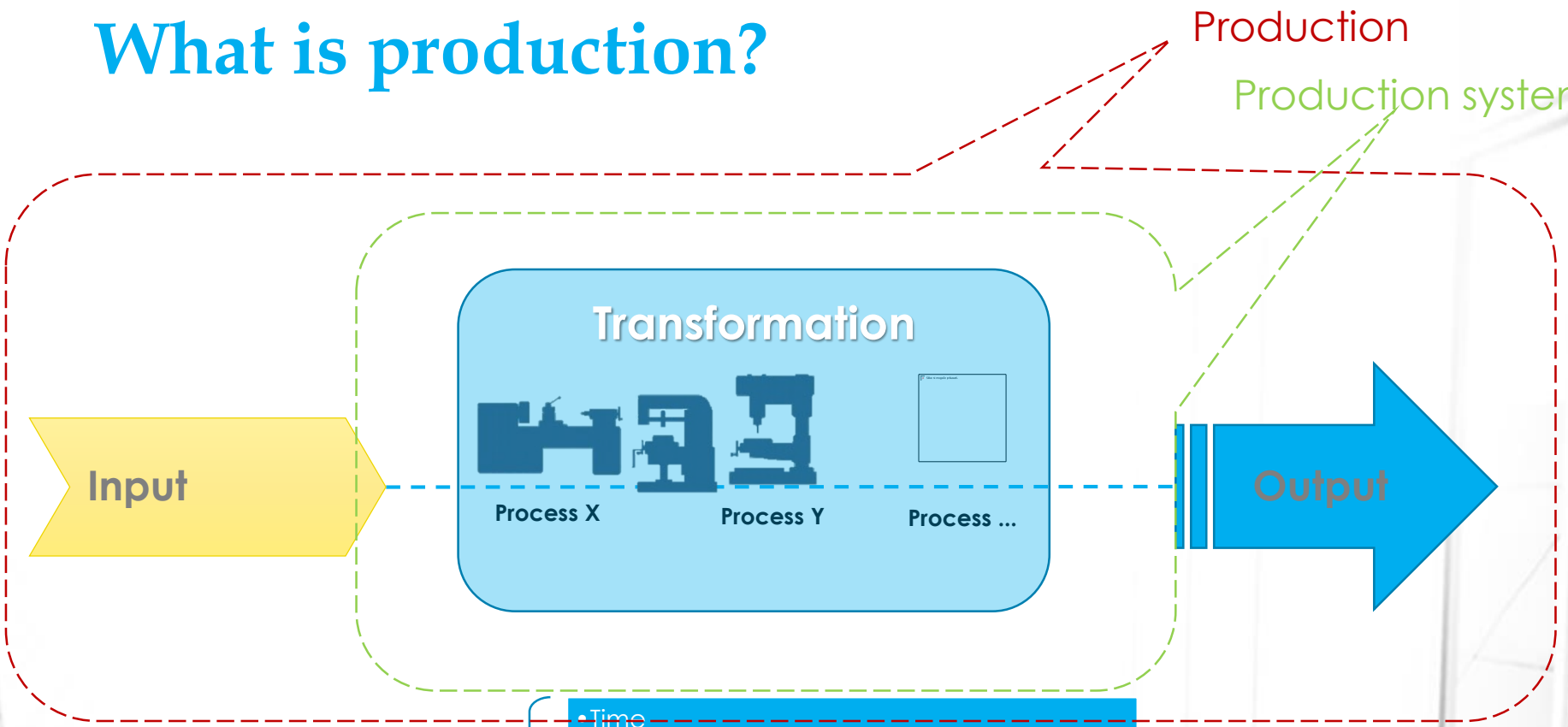
# Learning objectives

At the end of the lecture, you should be able to;

- Express the concept of lean with the theories behind,
- Consolidate fundamental principles of lean,
- Define waste and value & differentiate 7+1 types of wastes,
- Discuss Toyota Production System (TPS) and its constituents (Lean tools).

# What is production?




Constraints
- Time
- Money
- Resource
- ...

Uncertainties
- Machine breakdown
- Demand changes
- New technologies
- ...

Targets
- Economical
- Sales
- Timing

# The ultimate objective of production is

to produce

right product

of right quality

in right quantity

at right time

by optimum use of resources.

# Brief history...

## Henry Ford's right !

Henry Ford

"I will build a car for the great multitude. It will be large enough for the family, but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one – and enjoy with his family the blessing of hours of pleasure in God's great open spaces." (Video)

# Brief history…

´First flow production introduced by Henry Ford in 1913 for *Ford Model T*'

2 revolutionary concepts!

- Assembly line
- Interchangeable parts

| Model T | Before assembly line | After assembly line |
|---|---|---|
| Time to produce a car | 12 hrs | 1 hr |
| Selling price | $850 | $290 |
| Net income | $25 million | $78 million |

# Brief history...

HOWEVER

→ “Any customer can have a car painted any color that he wants so long as it is black.”

You had only 5 options (body styles) indeed!!

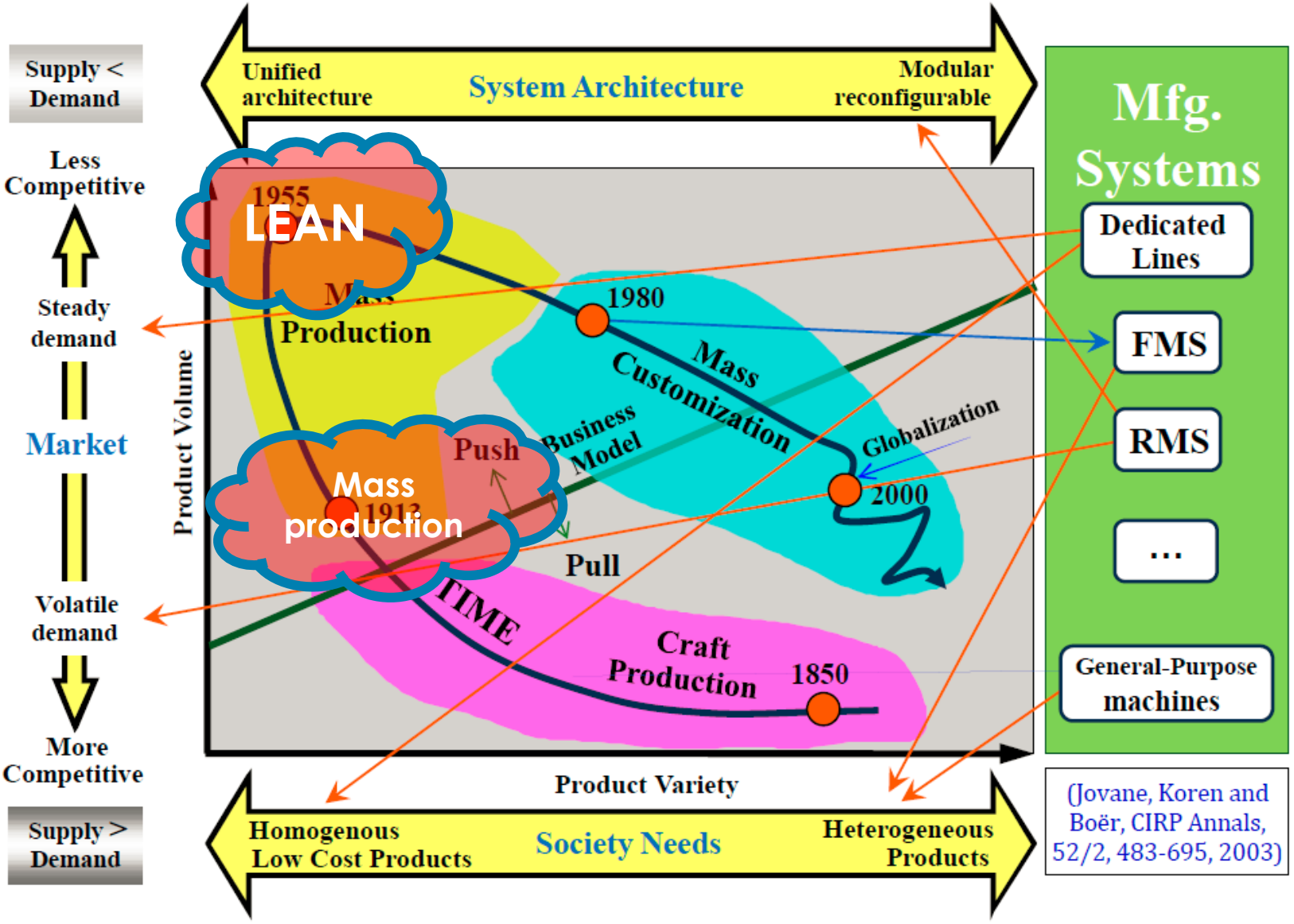
# Change

"It's not necessary to change. Survival is not mandatory."

-W. Edwards Deming



# A historical view of production




(KTH Sustainable Manufacturing, Lihui Wang, 2014 )

# Brief history...


Kiichiro Toyoda


*Taiichi Ohno*

Toyota Production System

- → by right-sizing machines for the actual volume needed,
- → introducing self-monitoring machines to ensure quality,
- → lining the machines up in process sequence,
- → pioneering quick setups so each machine could make small volumes of many part numbers,
- → having each process step notify the previous step of its current needs for materials,

**it would be possible to obtain**
low cost,
high variety,
high quality,
and very rapid throughput times to respond to changing customer desires.

# Lean is a…

***…operational excellence strategy that enables you to change better.***

***…systematic approach of eliminating all forms of waste with the goal of creating value.***

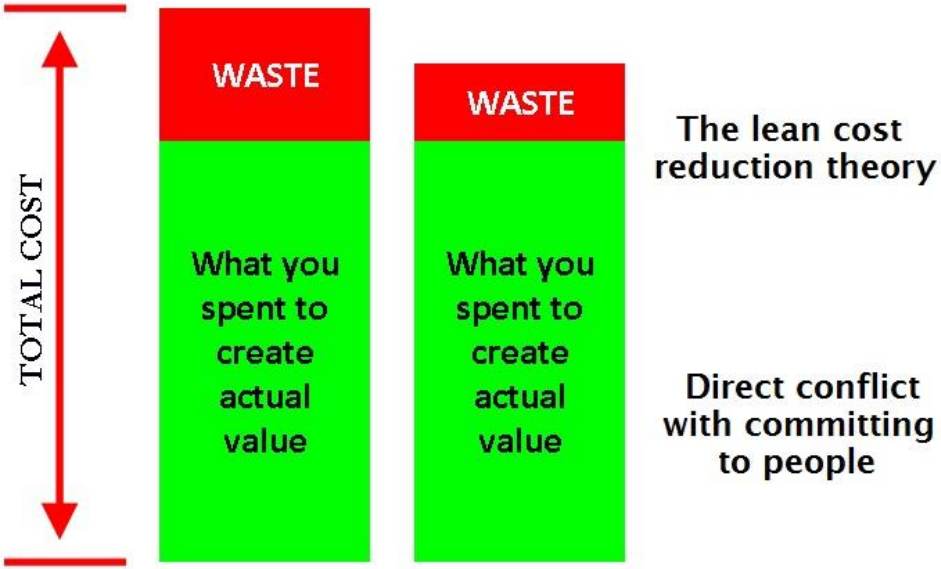
Note: This stands in contrast to definitions of lean that only focus on eliminating waste, which is too often interpreted as cost cutting – independent of its impact on value delivery…

**kai**
"change"

**zen**
"good"

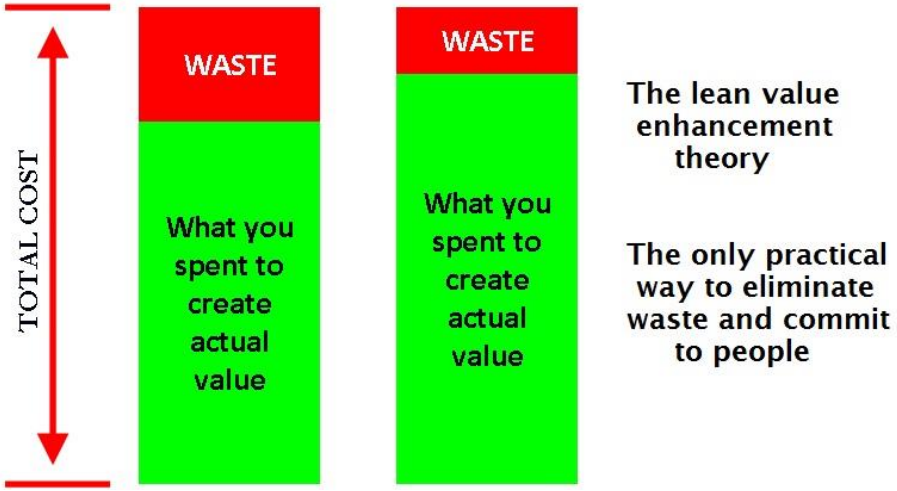
# Lean is not a...

