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# Lean Manufacturing Techniques

## For Textile Industry



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Exports Project

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International  
Labour  
Organization

**Promoting Workers' Rights and Competitiveness  
in Egyptian Exports Industries**

# **Lean Manufacturing Techniques For Textile Industry**

**2017**





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# Introduction

The international labour Organisation (ILO) is a tripartite United Nations (UN) agency. Since 1919, the ILO brings together governments, employers and workers representatives of 187 member States, to set labour standards, develop policies and devise programmes promoting decent work for all women and men.

The ILO encourages this tripartism within its constituents - employers , workers and member States - by promoting a social dialogue between trade unions and employers in formulating, and where appropriate, implementing national policy on social, economic, and other related issues.

Based on the above mentioned mission, the idea of developing this manual came as a contribution from the ILO Cairo Office to highlight the importance of adapting “Lean Manufacturing” principles in the production process especially in Food, Textile and Ready –made Garments industries. Lean manufacturing is a management philosophy that focuses on continuously eliminating any possible waste in the production process. This manual sheds the light on the points that increase the company capabilities to control a number of resources e.g. labour, overproduction, space, defects, unnecessary human motion, inventory and transportation.

By applying the principle of Lean Manufacturing in the Egyptian Exports Industries, this will result in short and long term benefits with regard to eliminating waste, minimizing inventory, maximizing flow, drive production from customer demand, meeting customer requirements, do it right the first time, empowering workers, and creating a culture of continuous improvement.

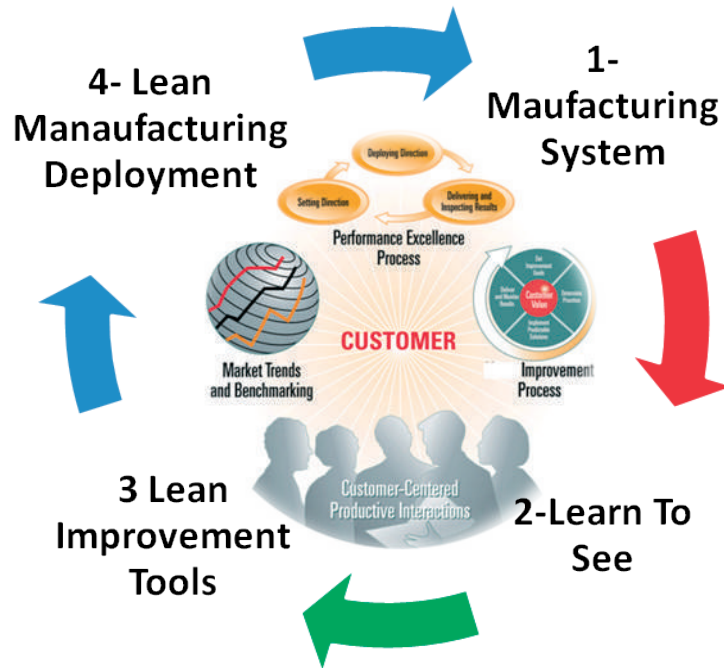
I seize this opportunity to thank the Exports project team for their exerted efforts in preparing this manual. Wishing that these efforts can contribute in raising the management and workers awareness on the importance of applying the Lean Manufacturing principles in the production process. Which may help in improving the productivity levels in the Egyptian Exporting market.

**Peter van Rooij**

Director

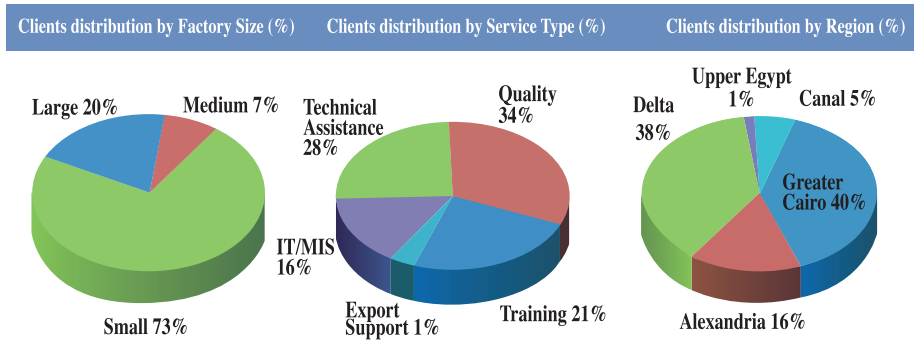
ILO Decent Work Team for North Africa/ Cairo

# 1. Manufacturing Systems



## 1.1 Introduction

The textile industry is one of the most important sources for foreign exchange in Egypt. The industry also accounts for 30% of Egypt's industrial production, 15% of its non petroleum exports and 30% of local employment, as Egypt has a number of competitive advantages; competitive labor costs and locally available raw materials.

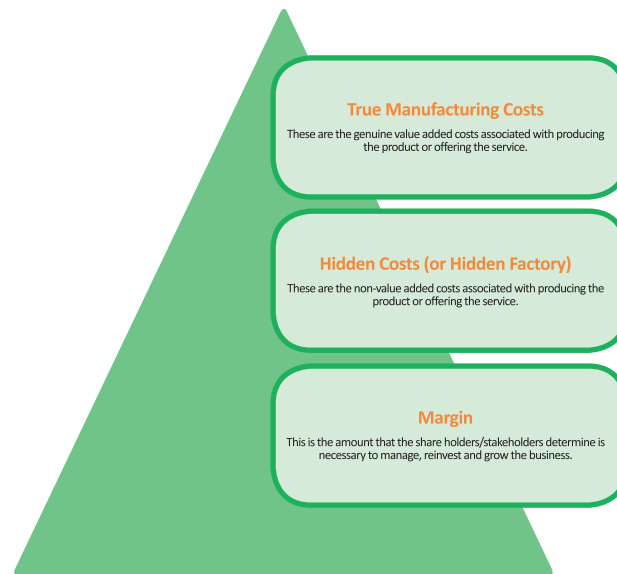


The major threat facing the Egyptian textile industry is the major competitive pressure brought on by the increased presence of low-cost and foreign manufacturers in the marketplace over the past several decades. This is the main problem, faced by all the textile manufacturers all over the world. Many domestic textile manufacturers have sought to improve their manufacturing processes and reducing the operation cost as they are in a position that they should readily compete with the overseas manufacturers.

In order to this sought, Egyptian textile manufacturers should be adapted to new initiative approach of waste management and cost saving techniques.



## Manufacturing Operations And Hidden Costs



The industry faces several challenges which finally impact on the export volumes and costs, some of these problems faces the industry are:

1. High inventory levels including.
2. Work in Process (WIP) inventory.
3. Incoming & finished goods inventory.
4. Long change over time.
5. The breaking down of the machinery and equipment owned by the majority of firms as a result of non- existence of suitable investments to carry out replacement and renewal operations.
6. Defective products, customer returns.
7. Decreased profit margin.
8. Marketplace Competition.
9. Insufficient sales.
10. Backorders.
11. No more space for inventories.
12. Quality problems in production lines and customer complaints.
13. Customer dissatisfied.
14. Delays in delivery time.

Such kinds of problems lead to a weak performance and increases manufacturing costs and the costs of poor quality. the resultants will be higher prices ,and low profit margin. such this factors represents a real threatens for Egyptian manufacturers in nowadays business environment.

## Strategic Alignment And Lean Manufacturing Techniques

The Egyptian manufacturers should adapt to new approach that focuses on: process improvement, cost reduction, eliminating wastes and increasing the value added to their customers, That finally increases ROI .

Seeking cost-saving using lean manufacturing techniques involves a variety of principles and techniques for eliminating wastes throughout production/service processes.

## 1.2 Module Objectives

The objective of this module is to guide a manufacturing company how to manage a successful lean transformation including: Lean Manufacturing implementation tools & techniques, elements of Lean management and lean tools & techniques.

This module is designed to deliver Lean knowledge to three managerial levels as following:

- I. Top & middle management
- II. Process owners & engineers
- III. Operators & technicians

The synchronization of knowledge delivered to these three levels shall grantee the successful implementation of Lean Manufacturing.

This module is defining the roles & responsibilities for each level to manage Lean transformation and overcome obstacles that might face lean implementation.

Coaching & Consulting services is consider a key element for the success of Lean transformation, thou this module shall be delivered in a training sessions in additional to implementations workshops at the job floor at participated companies.

A participated company shall expect the following results:

- Meeting customer demand on time by eliminating non-value added activities.
- Reducing Work in Process (WIP) inventory.
- Reducing the Finished goods inventory.
- Reducing inventory area.
- To create flexibility of style changeover.
- Reducing rework percentage.
- Creating a pool of multi-skilled workforce who can respond quickly for changing style.
- Reducing the backorders.
- Reducing machine downtime.
- Reducing processing lead time.
- Improving work place organization.
- Improving the safety conditions.
- Increasing customer satisfaction .

## 1.3 The Ultimate Goal of Lean Manufacturing

The ultimate goal of lean Manufacturing is reducing costs in business processes, offering products with competitive price in market, increase profit and ROI.

Reducing product cost and increasing business profits starting from reducing cost from bottom line at operation level which impact all in product or service cost (price)

## 1.4 Benefits of Lean Manufacturing

The main benefits of implementing Lean manufacturing are lower production costs; increased output quantity and shorter production lead times. Lean Manufacturing goals are:



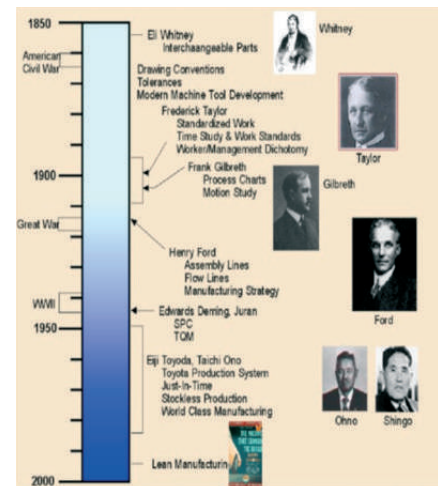
1. Defects and wastage - Reduce defects and unnecessary physical wastage, including excess use of raw material inputs, preventable defects, costs associated with reprocessing defective items, and unnecessary product characteristics which are not required by customers.
2. Cycle Times - Reduce manufacturing lead times and production cycle times by reducing waiting times between processing stages, as well as process preparation times and product/model conversion times.
3. Inventory levels - Minimize inventory levels at all stages of production, particularly works-in-progress between production stages. Lower inventories also mean lower working capital requirements.
4. Labor productivity - Improve labor productivity, both by reducing the idle time of workers and ensuring that when workers are working, they are using their effort as productively as possible (including not doing unnecessary tasks or unnecessary motions).
5. Utilization of equipment and space - Use equipment and manufacturing space more efficiently by eliminating bottlenecks and maximizing the rate of production through existing equipment, while minimizing machine downtime.
6. Flexibility - Have the ability to produce a more flexible range of products with minimum changeover costs and changeover time.

## 1.5 History of Lean Manufacturing

Although there are instances of rigorous process thinking in manufacturing all the way back to the Arsenal in Venice in the 1450s, the first person to truly integrate an entire production process was Henry Ford. At Highland Park, MI, in 1913 he married consistently interchangeable parts with standard work and moving conveyance to create what he called flow production. The public grasped this in the dramatic form of the moving assembly line, but from the standpoint of the manufacturing engineer the breakthroughs actually went much further.

Ford lined up fabrication steps in process sequence wherever possible using special-purpose machines and go/no-go gauges to fabricate and assemble the components going into the vehicle within a few minutes, and deliver perfectly fitting components directly to line-side. This was a truly revolutionary break from the shop practices of the American System that consisted of general-purpose machines grouped by process, which made parts that eventually found their way into finished products after a good bit of tinkering (fitting) in subassembly and final assembly.

The problem with Ford's system was not the flow: He was able to turn the inventories of the entire company every few days. Rather it was his inability to provide variety. The Model T was not just limited to one color. It was also limited to one specification so that all Model T chassis were essentially identical up through the end of production in 1926. (The customer did have a choice of four or five body styles, a drop-on feature from outside suppliers added at the very end of the production line.) Indeed, it appears that practically every machine in the Ford Motor Company worked on a single part number, and there were essentially no changeovers.





When the world wanted variety, including model cycles shorter than the 19 years for the Model T, Ford seemed to lose his way. Other automakers responded to the need for many models, each with many options, but with production systems whose design and fabrication steps regressed toward process areas with much longer throughput times. Over time they populated their fabrication shops with larger and larger machines that ran faster and faster, apparently lowering costs per process step, but continually increasing throughput times and inventories except in the rare case—like engine machining lines—where all of the process steps could be linked and automated. Even worse, the time lags between process steps and the complex part routings required ever more sophisticated information management systems culminating in computerized Materials Requirements Planning(MRP) systems.

As Kiichiro Toyoda, Taiichi Ohno, and others at Toyota looked at this situation in the 1930s, and more intensely just after World War II, it occurred to them that a series of simple innovations might make it more possible to provide both continuity in process flow and a wide variety in product offerings. They therefore revisited Ford's original thinking, and invented the Toyota Production System.

This system in essence shifted the focus of the manufacturing engineer from individual machines and their utilization, to the flow of the product through the total process. Toyota concluded that 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, and 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. Also, information management could be made much simpler and more accurate.

## Mass Production And Push System

Pioneered by Henry Ford, mass production adds the following to the industrial revolution era's principles:

- Standard products and operational efficiency
- Flow ( Usage of conveyors at final assembly )
- Economies of Scale
- Special purpose machinery ( product specific )
- Go - No Go gauges
- More precise parts for easy assembly.

## Problems With The Ford System (Push System)

- Long delivery times.
- Weakness in responding to customer demands.
- Increase in inventories.
- Decrease in quality.
- Increase in non value adding activities.
- Increasing hierarchy and bureaucracy.
  - Additional costs.
  - More capital requirement.
  - Lack of ability to provide product variety
  - Lack of model changeover ability because nearly all machines are focused on producing one specific part.
  - Unskilled workers perform simple, repetitive jobs, no pride in work.

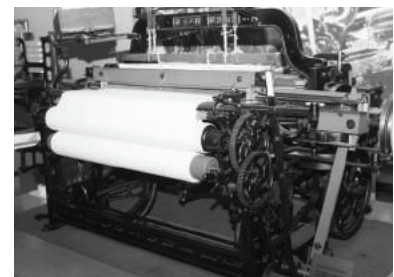


## The Case For Others

- To supply for customers' product variety demands
- Therefore process focused manufacturing systems – ( long throughput/lead time )
- Bigger and faster machines that reduce costs per process step
- As a result of this longer throughput/lead time and much larger inventories
- Necessity to use MRP systems.

## Toyota Production System (Pull System)

Many of the concepts in Lean Manufacturing originate from the Toyota Production System (TPS) and have been implemented gradually throughout Toyota's operations beginning in the 1950's.



TPS is a manufacturing system aims to increase production efficiency by the elimination of waste. The Toyota production system was invented and made to work, by Taiichi Ohno. While analyzing the problems inside the manufacturing environment; Ohno came to conclude that different kinds of wastes (non value added works) are the main cause of inefficiency and low productivity.

TPS house constructed of two main pillars, Just-In-Time (JIT) pillar and JIDOCA Pillar each element of this house is critical, but more important is the way the elements reinforce each other. By the 1980's Toyota had increasingly become known for the effectiveness with which it had implemented Just-In-Time (JIT) manufacturing systems. Lean Manufacturing is becoming an increasingly important topic for manufacturing companies in developed countries as they try to find ways to compete more effectively against competition.

### A. JIT-Pillar

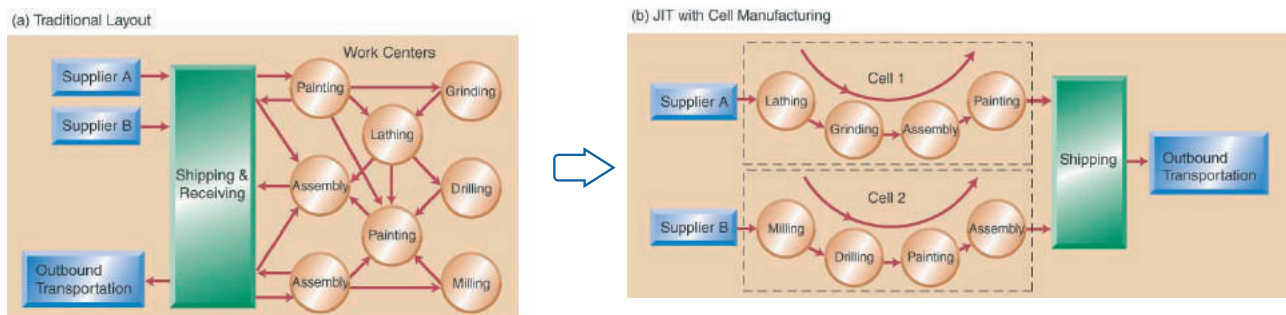
Just-in-time(JIT) manufacturing is a Japanese management philosophy applied in manufacturing. Just in Time (JIT) helps to optimize company resources like capital, equipment, and labor. The goal of JIT is the total elimination of waste in the manufacturing process. It is based on producing only the necessary units in the necessary quantities at the necessary time

by bringing production rates exactly in line with market demand or Takt time. Using smaller buffers (removing the “safety net”) means that problems like quality defects become immediately visible. This means workers must resolve the problems immediately and urgently to resume production. In short, JIT means making what the market wants, when it wants, by using a minimum of facilities, equipment, materials, and human resources

## Principles Of JIT-System

### 1- Continuous flow

Lean usually aims for the implementation of a continuous production flow free of bottlenecks, interruption, detours, backflows or waiting. When this is successfully implemented, the production cycle time can be reduced by as much as 90%.



### 2- Pull-production

Also called Just-in-Time (JIT), Pull-production aims to produce only what is needed, when it is needed. Production is pulled by the downstream workstation so that each workstation should only produce what is requested by the next workstation.



### 3- Leveling the production

Leveling is the sequencing of orders in a repetitive pattern, and the smoothing of day-to-day variations in total orders to correspond to longer-term demand.

Weekly Production Required				
A				10 units
B				20 units
C				5 units
D				5 units
E				10 units
Traditional Production Plan				
Monday	Tuesday	Wednesday	Thursday	Friday
AAAAA	BBBBB	BBBBB	CCCCC	EEEEEE
AAAAA	BBBBB	BBBBB	DDDDD	EEEEEE
JIT Plan with Level Scheduling				
Monday	Tuesday	Wednesday	Thursday	Friday
AABBBB	AABBBB	AABBBB	AABBBB	AABBBB
CDEE	CDEE	CDEE	CDEE	CDEE

### 4- Takt Time

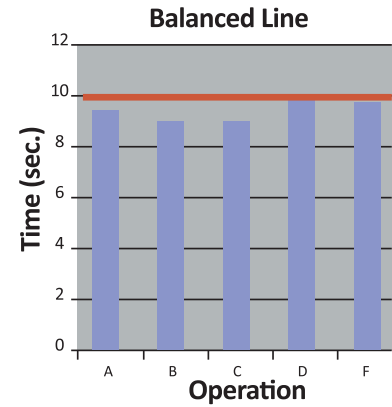
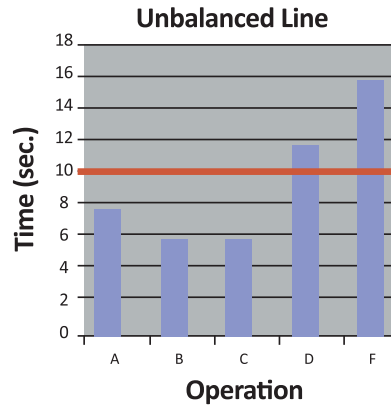
Takt is German word for a pace or beat, often linked to conductor’s baton. Takt time is a reference number that is used to help match the rate of production in a pacemaker process to the rate of sales. This can be formulated as below:

$$\text{Takt Time} = \frac{\text{Available work time per shift}}{\text{Customer order quantity per shift}}$$

Takt time can be defined as the rate at which customers need products i.e. the products should be produced at least equal to takt time to meet the customer demand.

### Basic Elements Of JIT

1. Flexible resources.
2. Cellular layouts.
3. Pull production system.
4. Kanban production control.
5. Small-lot production.
6. Quick setups.
7. Uniform production levels.
8. Quality at the source.
9. Total productive maintenance.
10. Supplier networks.



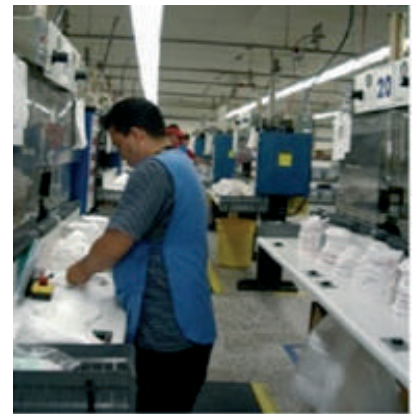
Takt Time = 10 seconds

## B. TPS - Jidoka Pillar (Quality at the Source)

Quality at the Source, also called "Do It Right the First Time", means that quality should be built into the production process in such a way that defects are unlikely to occur in the first place, Jidoka is authority to stop production line.

### Principles of Jidoka

#### 1- Andon lights & signal quality problems.



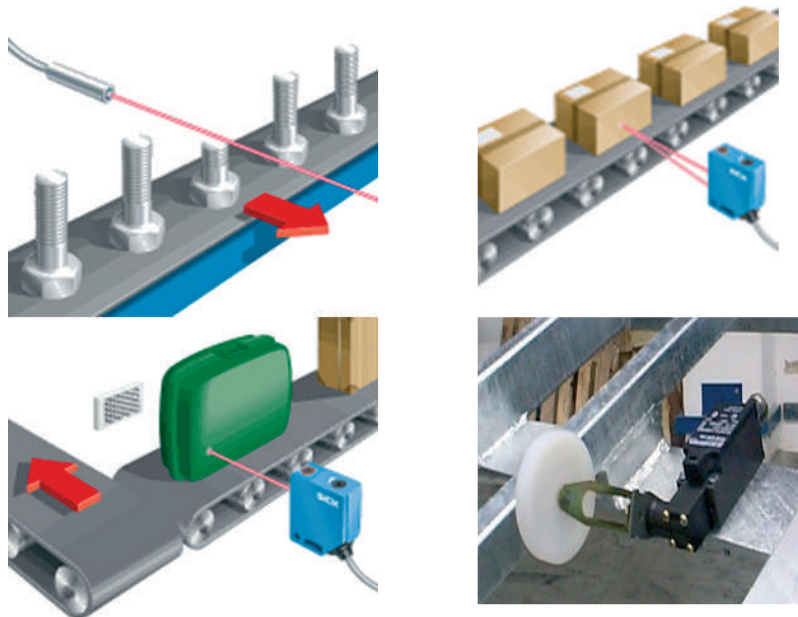
#### 2- Visual control makes problems visible.



### 3- Poka Yoke (Error Proofing) prevents defects.

Poka Yoke – Simple methods for in-line quality testing (not just visual inspection), sometimes referred to as “Poka Yoke”, are implemented so that defective materials do not get passed through the production process.

The Machines shutdowns – When defects are generated, production is shut down until the source of the defect can be solved. This helps ensure a culture of zero tolerance for defects and also prevents defective items from working their way downstream and causing bigger problems downstream. For example, at Toyota any worker can shut down the production line. This also helps ensure accountability by upstream workers.



## Comparison of Pull system and Push system

### Exercise

What are the differences between the push system and pull system ?

Factor	Traditional (Push system).	JIT(Pull system).
Inventory		
Deliveries		
Lot sizes		
Setup; runs		
Vendors		
Workers		

Exercise

What changes required for JIT-System transformation in your factory?	
1	
2	
3	
4	
5	
6	
7	



## 1.6 What is Lean Manufacturing?

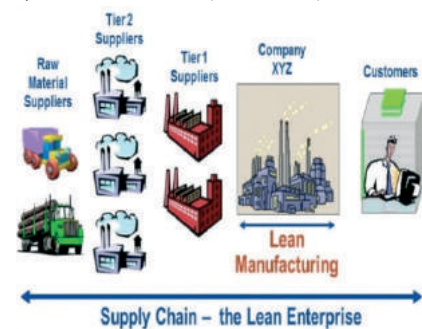
### What is lean?

- Lean : The part of meat that consists principally of lean muscle ( fat-free)
- Lean Thinking is an approach that aims to get rid of all the wastes (fats) that bring a burden to the system.
- The popular definition of Lean Manufacturing usually consists of the following:
  1. It is a comprehensive set of techniques which when combined allows you to reduce and eliminate the wastes. This will make the company leaner, more flexible and more responsive by reducing waste.
  2. Lean is the systematic approach to identifying and eliminating waste through continuous improvement by flowing the product or service at the pull of your customer in pursuit of perfection.



### Lean Enterprise Definition

An enterprise with a focus on waste elimination and the customer's needs in all parts of its operations, manufacturing, and administration. Emphasis is given to lean structures and processes, flexibility of response, and methods and techniques to continually seize new opportunities as they arise.

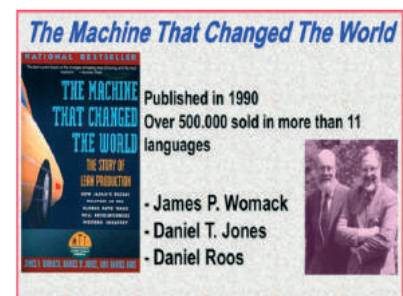


## 1.7 Lean Thinking Principals

Lean manufacturing or lean production are reasonably new terms that can be invented to Jim Womack, Daniel Jones and Daniel Roos in their book, The Machine that changed the world [1991]. In the book, the authors examined the manufacturing activities exemplified by the Toyota Production System. Lean manufacturing is the systematic elimination of waste. Most of these benefits lead to lower unit production costs – for example, more effective use of equipment and space leads to lower depreciation costs per unit produced, more effective use of labor results in lower labor costs per unit produced and lower defects lead to lower cost of goods sold.

Another way of looking at Lean Manufacturing is that it aims to achieve the same output with less input – less time, less space, less human effort, less machinery, less material, less cost.

### The Machine That Changed The World



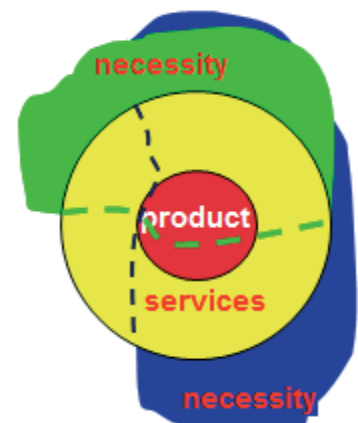
### 1.7.1 Value & Waste Definition

#### 1. Value

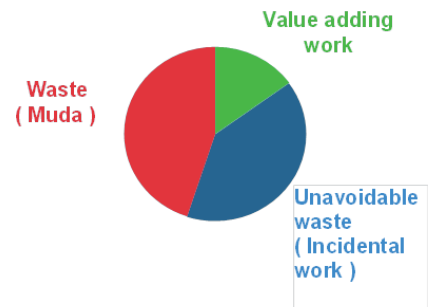
##### what is the Value?

- In Lean Manufacturing, the value of a product and / or service is defined solely based on product and/or service with definite specifications, for which the customer is ready to pay for, and that meets the customer's requirements in a given period of time, with a definite price.
- Production operations can be grouped into following three types of activities.

##### Types of Activities in a Value Stream :



1. Value-added activities are activities which transform the materials into the exact product that the customer requires.
2. Necessary non value-added activities are activities that don't add value from the perspective of the customer but are necessary to produce the product unless the existing supply or production process is radically changed. This kind of waste may be eliminated in the long-run but is unlikely to be eliminated in the near-term. For example, high levels of inventory may be required as buffer stock, although this could be gradually reduced as production becomes more stable.  
Example : Die change, adjustment, get/drop tool

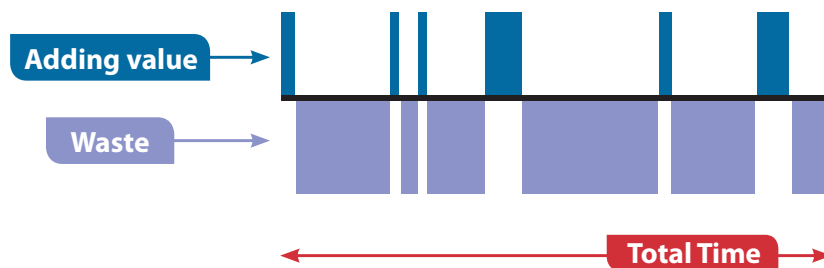


3. Non value-added activities are activities which aren't required for transforming the materials into the product that the customer wants. Anything which is non-value-added may be defined as waste. Anything that adds unnecessary time, effort or cost is considered non value-added. Another way of looking at waste is that it is any material or activity for which the customer is not willing to pay. Testing or inspecting materials is also considered waste since this can be eliminated insofar as the production process can be improved to eliminate defects from occurring.

Research at the Lean Enterprise Research Centre (LERC) in the United Kingdom indicated that for a typical manufacturing company the ratio of activities could be broken down as follows:

- Value-added activity 5%
- Non value-added activity 60%
- Necessary non value-added activity 35%
- Total activities =100%

### Lead Time and Non value addeed





## Exercise

What are the value you offering to your customers?	
1	
2	
3	

## 2. Wastes

### What is the waste?

“Waste is anything other than the minimum amount of equipment, materials, parts, space, and workers’ time which are absolutely essential to add value to the product.”

*Shoichiro Toyoda ,President, Toyota Motor Co.*

### Main Types of Wastes:

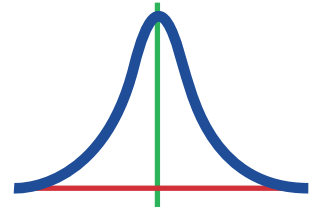
#### Enemy #1: Waste (Muda)

Originally 7 main types of waste were identified as part of the Toyota Production System. However, this list has been modified and expanded by various practitioners of lean manufacturing and generally includes the following:

- 1. Over-production** – Over-production is unnecessarily producing more than demanded or producing it too early before it is needed. This increases the risk of obsolescence, increases the risk of producing the wrong thing and increases the possibility of having to sell those items at a discount or discard them as scrap. However, there are some cases when an extra supply of semi-finished or finished products are intentionally maintained, even by lean manufacturers.
- 2. Defects** – In addition to physical defects which directly add to the costs of goods sold, this may include errors in paperwork, provision of incorrect information about the product, late delivery, production to incorrect specifications, use of too much raw materials or generation of unnecessary scrap.