... tactic or cost reduction program




# Lean is not a...

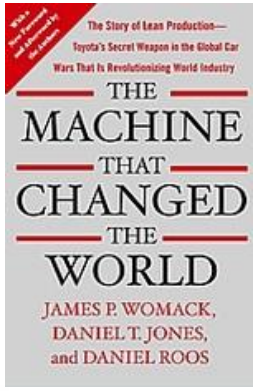
...cost reduction program




So what?

1. additional capacity - the ability to produce more product with the same cost base
2. able to build more value into each product you sell for the same cost - which means you can charge higher prices since you are delivering superior value.

# Brief history…

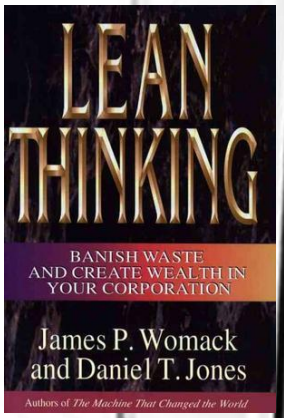



*"The machine that changed the world"* (Womack et al., 1990)

-Comparison of Japanese production versus Western mass production

*"Lean thinking: Banish waste and create wealth in your organization"*
(Womack and Jones, 1996)

-lean principles with action guide
-coined the phrase "lean production"



# Lean vs Mass...

| | Mass production | Lean production |
|---|---|---|
| Basis | • Henry Ford | • Toyota |
| People–design | • Narrowly skilled professionals | • Teams of multi-skilled workers at all levels in the organization |
| People–production | • Unskilled or semi-skilled workers | • Teams of multi-skilled workers at all levels in the organization |
| Equipment | • Expensive, single-purpose machines | • Manual and automated systems which can produce large volumes with large product variety |
| Production methods | • Make high volumes of standardized products | • Make products which the customer has ordered |
| Organizational philosophy | • Hierarchical—management take responsibility | • Value streams using appropriate levels of empowerment—pushing responsibility further down the organization |
| Philosophy | • Aim for 'good enough' | • Aim for perfection |

# Fundamental lean principles

1. Identify value from the standpoint of the end customer by product family.
2. Identify all the steps in the value stream for each product family
3. Make value flow continuously
4. Let customers pull value from the next upstream activity
5. Pursue perfection: Pursue continuous process of improvement striving for perfection

# 1-Identify Value

| Value adding | versus | Non-value adding |
|---|---|---|
| • An action that a customer is willing to pay for | | • An activity that consumes resources without creating value for the customer |
| • An activity that transforms a product or service | | • An activity that is unpredictable in creating value |
| • An activity done correctly the first time. | | • An activity that requires more time, effort or resources than necessary. |

# Who is customer?

→External customers - are outside an organization, money is typically exchanged with external customers.

End users are customers who pay for an operational or consumable product or service.

→ Internal customers - are inside an organization, money is typically not exchanged directly with internal customers.

Customers also drive the inputs to a process through their needs and requirements.

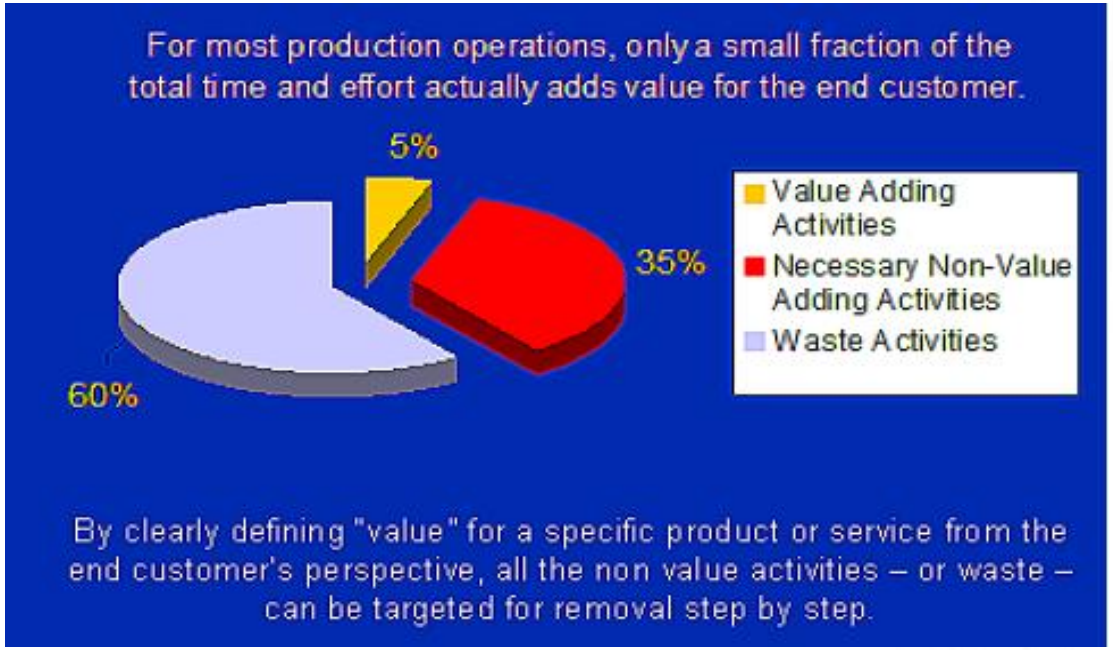
# Enemy of lean


'Muda' means waste in Japanese.

**WASTE:** Any activity absorbing energy (resource, human effort, material...) without contributing to the end value.

# Recognize waste

We cannot eliminate the waste of material, labor, or other resources until we recognize it as waste.

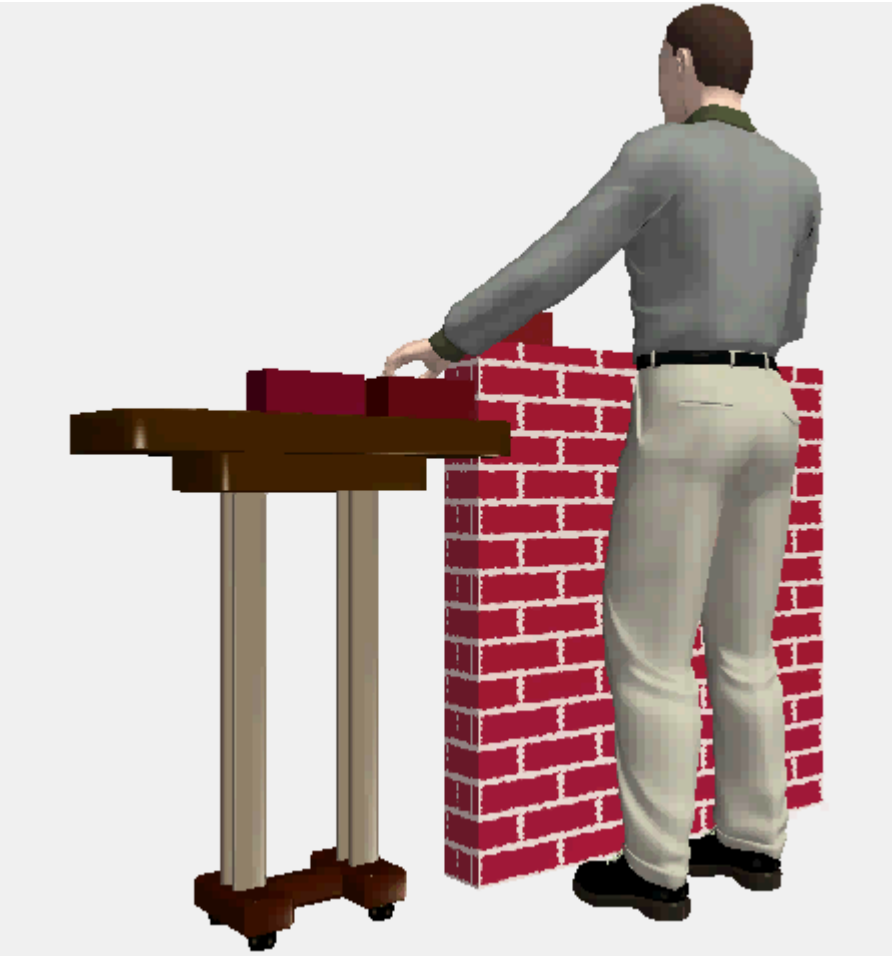



www.1000ventures.com

# Waste of…?

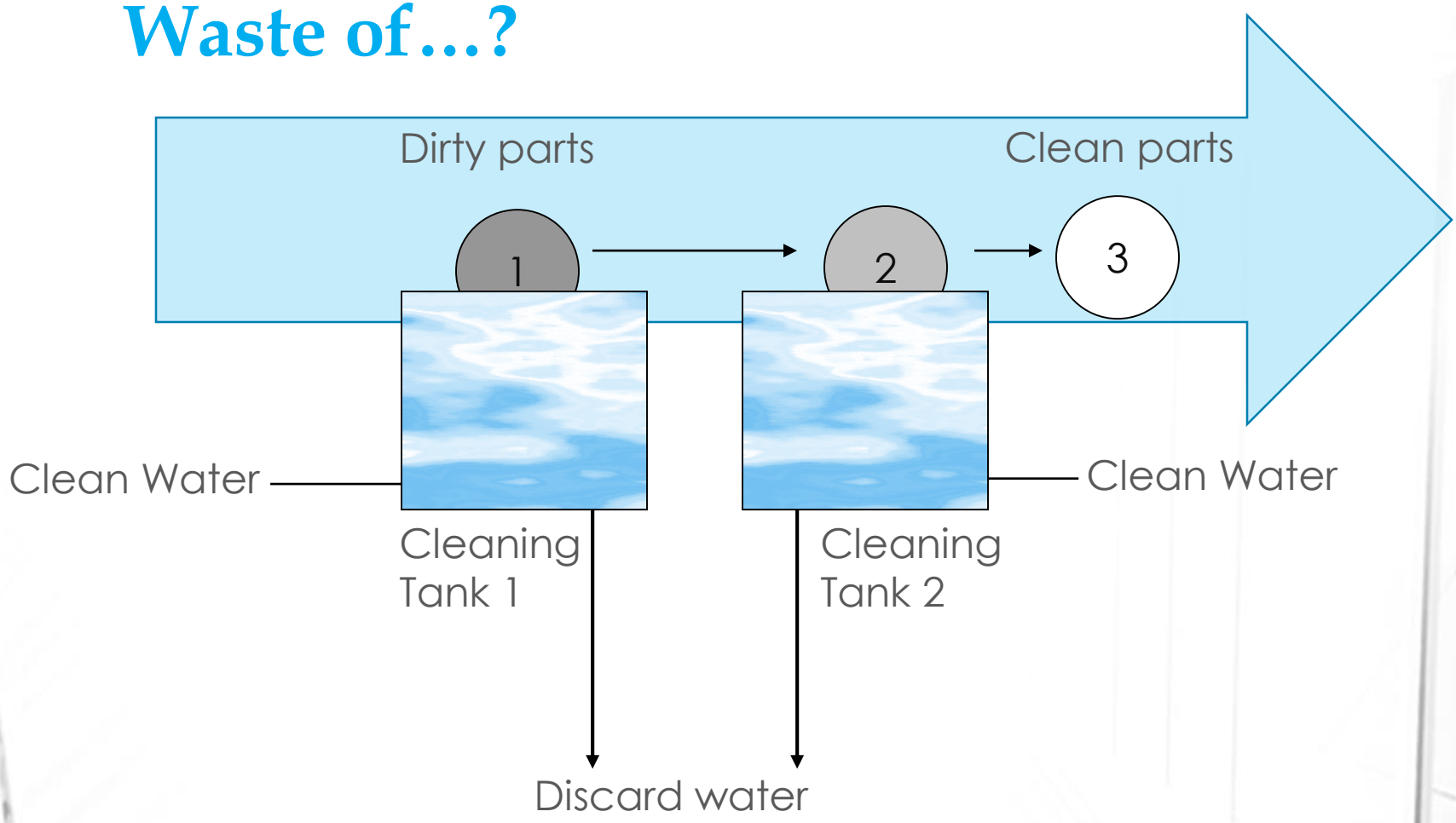
Waste is often built into jobs

# Waste of…?



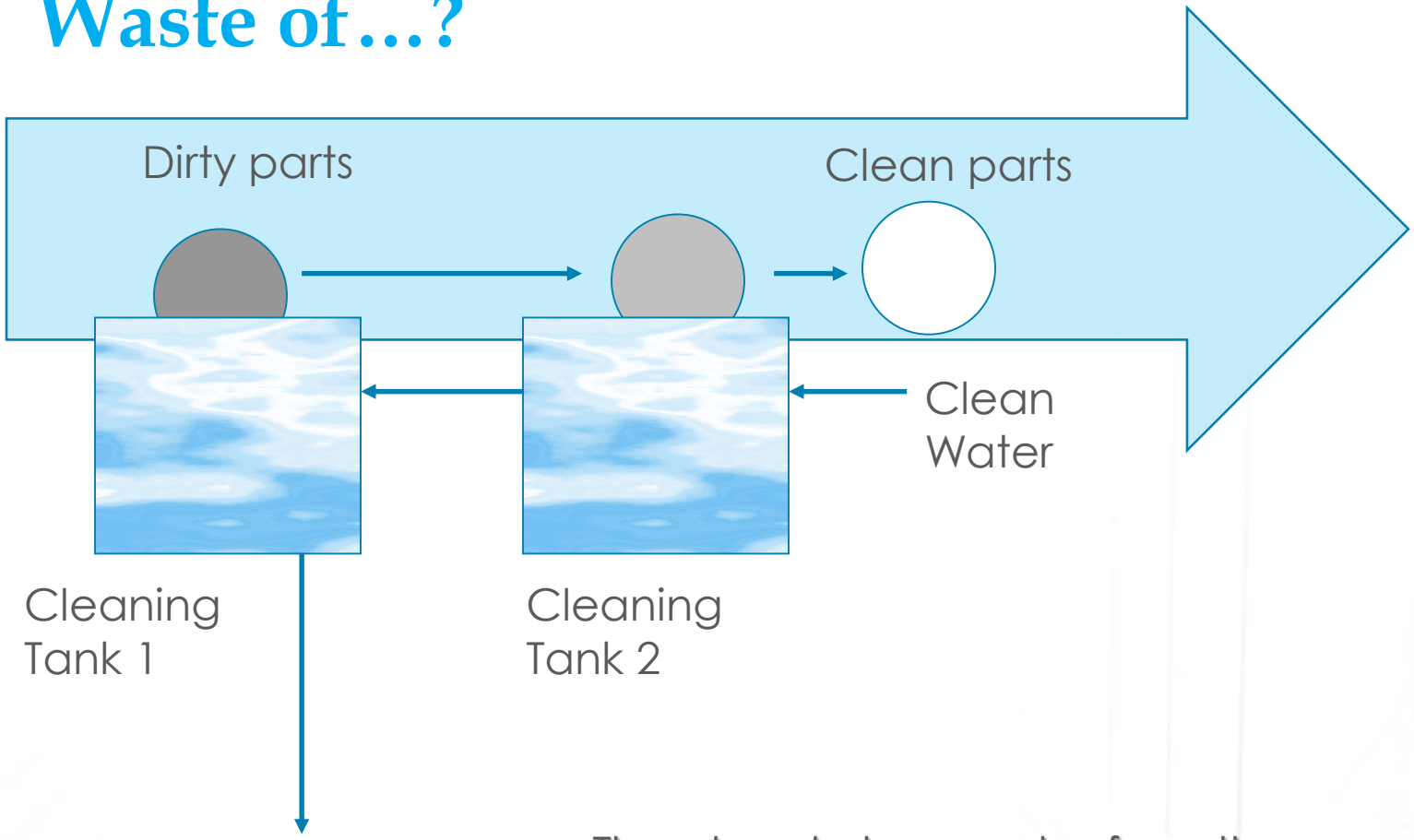
The solution is obvious but we have to recognize first that we have a problem !

# Waste of…?




The parts get clean, so no one questions this. What is wrong with this picture?

# Waste of…?




The *almost* clean water from the second tank is good enough for use in the first tank.

*Water usage can be cut 50 percent.*

# Zero waste store

>>VIDEO

# 7+1 types of waste

1. Transportation
2. Inventory
3. Motion
4. Waiting
5. Overproduction
6. Over Processing
7. Defects (Correction or Rework)

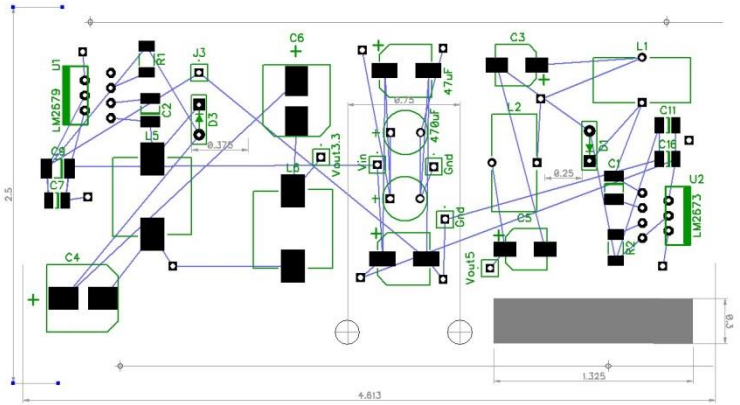
+

Waste of creativity

> Waste is anything other than the minimum amount of equipment, materials, parts and working time which is absolutely essential to add value to the product or service.
>
> Ohno Taiichi

# 1- Transportation

- Transporting products from one location to another ( it can be from one station to another, from the supplier to producer etc.) is a cost incursion which adds no value to the product.



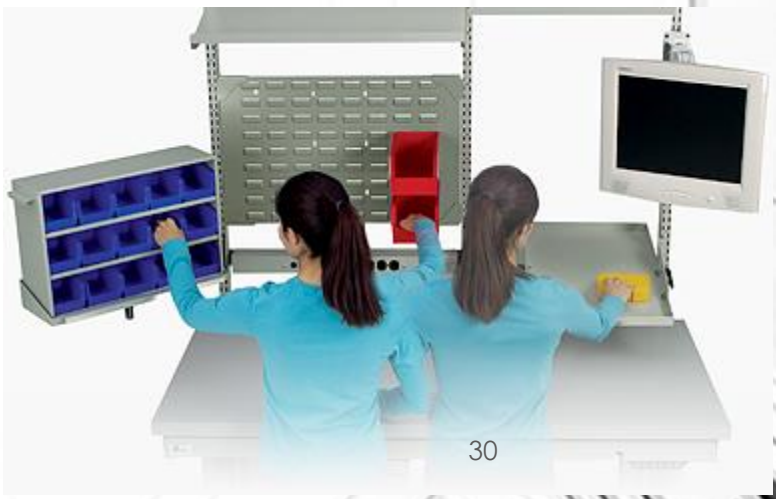
- Underlying reasons might be;
  - Poor layouts
  - Complicated material handling systems
  - Large batch sizes

# 2- Inventory

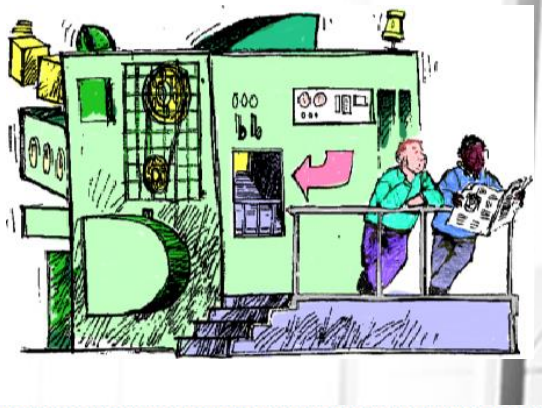
- There are 3 inventory types;
  - raw materials,
  - components,
  - work in progress,
  - finished goods.
- Carrying stock attracts cost & storage problems. Storage leads to stacking, racking, sophisticated computers, bar coding & automation, all for an activity that adds no value to the product.
- Underlying reasons might be;
  - Unbalanced work flow, forcing inventory accumulation between processes
  - Large batch sizes
  - Long setup times
  - Unstandardized processes

# 3-Motion

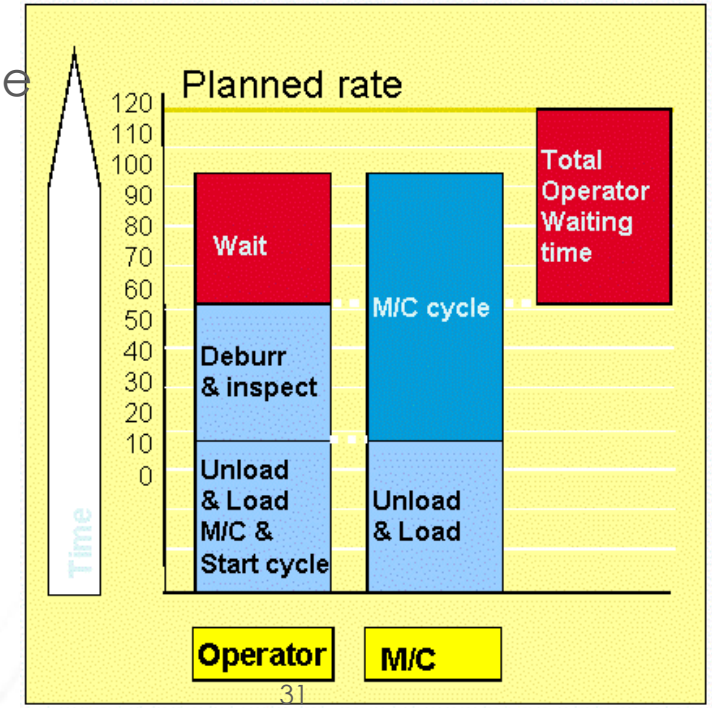
- Waste of motion is any motion of a resource (can be both operator or equipment) that does not add value to the product or service.
- Underlying reasons might be
  - Ergonomically poor conditioned workstations (excessive walking, bending, reaching etc.)
  - Poor method design – transferring parts from one hand to the other
  - Poor workplace organization
  - Reorientation of materials



# 4-Waiting



- Waste of being idle when two interdependent processes are not completely synchronized.
- Operators are waiting or working slowly
- Underlying reasons might be;
  - Poor coordination of operator and machine
  - Long setup times
  - Unreliable and not standardized processes
  - Batch production



# 5-Overproduction

- Worst waste among the others since it leads to other wastes
- It results from producing more than the actual demand or producing earlier than it is needed.
- The reasons behind;
  - Large batch sizes,
  - Unreliable processes
  - Unstable schedules
  - Unbalanced lines
  - Planning based on forecasts not on actual information.

# 6-Overprocessing

- Overprocessing is adding more value to a product than the customer actually needs.
  - Painting of unseen areas
  - Unnecessarily tight tolerances
  - Cleaning and polishing beyond the level required
- Underlying reasons might be;
  - Unstandardized processes
  - Unclear specification/quality acceptance standards


"Sixty-six flavors."