3. **Inventory** – Inventory waste means having unnecessarily high levels of raw materials, works-in-progress and finished products. Extra inventory leads to higher inventory financing costs, higher storage costs and higher defect rates.
4. **Transportation** - Transportation includes any movement of materials that does not add any value to the product, such as moving materials between workstations. The idea is that transportation of materials between production stages should aim for the ideal that the output of one process is immediately used as the input for the next process. Transportation between processing stages results in prolonging production cycle times, the inefficient use of labor and space and can also be a source of minor production stoppages.
5. **Waiting** – Waiting is idle time for workers or machines due to bottlenecks or inefficient production flow on the factory floor. Waiting also includes small delays between processing of units. Waiting results in a significant cost insofar as it increases labor costs and depreciation costs per unit of output.
6. **Motion** – Motion includes any unnecessary physical motions or walking by workers which diverts them from actual processing work. For example, this might include walking around the factory floor to look for a tool, or even unnecessary or difficult physical movements, due to poorly designed ergonomics, which slow down the workers.
7. **Over-processing** – Over-processing is unintentionally doing more processing work than the customer requires in terms of product quality or features – such as polishing or applying finishing on some areas of a product that won't be seen by the customer.



**Exercise****Which are Value Added and Non-Value Added Activities and why?**

Activity	VA	NVA	BVA	Why
Entering order				
Waiting/sorting				
Ordering materials/supplies				
Kitting/staging				
Filing				
Preparing drawings				
Checking				
Assembling				
Inspecting				
Shipping to customers				
Counting				
Revising/reworking				
Tracking work				
Testing				
Copying				
Processing customer deposits				
Examining patients				
Filing insurance claims				
Dispensing event tickets				
Fueling airplane				

**Enemy # 2 –Waste (MURA):**

It means difference, a thing which occurs irregularly in process. In KAIZEN we eliminate Mura.

It includes:

- Irregular occurring events.
- Things occurring at some fixed place.
- Things happening with some fixed humans.
- When one side is true and another one is wrong.

**Enemy # 3 –Waste (MURI):**

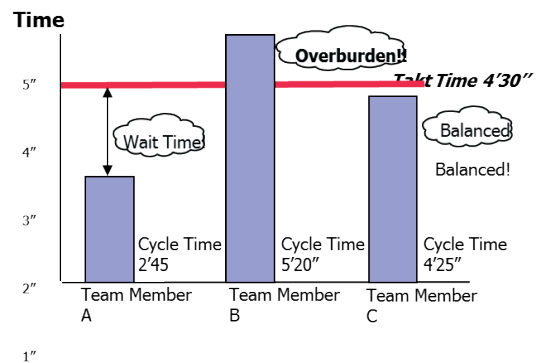
It means stress, tension and difficulties in a process. In KAIZEN we eliminate or reduce Muri.

It includes:

- Bending while working in a process.
- Require more energy while working.
- Picking more weight while working.
- Repeating things.

**Additional Wastes within Manufacturing**

1. Wasted power and energy.
2. Wasted human potential.
3. Environmental pollution.
4. Inappropriate design.
5. Departmental culture.
6. Inappropriate information.



Exercise

Identify the waste in the following pictures:



## 1.7.2 Value Stream Map

### What is the value stream?

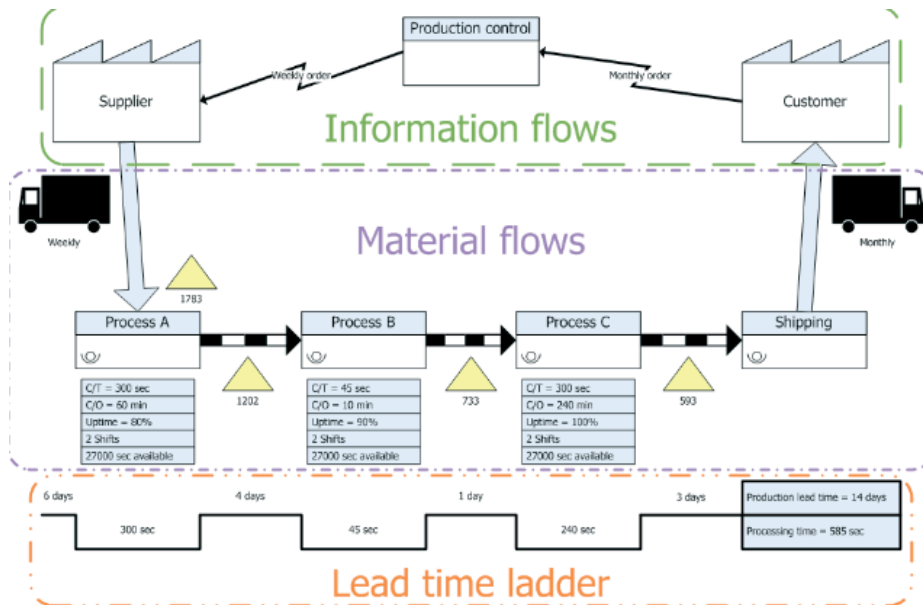
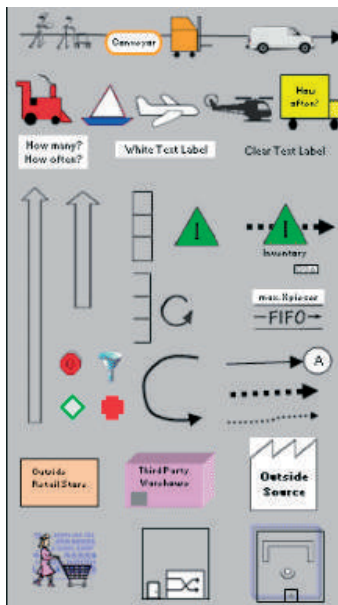
The value stream is the process which creating the value you provide to you customer.

### What is value steam map?

Value stream mapping is a set of methods to visually display the flow of materials and information through the production process.

The objective of value stream mapping is to identify value-added activities and non value-added activities. Value stream maps should reflect what actually happens rather than what is supposed to happen so that opportunities for improvement can be identified.

Value Stream Mapping is often used in process cycle-time improvement projects since it demonstrates exactly how a process operates with detailed timing of step-by-step activities. It is also used for process analysis and improvement by identifying and eliminating time spent on non value-added activities.



## 1.7.3 Flow

### What is mean by process flow? No wastes in VSM .

An action plan for eliminating all identified non-value added (wastes) in VSM using lean improvement tools.

### When we improve flow, we will:

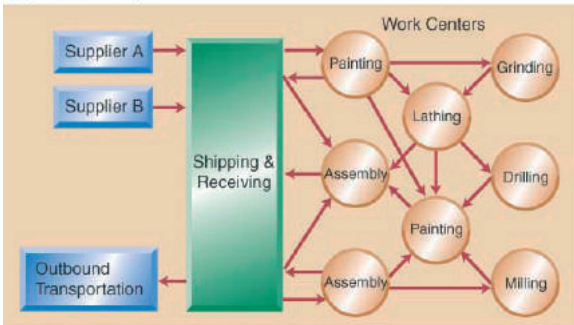
1. Increase effectiveness.
2. Uncover hidden capacity.
3. Generate more revenue.
4. Reduce costs.
5. Improve customer satisfaction.
6. Improve employee morale.

Attack the waste identified in the mapping process: eliminate, reduce, mitigate impact.

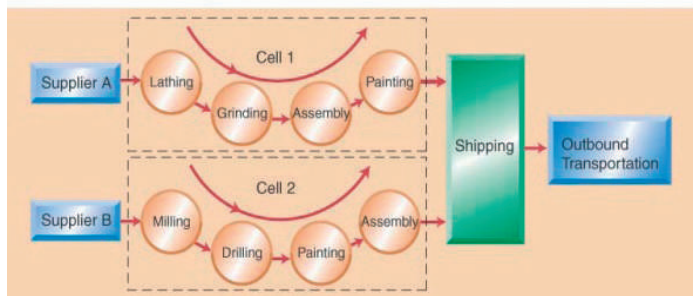
Lean usually aims for the implementation of a continuous production flow free of bottlenecks, interruption, detours, backflows or waiting. When this is successfully implemented, the production cycle time can be reduced by as much as 90%.

**Example for lean.** Make the value-creating steps occur in right sequence so the product will flow smoothly toward the customer, no transportation and waiting wastes.

(a) Traditional Layout



(b) JIT with Cell Manufacturing



### Team Activities

#### What are the benefits to make the process flow?

1. ....
2. ....
3. ....

#### How to make the process flow?

1. ....
2. ....
3. ....



## 1.7.4 Pull

As flow is introduced before, let customers pull value from the next upstream activity.

- In manufacturing: the production of items only as demanded to replace those taken.
- In material control: withdrawal of inventory as demanded by a user. material is not issued until a signal is received from the user.
- In distribution: a system for replenishing field warehouse inventories where replenishment decisions are made at the field warehouse itself and not at the central warehouse or plant.

### What is kanban?

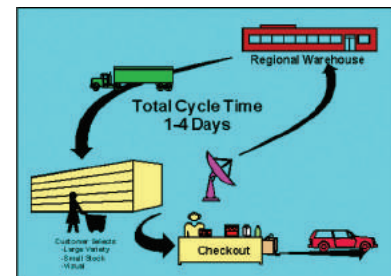
A Kanban is a Visual Information System established to maintain the discipline of a JIT System on the shop floor.

### Pull vs.Push System

The push system is also known as the Materials Requirements Planning (MRP) system.

This system is based on the planning department setting up a long-term production schedule, which is then dissected to give a detailed schedule for making or buying parts.

In pull system; each work station pulls the output from the preceding station as it is needed. Output from the final operation is pulled by customer demand or the master schedule. Thus in pull system work is moved in response to demand from the next stage in the process. The Kanban system is used to monitor the effective pull process.



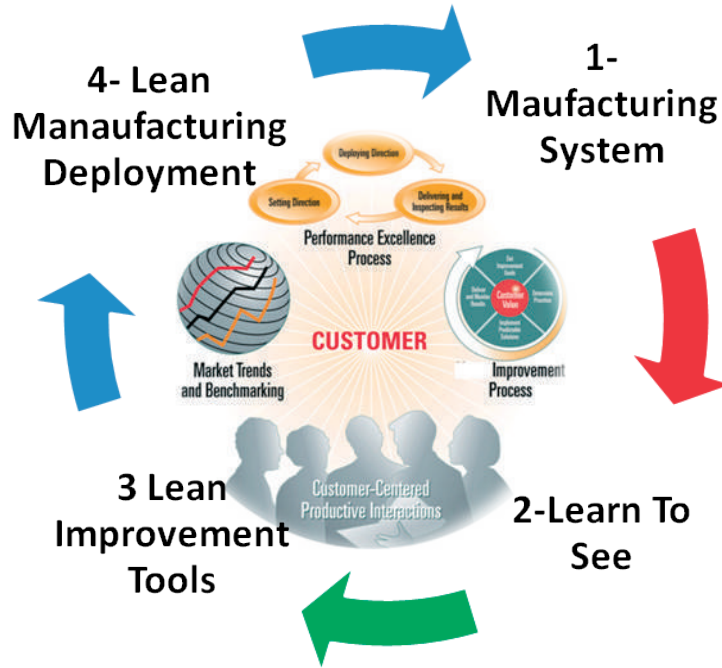
## 1.7.5 Perfection

When the value is specified, the 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.





# 2-Learn To See

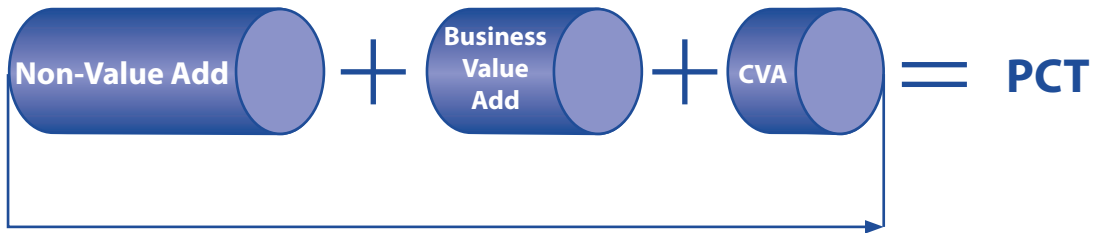


## 2.1 VSM Metrics

The goal of Lean Improvement projects is to increase the speed of a process, so we should measure our process performance:

### 2.1.1 Process cycle time

Process Cycle Time (PCT) is the total time to complete an activity or process



### 2.1.2 Process Efficiency cycle time

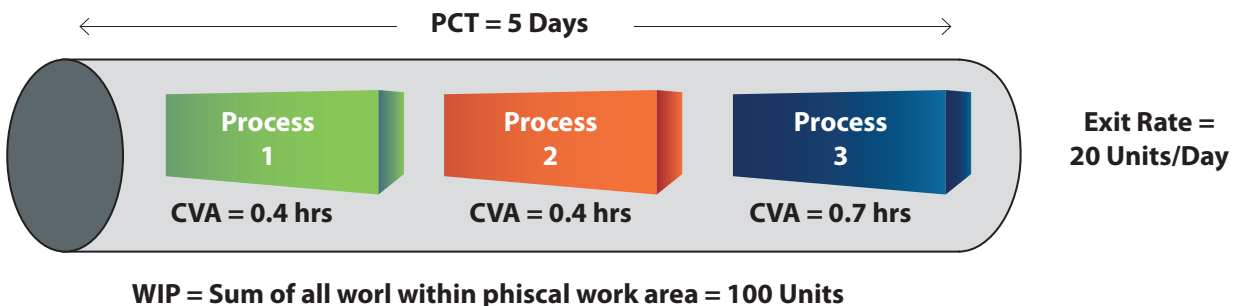
PCE is the performance indicator of how efficiently the process is converting work-in-process into exits:

$$\text{Process Cycle efficiency} = \frac{\text{Customer Value Add Time}}{\text{Process Cycle Time} \div}$$

#### Team Activities

#### Calculating PCE

What is the Process Cycle Efficiency for the process below?

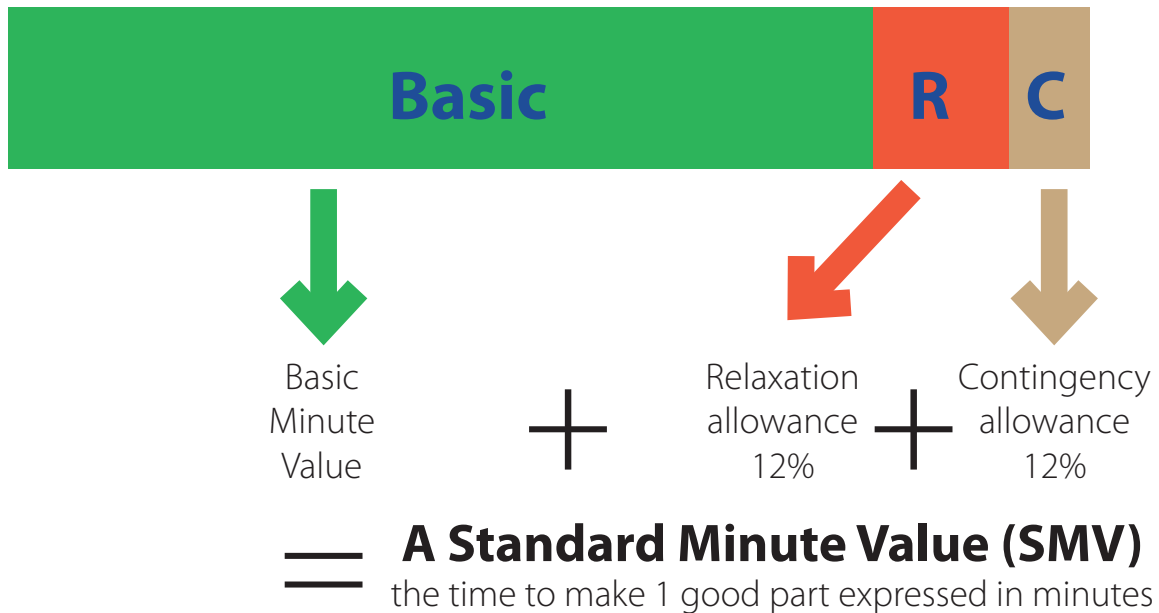


## 2.1.3 SMV.( Standard Minute Value).

### Why SMV? SMV support manager in:

1. Capacity calculation.
2. Costing.
3. Scheduling production and delivery
4. Long term planning.
5. Production and inventory control.
6. Plant layout.
7. Determining number of production manpower.
8. Line balance.
9. New products
10. Performance & Improvement.

### (SMV) Elements



Constructing SMV



Multi Cycle Time Study Analysis - دراسة تحليل للوقت			Study By		دراسة بواسطة										
Plant Details: تفاصيل المصنع			Date		التاريخ										
Product/Part no:      Material :			Shift Number		الوردية										
			Shift Productive Time		الوقت										
Comments			Operator		العامل										
			Basic Minutes		الوقت الاساسي										
			Standard Minutes		الوقت النمطي										
			Units per Hour		عدد الوحدات بالساعة										
			Units per Shift		عدد الوحدات بالوردية										
Number	Description of Element وصف العملية		Timings and Ratings الموقت والمعدل										Summary		
			1	2	3	4	5	6	7	8	9	10	Sum	Obs	Avg
1	Rating المعدل												0.00		#DIV/0!
	Observed الملاحظ												0.00		#DIV/0!
	Basic الاساس												0.00		#DIV/0!
2	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!
3	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!
4	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!
5	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!
6	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!
7	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!
8	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!
9	Rating												0.00		#DIV/0!
	Observed												0.00		#DIV/0!
	Basic												0.00		#DIV/0!

<b>Rating</b>		50	75	100	125
<b>Observed time</b>	1.2		0.8	0.6	0.5
<b>Basic time</b>		1.2*50	0.8*75	0.6*100	0.5*125
		100	100	100	100
	=	0.6	0.6	0.6	0.6

## Example

<b>Rating</b>		50	75	100	125
<b>Observed time</b>	1.2		0.8	0.6	0.5
<b>Basic time</b>		$1.2 \times 50$	$0.8 \times 75$	$0.6 \times 100$	$0.5 \times 125$
		100	100	100	100
	=	0.6	0.6	0.6	0.6

## Exercise

## SMV Calculation

Element Description	Obser. Rating	Obser. Time	Basic Time	Freq.	Basic Time/Gmt
Get bundle and sort parts	95	0.32	0.304	1/30	0.010
Match pocket flap to lining	105	0.11	0.116	1/1	0.016
Sew round flap	100	0.48	0.480	1/1	0.480
Trim threads and turn out flab	58	0.35	0.298	1/1	0.298
top stitch flap	90	0.56	0.504	1/1	0.504
Close bundle and place aside	110	0.23	0.253	1/30	0.008
<b>Total</b>					1.416

## 2.1.4 Takt Time

- What is the Takt Time ?
- Why Measuring the take time ?

It is customer demand time and the time of production output rate

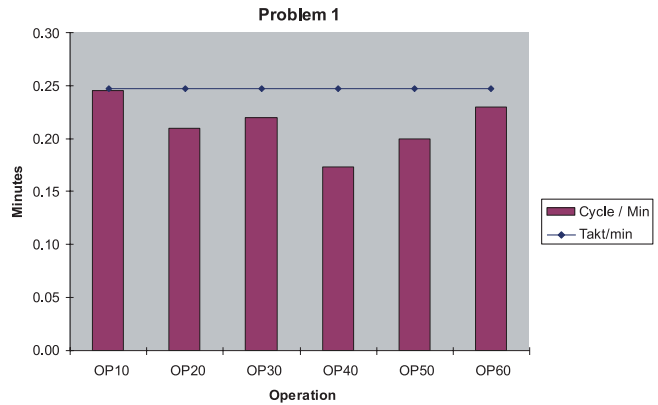
**Takt Time = Net Available Time per Day / Customer Demand per Day**

Shifts	2	Daily Demand	
Minutes/Shift	420 (7*60)	Monday	3400
Days/WK	5	Tuesday	3400
Time Available	<u>4200</u>	Wednesday	3400
		Thursday	3400
		Friday	3400
		Demand	<u>17000</u>

**Calculate Takt = Available time / Demand (A/D)**

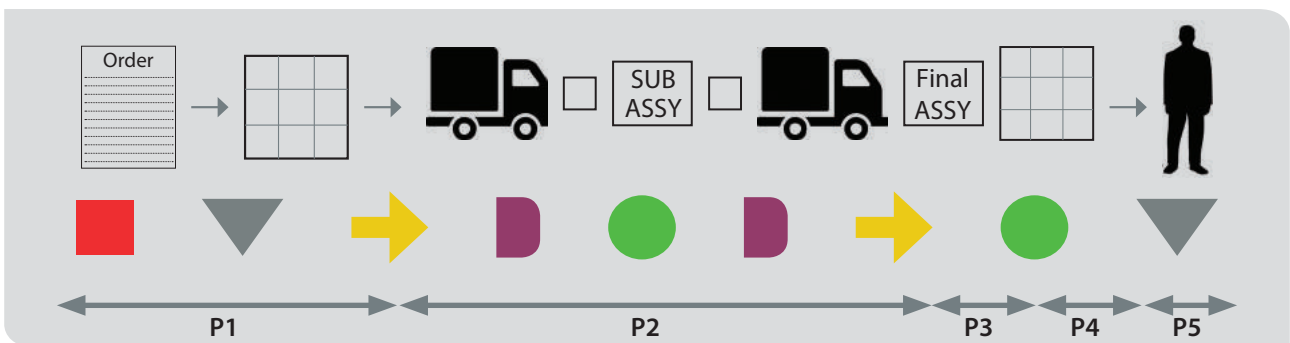
$$\frac{\text{Available time } 4200}{\text{Demand } 17000} = 0.247 \text{ Minutes}$$

Pitch = Takt x Pack Quantity  
 Pitch = 60s x 20 pieces  
 = 20 minutes



### 2.1.5 Lead time and throughput time

- What stages of process?
- What symbols in process?
- What is the time for each step process
- What is the total lead time – as total lead time – order to customer?
- What waste in process?



There are 9 activities shown, but only 2 of them actually add value to the product. All the other activities increase the lead time and are WASTE.

One of the main objectives of Just-in-Time is to streamline supply processes to minimize lead time and minimize all forms of waste.

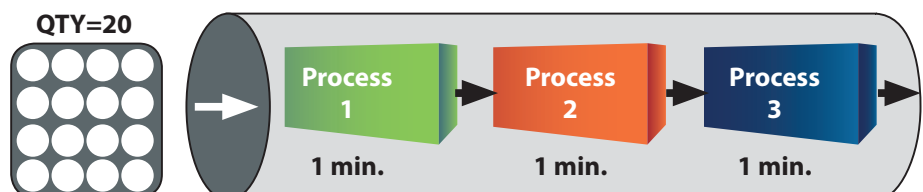
Most supply processes, when studied in this way, show similar levels of waste.

Just-in-Time processes reduce waste through eliminating or greatly reducing;

- Storage
- Transportation
- Delay

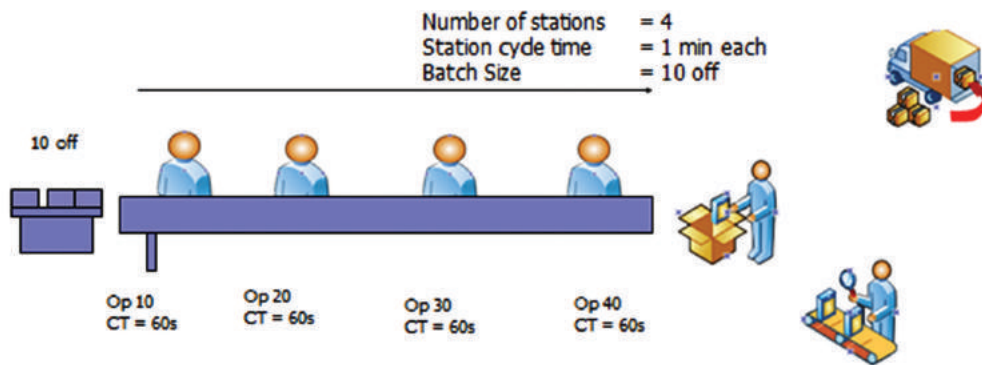
### Batch Production and Throughput Time Relation

1. What is waste types in this process ?
2. What is throughput time ?



Exercise

# Batch and Queue System



How long to complete all 10 pieces?

1. What if the batch of 5?
2. What if the batch of 2?

## 2.1.6 Batch and Queue System-Little Law

The system output rate is fixed even increased the batch size.

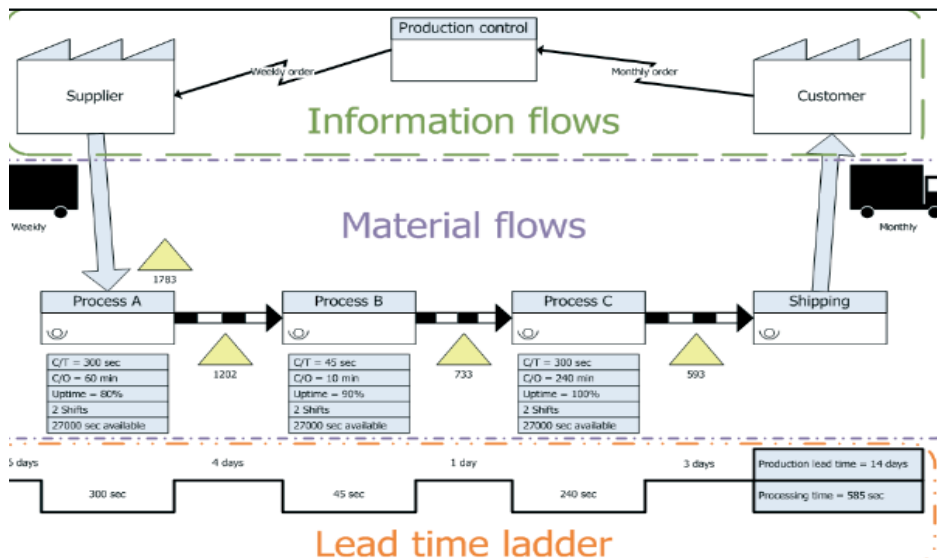
Batch Size (WIP)	Throughput Time (Tp)	Output Rate upm	Output Rate uph
1	4	0.25	15
2	8	0.25	15
3	12	0.25	15
4	16	0.25	15
5	20	0.25	15
6	24	0.25	15
7	28	0.25	15
8	32	0.25	15
9	36	0.25	15
10	40	0.25	15

**Little's law Output = Batch Size (WIP) / Throughput Time**

## 2.2.0 Value Stream Map

### What is value stream mapping?

Value stream mapping is a set of methods to visually display the flow of materials and information through the production process.



### The purpose of a Value Stream Map

Why is a Value Stream Map so useful? What does a VSM provide that other process diagrams or activity descriptions don't? Here's the rundown:

- The VSM, in a single view, provides a complete, fact-based, time-series representation of the stream of activities - from beginning to end - required to deliver a product or service to the customer.
- The VSM provides a common language and common view to analyze the value stream.
- The VSM shows how the information flows to trigger and support those activities.
- The VSM shows you where your activities add value and where they don't, enabling you to see what ultimately impedes your ability to supply and satisfy your customer.

### 2.2.1 Mapping the value stream

The Value Stream Maps are often hand-drawn. However, software tools that enable the drawing, archiving, and e-mailing of VSMs are now available.

The first Value Stream Map that you construct shows the current state – the way things are now. Next, you identify the ideal Value Stream Map – the current state, you update the Value Stream Map to reflect the changes to the process.

The goal is to be continually improving the process – constantly moving it in the direction of the ideal state

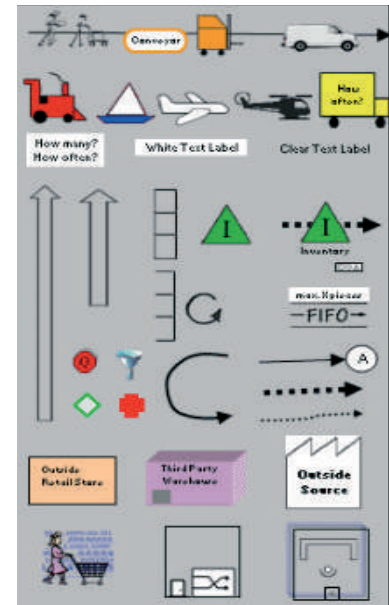
### 2.2.2 The elements of a Value Stream Map

The VSM is a snapshot of the value stream at a specific point in its evolution.

It's a graphical representation of all the steps occurring in a process. In addition, a VSM contains essential, descriptive process information. Generally, a VSM contains the following:



- **Process Steps:** The VSM depicts each of the process steps in the value stream, including both value-added (VA) and non-value-added (NVA). The VSM reveals process statistics like cycle time, NVA time, changeover time, number of operators, number of pieces, amount of inventory, and percent defective.
- **Inventory:** The VSM highlights storage, as well as the amount and movement of inventory within the process.
- **Information flow:** All supporting information required by the process is depicted on the VSM. This can include orders, schedules, specifications, kanban signals (a kanban is a signal to replenish inventory in a pull system), shipping information, and more.
- **Box score:** A VSM includes a summary of the key operational metrics of the process. At a minimum, this includes a summary of the total lead time of a process with the value-added and non-value-added times identified. The summary may also include such information as distance traveled, parts per shift, scrap, pieces produced per labor hour, changeover time, inventory turns, uptime, downtime, and more - it's whatever matters to your business.
- **Lead time:** Along the bottom of the VSM is the current lead time performance of the value stream. Lead time is the amount of time that one piece takes to flow completely through the process. The time is divided into value-added and non-value-added portions. At a glance, you can see where the major portions of non-value-added time occurs.
- **Takt time:** A box in the upper-right-hand corner of the VSM shows the customer demand rate or takt time. This rate is determined by the customer demand and production time available. Ideally, all steps in the value stream should then produce to this rate. The takt time is like a metronome setting the pace for music.
- Teams often find it unwieldy to try to map the whole value stream at a detailed level all at one time. Start with your immediate customer and map the stream back to the point where you receive inputs from a supplier. Just don't lose sight of where in the overall value stream your process fits.
- Pick one product family (a series of products or services that pass through the same processing steps) to map. If the product family is processed at more than one location, for instance a eastern service center and a western service center, then focus on one location, but include representatives from the other location on the improvement team.