# 7-Defects

- Defects are the products/services that deviate from what the customer actually asked for.
- It leads to additional waste as identification of defect, work of correction etc.
- Possible reasons are;
  - Inadequate training
  - Unskilled workers
  - Unstandardized processes
  - Excessive stocks
  - Transportation

# 7+1 - Waste of talent or creativity

- It is the failure to make good use of your employees.
- Failure to involve the work force in the design and development of their workplace to incorporate practical solutions and build ownership leads to sub-optimal performance.
- Continuous development of skill levels beyond the immediate job requirements will support effective problem solving at the heart of the process.
- Reasons behind might be;
  - Inappropriate policies
  - Incomplete measure
  - Tight working schedules

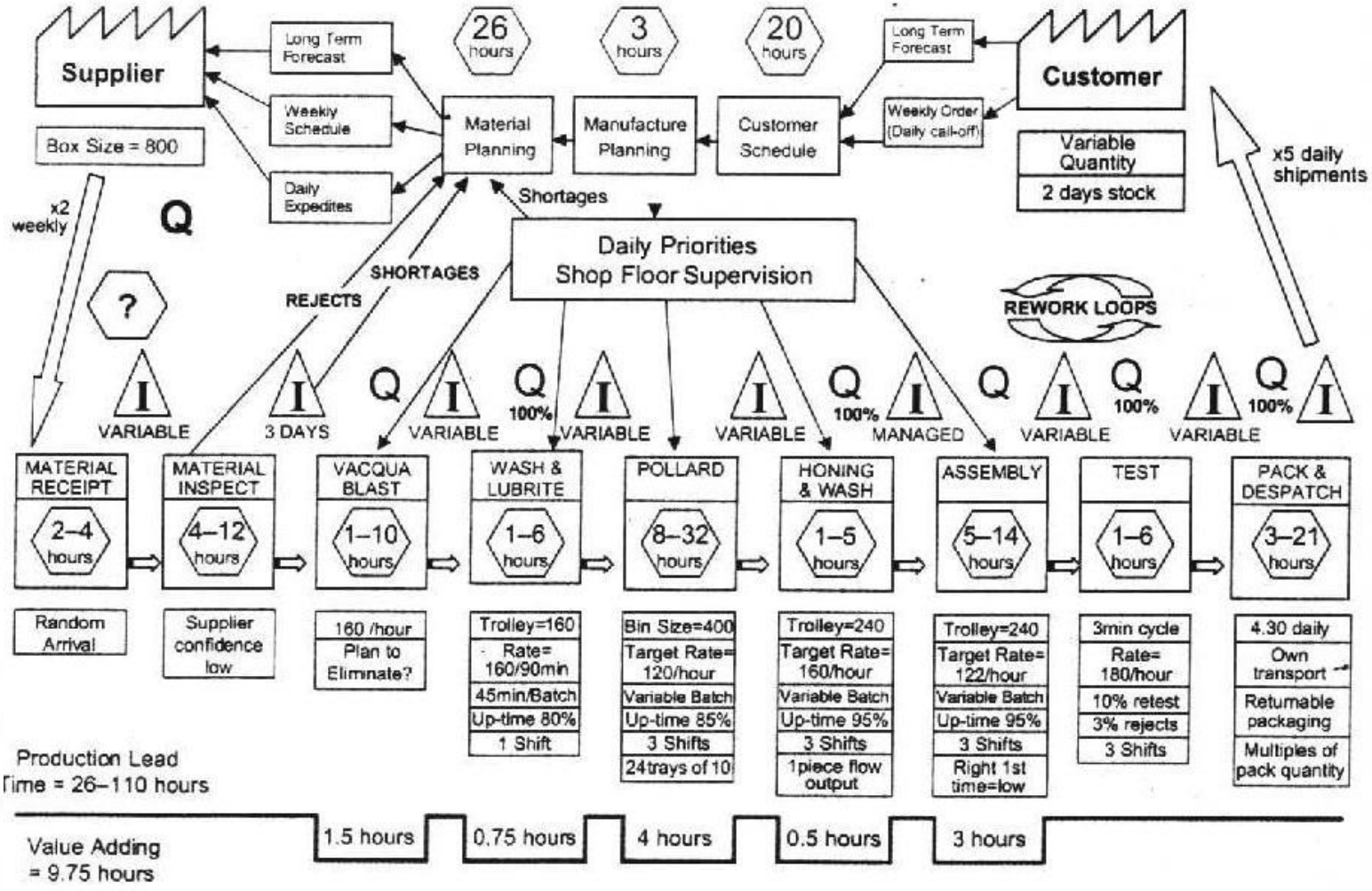
# Map the value stream

- A value stream is all the activities performed from raw material to finished product for a specific product or product family,
- Value stream mapping is a powerful approach to visualize the flow of material and information and to recognize waste,
- It is especially powerful to elucidate the wastes of Overproduction, Idle Material & Transportation,
- Value stream maps show all actions required to deliver a product…i.e. value added & non-value added.

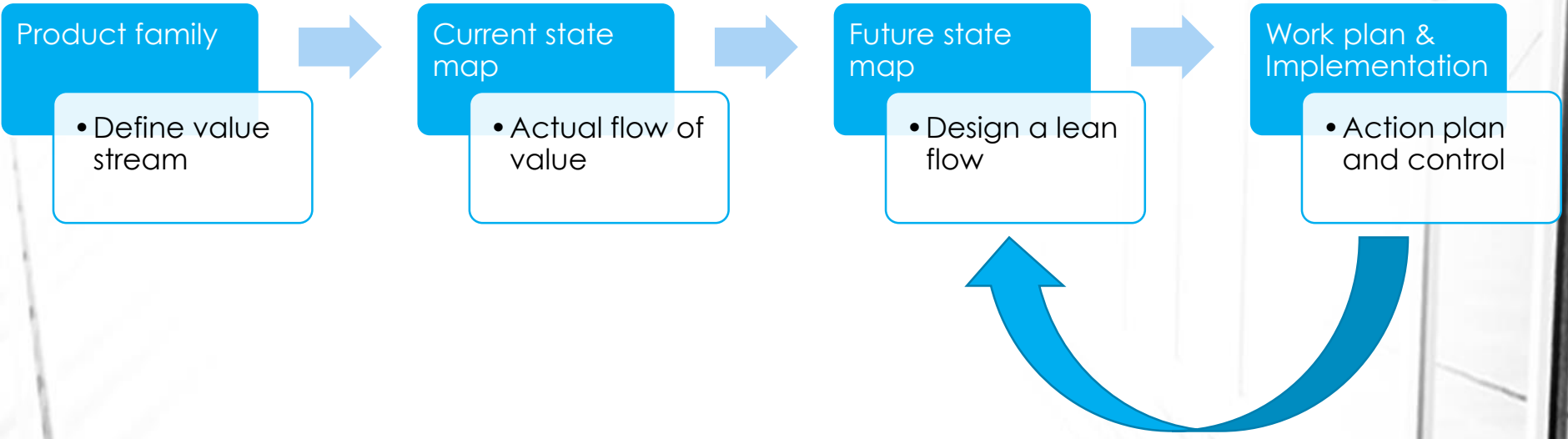
# Value stream mapping - VSM

- Construct process map of the value stream
  - Avoid using existing maps, may be out of date or have misconceptions
- Analyse the process map
  - Focus on customer
  - Identify value-added and non-value-added activities
- Calculate the value-add ratio
- Reduce and eliminate wasteful steps

# Value stream mapping



# Value stream mapping



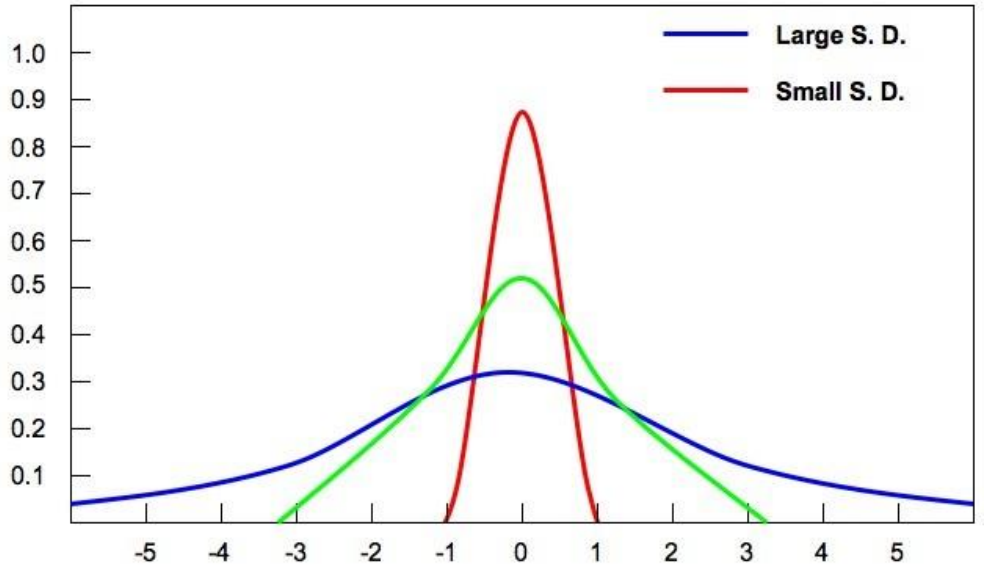
# 3- Create flow

- Once value is specified and waste is eliminated by means of value stream mapping, remaining value-creating processes are designed to be performed in tight sequence so the product will flow smoothly toward the customer.

# Standardization

- A simple written description of the safest, highest quality, and most efficient way known to perform a particular process or task
- The only acceptable way to do the process it describes
- Expected to be continually improved
- Includes the amount of time needed for each task
- Reduces variation, increases consistency
- Needed in all work areas

When correctly applied, standard work will not only sustain kaizen improvements, but also expose and eliminate previously unseen waste.



# 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.

Before

After

→ Sort (eliminate that which is not needed)

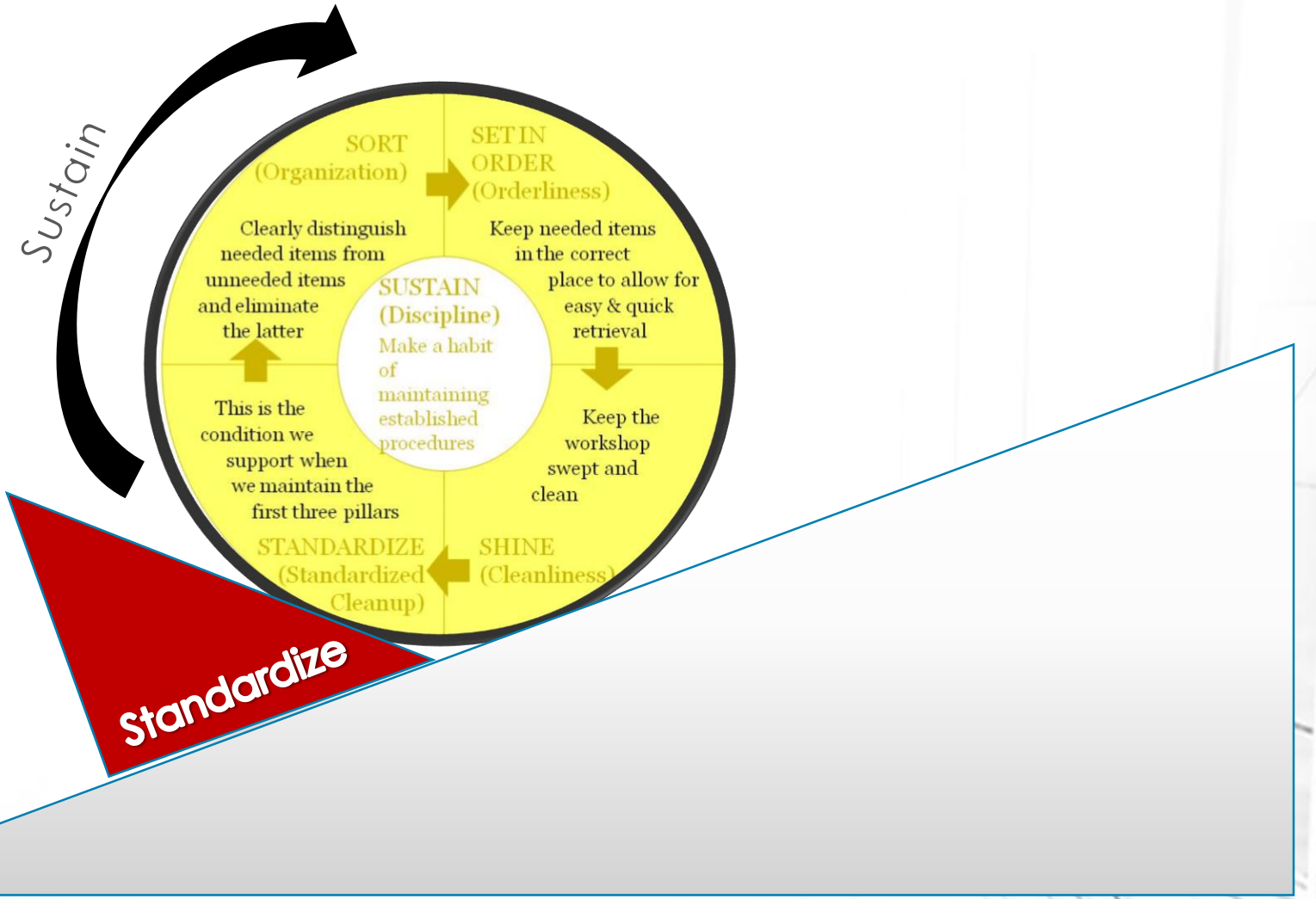
→ Set in order (organize remaining order)

→ Shine (clean and inspect work area)

→ Standardize (write standards for above)

→ Sustain (regulary apply the standards)

# 5S


Sustain
SORT
(Organization)
Clearly distinguish needed items from unneeded items and eliminate the latter
SET IN ORDER
(Orderliness)
Keep needed items in the correct place to allow for easy & quick retrieval
SUSTAIN
(Discipline)
Make a habit of maintaining established procedures
This is the condition we support when we maintain the first three pillars
Keep the workshop swept and clean
STANDARDIZE
(Standardized Cleanup)
SHINE
(Cleanliness)
Standardize

# Takt time

- The pace of production aligning the production with the customer demand.

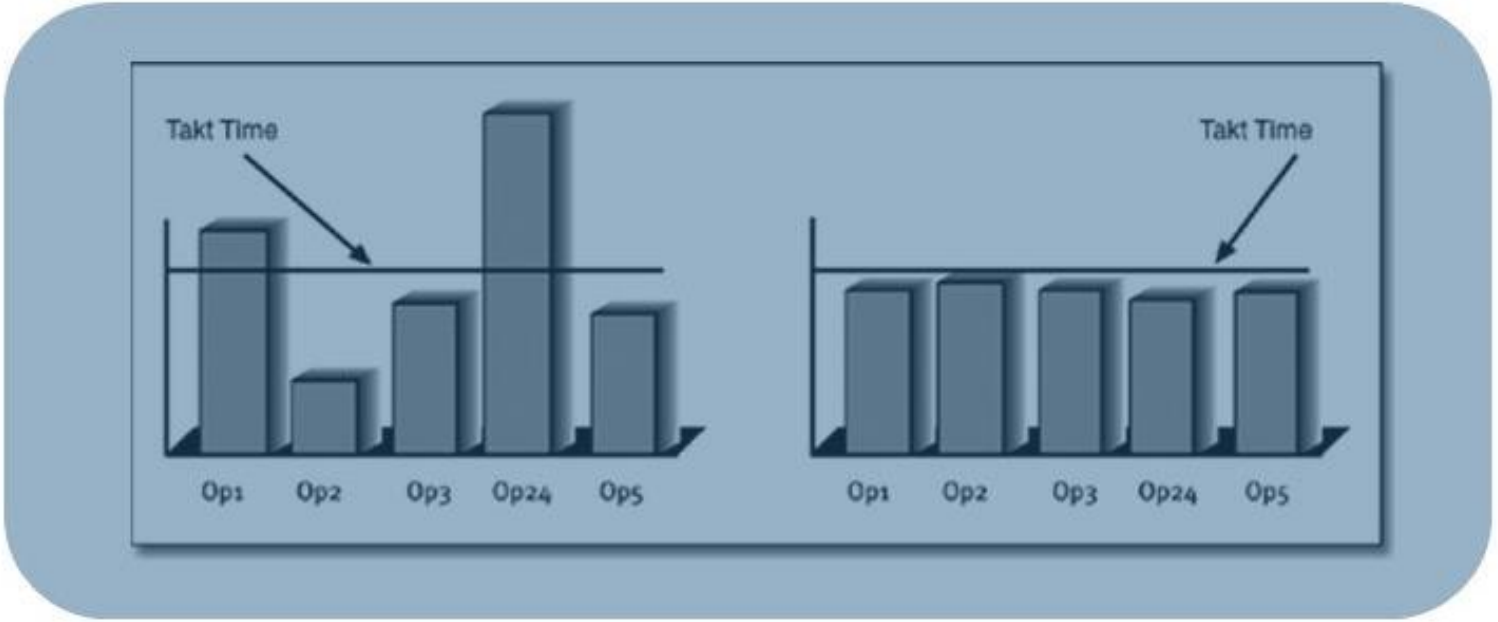
$$\text{Takt Time} = \frac{\text{Available Time}}{\text{Product Demand}}$$

Aircraft Engine Assembly Line;

Demand: 500 engines per year.
Available time: 2 shifts X 7 hrs => 14 hrs/day X 250 day/year = 3500hrs.
Takt time = 7 hrs.

# Takt time

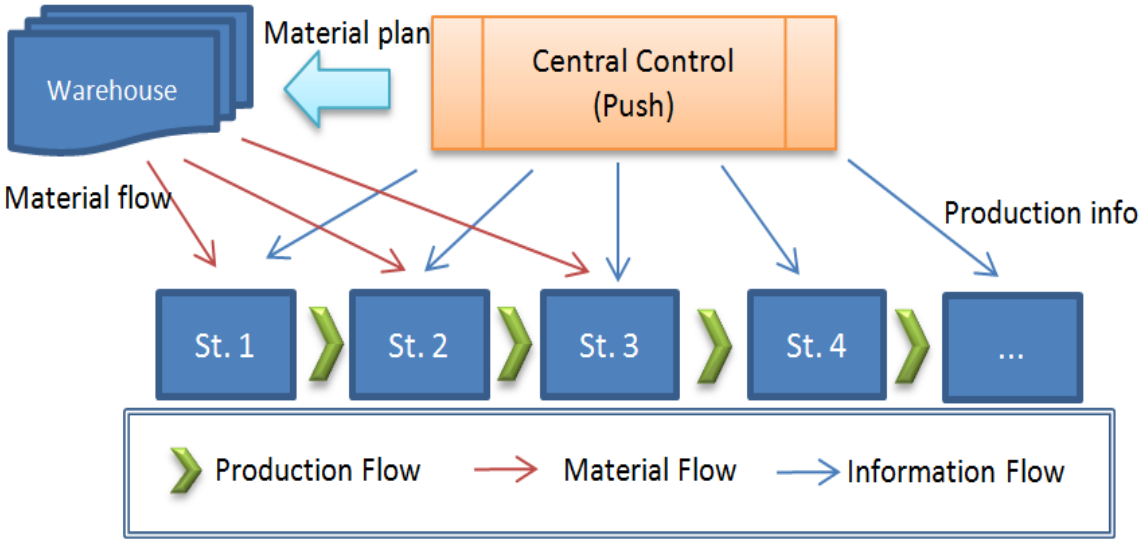
- Takt time does not represent cycle time, it represent customer demand rate,
- The only way to change takt time for a given demand is to change available production time by adding extra shifts or overtime



# 4-Establish pull

Production in the pull system is based on customer demand. Whereas in the push system projected demand rules production processes.

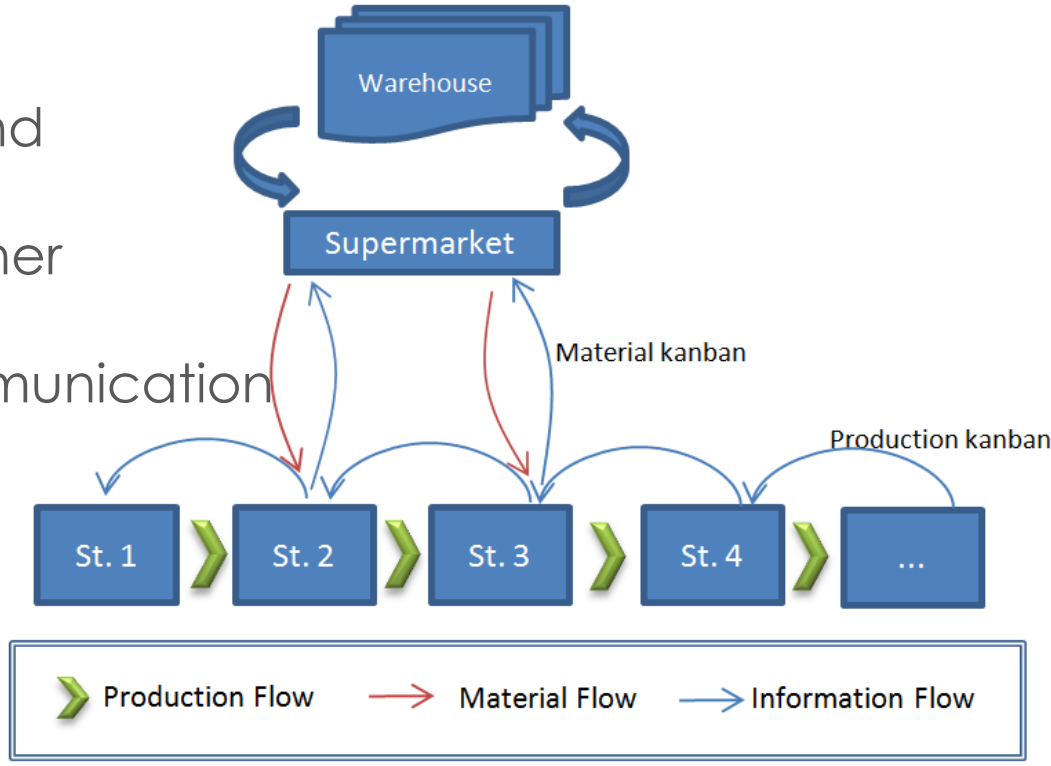
Push system



# Establish pull

## Pull system

- Make to the customer demand
- Workcenters are linked together
- Tight linkages and close communication
- Less inventory
- Shorter lead time




Pull system relies on many lean tools, such as Continuous Flow, Heijunka, Kanban, Standardized work and takt time to be applied properly.