## 2.2.3 Supporting information

### Supporting information needed to build a VSM may include the following:

- The end consumer's requirements and expectations
- A macro-level view of the entire value stream from the consumer all the way back through to raw materials and information
- Customer schedules and demand information
- Process-time studies, including
  - Cycle time (C/T)
  - Lead times
  - Number of operators
  - Changeover time (C/O)
  - Working time, less breaks
  - Photos and video of the operations in their current state
- Standard work instructions
- Quality information

- Equipment uptime and availability
- Product and process variations
- Inventory and work-in-process (WIP)
- Batch sizes
- Pack quantities and other shipping information
- Cost data
- Any other information that will help you characterizes the process.

### 2.2.4 Creating the Current-State Value Stream Map

Start at the end closest to the customer and record the process from the end, working your way upstream to the beginning. You'll see what your value stream is doing the farther away from the customer you travel

#### 1) Identifying the activities.

##### a) Characterizing the process time

- What is the actual time required to perform the task identified in the process step?
- What is the waiting time before each step?
- If inventory is involved, how long does it take to deplete it?
- What is the transport or conveyance time?
- What is the inventory between the last operation and the consumer?
- How many operators are active at each process step?
- How long does it take to change over a process when changing product types?

##### b) Deciding what is (Value-added and what is non-(Value-added)

Now it's time to decide which process steps are value-added (VA) and which ones are the dreaded non-value-added (NVA) steps in the process.

To be value-added, an activity must meet the three VA criteria:

- The customer must be willing to pay for it
- It must transform the product or service in some way
- It must be done correctly the first time
- Quantifying other lead time

#### 2) Determining the information flow

- What information is being transmitted?
- When is information being sent?
- Who receives the information and are they the right people to receive the information?
- Where in the value stream does the information transmittal occur?
- How is the information being sent - manually or electronically

## 2.2.5 Analyzing the Current-State Value Stream Map

Ask these types of questions to identify issues in the value stream that are directly affecting the customers:

- Are the operations running slower than takt time?
- Are there deviations to the work standards?
- Is the product not available for shipment?
- Have there been material supply issues?
- Are the drivers leaving late from the facility?
- Have there been any personnel changes?

### a) Searching for Muda

Lean strives to eliminate all wasteful forms. To find waste, ask the following types of questions:

- Is excess inventory or work-in-process accumulating along the value stream?
- Does the step create value? If not, why does the step exist in the process and can it be eliminated?
- Does the step create scrap or rejects? If so, it's a candidate for improvement and, at the very least, further study.
- Does the step perform as designed?
- Is the equipment needed to perform the step functioning?
- Are the materials required available, at the right quality level, and in the right quantity?
- What is the capacity of the process step? How does it compare to the takt time?
- Is the step flexible?
- When changing from one product or service to the next, how long is the process step not producing? (This question is aimed at understanding changeover time.)
- Does the process step flow or is the step a bottleneck in the process?
- How does the process time of the step compare to the customer demand?

### b) Lean principles: The Lean sensei's view

The Lean sensei guides and teaches the organization to learn, implement, and embody the Lean philosophy. The lens through which the sensei evaluates the Current State VSM highlights the short-term and long-term opportunities to institutionalize Lean in the organization. The Lean view poses these types of questions:

- How closely is the process producing to takt time?
- How can the process be more visual?
- How can workers be more empowered to stop the line when quality issues arise?
- How is the material flowing through the process?
- Where best can continuous flow be implemented?
- Where do supermarkets need to be implemented?
- Are standardized work instructions available, being followed, and visible?
- How can the workload be leveled?
- Where can operations be combined to improve flow?

What exists in the value stream preventing the implementation of Lean at this time?  
How can it be?

### c) Quality

The quality practitioners - whether they're from a formal quality function, or, trained lean Six Sigma experts - examine value-added from the perspective of correctness: Does the transformation happen correctly? Is it done right the first time? Is the process capable of producing defect-free results regularly?

Think of debris dumped into a river and what it does to the flow of the current. When quality losses occur in the value stream, it is like debris dumped into stream - impeding its flow. The quality practitioners evaluate the process to identify where it isn't capable of creating good product or service, and where suppliers or downstream contributors create poor quality for the consumer. Analyzing the value stream from a quality perspective will lead you to ask the following types of questions:

- Where is poor quality reaching the customer? What are the defects?
- How are quality issues reported from the customer, transmitted into the organization, and resolved?
- What is the fall-off rate at each step?
- Where are the losses the greatest?
- What is the most common cause of scrap?
- What is the root cause of the scrap (design, equipment, training, and so on)?
- How are suspect items handled?
- How are reworked items returned to the normal flow?
- How can the process, design, or equipment be designed to prevent errors?
- What is the capability of each step?
- Which suppliers are the providers of the poorest quality?
- How frequently have quality spills occurred and in what location?
- What steps have been taken to quarantine defective product?

### d) Supply

Most processes have inventory - either by accident or by design. Inventory can collect at the beginning, somewhere in middle, or at the end of the process. Inventory acts like a dam to the flow of the value stream. Where there is inventory, there is no flow. Likewise, where there are outages, there is no flow. Balance comes in orchestrating the flow of material supply and processing precisely to customer demand - in other words, matching the cycle time to the takt time.

Strategically design the location of the inventory, the size of the inventory, and the information flow throughout the value stream. Examine the CurrentState VSM for how well it consumes supply and moves material through the process. You can do so by asking the following questions:

- What is the inventory turn level?
- What is the size of the storage?
- Where is the storage? In a warehouse? In process?
- How low can it go? Can you maintain an inventory of one?
- How is the inventory managed?
- Do you practice first in first out (FIFO)?
- What signals the withdrawals from the inventory?
- What are the reorder signals in the process?
- Where is material pushed through the system?
- Where is the material pulled through the system? Where else can pull signals be used in the process?

- How are the raw material quantities balanced with the shipping quantities?
- How far does material travel in the value stream?
- How are the incoming material shipments coordinated?
- How is first in first out managed?
- When a quality issue arises, how is the inventory handled/quarantined?
- What is the dollar value of the inventory?
- What is the cost of floor space to handle the inventory?

## e) Engineering

Evaluate the Current-State Value Stream from the perspective of the engineering disciplines: design, production, and maintenance. The engineering perspective will also help you examine the interfaces of the people, equipment, and processes.

Analyzing the value stream from a production-manufacturing engineering perspective, will lead you to ask the following types of questions:

- Is the process designed for flow?
- Can processes be combined? Can alternative processes be used?
- How can operations be laid out to maximize the effectiveness of operators?
- How far away is the material or inventory being stored? How far does it travel between operations?
- How is material presented into the process?
- How are the raw material quantities balanced with the shipping quantities?
- How can changeovers occur more quickly? How can concepts like the "Indy pit crew" be applied during changeovers?
- What modifications can be done to equipment to prevent errors, facilitate the operation, eliminate workload from operators, combine operations, or facilitate flow?
- Is standardized work being followed? How can it be modified to improve quality and eliminate unnecessary processing or movement?
- How can cycle times be balanced with takt time?

Analyzing the value stream from a design engineering perspective, will lead you to ask the following types of questions:

- How can features be built into the design so it cannot be made incorrectly?
- What type of product defects occur during the process? Where do they occur?
- What issues in the current design might be in the future designs?
- Can the design be simplified to facilitate production without compromising customer requirements?
- Are certain design specifications unnecessary for the customer requirements?
- Where can specifications be eliminated or changed without impacting customer requirements?
- Are the design tolerances properly specified to ensure the product can be made right the first time, every time?

Analyzing the value stream from a maintenance/equipment engineering perspective, will lead you to ask the following types of questions:

- What is the uptime of the equipment?
- What is the current maintenance schedule? Is it reactive or planned? If planned, is it preventive or predictive?
- What modifications can be made to the equipment to prevent defects from being produced?
- What pieces of equipment have the greatest maintenance issues?
- Are there different brands of equipment performing the same function/operation? Is there a difference in

performance level?

- What modifications can be made to the equipment, tooling, and process to facilitate quick changeovers?
- What is the process to notify maintenance? How can it be improved?
- When there is an issue, what is the response time for maintenance to respond? What is the time to resolve the issue?
- What simple maintenance activities can be transferred to the operators to perform?
- What modifications, features, or controls can be added to the equipment to enable operators to run multiple pieces of equipment?
- What controls can be added to the equipment to automatically stop when defects are produced or equipment problems arise?

### f) Information

The VSM depicts the flow of information that supports the product and material flow. Your analysis of the current state should include a focused examination of the information component. The purpose of this analysis is to find opportunities to eliminate waste or make improvements based on information.

Answering the following questions will help you when determining where waste, or muda, exists in the information flow:

- Does the information flow to the customer, without delays?
- Does the information flow from the customer, without delays?
- Does the information flow through the organization smoothly?
- Is the information flow accurate? Is the right information going to the right people in the right place? Complete? Contradictory?
- Does the information arrive at the right time? Is it too early or late? Is there too much or too little?
- Are the right people in the information flow and receiving the right information?
- Is the information being transmitted in the most efficient way?
- Is the information being acted upon?
- Are prompt and proper approval chains in place

## 2.2.6 Future-State Value Stream Map

Now it's time to take all the mapping efforts, the analyses, and the ideal-state visions and marry them to define the future state. The improvements that you select now become the foundation for your planning activities. The Future-State Value Stream Map is your next increment of performance improvement.

### Pacemakers, supermarkets, and heijunka

**Pacemaker operation:** The pacemaker operation sets the pace for the rest of the value stream. It's the one and only operation that receives the production schedule. The pacemaker produces to the takt time and sets the pace for the upstream operations to produce only enough to replenish what the pacemaker operation has consumed. Downstream of the pacemaker operation, the process must produce in a continuous flow (unless a storage area, known as a supermarket - see later in this chapter - is required for finished goods). Multiples of pacemaker production fit the quantity shipped to the customer. For example, if the shipping quantity to the customer is 60 per container, then you may release 20 at a time to the pacemaker operation.

**Bottleneck process:** The bottleneck process is the process with the longest cycle time.

**Work modules:** Work modules are aggregated operations fit into a compact area, in order to facilitate continuous flow,

and single-piece production. Work modules are capable of performing all, or most, of the operations required for the value stream to deliver its product or service. This is wholly different from a traditional departmental organization.

**Supermarkets:** Supermarkets are stores of in-process inventory used where the process cannot produce a continuous flow. Examples of supermarkets include when one operation services many value streams, when suppliers are too far away, or when processes are unstable, have long lead times, or have out-of-balance cycle times. The supplying operation controls the supermarket and its inventory. Supermarket inventory is tightly controlled.

**Standardized work:** Standardized work is the description of the work being performed, and it includes the takt time, specific sequence or activities and defined work-in-process inventory. It's the standard to which the actual process is compared, and it represents the foundation on which to improve.

**Kanban:** Kanban are the signals to move and produce. In a pull system, where material or work is "pulled through" a process by demand, kanban is instruction that declares that a withdrawal has been made, so you can produce more. The signal can come in many forms: an empty container, a card, a ball - it takes whatever form best tells the supplying operation to produce. Kanban identifies a standard production quantity.

**Heijunka:** Heijunka, also known as workload leveling or production smoothing, is the practice of smoothing out the volume and mix of the schedule for what's to be produced. The goal of heijunka is to level work schedules to the point where there is

little variation on a daily basis. Heijunka makes continuous flow, pull Signals, and inventory minimization possible.

Pitch: Pitch is the amount of time required to make a standard container of finished product. If the standard container is 60 pieces and the takt time is 45 seconds, the pitch is 45 minutes.

## Marking up the Current - State VSM

The Future-State VSM begins as a markup of the Current-State VSM. Don't start with a clean sheet of paper; make changes directly on the Current-State Map. Identify where and what type of improvements you intend to make. Based on the team's evaluations and observations, indicate what changes will address the issues. The markup technique is to indicate the changes in a sunburst icon called a Kaizen burst.

Marking all of the areas you want to change doesn't imply that you'll necessarily make all the changes at the same time, but it defines an endpoint to this particular improvement phase. With this picture, you can predict the type and extent of improvement you anticipate from the implementation. By identifying such things as how much NVA time will be reduced, and how much key process times are reduced, you can quantify the improvement goals.

- Also ask yourself a set of qualifying questions
- What is the takt time (confirming it hasn't changed from the current state)?
- Where is the bottleneck operation?
- Where can continuous flow happen?
- Where can work cells be implemented?
- Which is the pacemaker operation?
- What process will be scheduled?
- Where will you use kanban signals?
- Where do supermarkets need to be located?
- What is the right lot size between processes?
- What is the standard shipping quantity for the customer?
- What is the pitch?

- What are the current setup times?
- How can schedules be smoothed at the pacemaker operation?
- How much time, of the available hours, is being used for production and How much is left over for changeovers?

After you've answered these questions and indicated the changes on the Future-State VSM draft, you can analyze the map and predict what the future state process should look like. If you're using a software program, the lead time along the bottom will update as you change the information for the step in the value stream.

### Team work activity no.1

Select a one of your process , draw the VSM and identify the following :

1. The process value
2. Process inputs
3. Process steps
4. Customer

Mentioned what are the value added and non -value added in process

### Team activity no.2 –VSM improvement project

Company G is a small RMG factory, with under 150 employees, producing T-shirts for a variety of end users.

Production Process

#### Process involves:-

- Cutting
- Ticketing/ bundling
- Assembly
- Thread trimming
- Ironing
- Packaging
- Shipping

#### Customer Requirement

- 1000 T-Shirt per day
- Customer operates 2 shifts
- Palletised returnable packaging
- One daily shipment to The Company G by truck

#### Work Time

- 20 days per month
- 2 shifts in all areas
- 8 hours every shift, with overtime if necessary
- Two 10 minute breaks during each shift.

#### Production Control Department

##### Receives forecasts 4 WEEK

- Weekly scheduling meeting.
- Issues 6 weeks forecast to The Supplier Company via e-mail.
- Secures raw material by weekly Faxed order release to the supplier.
- Receives daily firm order from The customer.
- Requirements based upon customer order, WIP inventory levels, Finished Goods inventory levels, and anticipated



scrap and downtime.

- Issues weekly open order to finishing and packing process.
- Issues daily shipping order to Shipping process.

### Cutting

- Cycle Time - 0.0125 seconds
- Operators - 1
- Changeover Time - 120 minutes
- Machine Reliability - 85%
- Inventory - 21 days - before this process
- - 16.8 days after the process

### Ticketing/ bundling

- Cycle Time -0.43 minutes
- Operators - 1
- Changeover Time -24.3 minutes
- Machine Reliability - 90%
- Inventory - 2.5 days after the process

### Assembly

- Cycle Time - 0.6 minutes
- Operators - 1
- Changeover Time - 83 minutes
- Machine Reliability - 80%
- Inventory - 3.7 days after the process

### Thread trimming

- Cycle Time - 0.5 minutes
- Operators - 1
- Changeover Time - 88 minutes
- Machine Reliability - 80%
- Inventory - 14 days after the process

### Ironing

- Cycle Time - 0.05 minutes
- Operators - 1
- Changeover Time - 40 minutes
- Machine Reliability - 80%
- Inventory - 0 day after the process

### Packing

- Cycle Time - 0.016 minutes
- Operators - 1
- Changeover Time - 40 minutes
- Machine Reliability - 80%
- Inventory -3.7 days after the process.

**Shipping**

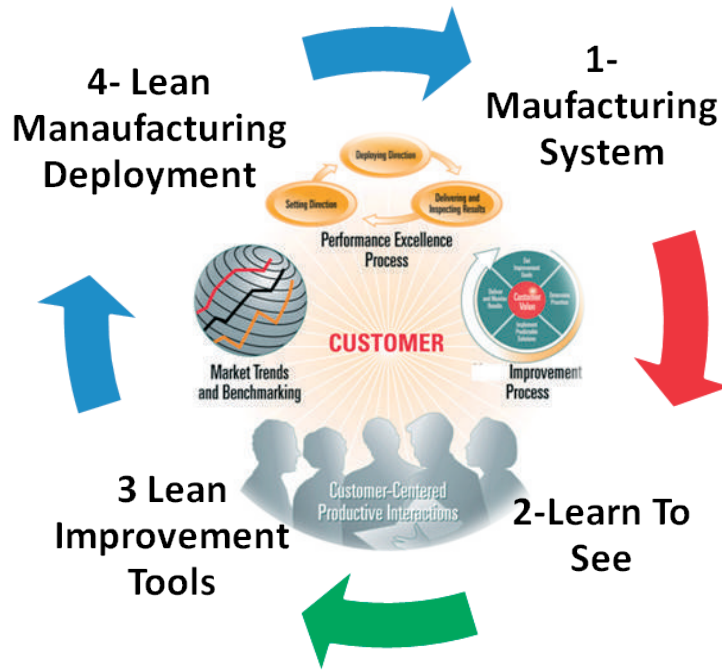
- Cycle Time - 0.083 minutes
- Operators - 1
- Changeover Time - 35 minutes
- Machine Reliability - 95%
- Inventory -3.7 days before the process

**Draw the current state Value Stream map and answer the following questions :**

1. Calculate the take time?
2. Where are constrains in the value stream map?
3. Why this constrains existed?
4. What is the process efficiency lead time?
5. What is the thought put time of the process?
6. What is the non-value added time in the process?
7. Calculate the value added/total lead time?
8. High light all kaizen projects in value stream map and in kaizen charter?
9. Draw the process cycle time for each process steps and plot take time?

Problem identification	kaizen no	Lean Tools	Dep.	Area	Team leader	Team leader	B.IMPACT			Start date	due date	Status
							L	M	H			

# 3- Lean Improvement Tools



### 3.1 KAIZEN

#### What is KAIZEN?

KAIZEN is a Japanese word which consists of two terms i.e. KAI means "CHANGE" and ZEN means "GOOD". So over all KAIZEN means "Changes done for better improvement in a management system of companies". In simple manner KAIZEN means continuous improvement by including all members, Higher authorities, Managers, Workers and each and everyone related to it with practical implementation of ideas.

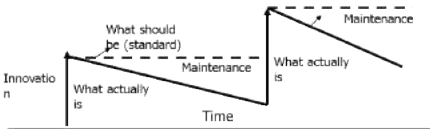
- One of the Lean tools (TPS).
- Focus on Gradually change, a lot of little improvements add up to huge gains in productivity (elimination of waste) and quality.
- Importance of EVERYONE buying into the concept and the vision.

#### Advantages of KAIZEN:

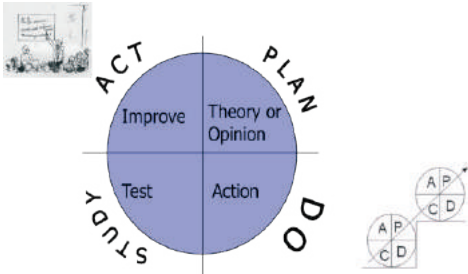
1. Continuous improvement.
2. People learn from their mistakes.
3. People find ways to make things better.
4. Goods and services also improve over time.
5. Leads to improved morale, better products, and satisfied customers and reduced cost.
6. Improves quality.
7. Increases efficiency.
8. Improves customer satisfaction.
9. Value can be added using kaizen in service industries.
10. Applies to all non-manufacturing fields.
11. Tools specifically adapted for this purpose.



Innovation alone



Innovation plus KAIZEN

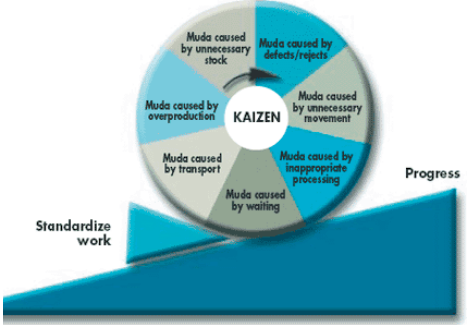


#### Kaizen and Deming Cycle for Continuous improvement

KAIZEN implementation starts with sensation of problem, Understanding of that problem. If there is not sensation of problem then no question of solving or improving it. KAIZEN is the process of solving problems and solving each problem means leading one step ahead. And to make this improvement constant we have to standardize the improved situations.

#### Some more about KAIZEN:

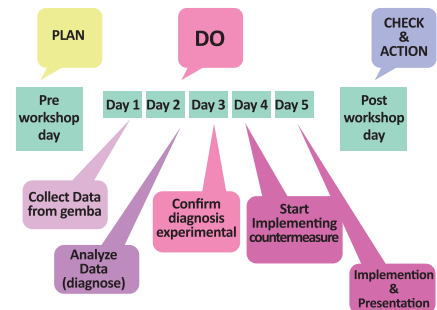
- KAIZEN's area is not only continuous improvement but it is bigger than that.
- It means confidence on unlimited power of imagination in the human and implementation of it.



- KAIZEN tells us not to adjust the conditions to improve the conditions.
- In KAIZEN there is not specific time for solving problem. It should be minimum as possible.
- While implementing KAIZEN it is important to utilize some values and following guidance principles.
- We have to consider current process worst and try to make it better using KAIZEN.
- KAIZEN is series of small-small improvements in which less technology, less cost are used which causes tremendous improvements in quality and process.
- KAIZEN is not “Brian Storming” but it is “Try Storming”.

Go to gemba and have a good look.  
Look for muda, mura, muri

#### The GEMBAKAIZEN Workshop



## GEMBA:

The meaning of this Japanese word is GEM means “Real” and BA means “Place”. It is focused improvement. It includes:

- Making of group including members of all department
- Deciding specific period (4 to 5 days)
- ZERO investment
- Using Deming cycle

In GEMBA kaizen we have to go at the real place where problem is occurring. And according to rules we have to arrange Pre-workshop day, making groups, managing day wise activities like Collecting data, Analyzing data, Confirm diagnosed data experimentally, Start implementing countermeasure, Implementation and presentation and Post workshop day.



## Kaizen Event Process Steps and Deming Planning

### Step 1: Identifying Current Situation

- Crucial first step in process improvement.
- Deep understanding of the existing processes and dependencies.
- Identify all the activities currently involved in developing a new product.
- Observe the process first hand.
- Identify Value Added (VA), Non-Value Added Required (NVA-R), and Non-Value Added (NVA).
- Generally creates more questions than answers



### Step 2: Planning and Preparation

- identify the correct area in the organization that requires the immediate implementation of rapid improvement event.
- After identifying the most appropriate production, administrative or a specific segment in the workplace, the focus

should be given in particular to “waste elimination” issue prevailing in that department for implementing the kaizen event.

- After identifying the problematic area, the managers have to build a cross-functional team of employees.
- Prior to the training, the entire team should be completely aware of the organization’s rapid improvement process and given appropriate training on the process.
- The duration of kaizen events varies from one day to seven days, depending on the length of the process involved and depth of the problem.

**Step 3: Implementation**

- The first and foremost work of the team is to identify and clearly understand the “current state” of the targeted process.
- This would give the team members a common and a clear picture of problem that they are aiming to solve.
- Five Whys: Toyota designed and followed a method of asking “why” five times and answering them one by one to make someone to understand the root cause of a problem step by step.
- Value Stream Mapping: Non-value-adding elements in the targeted process can be easily eliminated through this process.
- The team members would raise queries on the aim of the process, and clearly observe the wastes, reasons for waste and analyze it.
- The most appealing and fruitful ideas are selected and suggested for implementation.

**Step 4: Follow up**

This is the very important phase in the kaizen event as this ensures that the improvements are consistent and not just for time being:

- On completion of kaizen event, the team members should keep track of performance as a routine in terms of metrics measures to record the gains.
- In general the follow up kaizen events are conducted in 30 to 90 days after the first kaizen event in aim of assessing the performance and locate the follow-up changes that should undertaken to maintain the consistency in performance and development.
- Normally targeted process employees are requested for feedback and idea Reporting Improvement.

**KAIZEN NEWSPAPER**

TEAM: \_\_\_\_\_ DATE: / /

NO.	Problem	Who	By When	Check

### KAIZEN –PROJECT CHARTER

Location	Objective	Date	Operator
	Before		After
	Problem	Effects (cycle time / inventory / changeover time reduction,poka yoke etc.)	

### 3.2 5S's

- To eliminate waste, you must first find it.
- Visual order makes waste evident and is a starting point for managing resources.

Good housekeeping uses the Toyota Production System's 5 Ss as the method for improvement by exposing waste and poor utilization of resources

	Japanese	American
1.Seiri:	Organization	Sort
2.Seiton:	Tidiness	Set in order
3.Seiso:	Purity	Shine
4.Seiketsu:	Cleanliness	Standardize
5.Shitsuke:	Discipline	Sustain



### The 5S's with Safety:

#### Sort:

Classify tools, parts, instructions into necessary and unnecessary. Get rid of the later

- High use Equipment Used hour by hour, day by day. Keep within arms reach of point of use.
- Medium Use Equipment Used once a month. Keep within work area.
- Low use Equipment Used once a year Store in a distant location.
- Unneeded Equipment Throw it away.



#### Set in Order:

Make it visible and easy to use:

- Place for every thing .
- Everything in place .

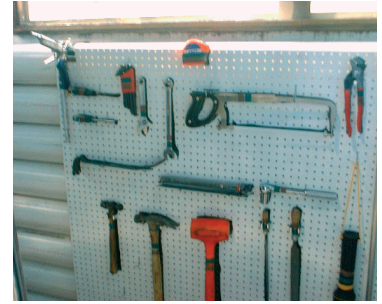


- Easy to get part in short time.
- No waste.

3 Es = easy to see, easy to get, and easy to return.

## Shine-Cleaning:

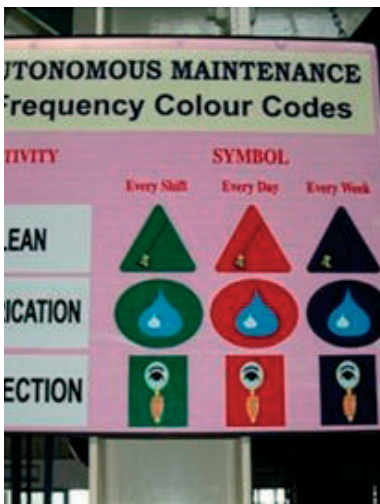
Cleaning is a workplace inspection process. Cleaning is done with the purpose to identify and eliminate the sources of contamination!



## Standardize:

Put a system in place to readily identify abnormal conditions.

- Standardize - identification methods are consistently applied
- Everything in its place.
  - Visual Maps.
  - Standards Clear.( Procedures – work station process )
- Using standard Colour coding .



SL. NO	COLOUR	COLOUR DESCRIPTION	CONTENT
01		YELLOW, BLUE BAND ON RED PIPES	LPG LINE
02		YELLOW	OXYGEN GAS LINE
03		DARK GREEN	HOT WATER LINES
04		SEA GREEN	COLD WATER
05		SKY BLUE	AIR LINES
06		VIOLET	ACID LINES
07		WHITE BAND ON GREEN PIPES	RAW WATER
08		RED & BROWN BAND ON GREEN PIPES	R/O WATER
09		ORANGE BAND ON GREEN PIPES	DM WATER



(Example)



REQUIRED FOR SCRAP PRODUCT/CONTAINERS (SCRAP BINS PAINTED RED DO NOT REQUIRE A TAG) (IF YELLOW IS NOT USED TO DISTINGUISH SCRAP FROM SUSPECT, THE RED TAG MUST HAVE DISPOSITION.)



REQUIRED FOR REWORK, REINSPECT, SUSPECT PRODUCT/ CONTAINERS TAG MUST SHOW LAST OPERATION TO ASSURE PROPER REINTRODUCTION



ANY COLOR (except red or yellow) FOR CONFORMING PRODUCT IS ACCEPTABLE



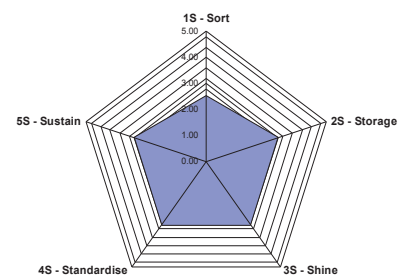




### Sustain:

Make a habit of properly maintaining and following standard practice:

- Daily 30 second behaviours
  - Re-auditing
  - System Ownership.
- Leadership behavioural reinforcement



### Safety:

Identify and eliminate dangerous and hazardous conditions.

Why do I need to know about Safety?

- People expect to work in a safe environment.
- Accidents can be expensive.
- Legal Responsibility
- Your responsibility.