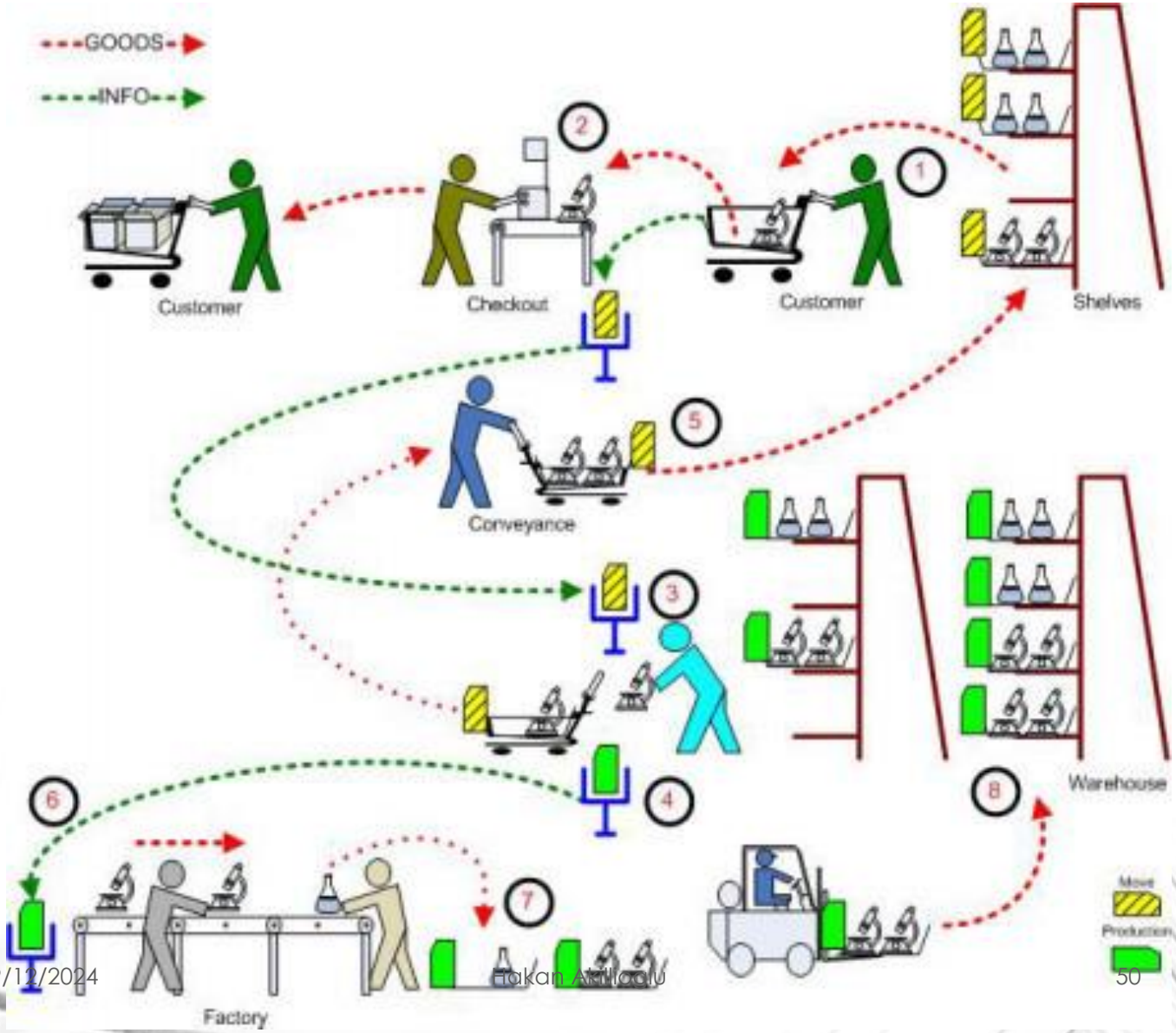
# Just in time - JIT

- Just in time is a Japanese management philosophy applied in manufacturing which involves having the right items of the right quality and quantity in the right place and at the right time.
- Proper use of JIT manufacturing results in increased quality, productivity and efficiency, improved communication and decreases in costs and wastes.

# Kanban

- ✓ At Toyota, empty bin (a kanban) is send upstream after a demand instance.
- ✓ It is a signal to refill it with a specific number of parts or send back a card with detailed information about the part location.
- ✓ Even today, one can see Kanban cards and bins moving on the shop-floor.
- ✓ Instead of using sophisticated computer scheduling techniques, this is a simple, effective and visual system of managing and ensuring the product flow and JIT production system.

# Kanban cards



# Number of kanban cards

$$K = \frac{D + S}{C}$$

**K**= Kanban card number
**D**= Expected demand during lead time
**S** = Safety stock
**C**= Container size

$$K = \frac{dL(1 + s)}{C}$$

**K**= Kanban card number
**d**= Average number of units demanded over unit time
**S**= Safety stock expressed as a percentage of demand during lead time
**L**= lead time to replenish an order (same units of time as demand)
**C**= Container size

# Number of kanban cards

- Suppose that hourly demand is 200 units, lead time is 12 hours, and the container capacity was 144 units. Assume that there is variation in lead time or demand, then we can set the safety factor to 15%:

$$K = \frac{dL(1+s)}{C} = \frac{200*12*(1+0.15)}{144} = 20$$

# Just in time

- What are the underlying enablers of JIT?
  - ✓ Kanban cards, production levelling and shorther setup times.
- How to achieve shorter setup times?
  - ✓ Single Minute Exchange of Dies (SMED)

# Single Minute Exchange of Dies

- The name Single-Minute Exchange of Dies comes from the goal of reducing changeover times to the "single" digits (i.e. less than 10 minutes)
- SMED (Single-Minute Exchange of Dies) is a system for dramatically reducing the time it takes to complete equipment changeovers

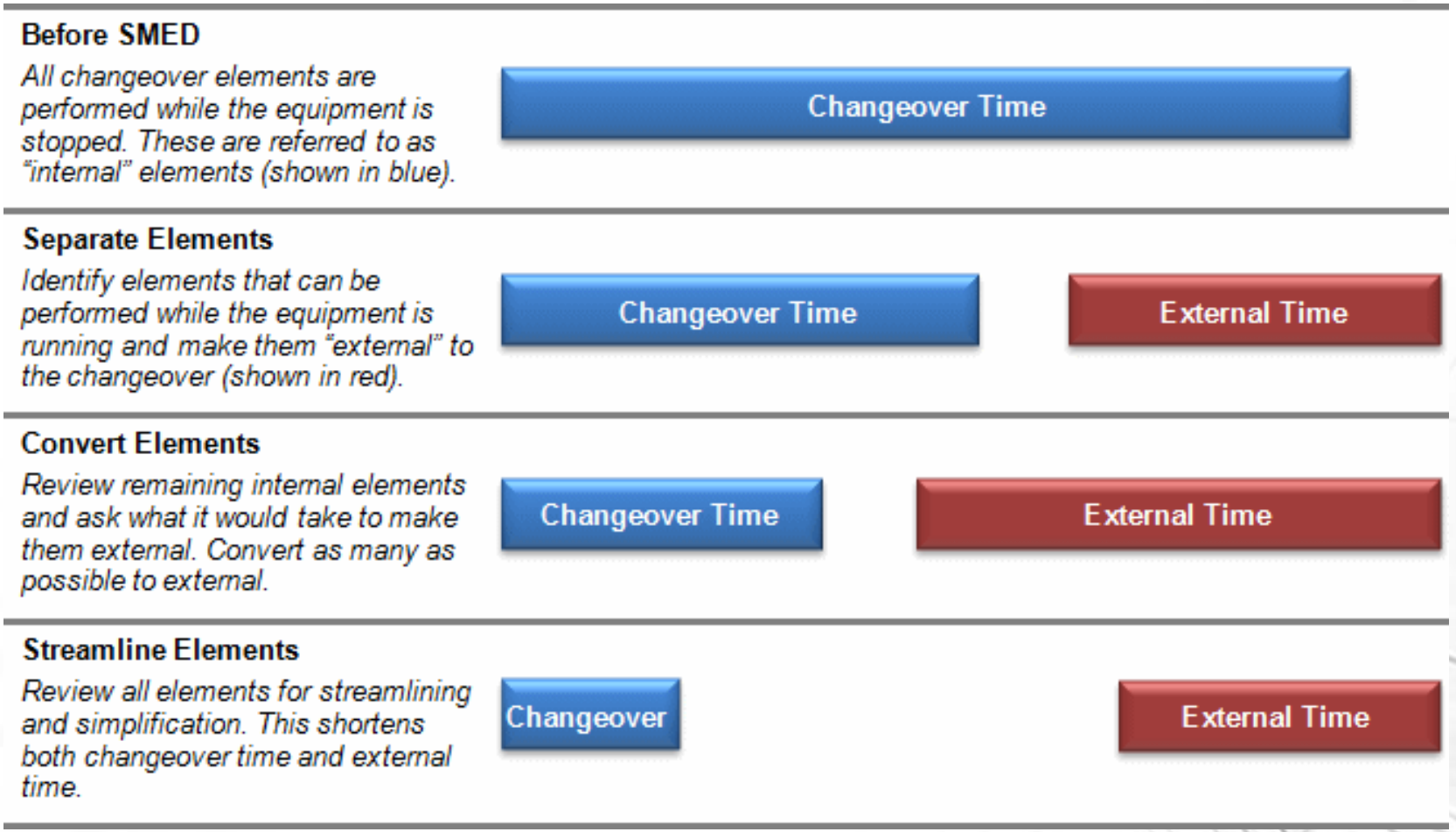
>>VIDEO

# Single Minute Exchange of Dies

1. Internal setup processes require the tool to stop.
   - Reduce internal setup time, or convert internal to external setup.

2. External setup processes can be performed while the tool is working.

# Single Minute Exchange of Dies

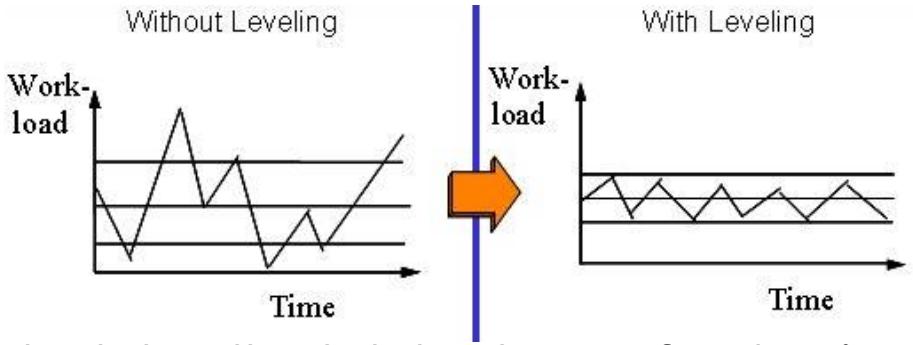


# SMED benefits

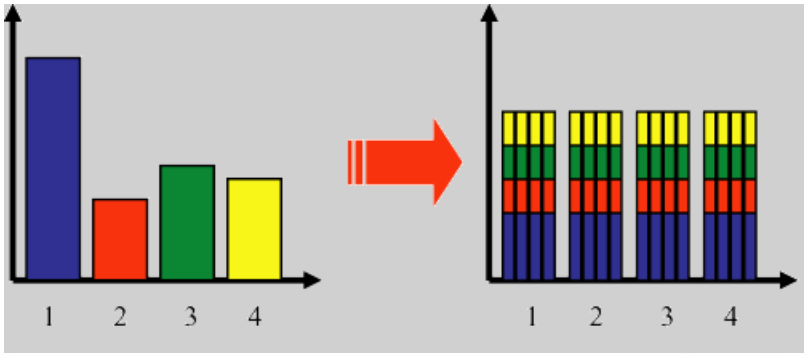
- Lower manufacturing cost (faster changeovers mean less equipment down time)
- Smaller lot sizes (faster changeovers enable more frequent product changes)
- Improved responsiveness to customer demand (smaller lot sizes enable more flexible scheduling)
- Lower inventory levels (smaller lot sizes result in lower inventory levels)
- Smoother startups (standardized changeover processes improve consistency and quality)

# Production leveling-Heijunka

- Heijunka is the leveling of production by both volume and product mix.




- Heijunka takes the total volume of orders in a period and levels them out so the same amount and mix are being made each day.



# Production leveling-Heijunka

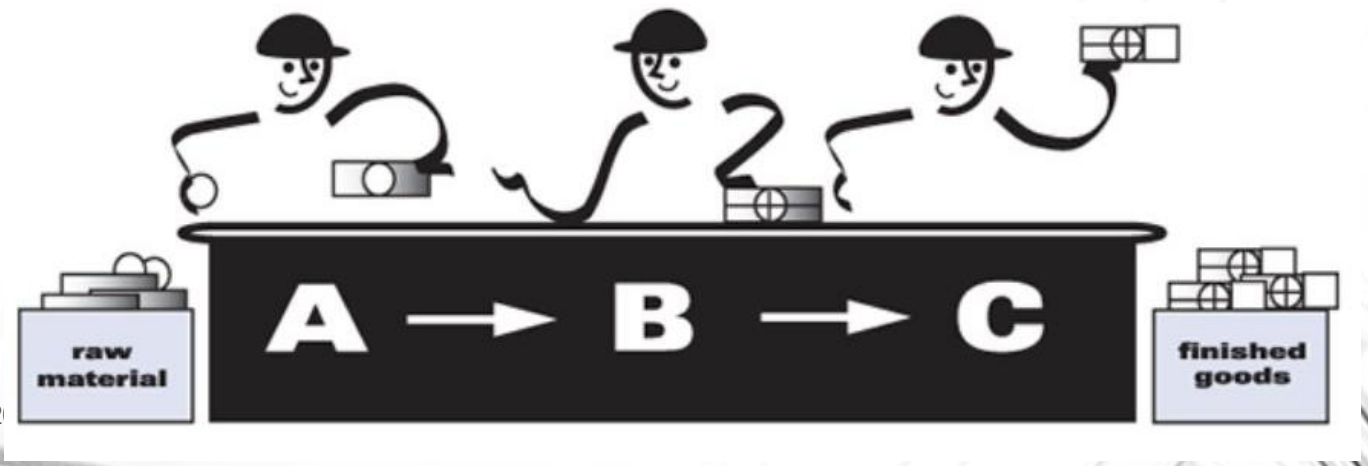
1. Determine total monthly demand for each type of product.
   - Say Product A – 1400 units; Product B – 200 units
2. Establish the daily requirement for each product type
   - Product A – 1400/20 = 70 units (Assuming 20 working days)
   - Product B – 200/20 = 10 units
3. Calculate the ratio and production frequency
   - Product A – 70/10 = 7
   - Product B – 10/10 = 1
   - Total production frequency = 8
4. Set a schedule
   - BAAAAAAABAAAAAAB

# 5- Perfection

- As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste.

# One piece flow (single piece flow)

- It is an ideal state of the operations where batch production is replaced by working on one product at a time.
- How to achieve?
  - Calculate the takt time
  - Take process and equipment capacity into account
  - Introduce pull system with one piece flow
  - Ensure that the layout is feasible for one piece flow



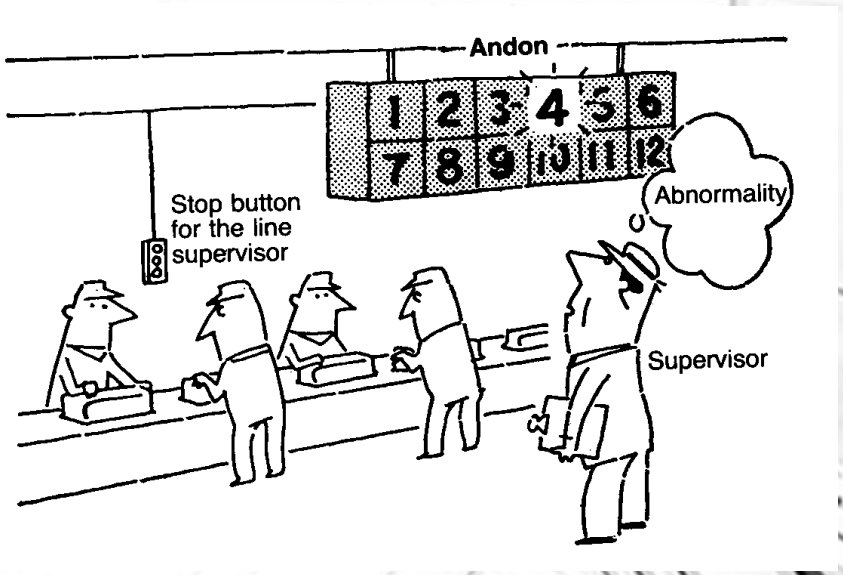
# Benefits of One-Piece Flow

- **Builds in quality** – Every operator is an inspector and works to fix problems in station before passing them on. If defects do get passed on, they are detected quickly and problem can be immediately diagnosed and corrected.
- **Creates flexibility** – If shorter lead times, more flexibility to respond and make what customer really wants. Pushes for set-up time reduction.
- **Creates higher productivity** – Very easy to spot the busy or idle station and easier to calculate the value-added work.
- **Frees up floor space** – Because of inventory storage reduction.

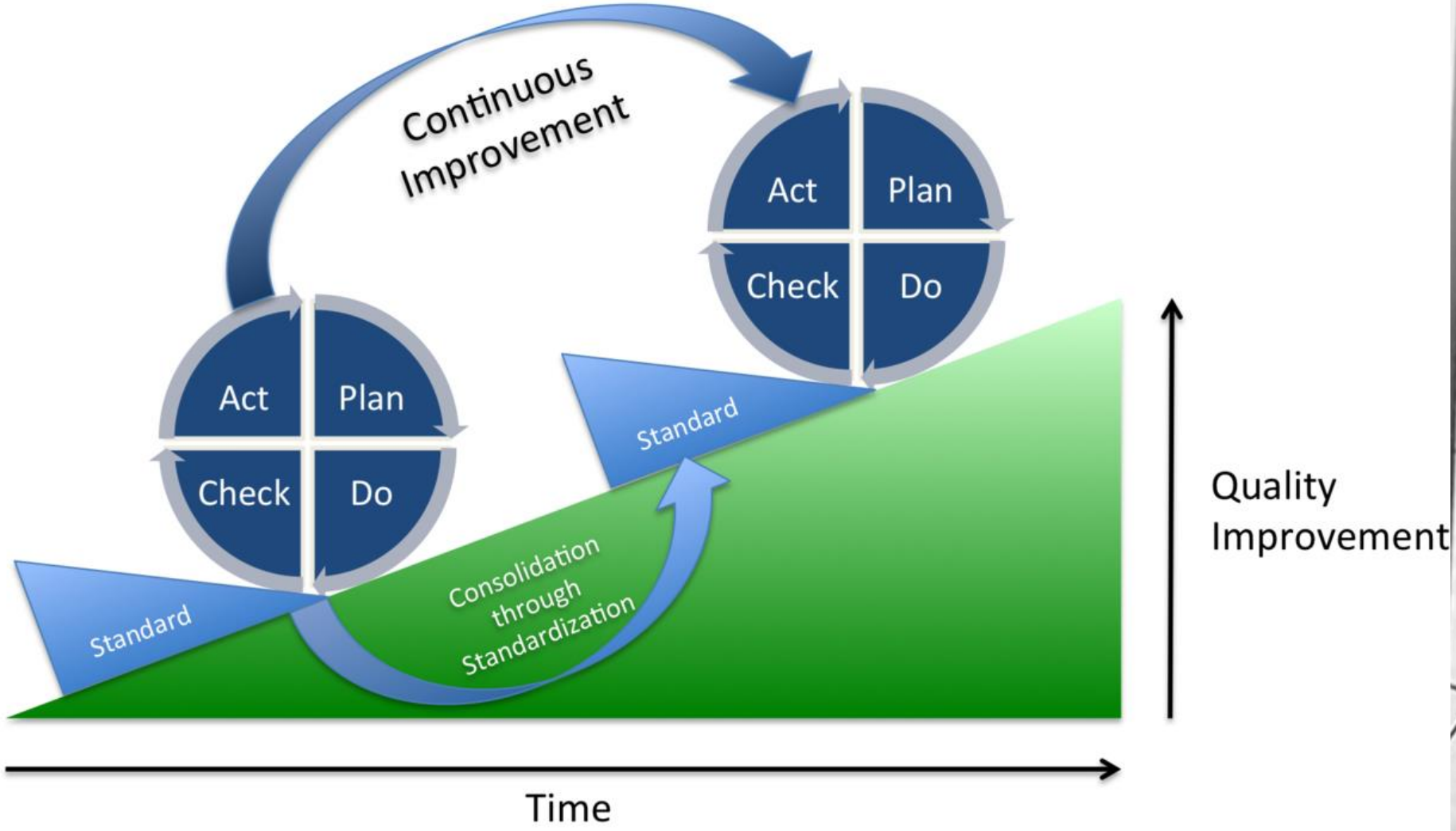
# Andon

Visual feedback system for the plant floor that indicates production status, alerts when assistance is needed, and empowers operators to stop the production process.