5S AUDIT

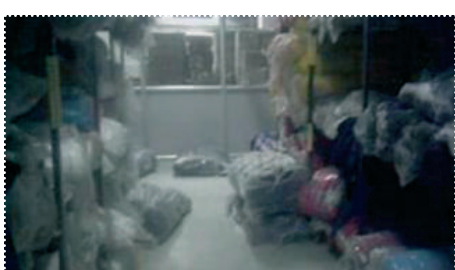
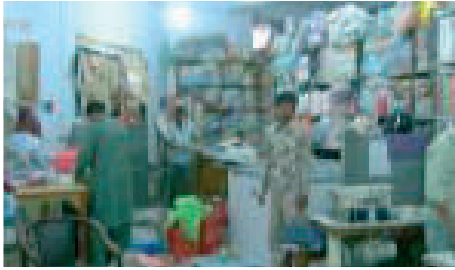
5 S Inspection / Audit				Ranking		
Area Reviewed :		A = 0 Perfect Score				
Date :		B = 1 1- 2 problems identified				
Reviewed by :		C = 3 3or more problems identified				
Category	Description	Evaluation			Avg	Std Dev
		1	2	3		
<b>Sort 1S (Seiri)</b>	<b>Distinguish between what is needed and not needed</b>					
	Have all unnecessary items been removed?					
	Are all remaining items neatly arranged? Are walkways and work areas clearly outlined?					
	Are unneeded items stored in an appropriate place? Does a procedure exist for dispensing unneeded items?					
	<b>1S result</b>					
<b>Storage 2S (Seiton)</b>	<b>A place for everything and everything in its place</b>					
	Is there a visually marked, specified place for everything?					
	Is everthing in its specified place? Are standards and limits easily recognizable?					
	Is it easy to see what needs to be where? Are things put away after use?					
	<b>2S result</b>					
<b>Shine 3S (Seiso)</b>	<b>Cleaning and looking for ways to keep it clean</b>					
	Are work areas clean?					
	Is equipment kept clean? Are cleaning materials easily accessible?					
	Are cleaning guidelines and schedules easily visible? Are demarcation lines clean and unbroken?					
	Is cleaning used as a form of inspection?  <b>3S result</b>					
<b>Standardise 4S (Seiketsu)</b>	<b>Make standards obvious and maintained</b>					
	Is all necessary information visible? Are all standards known and visible?					
	Is there a checklist in the area? Is there a 5S map in the area?					
	<b>4S result</b>					
<b>Sustain 5S (Shukan)</b>	<b>Stick to the rules and follow up</b>					
	Does everyone observe standard procedures?					
	Are red tag procedures followed? Are personal belongings stored neatly?					

Examples: Before and After

Before

IMPROVEMENT

After



Team activity: Project 1

In need to kaizen -CI Projects?



For above pictures, using as 5S + Safety audit check list, and kaizen project charter Identify:

- 1) The problem statement
- 2) Operational and business impact
- 3) Kaizen team for improvement
- 4) Project KPIS's
- 5) Action plan for implementation kaizen projects.



### 3.3 Visualization.

Visual Management systems enable factory workers to be well informed about production procedures, status and other important information for them to do their jobs as effectively as possible. Large visual displays are generally much more effective means of communication to workers on the factory floor than written reports and guidelines and therefore should be used as much as possible. When it comes to improving compliance with a process, visual presentation helps the team better understand a complicated process including the correct sequence of events, the correct way to perform each action, internal and external relationships between actions, and other factors



#### These visual tools may include the following:

**1) Visual Displays -** Charts, metrics, procedures and process documentation which are reference information for production workers. For example, trend chart of yield performance, % variation of defect rate, month-to-date shipping volume status, etc.



اعملها صح من المرة الأولى  
MAKE IT RIGHT FIRST TIME

هافطالك الإنتاج (سوي لطف الإنتاج) HAFITALUK (URETIM TAKIMI)

BANT ADI : T-15  
MODEL ADI : Tesco  
BANT SEFI : Miree

تاريخ الإنتاج	عدد الإنتاج	عدد الإنتاج	عدد الإنتاج	عدد الإنتاج	عدد الإنتاج
2015-11-10	200	201	200		200
2015-11-11	200	300	200		250
2015-11-12	300	200	250		200
2015-11-13	300	200	200		200
2015-11-14	1000	100	850		600

**2) Visual Controls –** Indicators intended to control or signal actions to group members. This may include production status information, quality tracking information, etc. For example, color-coded panel for temperature or speed setting control limits that help an operator quickly identify process is out of the control range. Kanban cards are another example of visual controls.

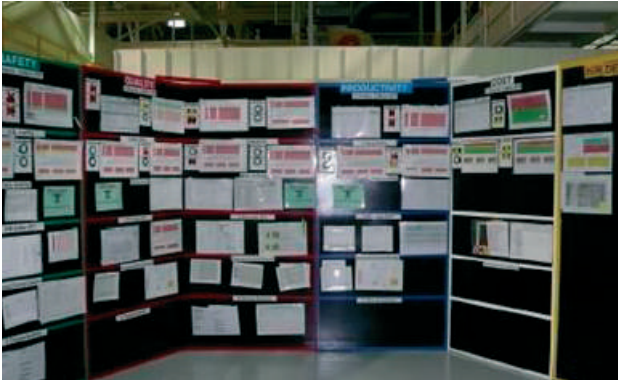


Before

After



**3) Visual process indicators** – These communicate the correct production processes or flow of materials. For example, this would include the use of painted floor areas for non-defective stock and scrap or indicators for the correct flow of materials on the factory floor.



**Team activity: Project 2**

In the following Pictures , how to make the the work place visualized and controlled .



- 1 .....
- 2 .....
- 3 .....



- 1 .....
- 2 .....
- 3 .....



- 1 .....
- 2 .....
- 3 .....

### 3.4 Standard Operation Procedures (SOP)

If people worked in different ways, we would have big problems! Our operation times would vary, our quality would suffer, and we would be creating waste! Efficient production of good products would be sporadic and ultimately impossible



#### The Importance of Standardized Work:

Without it, all improvement efforts using Kaizen to eliminate waste (muda) are not sustainable. You will go back to the original position before Kaizen.

#### Standardized Work Definition:

- The document of work functions performed in a repeatable sequence, which are agreed to, developed, followed, and maintained by the functional organization
- Standardized work is used when there is a definable, repeatable process. as Production and repair work .
- some suppliers are referring to standardized work as :Job Instructions, Work Instructions, Method Sheets, Operator Instructions.

#### Standard Work Provides Foundation for:

- Ensuring operators are consistently performing the same
- Tasks and procedures.
- An efficient production sequence.
- Reduced variation within a process.
- Waste reduction, problem solving and quality control.
- Identifying value added tasks.
- Continual improvement.
- A lean organization.
- Auditing operator conformance to work instructions.



Constructing SOP

STANDARD OPERATION SHEET - STATIC

Group / Team:		JOB NAME		Date:	
Address:				Written By:	
Element No.	ES Register Number	Element Name	Element Time	Legend	
			Work		
			Walk	<p><b>WORK FLOW DIAGRAM</b></p>	
			Totals	0	0
			Total Cycle Time	0	
			% of Mix		
			Weighted Totals	0	
Take Time	seconds	Total Cycle Time		0	
Actual Takt Time	seconds	% of Mix			
			Weighted Totals	0	
<p>Place symbols on the layout as appropriate:</p> <ul style="list-style-type: none"> <li> Safety As Indicated on Job Element Sheet</li> <li> Quality Check 100% Gauging / Testing</li> <li> Standard In-Process Stock- (Minimum in one container at workstation)</li> <li> Critical Operation</li> <li> Mandatory Sequence</li> </ul>					
<p><b>Work Flow</b> Add team member work path to the layout</p> <ul style="list-style-type: none"> <li> - Identify Team Member/process</li> <li> - Identify location where each job element is performed</li> <li> - Indicate forward walk path through process</li> <li> - Indicate return walk path from last job element to first</li> </ul>					
Signature Block - All Shifts			Cycle Time Chart		Other Activities
Shift	Team Leader	Date	Group Leader	Date	PPE - Personal Protective Equipment
Days					
AA					
			Time		



	Singeing	De-sizing	Mercerization	Bleaching	Cold pad batch Dyeing
How often is measured?	1 time / hr	Once	2 time/hr Analysis	1 time / hr - 2 time Analysis	2 Time/ 4000 m
What is measured?	Detect the Blue Flam color	PH Temperature	% Caustic Soda	% Caustic Soda H2O2 CH3COOH	Calibrate bet. Alkali Soda & Dyeing
Where it is measured?	All the process Time	At the beginning of each preparation	All the process Time	All the process Time	At the beginning In the process
What is the method?	Monitoring	Measuring	Monitoring	Monitoring	Measuring
How often is measured?	Jig Dye 2 Time / Batch	Jet Dye 1 Time/ Batch	stenter 1 Time/ Batch	Calender 1 Time/ Batch	Sanfor 1 Time/ Batch
What is measured?	Temperature PH Pressure % Soda % Hydrous	Temperature PH % Soda Pressure H2O2	Temperature Pressure of the Squeezer Width	Temperature Pressure	Temperature Pressure

Team Activity – Project 4

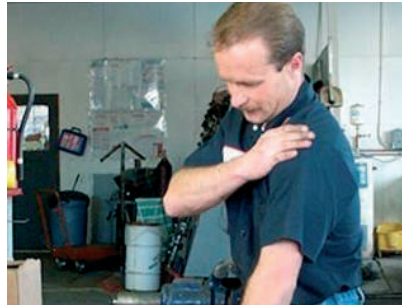
Select one of your process , and construct the SOP



## 3.5 Ergonomics

### What is Ergonomics?

Fancy word for the science of arranging and adjusting the work environment to fit the employee's body



### Benefits of Ergonomics

- Decreased risk of injury
- Increased productivity
- Increased quality and efficiency
- Decrease lost work days
- Decrease turnover
- Improve morale



### Ergonomics Control Techniques

- Work station design.
- Work methods.(SOP).
- Tool design.
- Reducing or spreading force.
- Obtaining better mechanical advantage.



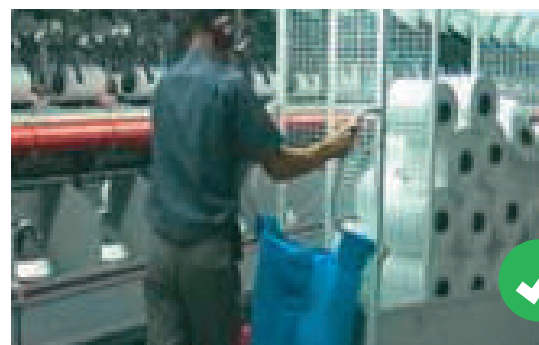
### How Ergonomics Can Help

#### EMPLOYEE:

- Fewer injuries
- Improved Health & Safety
- Reduce absenteeism
- Lower worker turnover
- Fatigue
- Quality of life

#### EMPLOYER:

- Increase in work quality
- Morale improves
- Increase productivity & efficiency
- Lowered workers' compensation rates
- Less likelihood of OSHA fines



## 3.6 Quick Change Over

### What is Changeover time ?

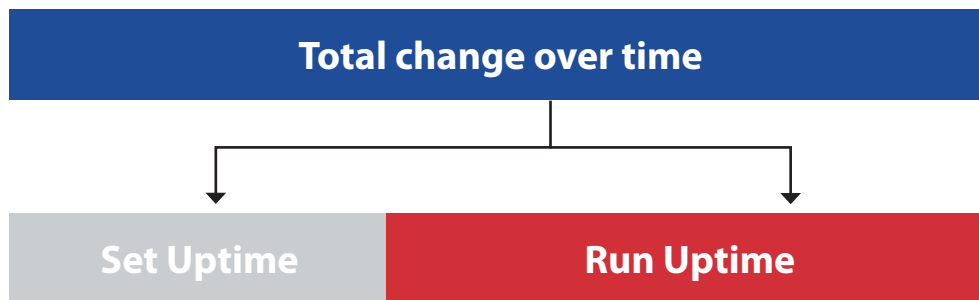
- Changeover time is the total elapsed time between the last unit of good production of the previous run, at normal line efficiency, to the first unit of good production of the succeeding run, at full line efficiency.
- Quick changeover is a fundamental requirement for Lean manufacturing system



### Achieving Quick Change-Over (AQCO)

Is a modern and broad development of Shigeo Shingo's SMED - Single-Minute Exchange of Dies and kills once and forever two obsolete assumptions, typical of the manufacturing sector?

1. Changing-over efficiently and effectively requires a high level of knowledge and ability, which are the result of long training and experience
2. Producing in large lots mitigates the effects and counterbalances the costs of long change-over times



### Set-up Time Definition

It is whatever takes place in a machine, a line, or a productive operation, between the end of production of a certain type of product and the start of production of another type of product.

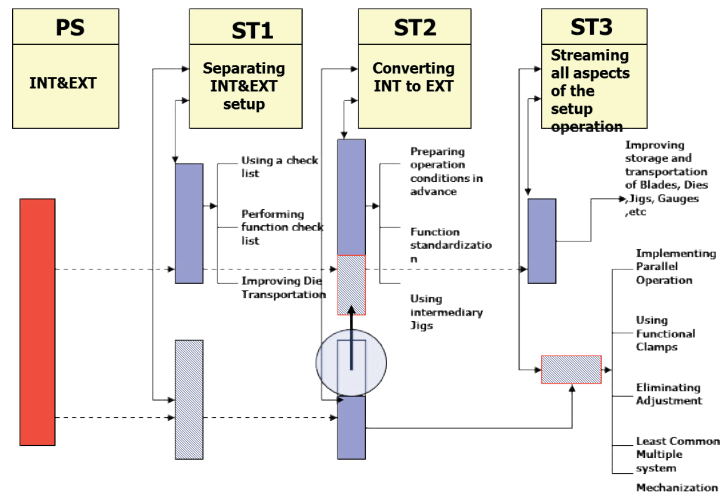
If, in order to produce the new product (or component, workpiece, sub-product, quasi-product....) a machine or a line or any productive facility needs to be re-set, then we talk of a set-up

### Classification of Setup Activities

- **EXCHANGING DIES & BLADES:** dies, moulds, drill bits, saw-blades and other tools, silk-screening plates, etc. And also: cleaning and replacing filters (ex. in plastic extruders) and similar operations that cause a temporary stop to production.
- **SWITCHOVER" or "RE-TOOLING".**For instance:
  - In assembly lines - includes exchanging supplies of components, materials, assembly jigs and tools, templates, etc.
  - In certain machines - includes, for instance, new material feed to machine (new rolls of paper in winders, or new rolls of paper or material or plastic film in printers, etc.)
- **CHANGING STANDARD PARAMETERS:** in NC machines, dairy processes, chemical processes....  
GENERAL PREPARATION before manufacturing starts: arranging the equipment, assigning tasks, checking drawings & work schedules, etc. Under this class of set-ups fall also the general wind-down activities at the end of a day or a shift (cleaning, putting tools in order, and switching-off equipment...).

- **Benefits of setup reduction**
  - Better quality.
  - Lower cost.
  - Reduced inventory.
  - Better flexibility.
  - Better worker utilization.
  - Shorter lead time and more capacity.

## Improving the change over time



### INTERNAL CHANGE-OVER TIME

This is defined as that interval of time during which the productive process must stop, or no set-up could be made. This is the real and proper change-over time, that begins when the current lot process finishes, and ends when the next lot process produces the 1st defect-free item. Throughout this time no value is added to products.

### INTERNAL REPLACEMENT ACTIVITIES

In manufacturing, these include: stripping previous process ancillary tools (moulds, dies, plates, guides, rollers...) and fitting next lot's corresponding ones. Generally, there is a lot of bolting and un-bolting operations to be done, rather time consuming, and a number of moving activities, such as lifting, lowering, removing.... AQCO strategy is to minimise these activities' duration by applying a number of dedicated techniques, addressed to: eliminating the need for bolts, nuts and other fasteners, or - replacing traditional fasteners with faster-action fasteners, or - streamlining as much as possible the un-fastening/fastening activities in order to cut drastically their duration, or - many other similar initiatives.

### INTERNAL ADJUSTMENT ACTIVITIES

These include: centring, precision-positioning (for instance moulds and dies), measuring, calibrating, fine-tuning, and the like. This is done to ensure the correct quality standards of the output product.

Strictly associated, there is a number of trial activities, to verify that the adjustment/s made were actually correct.

All this is time consuming (also because of possible re-iterations) and may require knowledge, abilities and experience.

AQCO approach is very simple again: eliminate the need for any adjustment, by inventing ways of doing it once and forever with a permanent, poka-yoke solution. This cuts to zero the need for any adjustment and for any particular knowledge/skill/experience. The target is to enable any operator with some decent industrial skill to "precision-replace" or "precision-set", without any need for measuring, calibrating and checking.

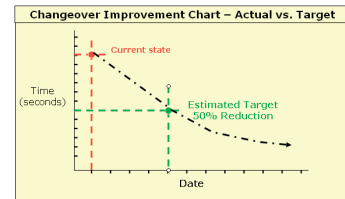


### EXTERNAL CHANGE-OVER TIME

This is defined as that interval of time during processing (of previous and next lot) during which change-over related activities (like transport, preparation, etc.) are implemented by various personnel (fitters, workers, operators....). Part of this time may elapse before Internal Change-Over Time, and part after it.

### Road map for QCO Improvement .

1. Process activity map .
2. Map the current walk pattern .
3. Identify each process step time .
4. Identify each process step VA,NVA.
5. Identify each process Internal or external activities.
6. Follow processes of improvement change over time.



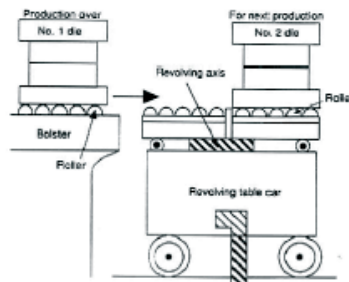
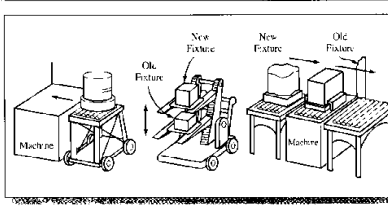
### Setup Reduction (Improving Internal Setup)

Quick-attachment Devices



### Setup Reduction (Improving External Setups)

examples of material handling equipment.



COT- Matrix Help in scheduling production –delivery and commitment .

To	A	B	C	D
A		13 mins	28 mins	19 mins
B	43 mins		16 mins	35 mins
C	25 mins	23 mins		16 mins
D	23 mins	16 mins	43 mins	



## 3.7 (Total Productive Maintenance –TPM)

### 3.7.1 TPM - Definition

TPM is a low cost people intensive system for maximizing equipment effectiveness by involving entire company in a preventive maintenance program.

- TOTAL - All encompassing by maintenance, production individuals working together.
- PRODUCTIVE - Production of goods, services that meet or exceed customer's expectations.
- MAINTENANCE - Keeping equipment, plant in as good as or better than the original conditions at all times.

It is a culture that focuses on improving the effectiveness of the plant, equipment and processes through the empowerment of PEOPLE

In the old-fashioned maintenance (American-style) it was the "I operate, you fix" concept, where operators merely operate the machine and maintenance is the domain of the maintenance department. Although the United States was the pioneer in the development of preventive and productive maintenance, but due to the determination of the Japanese manufacturers to compete in the world market after the World War II, they imported these ideas to improve their equipment maintenance.

The "I operate-you fix" concept prevailed until the TPM or total productive maintenance was first developed at Nippondenso (one of the automobile part supplier for Toyota) in Japan in 1969 with total employees participation (Nakajima, 1989). The word "total" in "total productive maintenance" has three meanings related to three important features of TPM (Nakajima, 1989). The first will be the "total effectiveness" in the pursuit of economic efficiency or profitability. Second, "total preventive maintenance" to improve maintainability as well as preventive maintenance. Finally the total also means "total participation" where machine operators are involved in the autonomous maintenance and the activities of small groups in every department and at every level.

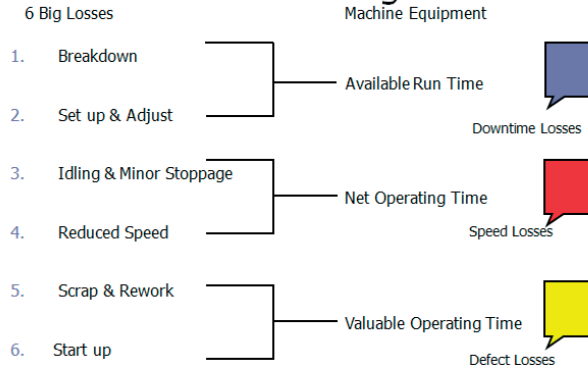
### Objectives of TPM

- Avoid wastage in a quickly changing economic environment.
- Producing goods without compromising product quality.
- Reduce cost.
- Produce a low batch quantity at the earliest possible time.
- Goods sent to the customers should be without defects.

### 3.7.2 The 6 Big Losses

TPM represents a major shift in the way an organization approaches the maintenance function; from being the responsibility of the maintenance department to being everyone's responsibility. TPM is designed to maximize equipment effectiveness by establishing a comprehensive productive maintenance system covering the entire life of the equipment, spanning all equipment-related fields and with participation of all employees from the top management to the shop-floor workers, to promote productive maintenance through motivation management or voluntary small group activities (Tsuchiya, 1992). In maximizing the equipment effectiveness, the following six big losses of equipment effectiveness has to be eliminated or reduced.

## The Effect of The 6 Big Losses



To eliminate these six big losses, it is important that first, attitudes of people have to be changed through motivation, training and also by creating a work environment that is conducive to TPM implementation.

In implementing TPM, a master plan is needed and this has to be formulated, prior to embarking on the program. This master plan needs to be broken down into distinct stages in order to progress. TPM contains short-term and long-term elements, where the short-term elements focus on the autonomous maintenance for the production department, a planned maintenance program for the maintenance department, followed by skill development for operations and maintenance personnel. The focus of the long-term elements will be is on new equipment design and the elimination of sources of lost equipment time. By properly adhering to the foci, TPM should result into what the Japanese philosophers termed as zero defect, zero downtime, zero accident, and zero waste (Stephens, 1994).

### 3.7.3 Overall Equipment Effectiveness

In this competitive age, firms are striving to improve customer's satisfaction and minimize production costs. Traditionally, production costs are minimized by increasing the meantime between failures of the production equipment on the one hand and minimizing maintenance costs on the other (Raouf, 1994). Cutting maintenance costs alone will not help to minimize the production cost, but may lead to ineffectiveness of the production equipment. As such the basic underlying approach of TPM is to maximize production equipment effectiveness, which is typically measured by the OEE (Overall Equipment Effectiveness).



$$\text{OEE} = \text{Availability} \times \text{Performance rate} \times \text{Quality rate}$$

Availability	$\frac{\text{Operating time} - \text{downtime}}{\text{Operating time}}$
Performance	$\frac{\text{Number of parts produced}}{\text{Number of parts expected to be produced}}$
Quality	$\frac{\text{Number of parts produced} - \text{Scrap}}{\text{Number of parts produced}}$

An OEE rating may be used to compare different sites within an individual business group, and may influence strategic investment and other important decisions (Mileham et al., 1997). If a company has an OEE of 85% or above, then it is considered to be a world-class company.



### 3.7.4 TPM Deployment Stages

1. Preparatory Stage .
2. Introduction Stage .
3. Implementation Stage .
4. Institutionalizing Stage .

#### 1) Preparatory Stage

##### Step 1: Announcement of TPM

- Proper understanding, commitment and active involvement of the top management is needed for TPM implementation.
- Top management needs to create an environment that will support the introduction of TPM.
- Without the support of management, skepticism and resistance will kill the initiative.
- Top management should have awareness programs, after which announcement is made to all.
- Publish it in the house magazine and put it in the notice board. Send a letter to all concerned individuals if required.

##### Step 2: Launch a formal education program

- This program will inform and educate everyone in the organization about TPM activities, benefits, and the importance of contribution from everyone.
- Training is to be done based on the need. Some need intensive training and some just an awareness.
- Take people who matters to places where TPM already successfully implemented.

##### Step 3: Create an organizational support structure

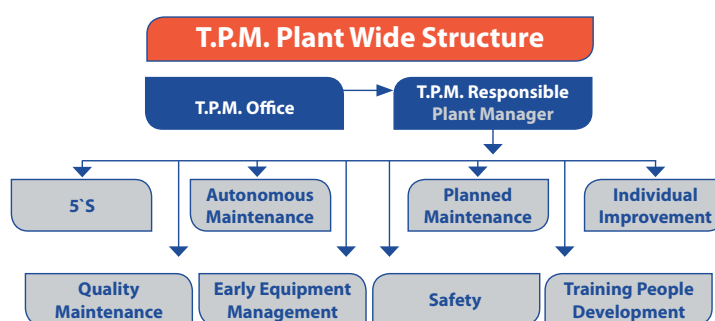
- This group will promote and sustain TPM activities once they begin.
- This group needs to include members from every level of the organization from management to the shop floor.
- This structure will promote communication and will guarantee everyone is working toward the same goals.

##### Step 4: Establish basic TPM policies, working systems and quantifiable goals

- Analyze the existing conditions and set goals that are SMART: Specific, Measurable, Attainable, Realistic, and Time-based.

##### Step 5: Outline a detailed Master Deployment Plan

- This step is an implementation leading to institutionalizing wherein TPM becomes an organizational culture.



- This plan will identify what resources will be needed and when for training, equipment restoration and improvements, maintenance management systems and new technologies.
- Achieving PM award is the proof of reaching a satisfactory level.
- Some may learn from us and some can help us and customers will get the communication from us that we care for quality output.

## 2) Introduction Stage

### Step 6: TPM kick-off

- Implementation will begin at this stage.
- This is a ceremony and we should invite all.
- Suppliers as they should know that we want quality supply from them.
- Related companies and affiliated companies who can be our customers, sisters concerns etc.

## 3) Implementation Stage

- In this stage 8 activities are carried which are called eight pillars in the development of TPM activity:

### Step 7: Improve effectiveness of each piece of equipment

- Project Teams will analyze each piece of equipment and make the necessary improvements.

### Step 8: Develop an autonomous maintenance program for operators

- Operators routine cleaning and inspection will help stabilize conditions and stop accelerated deterioration.



### Step 9: Develop a planned or preventive maintenance program

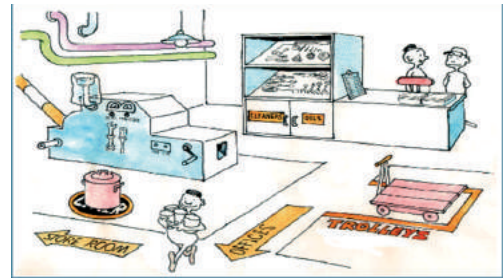
- Create a schedule for preventive maintenance on each piece of equipment.

### Step 10: Conduct training to improve operation and maintenance skills

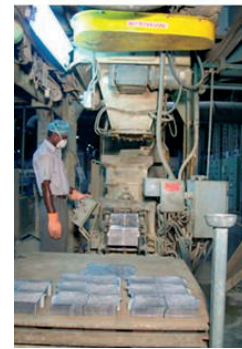
- Maintenance department will take on the role of teachers and guides to provide training, advice, and equipment information to the teams.

### Step 11: Develop an early equipment management program

- Apply preventive maintenance principles during the design process of equipment.
- **5S is the foundation for all the pillars** - Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement.
- **Autonomous Maintenance** - Autonomous maintenance is one of the unique features of TPM, which believes that individuals should be responsible for their own equipment and have to perform autonomous maintenance. Autonomous maintenance consists of cleaning, lubrication, retightening and inspection.
- **Kaizen - Gradual** - incremental and constant improvement in process by involving everyone in an organization. It is a continuous program to improve quality and increase productivity. It is said that Kaizen has been one of the key ingredients in Japan's competitive success in the world market.
- **Planned Maintenance** - A planned maintenance schedule should be planned for timely replacement of components which is must for the effective operation of equipment and long life. This has to be followed by the maintenance team. In spinning mills, components like card wires, top roller cots require timely grinding and buffing, respectively to keep them in good condition for the production of good quality slivers and yarns.



Before



After



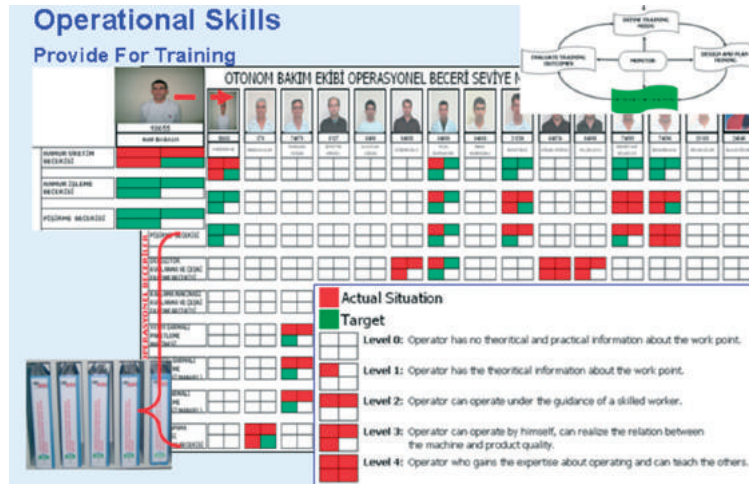
Activities	Maintenance Technician	Maintenance Engineer	Production Operator
Production			●
Set up & Adjustment			●
Cleaning			●
Lubrication			●
Tightening			●
Breakdown Maintenance	●	◐	●
Periodic Maintenance	●	●	◐
Predictive Maintenance	●	●	◐
Corrective Maintenance	◐	●	◐
Maintenance Prevention	◐	●	◐
Installation & Renovation	◐	●	◐



Activities	Maintenance Technician	Maintenance Engineer	Production Operator
Production			●
Set up & Adjustment	●	◐	◐
Cleaning	◐		●
Lubrication	●		
Tightening	●		
Visual Inspection	●	◐	
Breakdown Maintenance	●	◐	
Periodic Maintenance	●	●	
Predictive Maintenance	No predictive maintenance activities.		
Corrective Maintenance	●	●	
Maintenance Prevention	No maintenance prevention activities.		
Installation & Renovation	●	●	

- **Quality Maintenance** - It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. Transition is from reactive to proactive (Quality Control to Quality Assurance).
- **Education and training** - Education and training are investments in people that yield multiple returns. Operative in each department must be trained, in such a way that they must improve the understanding about functions of their machines, early detection of abnormalities, ability to do improvements, on machines operated by them.

- **Office TPM** - Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation.
- **Safety, Health and Environment (SHE)** - In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. The target of SHE is Zero accident, Zero health damage and Zero fire.



#### 4) Institutionalizing Stage

##### Step 12: Continuous Improvement

- As in any Lean initiative the organization needs to develop a continuous improvement mindset.
- By all their activities one would have reached maturity stage.
- Now is the time for applying for PM award.



## 3.8 Kanban

### 3.8.1 What is Kan-ban?

#### By this point you may be asking, “What is a Kan-ban?”

A Kan-ban is a card containing all the information required to be done on a product at each stage along its path to completion and which parts are needed at subsequent processes.

These cards are used to control work-in-progress (W.I.P.), production, and inventory flow. A Kan-ban System allows a company to use Just-In-Time (J.I.T) Production and Ordering Systems that allow them to minimize their inventories while still satisfying customer demands.

A Kan-ban System consists of a set of these cards, with one being allocated for each part being manufactured, that travel between preceding and subsequent processes.

### 3.8.2 Kan-ban Pull System

The Kanban System was developed (more than 20 years ago), by Mr. Taiichi Ohno, a vice president of Toyota, to achieve objectives that include :

- Reducing costs by eliminating waste/scrap .
- Try to create work sites that can respond to changes quickly.
- Facilitate the methods of achieving and assuring quality control.
- Design work sites according to human dignity, mutual trust and support, and allowing workers to reach their maximum potential.



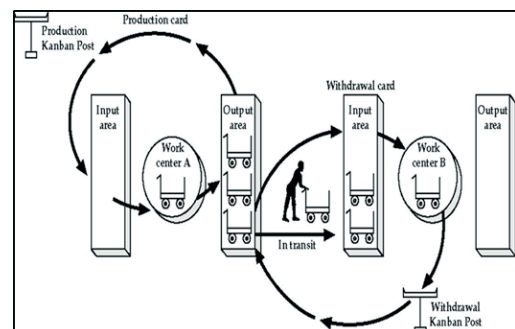
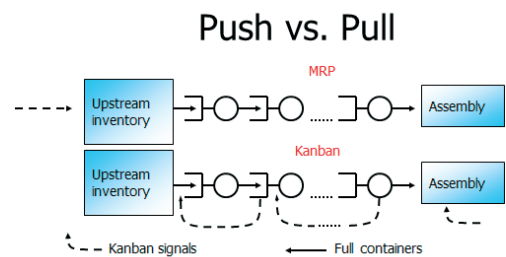
#### Why Kanban?

Dramatic changes away from high product throughput and high capacity loads towards the new idea of lower production times and work-in-progress have lead to the idea of incorporating Kan-ban Systems in manufacturing industries.

These systems are most commonly used to implement the pull-type control in production systems with aims at reducing costs by minimizing the W.I.P. inventory.

This allows an organization the ability to adapt to changes in demand, and therefore production more quickly.

A pull-type production line is a sequence of production stages performing various process steps on parts where each stage consists of several workstations in tandem. The flow of parts through the overall facility is controlled by a combined push/pull control policy, which is established by the Kan-bans.





A push-type policy is used for producing parts within each individual production stage.

However, parts are pulled between the production stages in accordance with the rate at which parts are being consumed by the downstream stages.

### 3.8.3 Types of Kan-bans

The two most common types of Kan-bans used today are:

1. Withdrawal (Conveyance) Kan-ban
2. Production Kan-ban (Make).




#### 1. Withdrawal (Conveyance) Kan-ban (Move)

The main function of a withdrawal Kan-ban is to pass the authorization for the movement of parts from one stage to another.

Once it gets the parts from the preceding process and moves them to the next process, remaining with the parts until the last part has been consumed by the next process.

The withdrawal Kanban then travels back to the preceding process to get parts thus creating the cycle. A withdrawal Kanban usually carries the following information:

- part number
- part name
- lot size
- routing process
- name of the next process
- location of the next process
- name of the preceding process
- location of the preceding process
- container type
- container capacity
- number of containers released

The withdrawal Kan-ban layout can be designed many ways in order to display this information.

#### 2. Production Kanban

The primary function of the production Kan-ban is to release an order to the preceding stage to build the lot size indicated on the card.

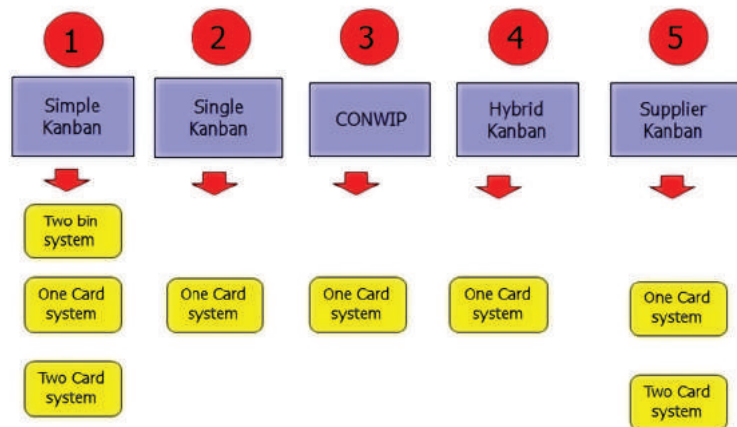
The production Kan-ban card should have the following information:

- materials required as inputs at the preceding stage
- parts required as inputs at the preceding stage
- information stated on withdrawals Kan-ban

The first two pieces of information are not required on the withdrawal Kan-ban as it's only used for communicating the authorization of movement of parts between work stations.



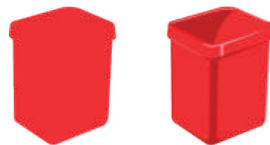
### 3. Production Kanban types



#### 1) Simple kanban

##### a) Two bin system

Two c A two-bin system is a kanban method used to simplify replenishment on a production line.



The process is simple. An operator pulls from one bin until it is empty, and then, depending on how the kanban card is attached, either turns in the kanban card (if fastened by hook and pile), or turns in the whole bin (if the card is permanently fixed).

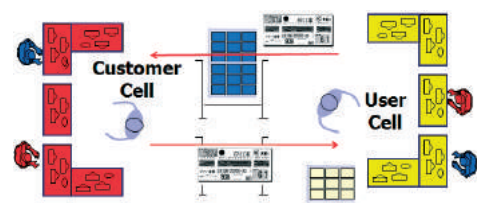
The operator then pulls from the second bin while the order is placed for materials to fill the first bin. If all goes well, the first bin is filled and replaced when there are a few items left in the second bin.

The two-bin system is generally designed with a bit of safety stock, hence those extra parts. If things don't go well, the safety stock is used while the delays are resolved. The bigger the potential for problems, the larger the safety stock.

A two-bin system is the most common form of kanban you will likely see. Parts using more than two kanbans are possible, but are generally used for local replenishment or for special situations.

##### b) One card system

- a. The production activity within the cell is controlled by the Production Kanban cards, but transportation activity from the cell is not controlled by the Withdrawal (transportation) Kanban cards.
- b. The production within the cell is controlled by the Kanban cards (there is an upper bound on the quantity in the cell).

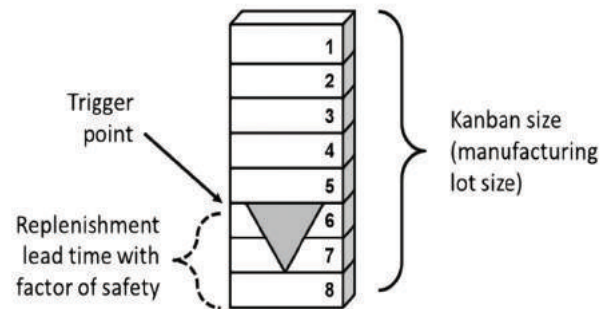


c. the transportation is not controlled by the Kanban cards there is no limit for the demand from the cell, which implies there is no upper bound back orders (unfilled demand) that can accumulate.

- Repetitive production.
- High Volume.
- Low Complexity / Constant.
- A card is transferred to the supplying cell with the quantity required.
- This card authorises Make and Move.

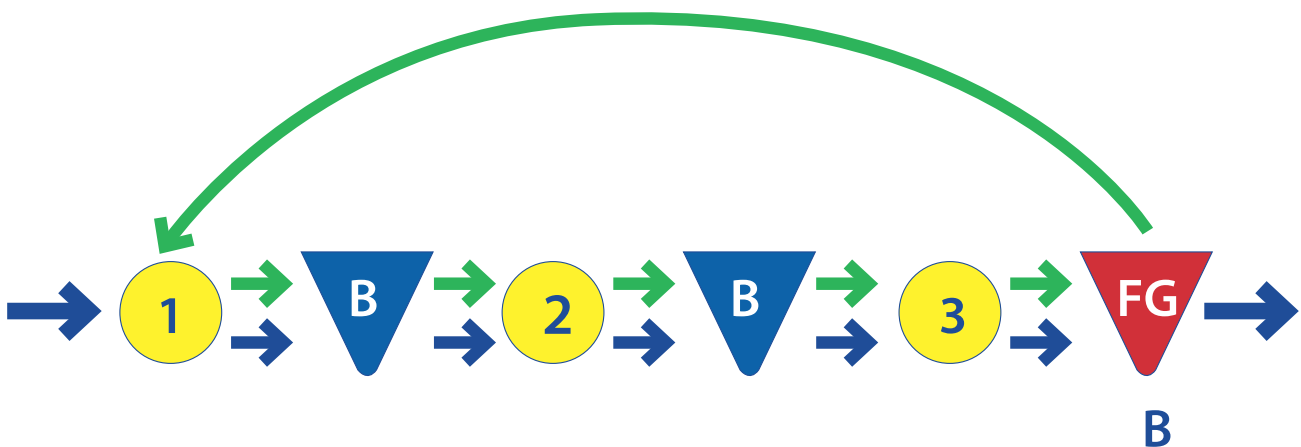
## 2) Single Kanban or Triangle kanban

The triangle Kanban is a single that alerts when the reorder point has been reached



## 3) CONWIP

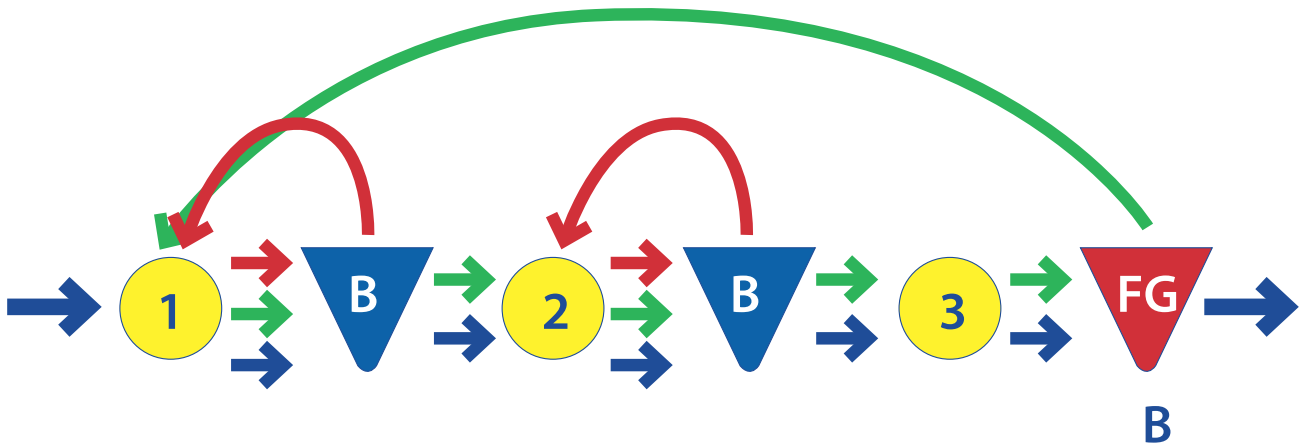
- CONWIP designates a control strategy that limits the total number of parts allowed into the system at the same time.
- Once the parts are released, they are processed as quickly as possible until they wind up in the last buffer as finished goods.
- Once the consumer removes a part from the finished goods inventory, the first machine in the chain is authorized to load another part.



- The CONWIP system only responds to actual demands that have occurred, so it is still a "pull" type system.
- But unlike kanban, the resting state of the system has all buffers empty, except finished goods, which is full. This occurs because any part released to the system will move to finished goods.
- New parts will not be released if the finished goods buffer is full.
- The inventory in finished goods is now available to serve the customer, and there is no internal inventory to collect dust.

## 4) Hybrid Kanban

If the system is very heavily utilized or there is a bottleneck in the line, the buffers towards the upstream end of a CONWIP line will have quite high levels. On the other hand, kanban control was designed to prevent individual buffer levels from exceeding designated limits.



Therefore, we construct a hybrid control policy where the CONWIP control is supplemented with secondary kanban cells. These detect problems in the line, and block release of parts to the line if they cannot be processed further. We do not need a separate kanban cell to block the last machine, since any material that has gotten this far surely will reach the finished goods buffer if the machine can do an operation. The resulting control policy acts mostly like CONWIP, but at decreased inventories when trouble occurs

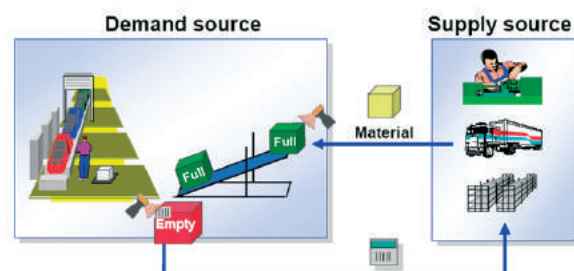
### 5) Supplier Kanban

When extending Kanban to suppliers, you need to assess their ability to re-supply your process.

#### This assessment should include:

- a. shipment intervals
- b. delivery time
- c. quality issues
- d. reliability issues
- e. demand fluctuation

#### KANBAN



#### kanban signals



#### Kan-ban Preconditions

Kan-ban is essentially a tool that can be used to manage a work place effectively.

As a result of its importance in the work place, six rules (or preconditions) have been developed to govern the operation of a kan-ban system They are as follows:

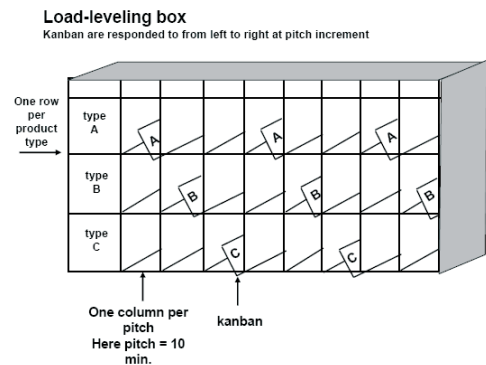
1. No withdrawal of parts without a kan-ban
2. The subsequent process comes to withdraw only what is needed
3. Do not send the defective part to the subsequent process
4. The preceding process should produce only the exact quantity of parts withdrawn by the subsequent process (ensures minimum inventory)
5. Smoothing of production
6. Fine tuning of production using kan-ban

### 3.8.4 Hijunka Box

A typical heijunka box has horizontal rows for each member of a product family, in this case five.

- It has vertical columns for identical time intervals of production, in this case 20 minutes.
- Production control kanban are placed in the slots created, in proportion to the number of items to be built of a given product type during a time interval.

In this example, the shift starts at 7 a.m. and kanban are withdrawn by a material handler every 20 min. for distribution to the pacemaker point along the value



stream. (In a lean production system of this type, there is only one pacemaker point along the value stream where production instructions are introduced. From that point back up the stream, parts are replenished at each break in continuous flow by means of simple pull loops from upstream parts supermarkets.) In the first 20 min., the value stream will produce one kanban of Type A, two kanban of Type B, one kanban of Type C and one kanban of type D.

- Whereas the slots represent the timing of material and information flow, the kanban in the slots each represent one pitch of production for one product type. (Pitch is takt time multiplied by packout quantity. This concept is important because it represents the minimum amount of material that can be moved from one operation to the next, and the number of items called for by a kanban resized to this amount.)
- In the case of Product A, the pitch is 20 min., and there is one kanban in the slot for each time interval. However, the pitch for Product B is 10 min., so there are two kanban in each slot.
- Product C has a pitch of 40 min., so there are kanban in every other slot. Products D and E share a production process with a pitch of 20 min. and a ratio of demand for Product D versus Product E of 2:1. Therefore, there is a kanban for Product D in the first two intervals of the shift, and a kanban for Product E in the third interval, and so on in the same sequence.
- Used as illustrated, the heijunka box consistently levels demand by short time increments, 20 min. in this case. This is in contrast to the mass-production practice of releasing a shift's, or a day's or a week's worth of work to the production floor. Similarly, the heijunka box consistently levels demand by mix. For example, it ensures that Product D and Product E are produced in a steady ratio in small batch sizes.
- Production process stability introduced by leveling makes it vastly easier to introduce lean techniques ranging from

standard work to continuous flow cells. As the mura (unevenness in productivity and quality) and muri (overburden of machines, managers and production associates) introduced by traditional production control recede, muda (waste) declines as well.

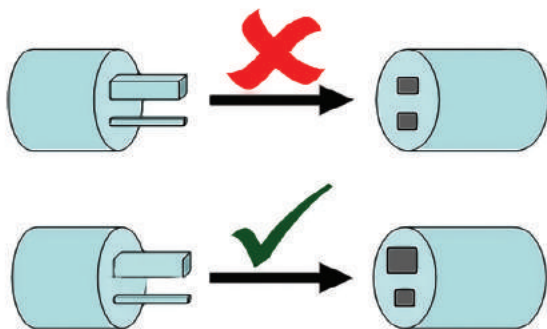
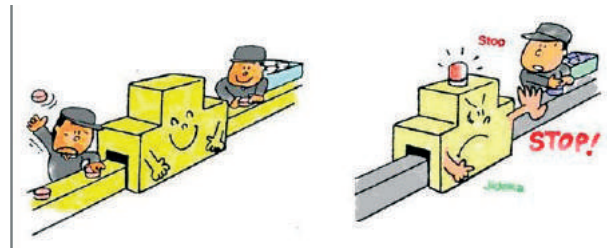
- When every process is leveled by volume and mix, it is a different world for employees -- who are no longer overburdened; for customers -- who get better products on the date promised; and for manufacturers -- who get to keep the money saved when muda, mura and muri are all reduced.

### 3.9 Poka Yoke

#### 1- Poka Yoke (Error Proofing) prevents defects

Poka Yoke – Simple methods for in-line quality testing (not just visual inspection), sometimes referred to as “Poka Yoke”, are implemented so that defective materials do not get passed through the production process.

The Machines shutdowns – When defects are generated, production is shut down until the source of the defect can be solved. This helps ensure a culture of zero tolerance for defects and also prevents defective items from working their way downstream and causing bigger problems downstream. For example, at Toyota any worker can shut down the production line. This also helps ensure accountability by upstream workers.



### 3.10 Lean Manufacturing Facilities

#### The Lean Facility

Layout is an integral part of a Lean Manufacturing Strategy. Meaningful re-structuring requires corresponding physical changes in the layout.

Conversely, a layout re-design can be the catalyst for re-structuring. A layout project, properly done, can demonstrate the need for change to an organization reluctant to tear itself apart and rebuild.

- Product-Focused work cells

- Focused Plant-Within-Plant Factories
- Reduced Storage & Handling Space
- Kanban Stock points
- Direct Delivery of Raw Materials
- Integrated Support Areas

## Facilities In Lean Manufacturing Strategy

Lean Manufacturing is all about adding value and avoiding waste. Facility planning (land, buildings, equipment, furnishings) provides the physical capability to add value.

Facilities are expensive. Their lifetime is in decades. They take years to commission. By their nature, they are one of the most important strategic elements of a business enterprise. This is why facility design and the strategic thinking that should precede it are so important.

Many symptoms of inappropriate business architecture appear as layout or material handling issues.

A properly designed plant layout is an important source of competitive advantage. It can:

- Operate At Low Cost
- Provide Fast Delivery
- Accommodate Frequent New Products
- Produce Many Varied Products
- Produce High or Low Volume Products
- Produce At The Highest Quality Level
- Provide Unique Services Or Features

## Requirements for effective layout to meet competitive priorities

- Reduce operating costs.
- Minimize Material handling costs.
- Utilize Space efficiently.
- Utilize Labor efficiently.
- Eliminate Bottlenecks .
- Facilitate Communication and interaction between workers, between workers and their supervisors, or between workers and customers .
- Reduce manufacturing Cycle Time and customer service time .
- Eliminate wasted or Redundant Movement .
- Facilitate the Entry, Exit, and Placement of Material, Products, and People .
- Incorporate Safety and Security measures .
- Promote product and service Quality .
- Encourage proper Maintenance activities .
- Provide a visual Control of Operations or activities .
- Provide Flexibility to adapt to changing conditions .



## Level of layout



Site

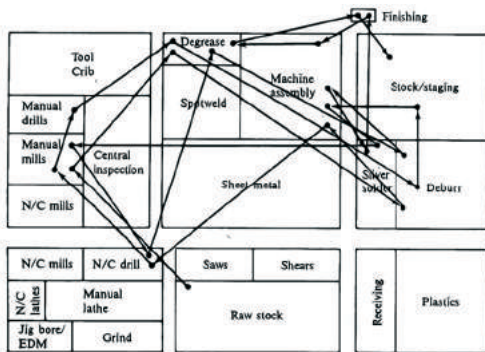


Macro

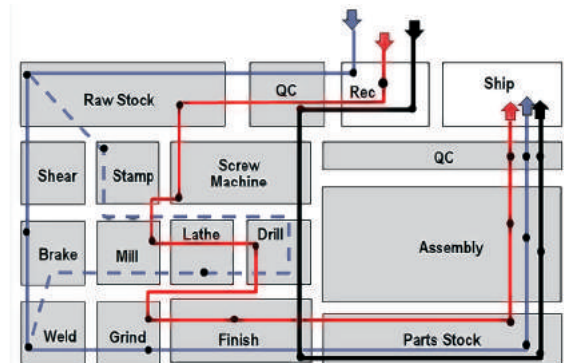


Micro  
(work station)

### Traditional Layout



### Plant Layout for Flow



## Layout Design Steps

1. Understand volume-variety characteristics of the operation
2. Define the process type
  - a. This is influenced by the volume-variety characteristics of the operation. Process types, e.g.
  - b. Jobbing process
  - c. Batch process
  - d. Mass production process
  - e. Continuous process

- f. Select basic layout. This is the general type of arrangement of the facilities or plant of the factory, e.g
- g. Fixed position layout
- h. Process layout
- i. Cell layout
- j. Product layout
- k. Mixed layout

The final stage is to design the layout based on above considerations. This entails the detailed location of machines. However the following need to be considered:

- a. Cycle time
- b. Task-time variation considerations
- c. Balancing line
- d. Arrangement of stages
- e. Safety.
- f. Accessibility

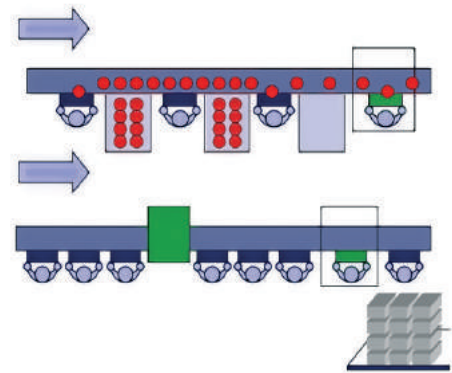
## Types of layouts

### A- Basic layouts:

1. Process Layouts (Functional Layouts/ Flexible-Flow Layouts)
2. Product Layouts (Assembly Lines/ Line-flow Layouts)
3. Fixed-Position Layouts

#### 1-Product Layout

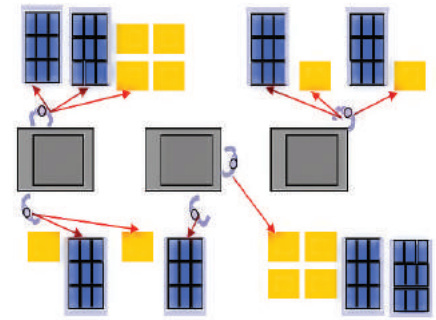
- Product layout consist of Series of standardized tasks, permitting specialization of equipment and division of labor .
- Standardized processing operations to achieve smooth, rapid, high-volume flow .&repetitive processing
- Product layouts are suitable for mass production or repetitive operations.
- Material moved in one direction .
- Using conveyors-conveyors can be automatic (at a steady speed).
- Aisles are narrow because material is moved only one way, it is not moved very far
- Storage space along an assembly line is quite small.
- Finished good inventory may require a separate warehouse for storage before they are sold



### Advantages of Product Layout

- Faster processing rates (High volume)
- Lower inventories
- Less unproductive time lost to changeovers and materials handling
- Low unit cost
- Low labor skill needed

- Low material handling cost
- High utilization of labor and equipment
- Simple routing and scheduling
- Routine accounting, purchasing and inventory control
- High efficiency and utilization
- Simple to track and control



### Disadvantages of Product Layout

- Lacks flexibility to changes in Volume, design and mix .
- Highly susceptible to shutdowns: Can not accommodate partial shut downs/breakdowns .
- Boring for labor: Creates dull, repetitive jobs .
- Poorly skilled workers may not maintain equipment or quality of output .
- Needs preventive maintenance .
- Low motivation .

### Product Layouts Designing Considerations

- Line balancing.
- attempt to equalize the amount of work at each work station and cuts down on idle time for the workers .
- Pacing
- The movement of product from one station to the next as soon as the cycle time has elapsed.
- Behavioural factors of workers.
- Number of models produced.
- A mixed-model line produces several items belonging to the same family.
- Cycle times.
- Depend on the desired output rate, and efficiency varies considerably with the cycle time selected.

### 2-Process Layout

Named also with ,

- Process layout.
- Fixed Position Layout.
- Function Layout

### Characteristics

- A layout that organizes resources (employees) and equipment by function rather than by service or product .
- It is a layout that groups similar activities together in departments of work centers according to the process or function that they perform.
- The operations of each work center could serve different customers different needs
- The equipment in a process layout is general purpose
- Workers are skilled at operating the equipment in their department
- Process layouts in manufacturing firms require flexible material handling equipment (such as forklifts) that can follow multiple paths, move in any direction, and carry large loads of in-process goods
- All areas of the facility must have timely access to the material handling equipment

## Advantages of Process Layout

- Flexibility
- General purpose.
- Flexible resources are less capital intensive
- Less vulnerable to changes in product mix or new market strategies
- Equipment utilization can be higher.
- Employee supervision can be more specialized
- Finished goods inventory is low because goods are being made for particular customers

## Disadvantages of Process Layout

- Slower processing rates and Longer manufacturing lead times
  - Jobs or customers do not flow through in an orderly fashion; backtracking is common
  - Lost production time during setups
  - Plus the workers may experience much "idle time" if they are waiting for more work to arrive from a different department
- Material storage space in a process layout must be large to accommodate the large amount of in-process inventory
- This inventory is high because material moves from work-center to work-center waiting to be processed, therefore More capital and more floor space tied up with inventory
- Costly materials handling, requiring variable path devices
- Production planning and control more difficult

## Designing Process Layouts

One main objective of the process layout is to minimize material handling costs. The main issue in design of process layouts concerns the relative positioning of the departments involved.

Departments must be assigned to locations.

This implies that departments that incur the most interdepartmental movement should be located closest to one another. The problem is to develop a reasonably good layout; some combinations will be more desirable than others.

### 3-Fixed Position project layout

Fixed-position layout is appropriate for a product that is too large or too heavy to move.

#### Disadvantages include

- Space. For many fixed-position layouts, the work area may be crowded so that little storage space is available. This also can cause material handling problems.
- Administration. Oftentimes, the administrative burden is higher for fixed-position layouts. The span of control can be narrow, and coordination difficult.



### 4- Mixed Model layout

Mixed model layout designed for producing different product type in same production line

Factors to consider in designing a mixed-model assembly line

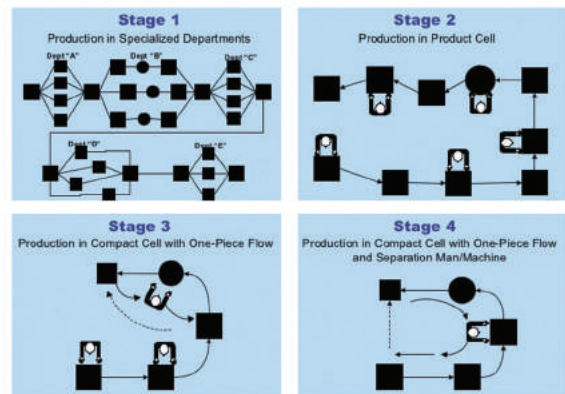
1. 1. Line Balancing
  2. 2. U-shaped lines
  3. 3. Flexible workforce
  4. 4. Model sequencing
- **U-shaped lines**
    - To compensate for the different work requirements of assembling different models, it is necessary to have a flexible workforce and to arrange the line so that workers can assist one another as needed .
    - Efficiency of the assembly line can be improved with a u-shaped line
  - **Flexible workforce**
    - Although worker paths are predetermined to fit within a set cycle time, the use of average time values in mixed-model lines will produce variations in worker performance. Hence, the lines are not run at a set speed. Items move through the line at the pace of the slowest operation.
  - **Model Sequencing**
    - Since different models are produced on the same line, mixed-model scheduling involves an additional decision- the order, or sequence, of models to be run through the line
    - Another objective in model sequencing is to spread out the production of different models as evenly as possible throughout the time period scheduled

## B-Hybrid layouts

1. Cellular Layouts
2. Hybrid Layouts (Combination)

### 1. Cellular Layouts

Cellular manufacturing is a type of layout where machines are grouped according to the process requirements for a set of similar items (part families) that require similar processing. These groups are called cells. Therefore, a cellular layout is an equipment layout configured to support cellular manufacturing.



### Advantages of cellular layout

- Reduced material handling and transit time .
- Cost. Cellular manufacturing provides for faster processing time, less material handling, less work-in-process inventory, and reduced setup time, all of which reduce costs
- Reduced setup time
- Reduced work-in-process inventory
- Better use of human resources:
  - Self-managed team, in most cases more satisfied with the work that they do
  - Flexible resource. Workers in each cell are multifunctional and can be assigned to different routes within a cell or between cells as demand volume changes.



- Easier to control .
- Easier to automate .