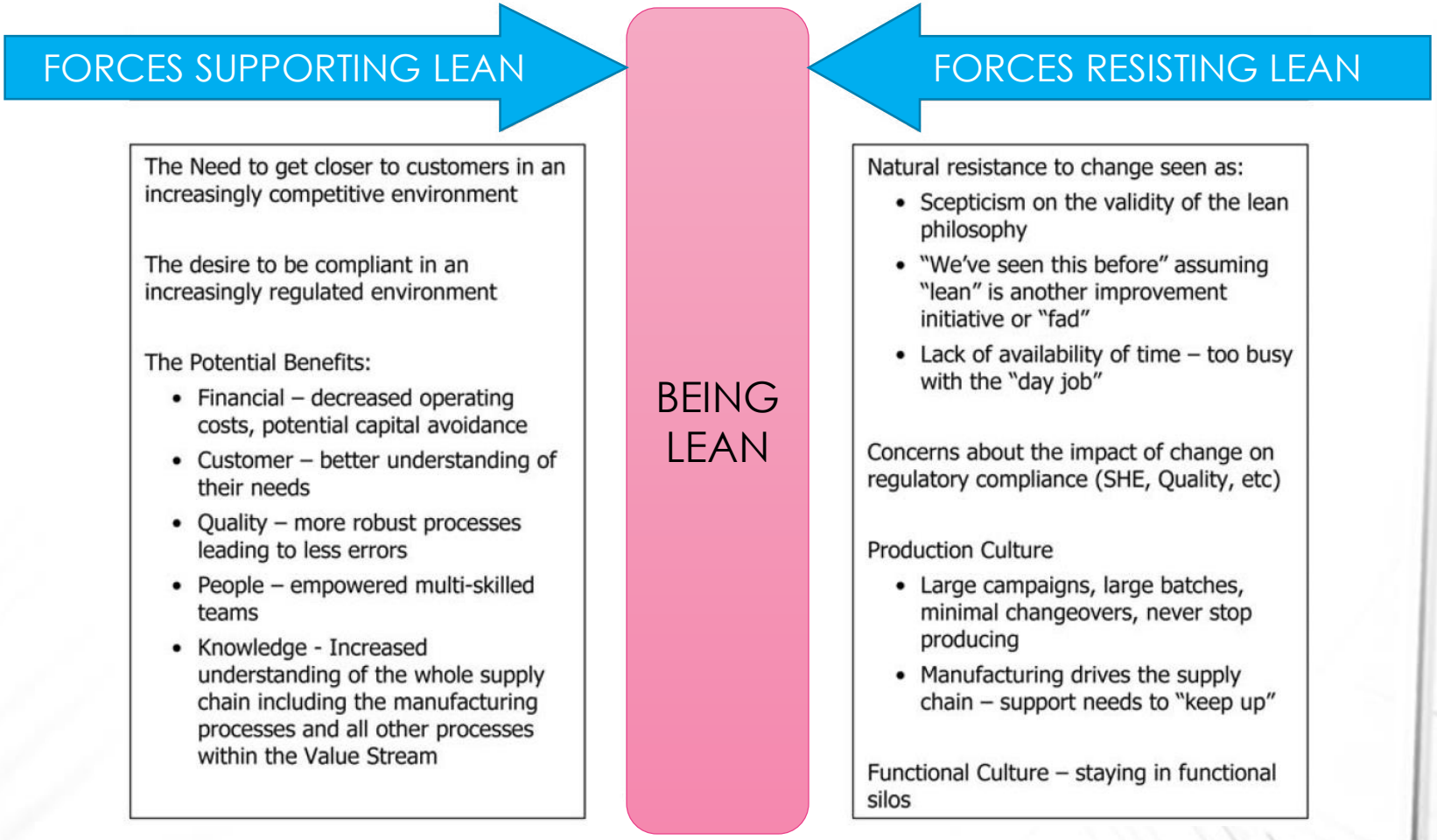




# Continuous improvement - PDCA



# Being lean

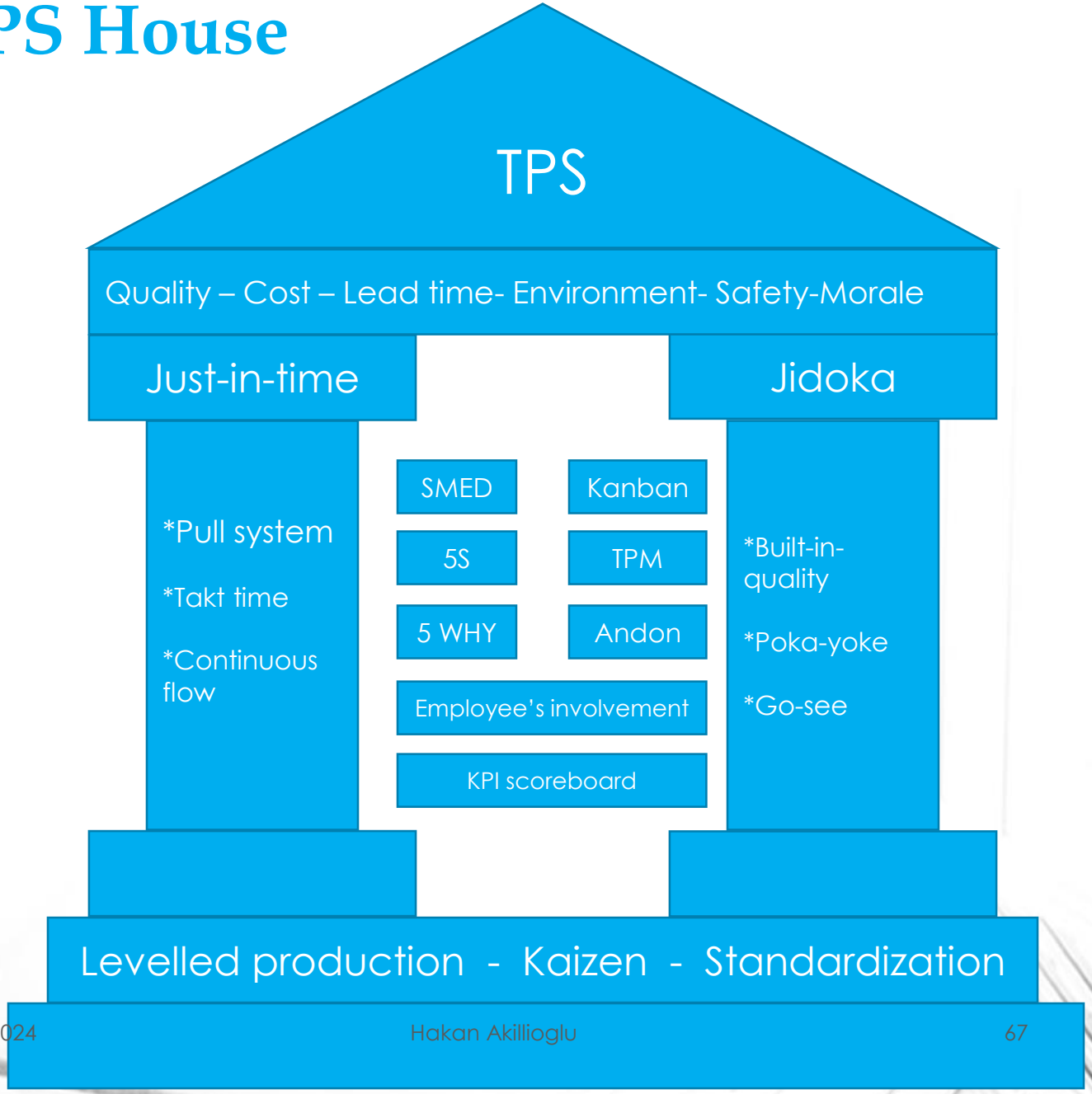



Melton T., the benefits of lean manufacturing, 2005.

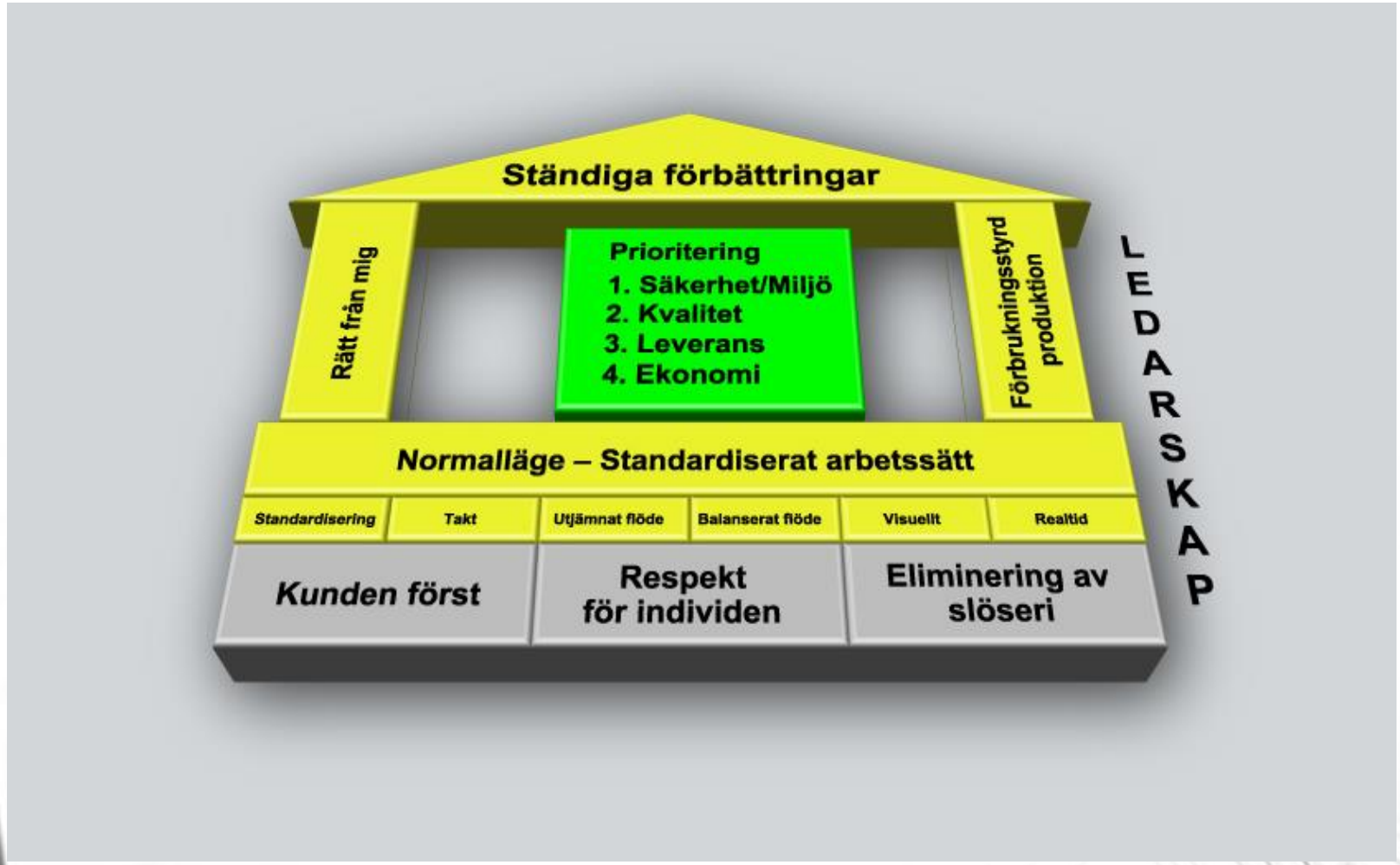
# Toyota Production System (TPS)

- The production system developed by Toyota Motor Corporation to provide best quality, lowest cost, and shortest lead time through the elimination of waste.
- TPS is comprised of two pillars, Just-in-Time and Jidoka (autonomation) , and is often illustrated with the "house" shown on the next slide.
- TPS is maintained and improved through iterations of standardized work and kaizen (continuous improvement), following Plan–Do-Check-Act (PDCA Cycle from Dr. Deming).

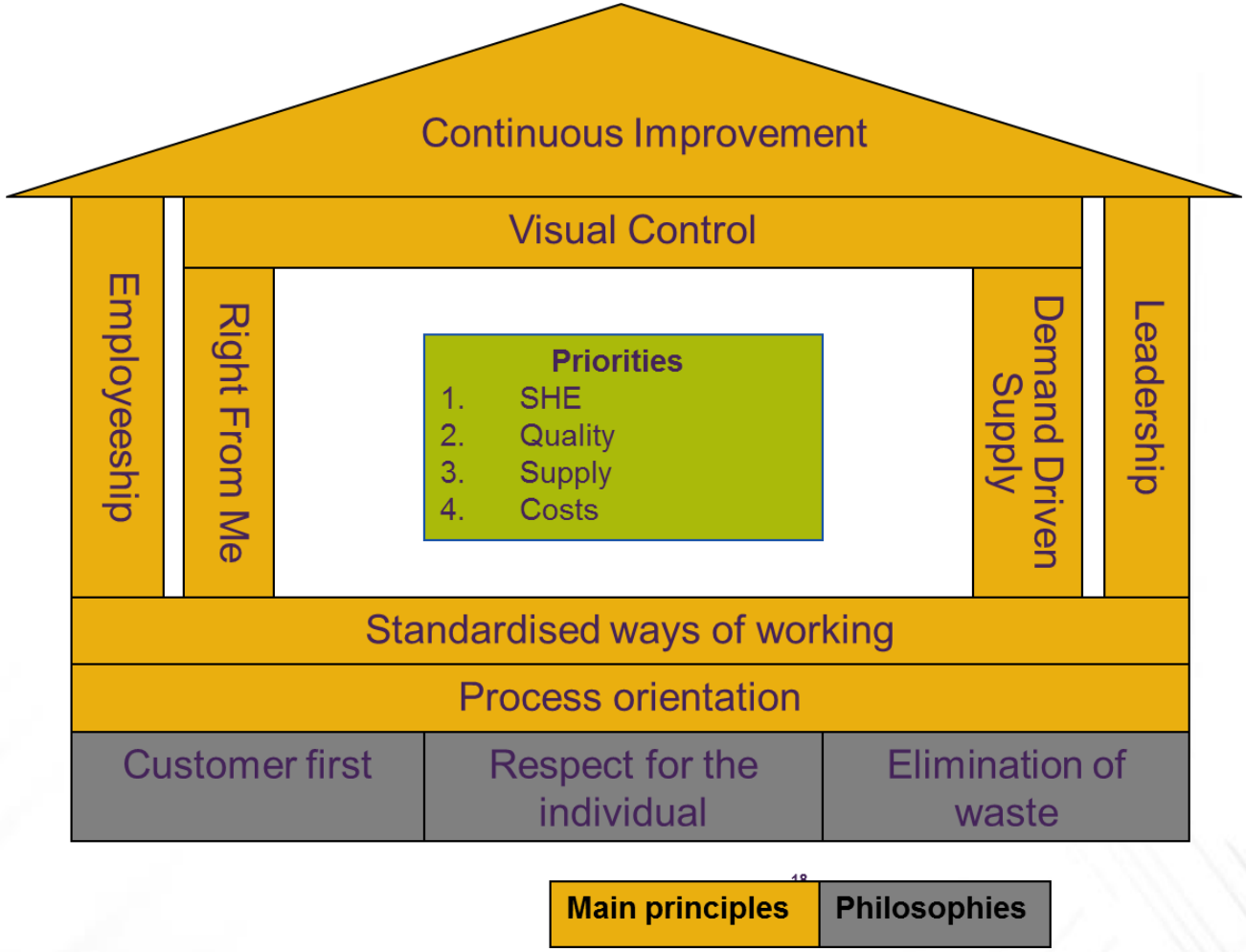
# TPS House


TPS
Quality – Cost – Lead time- Environment- Safety-Morale
Just-in-time
Jidoka
*Pull system
*Takt time
*Continuous flow
SMED
Kanban
5S
TPM
5 WHY
Andon
Employee's involvement
KPI scoreboard
*Built-in-quality
*Poka-yoke
*Go-see
Levelled production - Kaizen - Standardization

# Scania Production Systems



# Astra Zeneca




Thanks!