### Disadvantages of a cellular layout

- Poorly balanced cells
- It is more difficult to balance the flow of work through a cell than a single-product assembly line, because items may follow different sequences through the cell that require different machines or processing times.
- Expanded training and scheduling of workers .
- Training workers to do different tasks is expensive and time-consuming and requires the workers' consent.
- Increased capital investment
  - Existing equipment may be too large to fit into cells or may be underutilized when placed in a single cell.
  - Additional machines of the same type may have to be purchased for different cells.
- The cost and downtime required to move machines can also be high.

## 2. Combination Layout

Many situations call for a mixture of the three main layout types. These mixtures are commonly called combination or hybrid layouts. For example, one firm may utilize a process layout for the majority of its process along with an assembly in one area. Alternatively, a firm may utilize a fixed-position layout for the assembly of its final product, but use assembly lines to produce the components and subassemblies that make up the final product (e.g., aircraft).

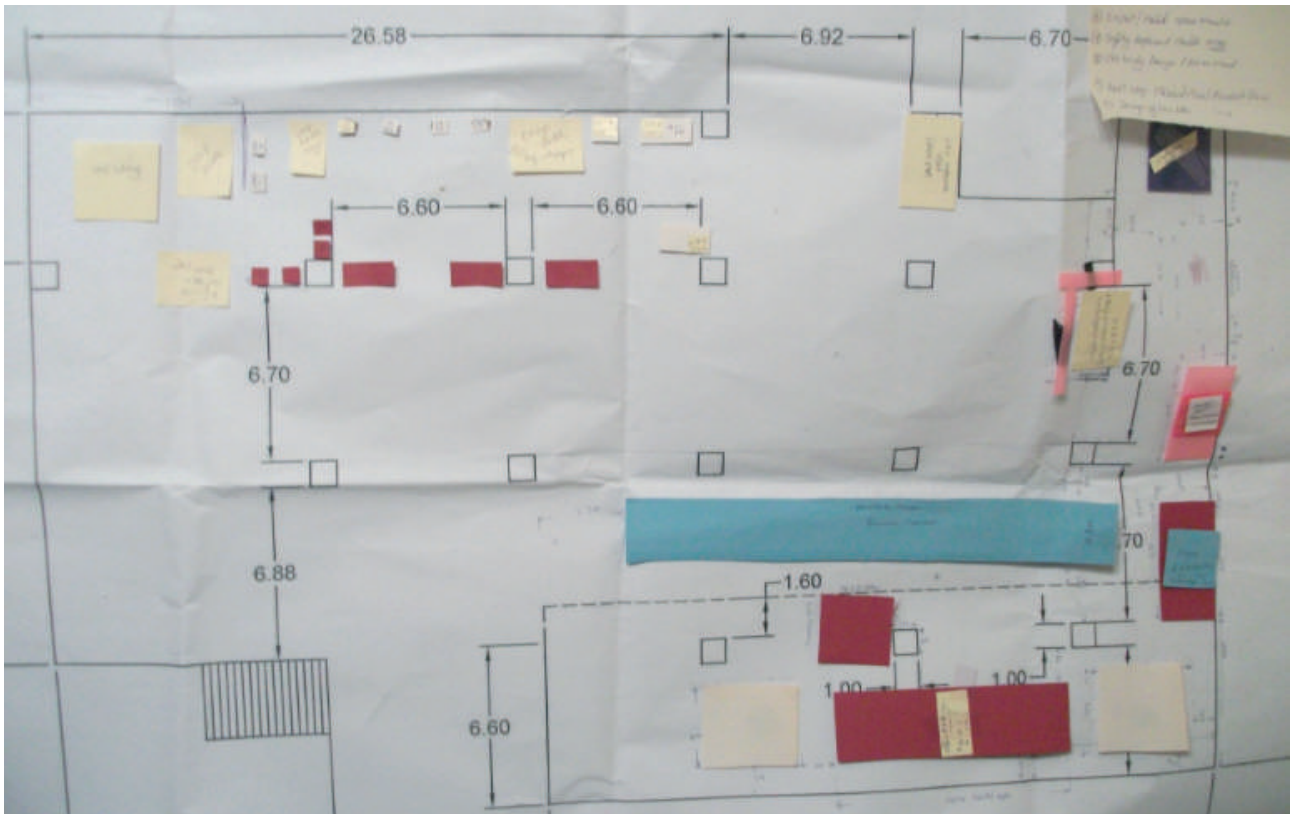
### In need of Kaizen –re-layout



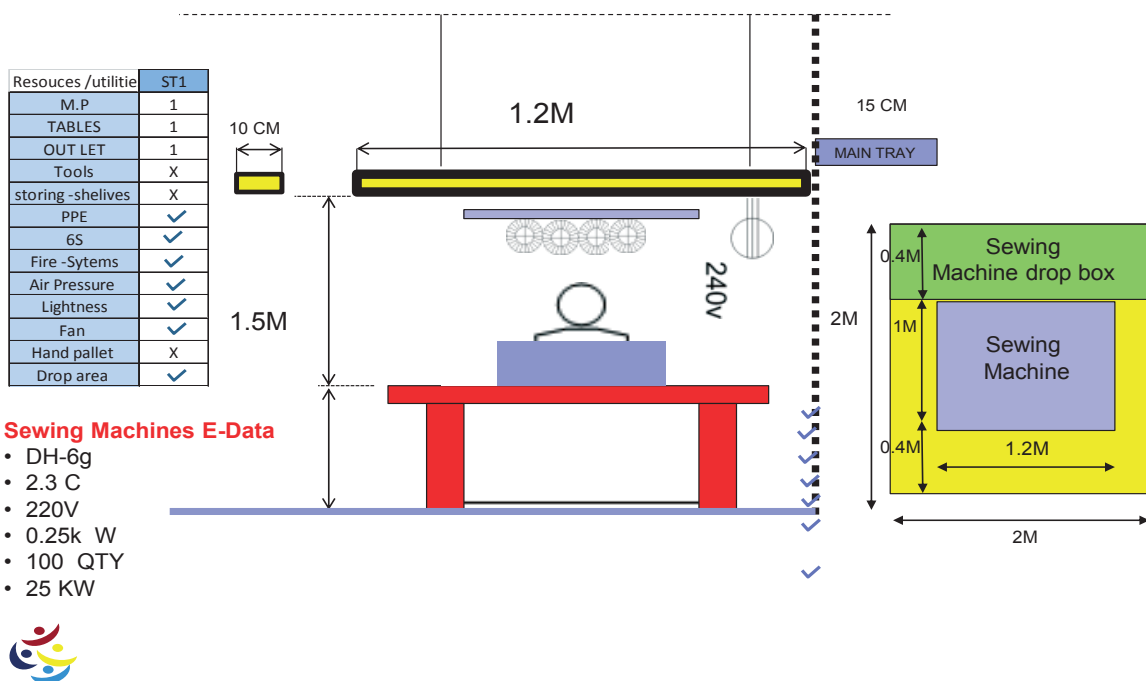




Factory Layout Kaizen Project



## 1.4 CeLL - Design Resources /utilities



### 3.11 Continuous Quality Improvement Tools

#### Introduction

Organizations around the world are using continuous quality improvement (CQI) as their strategy to bring about dramatic changes in their operations. Their purpose is to stay competitive in a world of instant communication and technological advancement.

These organizations need to meet or exceed customer expectations while maintaining a cost-competitive position. Continuous quality improvement (CQI), a systematic, organization-wide approach for continually improving all processes that deliver quality products and services, is the strategy many organizations are adopting to meet today's challenges and to prepare for those down the road.

#### In pursuing CQI, stick to these four basic principles:

##### 1) Develop a Strong Customer Focus

Total customer focus includes the needs of both external and internal customers. External customers are the end users; internal customers are your coworkers and other departments in the organization.

##### 2) Continually Improve All Processes

- Identify them. A process is a sequence of repeatable steps that lead to some desired end or output: a typed

document, a printed circuit board, a “home-cooked” meal, arrival at work, and so on.

- Improve them. Use the Plan, Do, Check, Act (PDCA) Cycle: PLAN what you want to accomplish over a period of time and what you might do, or need to do to get there. DO what you planned on doing. Start on a small scale! CHECK the results of what you did to see if the objective was achieved. ACT on the information. If you were successful, standardize the plan, otherwise continue in the cycle to plan for further improvement.

### 3) Involve Employees

Encourage teams—train them—support them— use their work—celebrate their accomplishments!

### 4) Mobilize Both Data and Team Knowledge to Improve Decision Making

- Use the tools to get the most out of your data and the knowledge of your team members.
- Graphically display number and word data; team members can easily uncover patterns within the data, and immediately focus on the most important targets for improvement.
- Develop team consensus on the root cause(s) of a problem and on the plan for improvement.
- Provide a safe and efficient outlet for ideas at all levels. Use this book and the tools in it to focus on, improve, involve employees in, and direct your path toward continuous quality improvement.

## 3.11.1 Brainstorming (Creating bigger & better ideas)

### Why use it?

To establish a common method for a team to creatively and efficiently generate a high volume of ideas on any topic by creating a process that is free of criticism and judgment.

### What does it do?

- Encourages open thinking when a team is stuck in “same old way” thinking
- Gets all team members involved and enthusiastic so that a few people don’t dominate the whole group
- Allows team members to build on each other’s creativity while staying focused on their joint mission

### How do I do it?

There are two major methods for brainstorming.

- Structured. A process in which each team member gives ideas in turn.
- Unstructured. A process in which team members give ideas as they come to mind.

Either method can be done silently or aloud.

#### A. Structured

1. the central brainstorming question is stated, agreed on, and written down for everyone to see
2. Be sure that everyone understands the question, issue, or problem. Check this by asking one or two members to paraphrase it before recording it on a flipchart or board.
3. Each team member, in turn, gives an idea. No idea is criticized. Ever!
4. With each rotation around the team, any member can pass at any time. While this rotation process encourages full participation, it may also heighten anxiety for inexperienced or shy team members.

5. As ideas are generated, write each one in large, visible letters on a flipchart or other writing surface
6. Make sure every idea is recorded with the same words of the speaker, don't interpret or abbreviate. To ensure this, the person writing should always ask the speaker if the idea has been worded accurately.
7. Ideas are generated in turn until each person passes, indicating that the ideas (or members) are exhausted
8. Keep the processes moving and relatively short— 5 to 20 minutes works well, depending on how complex the topic is.
9. Review the written list of ideas for clarity and to discard any duplicates
10. Discard only ideas that are virtually identical. It is often important to preserve subtle differences that are revealed in slightly different wordings.

## B. Unstructured

The process is the same as in the structured method except that ideas are given by everyone at any time. There is no need to "pass" since ideas are not solicited in rotation.

### Team Activity:

Perform a Brainstorming session on you company performance problems and list down the major problems:

Major company performance problems	
1	
2	
3	
4	
5	
6	
7	
8	

## 3.11.2 Cause & Effect / Fishbone Diagram

(Find & cure causes, NOT symptoms )

### Why use it?

To allow a team to identify, explore, and graphically display, in increasing detail, all of the possible causes related to a problem or condition to discover its root cause(s).

## What does it do?

- Enables a team to focus on the content of the problem, not on the history of the problem or differing personal interests of team members
- Creates a snapshot of the collective knowledge and consensus of a team around a problem. This builds support for the resulting solutions
- Focuses the team on causes, not symptoms

## How do I do it?

### 1) Select the most appropriate cause & effect format. There are two major formats:

- Dispersion Analysis Type is constructed by placing individual causes within each “major” cause category and then asking of each individual cause “Why does this cause (dispersion) happen?” This question is repeated for the next level of detail until the team runs out of causes. The graphic examples shown in Step 3 of this tool section are based on this format.
- Process Classification Type uses the major steps of the process in place of the major cause categories. The root cause questioning process is the same as the Dispersion Analysis Type.

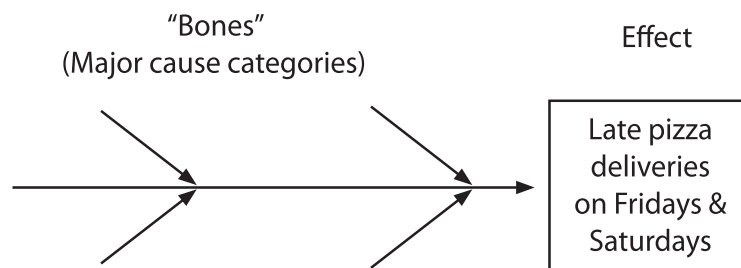
### 2) Generate the causes needed to build a Cause & Effect Diagram.

Choose one method:

- Brainstorming without previous preparation
- Check Sheets based on data collected by team members before the meeting

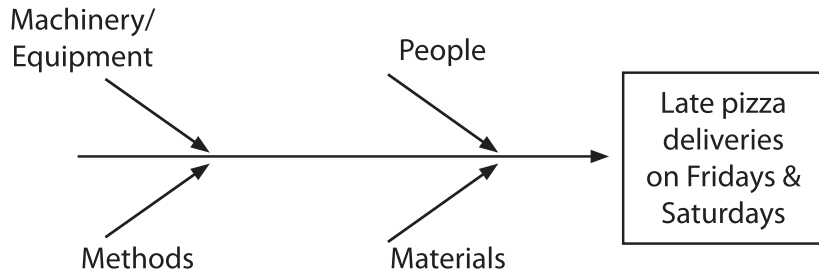
### 3) Construct the Cause & Effect/Fishbone Diagram

- Place the Effect in a box on the right hand side of the writing surface.
- Make sure everyone agrees on the problem statement. Include as much information as possible on the “what,” “where,” “when,” and “how much” of the problem. Use data to specify the problem.
- Draw major cause categories or steps in the production or service process. Connect them to the “backbone” of the fishbone chart.

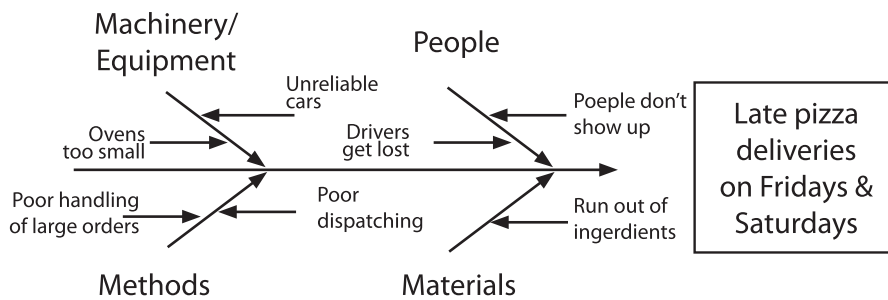


- In a Production Process the traditional categories are:
  - o Machines (equipment),
  - o Methods (how work is done),
  - o Materials (components or raw materials)
  - o Measurement.
  - Man (the human element).
  - Environment (buildings, logistics, and space),

- In a Service Process the traditional methods are:
  - Policies (higher-level decision rules),
  - Procedures (steps in a task),
  - Plant (equipment and space), and People.
  - Environment (buildings, logistics, and space),
  - Measurement (calibration and data collection) are also frequently used.
- There is no perfect set or number of categories. Make them fit the problem.

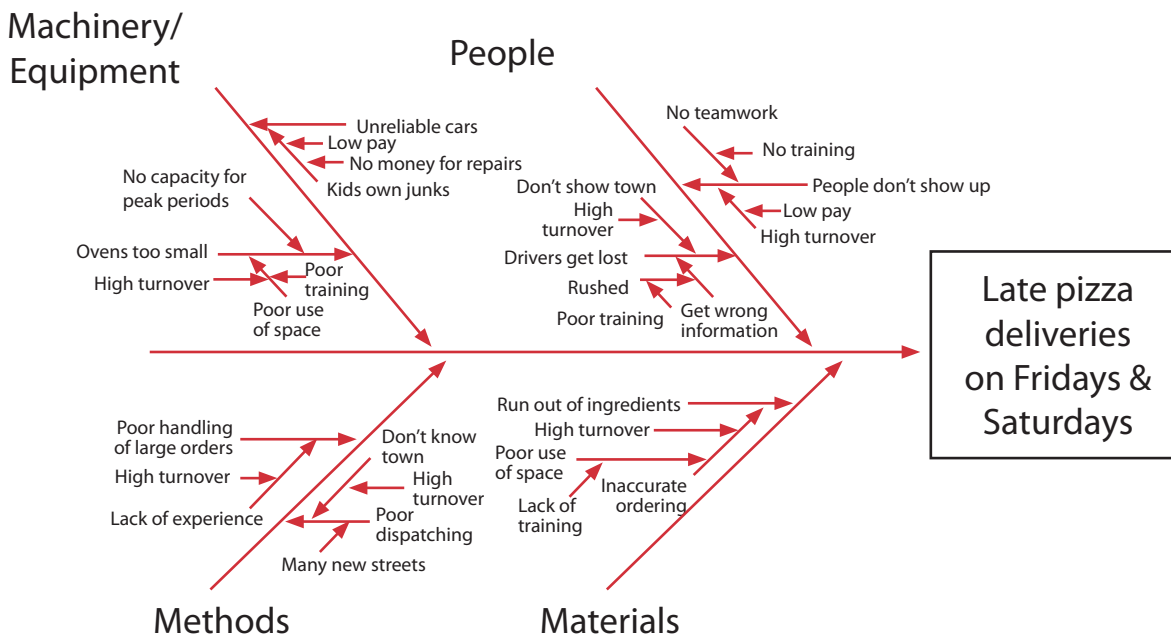


4) Place the brainstormed or data-based causes in the appropriate category



5) Ask repeatedly of each cause listed on the "bones," either:

- "Why does it happen?" For example, under "Run out of ingredients" this question would lead to
- "What could happen?" For example, under "Run out of ingredients" this question would lead to a deeper understanding of the problem such as "Boxes," "Prepared dough," "Toppings," and so on.



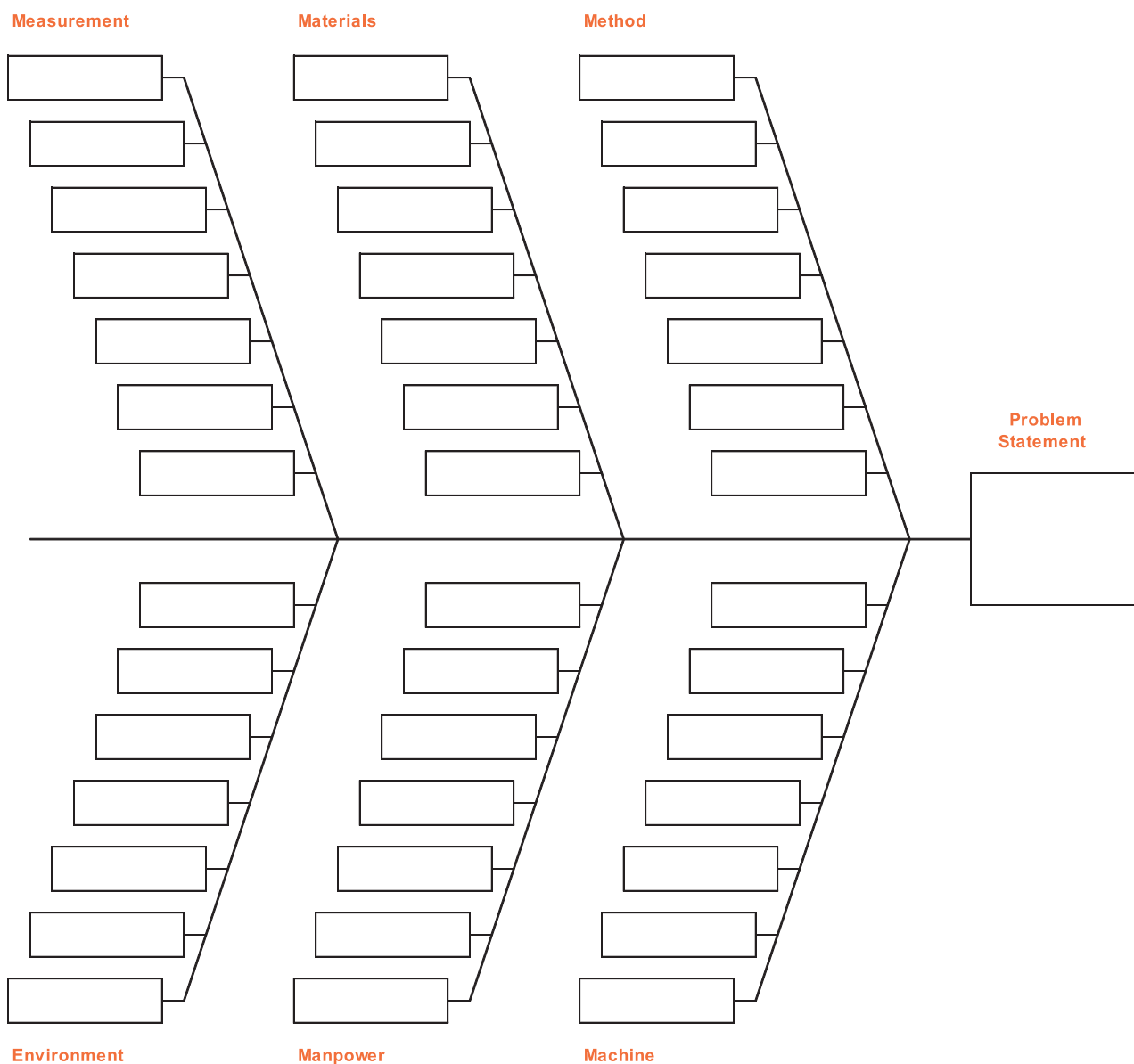


6) Interpret or test for root cause(s) by one or more of the following:

- Look for causes that appear repeatedly within or across major cause categories.
- Select through either an unstructured consensus process or one that is structured, such as Nominal Group Technique or Motivating.
- Gather data through Check Sheets or other formats to determine the relative frequencies of the different causes.

Exercise: Team Activity:

From the previous brainstorming team activity, do another brainstorming using the following fish bone diagram:



### 3.11.3 Flowchart (Picturing the process )

#### Why use it?

To allow a team to identify the actual flow or sequence of events in a process that any product or service follows.

#### What does it do?

Shows unexpected complexity, problem areas, redundancy, unnecessary loops, and where simplification and standardization may be possible

- Compares and contrasts the actual versus the ideal flow of a process to identify improvement opportunities
- Allows a team to come to agreement on the steps of the process and to examine which activities may impact the process performance
- Identifies locations where additional data can be collected and investigated
- Serves as a training aid to understand the complete process

#### How do I do it?

##### 1) Determine the frame or boundaries of the process

- Clearly define where the process starts and ends.
- Team members should agree to the level of detail they must show on the Flowchart to clearly understand the process and identify problem areas.
- The Flowchart can be a simple macro-flowchart showing only sufficient information to understand the general process flow or it might be detailed to show every finite action and decision point. The team might start out with a macro-flowchart and then add in detail later or only where it is needed.




##### 2) Determine the steps in the process



- Brainstorm a list of all major activities, inputs, outputs, and decisions on a flipchart sheet from the beginning of the process to the end.

##### 3) Sequence the steps

- Arrange the steps in the order they are carried out. Use Post-it™ notes so you can move them around. Don't draw in the arrows yet.

##### 4) Draw the Flowchart using the appropriate symbols

	<p>An oval is used to show the materials, information or action (inputs) to start the process or to show the results at the end (output) of the process</p>
	<p>A box or rectangle is used to show a task or activity performed in the process. Although multiple arrows may come into each box, usually only one output or arrow leaves each activity box.</p>
	<p>A diamond shows those points in the process where a yes/no question is being asked or a decision is required.</p>

	A circle with either a letter or a number identifies a break in the Flowchart and is continued elsewhere on the same page or another page.
	Arrows show the direction or flow of the process.

- Be consistent in the level of detail shown.
- A macro-level flowchart will show key action steps but no decision boxes.
- An intermediate-level flowchart will show action and decision points.
- A micro-level flowchart will show minute detail.
- Label each process step using words that are understandable to everyone.

**5) Add arrows to show the direction of the flow of steps in the process** Although not a rule, if you show all “yes” choices branching down and “no” choices branching to the left, it is easier to follow the process. Preferences and space will later dictated direction.

**6) Title your process flowchart & Add the date the diagram** was made, and the names of the team members.

### 7) Test the Flowchart for completeness

- Are the symbols used correctly?
- Are the process steps (inputs, outputs, actions, decisions, waits/delays) identified clearly?
- Make sure every feedback loop is closed, i.e., every path takes you either back to or ahead to another step.
- Check that every continuation point has a corresponding point elsewhere in the Flowchart or on another page of the Flowchart.
- There is usually only one output arrow out of an activity box. If there is more than one arrow, you may need a decision diamond.
- Validate the Flowchart with people who are not on the team and who carry out the process actions. Highlight additions or deletions they recommend. Bring these back to the team to discuss and incorporate into the final Flowchart.

### 8) Finalize the Flowchart (analyze it)

- Is this process being run the way it should be?
- Are people following the process as charted?
- Are there obvious complexities or redundancies that can be reduced or eliminated?
- How different is the current process from an ideal one? Draw an ideal Flowchart. Compare the two (current versus ideal) to identify discrepancies and opportunities for improvements.

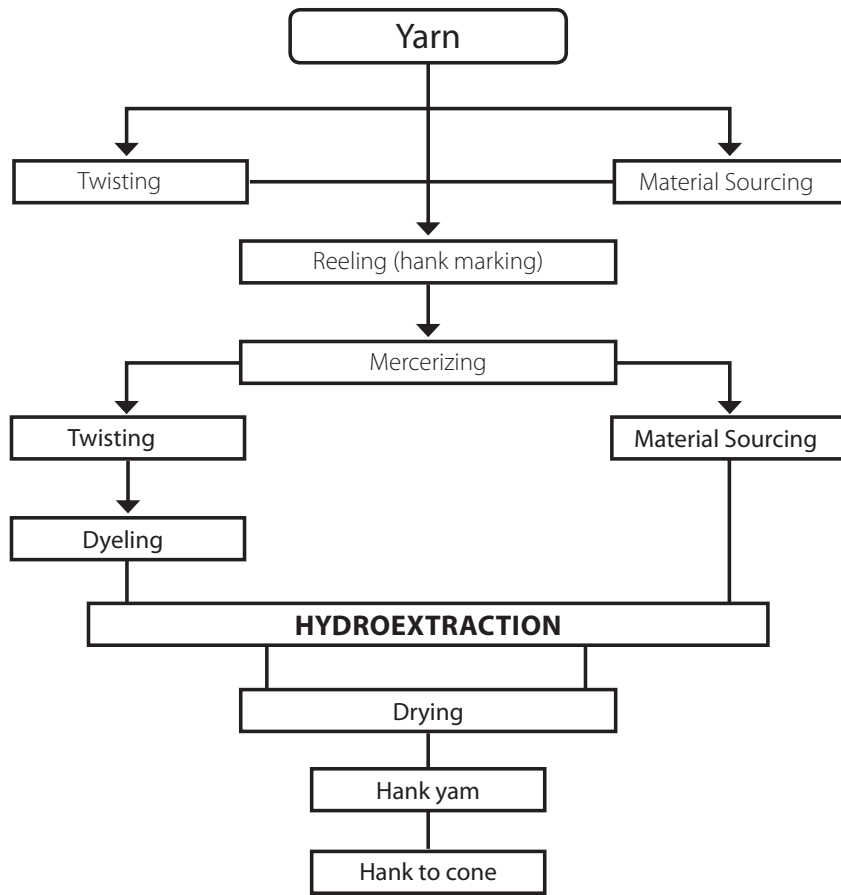
## Types of Flowcharts:

### 1. Detailed Flowchart

- The type of Flowchart just described is sometimes referred to as a “detailed”

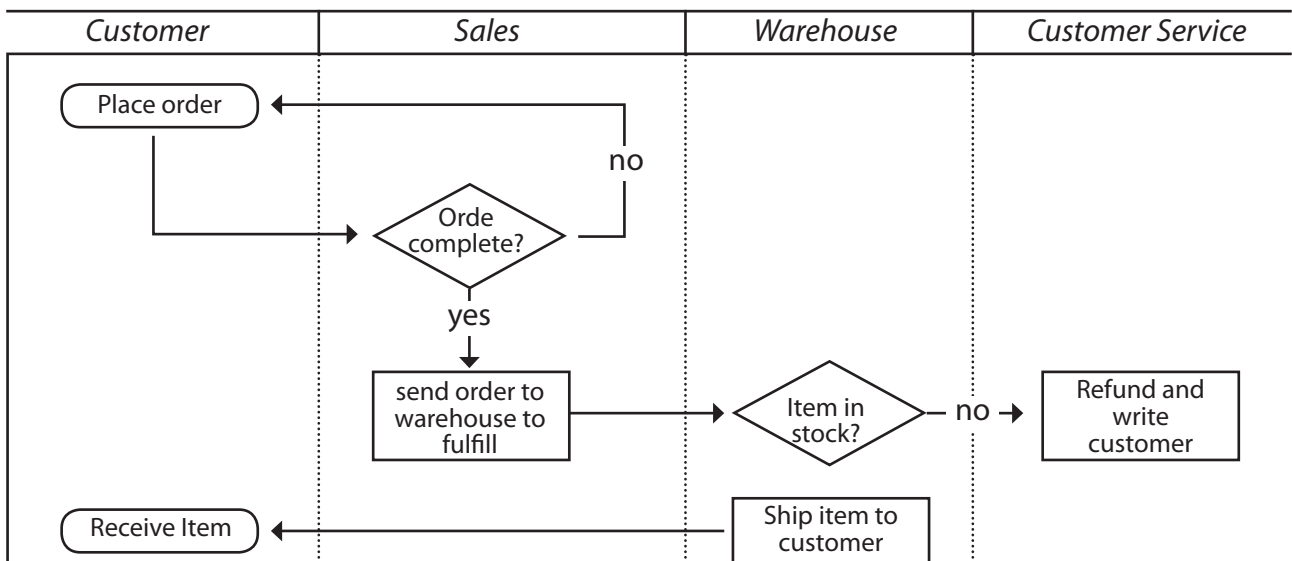
### 2. Macro Flowchart

Refer to the third bulleted item in Step 1 of this section for a description. For a graphic example, see Step 2 of the Improvement Storyboard in the Problem-Solving/ Process Improvement Model section.



### 3. Deployment Flowchart

This chart shows the people or departments responsible and the flow of the process steps or tasks they are assigned. It is useful to clarify roles and track accountability as well as to indicate dependencies in the sequence of events.



**Exercise: Team Activity:**

Select one of your process and draw the process steps in

1. High level process mapping
2. Detailed process mapping
3. Deployment process mapping

### 3.11.4 Histogram (Process centering, spread, and shape)

#### Why use it?

To summarize data from a process that has been collected over a period of time, and graphically presents its frequency distribution in bar form.

#### What does it do?

- Displays large amounts of data that are difficult to interpret in tabular form
- Shows the relative frequency of occurrence of the various data values
- Reveals the centering, variation, and shape of the data
- Illustrates quickly the underlying distribution of the data
- Provides useful information for predicting future performance of the process
- Helps to indicate if there has been a change in the process
- Helps answer the question "Is the process capable of meeting my customer requirements?"

#### How do I do it?

##### 1) Decide on the process measure

- The data should be variable data, i.e., measured on a continuous scale.  
For example: temperature, time, dimensions, weight, speed.

##### 2) Gather data

- Collect at least 50 to 100 data points if you plan on looking for patterns and calculating the distribution's centering (mean), spread (variation), and shape. You might also consider collecting data for a specified period of time: hour, shift, day, week, etc.
- Use historical data to find patterns or to use as a baseline measure of past performance.

##### 3) Prepare a frequency table from the data

- a. Count the number of data points,  $n$ , in the sample.
- b. In this example, there are 125 data points,  $n = 125$ .
- c. Determine the range,  $R$ , for the entire sample. The range is the smallest value in the set of data subtracted from the largest value. For our example:  
 $R = X_{\max} - X_{\min} = 10.7 - 9.0 = 1.7$

##### 4) Determine the number of class intervals, $k$ , needed

- Method 1: Take the square root of the total number of data points and round to the nearest whole number.  
 $k = \sqrt{125} = 11.18 = 11$  intervals
- Method 2: Use the table below to provide a guideline for dividing your sample into a reasonable

- For our example, 125 data points would be divided into 7–12 class intervals.
- These two methods are general rules of thumb for determining class intervals. In both methods, consider using  $k = 10$  class intervals for ease of “mental” calculation.
- The number of intervals can influence the pattern of the sample. Too few intervals will produce a tight, high pattern. Too many intervals will produce a spread out, flat pattern.

### 5) Determine the class width, H

- The formula for this is:  
 $H = R/k = 1.7/10 = .17$

Number of Data Points	Number of Classes (k)
Under 50	5 – 7
50 – 100	6 – 10
100 – 250	7 – 12
Over 250	10 – 20

- Round your number to the nearest value with the same decimal numbers as the original sample. In our example, we would round up to .20. It is useful to have intervals defined to one more decimal place than the data collected.

### 6) Determine the class boundaries, or end points

- Use the smallest individual measurement in the sample, or round to the next appropriate lowest round number. This will be the lower end point for the first class interval. In our example this would be 9.0.
- Add the class width, H, to the lower end point. This will be the lower end point for the next class interval. For our example:  
 $9.0 + H = 9.0 + .20 = 9.20$
- Thus, the first class interval would be 9.00 and everything up to, but not including 9.20, that is, 9.00 through 9.19. The second class interval would begin at 9.20 and be everything up to, but not including 9.40.
- Each class interval must be mutually exclusive, that is, every data point will fit into one, and only one class interval.
- Consecutively add the class width to the lowest class boundary until the k class intervals and/or the range of all the numbers are obtained.

### 7) Construct the frequency table based on the values you computed in item “e.”

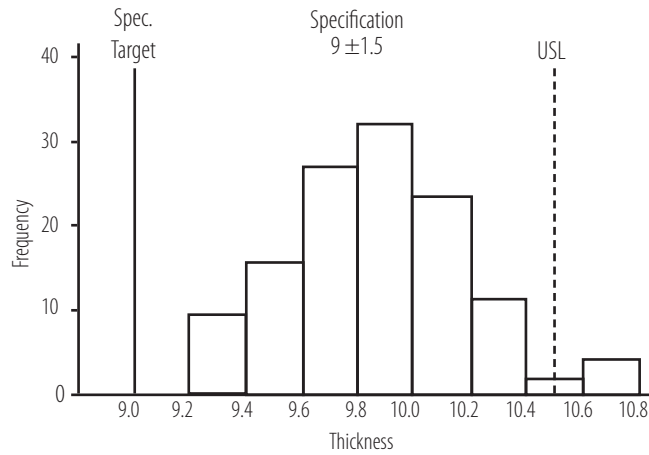
A frequency table based on the data from our example is shown below.

Class #	Class Boundaries	Mid-Point	Frequency	Total
1	9.00-9.19	9.1	I	1
2	9.20-9.39	9.3	IIII	9
3	9.40-9.59	9.5	IIII IIII I	16
4	9.60-9.79	9.7	IIII IIII IIII IIII II	27
5	9.80-9.99	9.9	IIII IIII IIII IIII IIII IIII I	31
6	10.00-10.19	10.1	IIII IIII IIII IIII II	22
7	10.20-10.39	10.3	IIII IIII II	12
8	10.40-10.59	10.5	II	2
9	10.60-10.79	10.7	IIII	5
10	10.80-10.99	10.9		0

### 8) Draw a Histogram from the frequency table

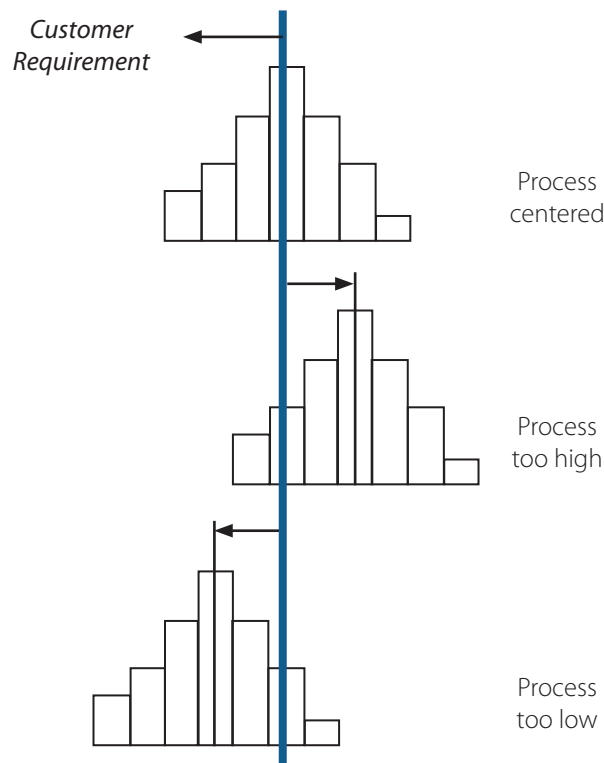
- On the vertical line, (y axis), draw the frequency (count) scale to cover class interval with the highest frequency count.
- On the horizontal line, (x axis), draw the scale related to the variable you are measuring.
- For each class interval, draw a bar with the height equal to the frequency tally of that class.



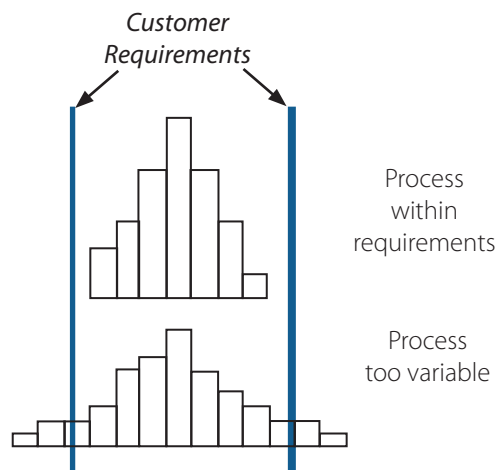


### 9) Interpret the Histogram

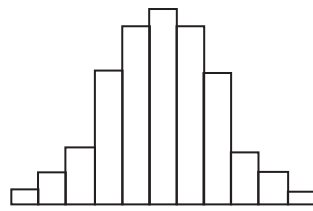
- a. Centering. Where is the distribution centered? Is the process running too high? Too low?



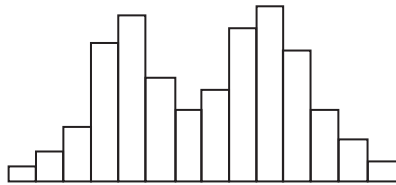
- b. Variation. What is the variation or spread of the data? Is it too variable?



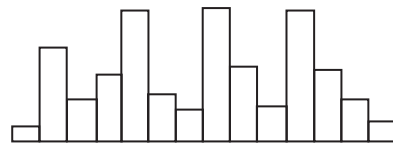
- c. Shape. What is the shape? Does it look like a normal, bell-shaped distribution? Is it positively or negatively skewed, that is, more data values to the left or to the right? Are there twin (bi-modal) or multiple



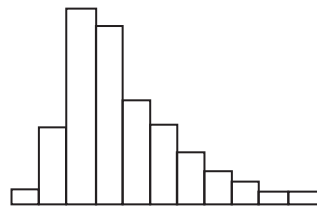
Normal Distribution



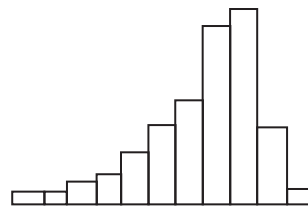
Bi-Model Distribution



Multi-Model Distribution



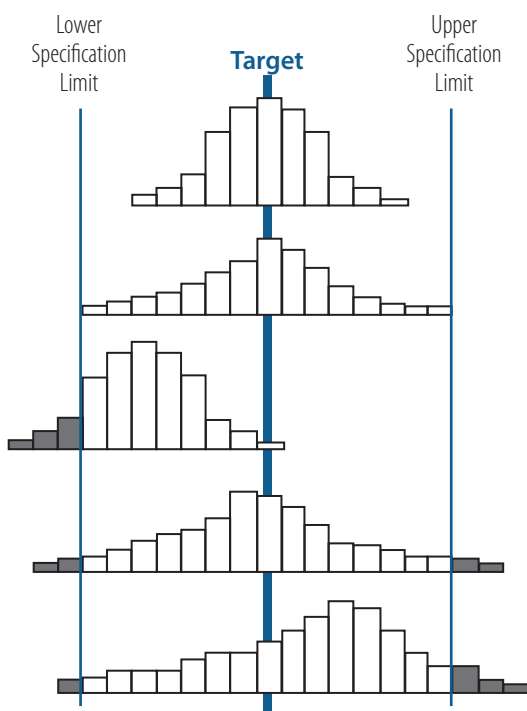
Positively Skewed



Negatively Skewed

- Some processes are naturally skewed; don't expect every distribution to follow a bell-shaped curve.
- Always look for twin or multiple peaks indicating that the data is coming from two or more different sources, e.g., shifts, machines, people, suppliers. If this is evident, stratify the data.

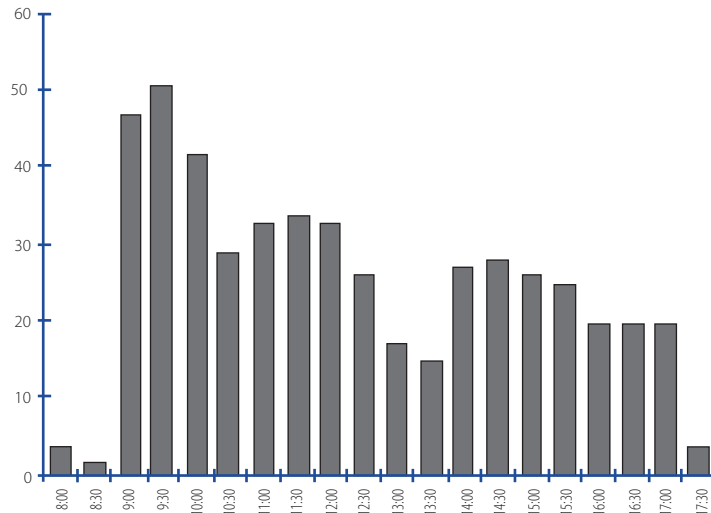
- d. Process Capability. Compare the results of your Histogram to your customer requirements or specifications. Is your process capable of meeting the requirements, i.e., is the Histogram centered on the target and within the specification limits?



- Centered and well within customer limits.  
Action: Maintain present state.
- No margin for error.  
Action: Reduce variation.
- Process running low. Defective product.  
Action: Bring average closer to target.
- Process too variable. Defective product.  
Action: Reduce variation.
- Process off center and too variable. Defective product.  
Action: Center better and reduce variation

- Get suspicious of the accuracy of the data if the Histogram suddenly stops at one point (such as a specification limit) without some previous decline in the data.
- It could indicate that defective product is being sorted out and is not included in the sample.
- The Histogram is related to the Control Chart. Like a Control Chart, a normally distributed Histogram will have almost all its values within  $\pm 3$  standard deviations of the mean. See Process Capability for an illustration of this.

### Histogram Time Distribution of Calls



Note: The Histogram identified three peak calling periods at the beginning of the workday and before and after the traditional lunch hour. This can help the company synchronize staffing with their customer needs.

#### Exercise: Team Activity:

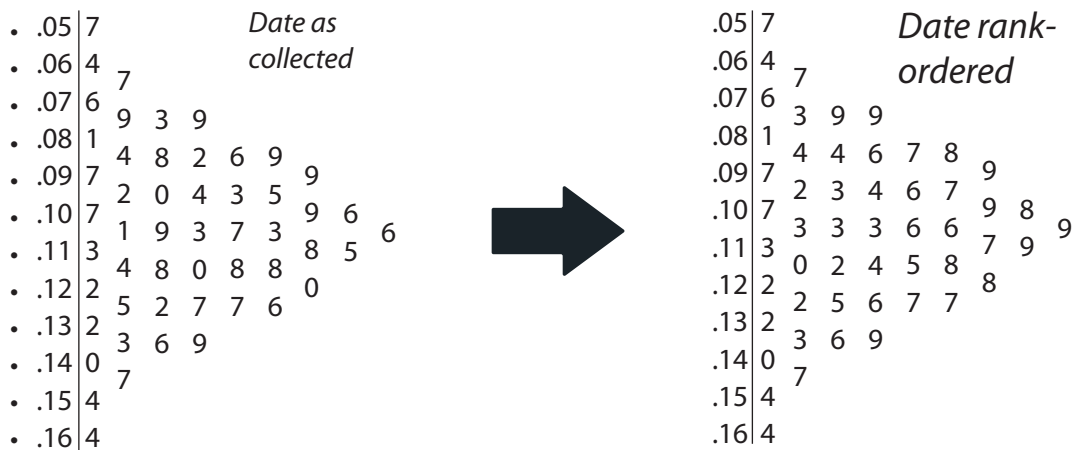


Draw a histogram for one of your products for orders delivery time during the last month & draw customer requirement on the histogram And answer the following questions:

1. Is your process centered?
2. What is the pattern of your delivery orders?
3. Does your process capable of meeting customer requirements?
4. How can you improve your process?

### 3.11.5 Similar Quality Tool to histogram : Stem & Leaf Plot

This plot is a cross between a frequency distribution and Histogram. It exhibits the shape of a Histogram, but preserves the original data values - one of its key benefits! Data is easily recorded by writing the trailing digits in the appropriate row of leading digits.



- In this example, the smallest value is .057 and the largest value is .164. Using such a plot, it is easy to find the median and range of the data.
- Median = middle data value (or average of the two middle values) when the data is ranked from smallest to largest.
- For this example, there are 52 data points. Therefore, the average of the 26th and 27th value will give the median value.
- Median =  $(.113 + .116)/2 = .1145$
- Range = Highest value – lowest value =  $.164 - .057 = .107$

### 3.11.6 Pareto Chart (Focus on key problems)

#### Why use it?

To focus efforts on the problems that offers the greatest potential for improvement by showing their relative frequency or size in a descending bar graph.

#### What does it do?

- Helps a team to focus on those causes that will have the greatest impact if solved
- Based on the proven Pareto principle: 20% of the sources cause 80% of any problem
- Displays the relative importance of problems in a simple, quickly interpreted, visual format
- Helps prevent “shifting the problem” where the “solution” removes some causes but worsens others
- Progress is measured in a highly visible format that provides incentive to push on for more improvement

#### How do I do it?

##### 1) Decide which problem you want to know more about

**Example:** Consider the case of HOTrep, an internal computer network help line:  
Why do people call the HOTrep help line; what problems are people having?

**2) Choose the causes or problems that will be monitored, compared, and rank ordered by brainstorming or with existing data**

- a. Brainstorming
- b. Example: What are typical problems that users ask about on the HOTrep help line?
- c. Based on existing data
- d. Example: What problems in the last month have users called in to the HOTrep help line?

**3) Choose the most meaningful unit of measurement such as frequency or cost**

- Sometimes you don't know before the study which unit of measurement is best. Be prepared to do both frequency and cost.

**Example:** For the HOTrep data the most important measure is frequency because the project team can use the information to simplify software, improve documentation or training, or solve bigger system problems.

**4) Choose the time period for the study**

- Choose a time period that is long enough to represent the situation. Longer studies don't always translate to better information. Look first at volume and variety within the data.
- Make sure the scheduled time is typical in order to take into account seasonality or even different patterns within a given day or week.

**Example:** Review HOTrep help line calls for 10 weeks (May 22–August 4).

**5) Gather the necessary data on each problem category either by “real time” or reviewing historical data**

- Whether data is gathered in “real time” or historically, check sheets are the easiest method for collecting data.
- Example: Gathered HOTrep help line calls data based on the review of incident reports (historical).

**6) Compare the relative frequency or cost of each problem category**

**Example:** Problem Category Frequency Percent (%) List the problem categories on the horizontal line and frequencies on the vertical line.

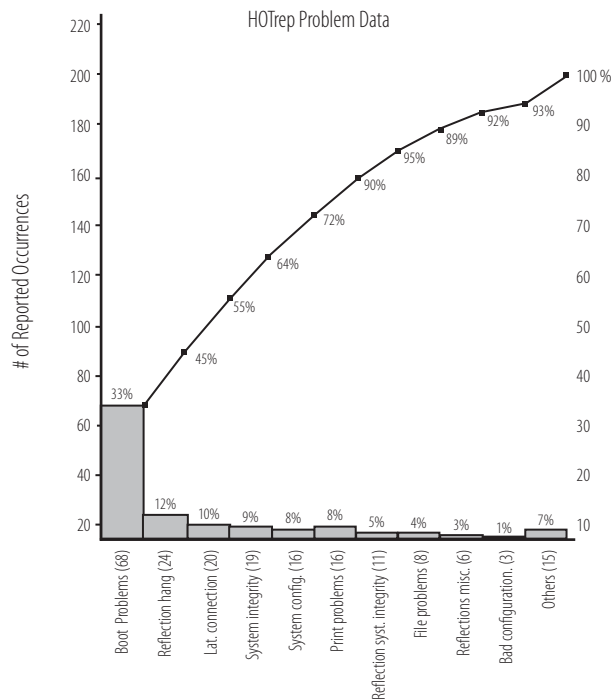
Problem Category	Frequency	Percent (%)
Bad configuraation	3	1
Boot problems	68	33
File Problems	8	4
Lat. connection	20	10
Print problems	16	8
Reflection hang	24	12
Reflection sys. integrity	11	5
Reflections misc.	6	3
System configration	16	8
System integrity	19	9
Others	15	7
<b>Total</b>	<b>206</b>	

**7) List the categories in descending order from left to right on the horizontal line with bars above each problem category to indicate its frequency or cost. List the unit of measure on the vertical line.**

**8) Draw the cumulative percentage line showing the portion of the total that each problem category represents**

- a. On the vertical line, (opposite the raw data, #, \$, etc.), record 100% opposite the otal number and 50% at the halfway point. Fill in the remaining percentages drawn to scale.
- b. Starting with the highest problem category, draw a dot or mark an x at the upper right-hand corner of the bar.
- c. Add the total of the next problem category to the first and draw a dot above that bar showing both the cumulative

number and percentage. Connect the dots and record the remaining cumulative totals until 100% is reached.



## 9) Interpret the results

Generally, the tallest bars indicate the biggest contributors to the overall problem.

Dealing with these problem categories first therefore makes common sense. But, the most frequent or expensive is not always the most important. Always ask: What has the most impact on the goals of our business and customers?

## Further analyze

The Pareto Chart is one of the most widely and creatively used improvement tools.

The variations used most frequently are:

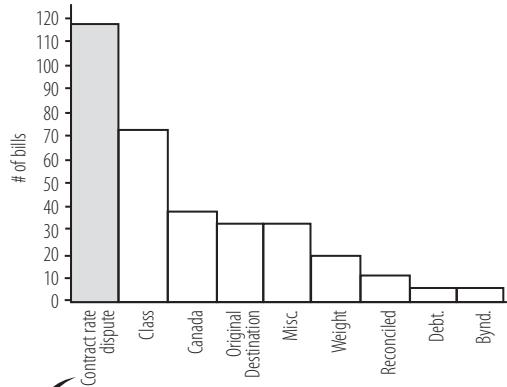
- Major Cause Breakdowns, in which the “tallest bar” is broken into sub-causes in a second, linked Pareto.
- Before and After in which the “new Pareto” bars are drawn side by side with the original Pareto, showing the effect of a change. It can be drawn as one chart or two separate charts.
- Change the Source of Data in which data is collected on the same problem but from different departments, locations, equipment, and so on, and shown in side-by-side Pareto Charts.
- Change Measurement Scale in which the same categories are used but measured differently. Typically “cost” and “frequency” are alternated.



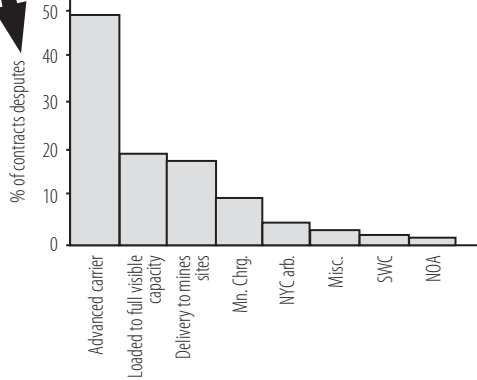
## Pareto

### A. Major Cause Breakdowns

Reduced Payment Freight Bills Total Bills (320)



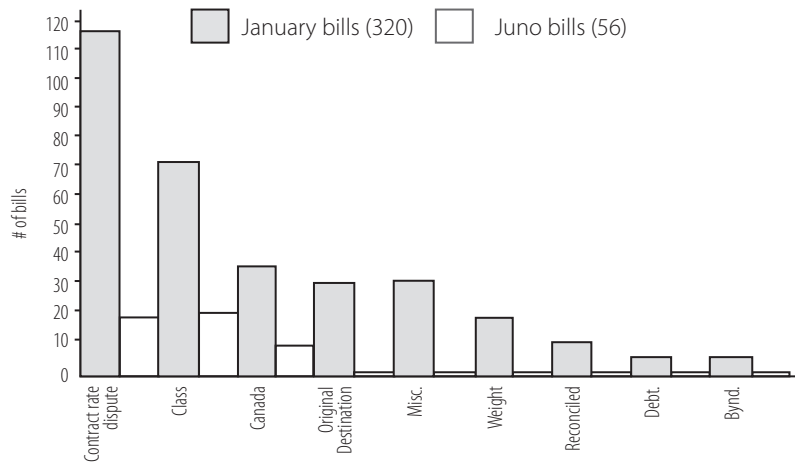
Reduced Payment Freight Bills Contract Rate Disputes



## Pareto

### B. Before and After

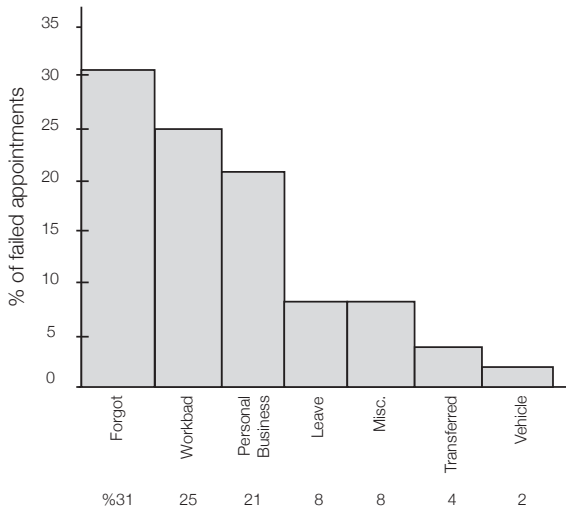
Reduced Payment Freight Bills - After Standardization -



**Pareto**

C. Change the Source of Data

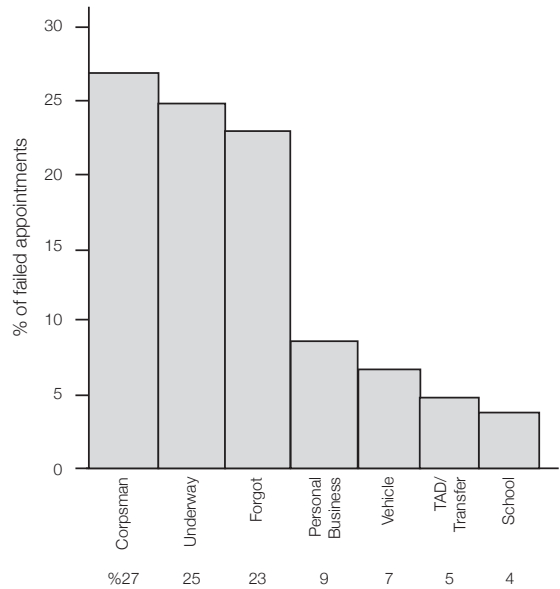
Reasons for Failed Appointments



**Pareto**

C. Change the Source of Data

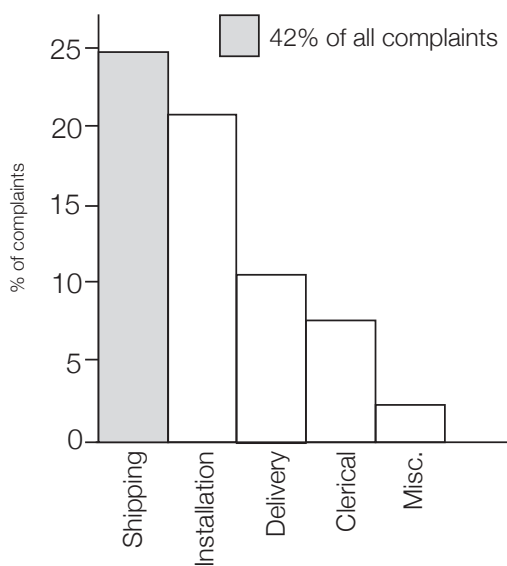
Reasons for Failed Appointments  
Source of Data is: Fleet Commands



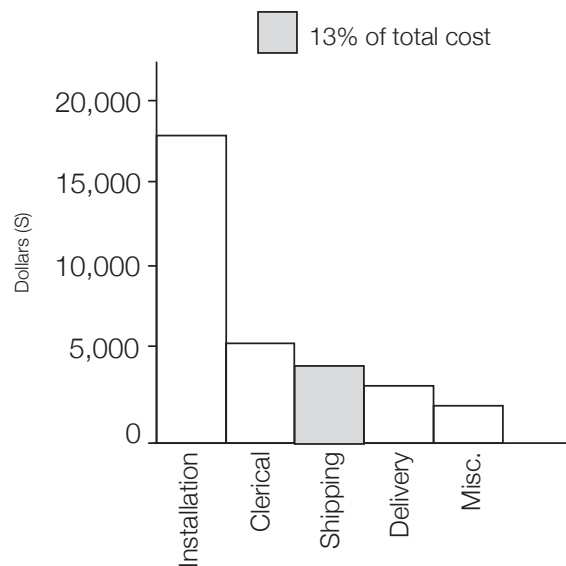
**Pareto**

D. Change Measurement Scale

Field Service Customer Complaints



Cost to Rectify Field Service Complaints

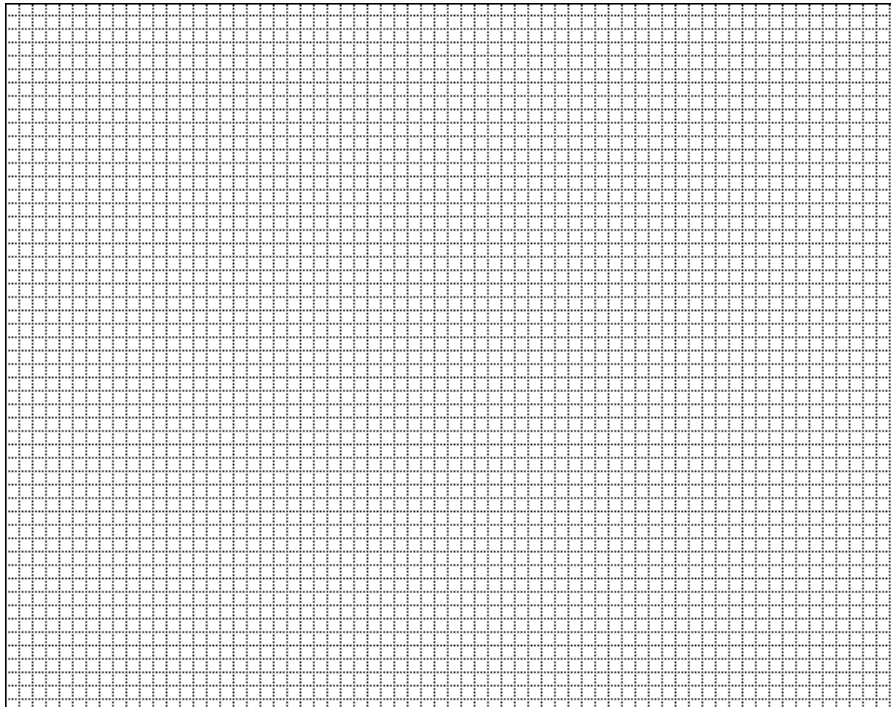


**Exercise: Team Activity:**



Back to the previous exercise in the Fish bone digram, draw a Pareto diagram for these performance problems and answer the following questions:

1. What is the most contributed problem?
2. What is the percentage of this problem contribution to the overall company problems?



### 3.11.7 Run Chart (Tracking trends)

**Why use it?**

To allow a team to study observed data (a performance measure of a process) for trends or patterns over a specified period of time.

**What does it do?**

- Monitors the performance of one or more processes over time to detect trends, shifts, or cycles
- Allows a team to compare a performance measure before and after implementation of a solution to measure its impact
- Focuses attention on truly vital changes in the process
- Tracks useful information for predicting trends

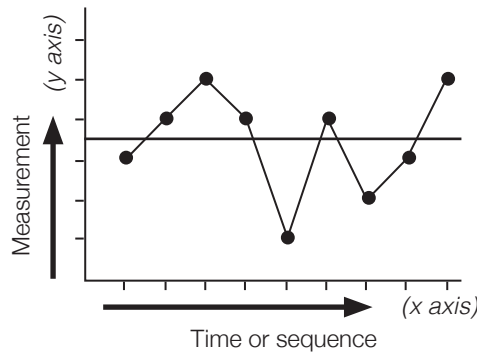
**How do I do it?**

1. **Decide on the process performance measure**
2. **Gather data generally, collect 20-25 data points to detect meaningful patterns**
3. **Create a graph with a vertical line (y axis) and a horizontal line (x axis)**
  - On the vertical line (y axis), draw the scale related to the variable you are measuring.

- Arrange the y axis to cover the full range of the measurements and then some, e.g., 1 1/2 times the range of data.
- On the horizontal line (x axis), draw the time or sequence scale.

**4. Plot the data**

- Look at the data collected. If there are no obvious trends, calculate the average or arithmetic mean. The average is the sum of the measured values divided by the number of data points. The median value can also be used but the mean is the most frequently used measure of the “centering” of the sample. (See Data Points for more information on averages.) Draw a horizontal line at the average value.

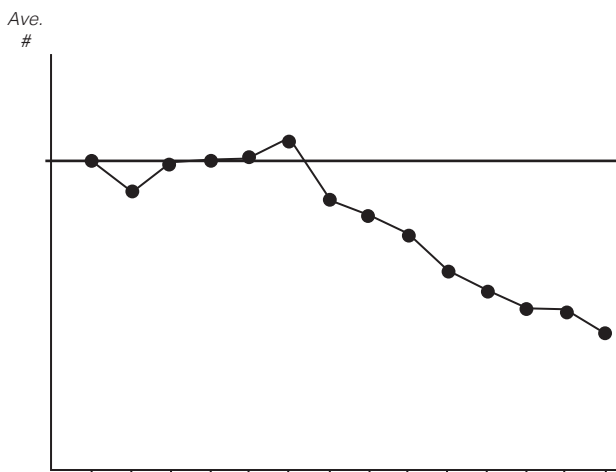


- Do not redraw this average line every time new data is added. Only when there has been a significant change in the process or prevailing conditions should the average be recalculated and redrawn, and then only using the data points after the verified change.

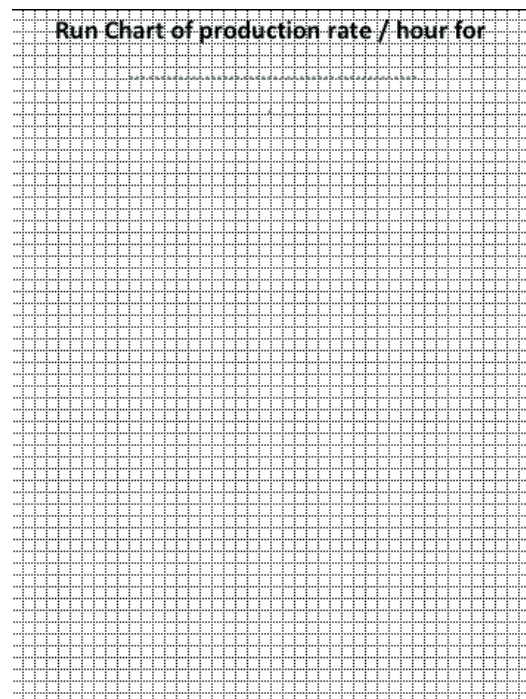
**5. Interpret the Chart**

- Note the position of the average line. Is it where it should be relative to a customer need or specification? Is it where you want it relative to your business objective?

**Average Number of Days for Determining Eligibility for Services**



**Run Chart of production rate / hour for**



### 3.11.8 Scatter Diagram

Measuring relationships between variables

#### Why use it?

To study and identify the possible relationship between the changes observed in two different sets of variables.

#### What does it do?

- Supplies the data to confirm a hypothesis that two variables are related
- Provides both a visual and statistical means to test the strength of a potential relationship
- Provides a good follow-up to a Cause & Effect Diagram to find out if there is more than just a consensus connection between causes and the effect

#### How do I do it?

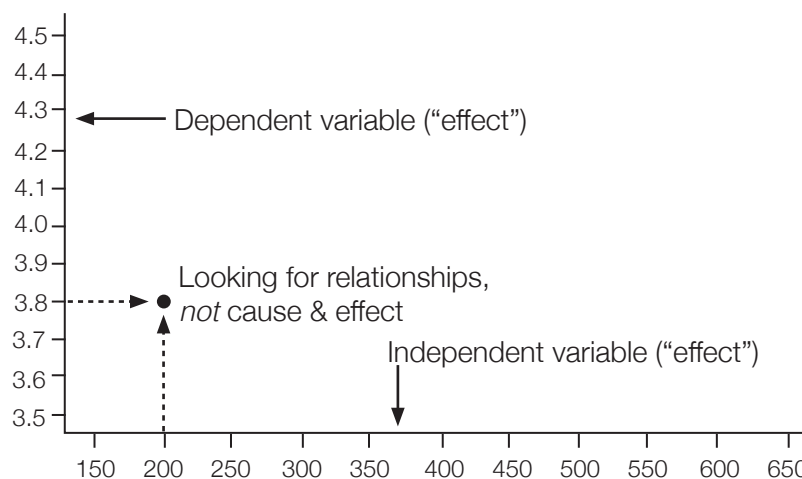
1. Collect 50–100 paired samples of data that you think may be related and construct a data sheet

Course	Average Session Rating (on a 1-5 scale)	Average Experience of Training Team (days)
1	4.2	220
2	3.7	270
3	4.3	270
•	•	•
•	•	•
•	•	•
40	3.9	625

**Theory:** There is a possible relationship between the number of days of experience the training team has received and the ratings of course sessions.

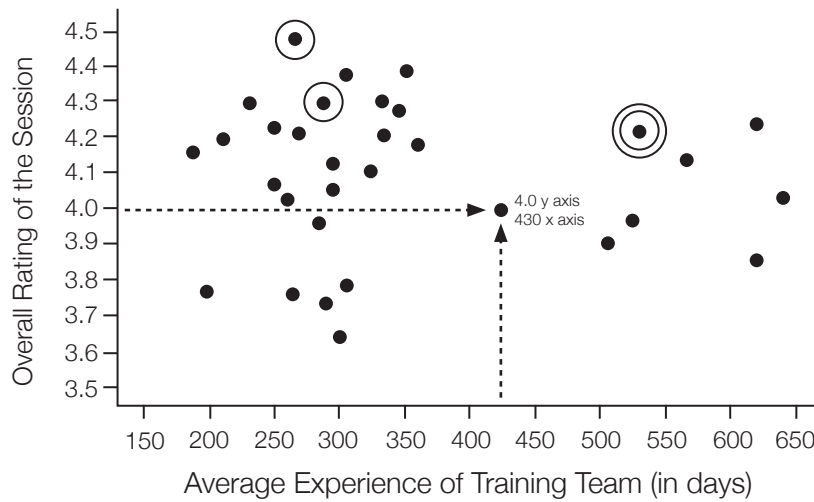
2. Draw the horizontal (x axis) and vertical (y axis) lines of the diagram

- The measurement scales generally increase as you move up the vertical axis and to the right on the horizontal axis.



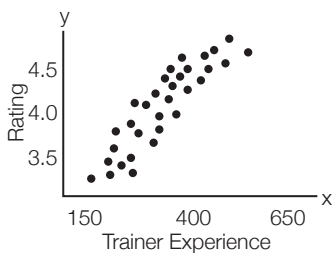
### 3. Plot the data on the diagram

- If values are repeated, circle that point as many times as appropriate.



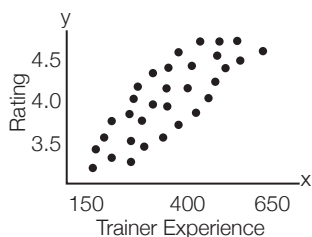
### 4. Interpret the data

- There are many levels of analysis that can be applied to Scatter Diagram data.
- Any basic statistical process control text, like Kaoru Ishikawa's Guide to Quality Control, describes additional correlation tests. It is important to note that all of the examples in this chapter are based on straight-line correlations. There are a number of nonlinear patterns that can be routinely encountered, e.g.,  $y = ex$ ,  $y = x^2$ ). These types of analyses are beyond the scope of this book.
- The following five illustrations show the various patterns and meanings that Scatter Diagrams can have. The example used is the training session assessment previously shown. The patterns have been altered for illustrative purposes. Pattern #3 is the actual sample.
- Tip The Scatter Diagram does not predict cause and effect relationships.
- It only shows the strength of the relationship between two variables. The stronger the relationship, the greater the likelihood that change in one variable will affect changes in another variable



#### 1) Positive Correlation.

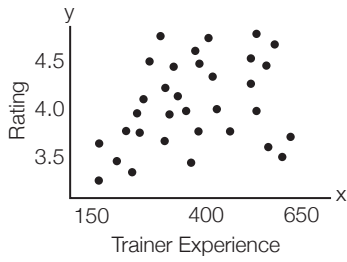
An increase in y may depend on an increase in x. Session ratings are likely to increase as trainer experience increases.



#### 2) Possible Positive Correlation.

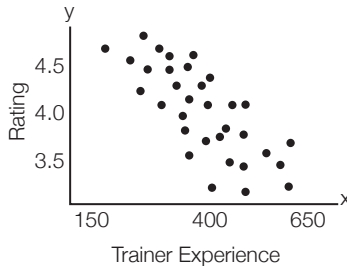
If x is increased, y may increase somewhat. Other variables may be involved in the level of rating in addition to trainer experience.





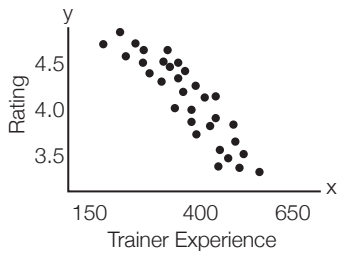
**3) No Correlation.**

demonstrated connection between trainer experience and session ratings.



**4) Possible Negative Correlation.**

As x is increased, y may decrease somewhat. Other variables, besides trainer experience, may also be affecting ratings.



**5) Negative Correlation.**

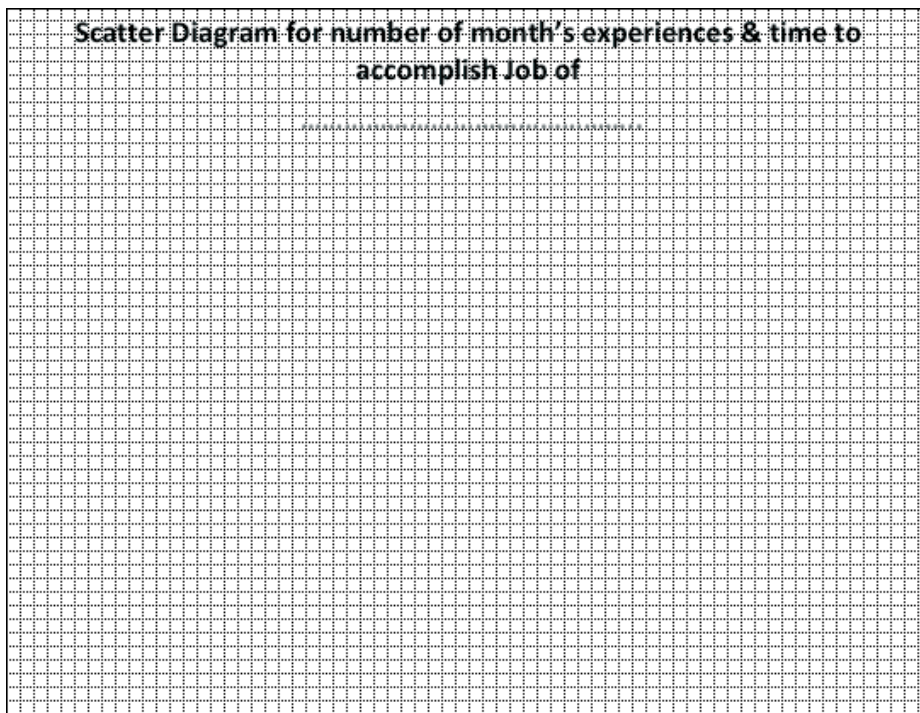
A decrease in y may depend on an increase in x. Session ratings are likely to fall as trainer experience increases.

**Exercise: Team Activity:**

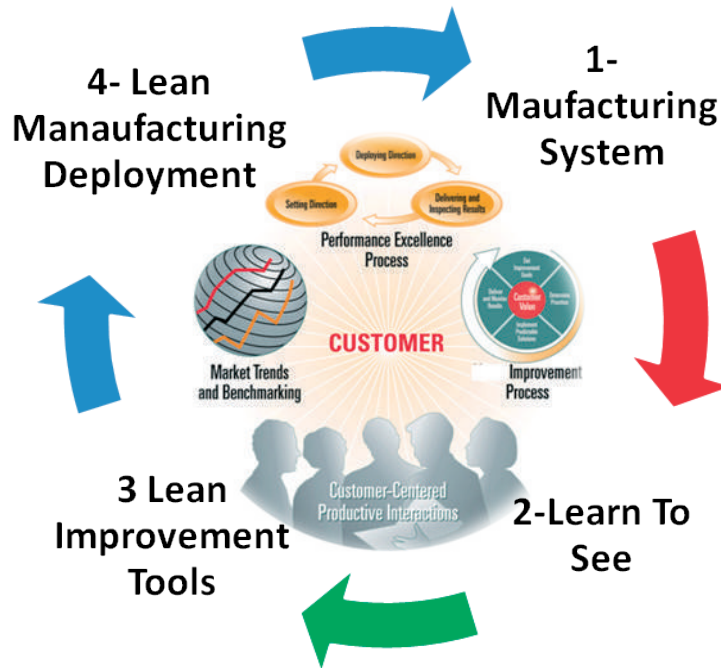


One of you team member stated that there is a relation between number of months experience & time taken to accomplish job

Plot a scatter diagram. for no. months experience & time taken to accomplish job:



## 4. Lean Manufacturing Deployment



## 4.1 Lean Metrics

### a. Lean metrics

Lean metrics help employees understand how well your company is performing. They also encourage performance improvement by focusing employees' attention and efforts on your organization's lean goals.

The goal of Lean Improvement projects is to increase the speed of a process. So we should measure our process performance

### b. The objectives of using lean metrics?

#### 1) After you use lean metrics to verify that you are successfully meeting your company's lean goals, you can do the following:

- a. Use the data you have collected to determine existing problems. Then you can evaluate and prioritize any issues that arise based on your findings.
- b. Identify improvement opportunities and develop action plans for them.
- c. Develop objectives for performance goals that you can measure (e.g., 100% first-time through quality capability = zero defects made or passed on to downstream processes).
- d. Evaluate the progress you have made toward meeting your company's performance goals.

#### 2) Lean metrics help you analyze your business more accurately in the following areas:

- a) Determining critical business issues, such as high inventory levels that drive up operational
- b) Costs, poor quality levels that create customer dissatisfaction, and extended lead times that cause late deliveries and lost orders.
- c) Determining whether you are adhering to lean metrics. These differ from traditional metrics, which can actually work against you. For example, adhering to traditional metrics such as machine efficiency can spur overproduction, and improving your inventory turnover can worsen your on-time-delivery performance.
- d) Determining the best way to use your organization's resources. For example, you can ask questions such as "What is our most frequent problem?" and "What is our costliest problem?"

Use a standard definition form for your metrics. The form should answer the following questions:

- What type of metric is it (financial, behavioral, or core-process)?
- Why was it selected?
- Where will the data be obtained?
- How will the data be collected?
- What formula will be used for calculating the metric?
- How often will it be calculated?
- How often will the metric be used?
- Revise your definition form as needed.

### c. Lean metrics

#### i. Financial metrics

You improve your organization's financial performance by lowering the total cost of operations and increasing revenue. If your company can become a lower cost producer without sacrificing quality, service, or product performance, it can strengthen its performance and market position.

### Examples of Financial Metrics

- |  |  |
|--|--|
| <ul style="list-style-type: none"> <li>• Cost</li> <li>• Cash flow</li> <li>• Direct and indirect labor costs</li> <li>• Direct and indirect materials costs</li> <li>• Facility and operational costs</li> <li>• Production systems</li> <li>• Information systems</li> <li>• Inventory carrying costs</li> </ul> | <ul style="list-style-type: none"> <li>• Total cost of ownership Revenue</li> <li>• Sales</li> <li>• Gross margins</li> <li>• Earnings before interest and taxes</li> <li>• Return on assets</li> <li>• Return on investment</li> <li>• Warranty costs</li> <li>• Product profitability</li> </ul> |
|--|--|

When making revenue or savings projections, it's important to understand the difference between hard and soft cost savings. Hard cost savings actually produce cash savings or profit in ceases. They directly affect your company's profit and loss statement.

### ii. Behavioral metrics

Behavioral metrics are measurements that help you monitor the actions and attitudes of your employees. Employees' commitment, communication, and cooperation all have a significant impact on your organization's success. Financial and core process metrics alone cannot show whether employees are working together in a cooperative spirit. Your company's long term success is possible only when employees' behavior is aligned and everyone works for the benefit of the entire organization.

### Behavioral Categories and Metrics

#### Category : Commitment

Performance Metrics

- Adherence to policies and procedures
- Participation levels in lean improvement activities
- Availability and dedication of human-resources department
- Efforts to train employees as needed

Category : Commitment

#### Performance Metrics

- Customer /employees surveys regarding quantity and quality of company communications efforts Elimination of service or production errors caused by ineffective communications
- Error-reporting accuracy and timeliness
- Formal recognition of employees communication efforts

Category :Commitment

#### Performance Metrics

- Shared financial risks and rewards
- Effective effort toward reporting and resolving problems
- Joint recognition activities
- Formal recognition of employees cooperation efforts

- Conduct teamwork and facilitation training to improve cooperation and communication within your organization
- Make sure your reward and recognition system is aligned with your company's lean goals

**iii. Core –process metrics**

There are many different types of core –process metrics which allow you to measure the performance of your core processes in different ways.

Be sure to measure all your core processes for both productivity and results. Productivity, the ratio of output to input, provides data about the efficiency of your core processes. Tracking the results and then comparing them to your desired outcomes provides you with information about their effectiveness. Some general core process metrics are shown in the table below.

Core –Process Metrics
<ul style="list-style-type: none"> <li>• New product launches</li> <li>• New product extensions</li> <li>• Product failures</li> <li>• Design cycle time</li> <li>• Time to market</li> <li>• Product life- cycle profitability</li> </ul>

Product life –cycle metrics include the identification of market potential, product design, new product launches, model extensions, product use, and product obsolescence.

Order fulfillment cycle metrics include activities related to sales, engineering procurement, production planning and scheduling, the production process, inventory management, warehousing, shipping, and invoicing.

Some specific core – process metrics are shown in the table below. These metrics are explained in detail on the following pages.

Core Process Metrics	
Results Metrics	Productivity Metrics
<ul style="list-style-type: none"> <li>• Health and safety (HS)</li> <li>• First-time-through (FTT) quality</li> <li>• Rolled-throughput yield (RTY)</li> <li>• On-time delivery (OTD)</li> <li>• Order-fulfillment lead time(OFLT)</li> </ul>	<ul style="list-style-type: none"> <li>• Inventory turnover (ITO) rate</li> <li>• Build to schedule (BTS)</li> <li>• Overall equipment effectiveness (OEE)</li> <li>• Value-added to non-value-added (VA/NVA) ratio</li> </ul>

**1. Health and safety metrics**

Health and safety (HS) metrics measure the impact of your Production processes on employees' health and safety.

*Why use Health and safety metrics?*

- A wholesome and safe workplace improves the availability and performance of your organizations Insurance rates are lowered,

- the cost of replacing workers is reduced,
- Production assets are more available. In addition,
- Improved morale and a sense of well-being increase employee productivity and participation in your company's improvement initiatives.

How to measure Health and Safety Metrics?

HS conditions can be measured in several ways. Metrics to consider when evaluating HS include: Days lost due to accidents, absenteeism, employee turnover, and experience. (Please review ILO's Health & Safety Module)

## 2. First Time Through (FTT)

First time through (FTT) is a metric that measures the percentage of units that go through your production process without being scrapped, rerun, retested, returned by the downstream operation, or diverted into an off-line repair area.

### Why use it?

- Increased process/output quality reduces the need for excess production inventory, improving your dock-to-dock (DTD) time.
- It improves your ability to maintain proper sequence throughout the process, improving the build-to-schedule (BTS) metric.
- That operation receives no defective parts. This enables you to increase your quality
- rate and reduce defects at the constraint operation. This in turn improves the over all-equipment effectiveness (OEE) metric.
- Your organization's total cost is improved due to lower warranty, scrap, and repair costs FTT is calculated using the following formula.(Remember that "units" can be finished products, components, or sales orders; FTT's use is not limited to a production environment.)

$$FTT = \frac{\text{units entering process} - (\text{scrap} + \text{reruns} + \text{retests} - \text{repaired off-line} + \text{returns})}{\text{Units entering process}}$$

### Example: ABC Company calculates its FTT

At ABC Company's Spinning Machine, 250,500 Yarn Cones are produced during an eight-hour shift .Of these, 4,450 are scrapped; none are rerun, retested, or repaired; and 4,318 are returned by the downstream operation. This equals an FTT of 96.5%, as shown below.

$$FTT = \frac{250,500 - (4,450 + 0 + 4,318)}{250,500} = 0.965, \text{ or } 96.5\%$$

ABC Company can easily calculate the total FTT capabilities of its four operations involved in Yarn Cone fabrication by multiplying the FTT results for each operation. These results are as follows: Process 1, 95%; Process 2, 96.5%; Process 3, 97%; and Process 4, 98%.

With this data, ABC Company calculated its overall FTT as Follows:

$$FTT = 95\% \times 96.5\% \times 97\% \times 98\% = 87\%$$

### 3. Rolled Throughput Yield (RTY)

Rolled throughput yield (RTY) is a metric that measures the probability that a process will be completed without a defect occurring. Six Sigma programs use this metric either instead of or in parallel with FTT.

RTY is based on the number of defects per opportunity (DPO). An opportunity is anything you measure, test, or inspect. It can be a part, product, or service characteristic that is critical to customer-quality expectations or requirements.

#### How does RTY differ from FTT?

FTT measures how well you create units of product; RTY measures how well you create quality. While FTT measures at the unit level and finds the percentage of defective parts, RTY measures at the defect level and finds how many defects a particular part has.

The RTY metric is sensitive to product complexity, as well as the number of opportunities for defects presenting a production process or aspect of a service. RTY can help you focus an investigation when you narrow down a problem within a complex or multi-step process.

To calculate RTY, you must first calculate defects per unit (DPU) and defects per opportunity (DPO). The result is then used to calculate RTY.

$$\text{DPU} = \frac{\text{number of defects per unit}}{\text{total number of units}}$$

Defects per opportunity (DPO) is the probability of a defect occurring in any one product, service characteristic, or process step. It is calculated as follows:

$$\text{DPO} = \frac{\text{DPU}}{\text{Opportunities pe unit}}$$

Finally, RTY is calculated as follows:

$$\text{RTY} = 1 - \text{DPO}$$

#### Case example: ABC Company calculates its RTY

ABC Company has four operations involved in its Yarn Cone fabrication process. Each operation has five opportunities and a DPO of 0.001. The RTY is calculated as follows:

$$1 - 0.001 = 0.999$$

$$\text{RTY} = (.9995)^4 = (.995)^4 = 0.98$$

### 4. On-Time Delivery (OTD)

On-time delivery (OTD) is a metric that measures the percentage of units you produce that meet your customer's deadline. For this metric, a unit is defined as a line item on a sales order or delivery ticket.

#### Why use it?

- OTD provides a holistic measurement of whether you have met your customer's expectations for having the right product, at the right place, at the right time.



- You can use OTD to track deliveries at both the line-item and order levels. OTD alerts you to internal process issues at the line-item level and shows their effect on your customers at the order level.
- OTD ensures that you are meeting optimum customer-service levels. When you balance OTD with the other internally focused core-process metrics—build-to-schedule (BTS), inventory turnover (ITO) rate, and dock-to-dock (DTD)—you can meet your customer-service goals without making an excessive inventory investment.
- OTD is calculated on an order-by-order basis at the line-item level using the following formula:

$$\text{OTD} = \frac{\text{line items received on time by the customer}}{\text{Total line items received}}$$

Sometimes OTD is measured at the order level rather than at the line-item level. When this is the case, the entire order is considered to be late if only one line item is late. Be sure to verify the level at which your customer wants OTD measured.

#### Case example: ABC Company calculates its OTD

ABC Company ships an order with six line items on it. One of these items is delivered late. If ABC Company tracks the OTD at the order level, then the total order is late, or 0% on time.

Last month, ABC Company shipped a total of 1,250 ton, of which 1,115 ton were delivered on time. Therefore, the monthly on-time delivery performance is 89.2%, as shown below.

$$\text{OTD} = \frac{1,115}{1,250} = 0.892 \text{ or } 89.2\%$$

- In the case of delivery windows (i.e., specified time frames for deliveries), early deliveries might not be considered to be on time.
- Only the customer can choose to change the required delivery time.
- Track customer request dates as well as internal ship/promise dates whenever these two dates are not the same

## 5. Order-Fulfillment Lead Time (OFLT)

Order-fulfillment lead time (OFLT) is the average time that elapses between your company's receipt of an order from a customer and when you send an invoice to your customer for the finished product or service. It extends the DTD metric to include all your sales order-entry, sales-engineering, production-planning, and procurement lead times before production, as well as your invoicing lead times after production.

### Why use it?

Order-fulfillment lead time (OFLT) is the average time that elapses between your company's receipt of an order from a customer and when you send an invoice to your customer for the finished product or service. It extends the DTD metric to include all your sales order-entry, sales-engineering, production-planning, and procurement lead times before production, as well as your invoicing lead times after production.

**Case example: ABC Company calculates its OFLT**

ABC Company developed its OFLT calculation based on the average time the company took to perform the following separate operations. (The team decided to exclude receipt of payment from their calculations.)

- Sales order (SO): The time from when an order is received until the time it is entered into the production-scheduling system.
- Production scheduling (PS): The time from when an order enters the production-scheduling system until the time actual production begins.
- Manufacturing (M): The time from when a manufacturing order is started until the order is released to the shipping department.
- Shipping (S): The time from when an order is received in the shipping department until it leaves the dock.
- Invoice (I): The time from when accounting is notified of a shipment going out until it sends the invoice to the customer.

$$\text{Thus, OFLT} = \text{SO} + \text{PS} + \text{M} + \text{S} + \text{I}.$$

$$\text{For ABC Company, OFLT} = 1 + 2 + 5 + 2 + 2 = 12 \text{ days.}$$

- Some companies break down their OFLT into separate financial measures, such as sales days outstanding (i.e., the average number of equivalent sales days currently out in receivables). This breakdown is often called quote-to-cash cycle time.
- To focus your team’s efforts, consider breaking down the OFLT into discrete measures within each functional area (e.g., sales, engineering, scheduling, procurement, and accounting), as shown in the ABC Company example above. Have each functional area develop value stream maps and then focus its improvement efforts on waste elimination and lead-time reduction.

**6. Inventory Turnover(ITO) rate**

Inventory turnover (ITO) rate is a metric that measure show fast your company sells the products you make—that is, how efficient your marketing efforts are.

**Why use it?**

- Inventory costs are a significant portion of your company’s total logistics-related costs.
- Your inventory levels affect your customer service levels, especially if a customer’s order lead time is less than your manufacturing lead time.
- Your company’s decisions regarding service levels and inventory levels have a significant effect on how much of the company’s money is tied up in inventor investment. This is commonly referred to as “inventory carrying cost.”
- High ITO rates reduce your risk of inventory loss and keep your return-on-assets rates competitively high.
- A low ITO rate can indicate excess inventory or poor sales—both bad signs. A high ITO rate, on the other hand, can indicate high efficiency.

Most companies struggle with low, single-digit ITO rates. The goal of most lean organizations is to achieve at least a double-digit ITO rate. A few exceptional companies are able to achieve triple-digit ITO rates across all their product lines. ITO is calculated using the following formula:

$$\text{ITO} = \frac{\text{cost of goods sold (COGS)}}{\text{year - end inventory (taken from your company's balance sheet)}}$$

**Case example: ABC Company calculates its ITO**

The people at ABC Company thought they were only in the Yarn Cone business. What they didn't realize, until they did the calculations below, was that they were also in the Yarn Cone inventory business.

$$\text{ITO} = \frac{\$ 275,000,000}{\$ 63,953,500} = 4.3 \text{ turns}$$

**7. Build to schedule (BTS)?**

Build to schedule (BTS) is a metric that measures the percentage of units scheduled for production on a given day that are actually produced on the correct day, in the correct mix, and in the correct sequence.

**Why use it?**

- BTS measures your company's ability to produce what your customers want, when they want it, and in the scheduled production order.
- BTS alerts you to potential overproduction situations.
- BTS enables you to lower your inventory levels and improve your DTD time.
- The lower materials-handling and inventory carrying costs that should result when you use BTS lead to improved total cost results for your company.

BTS is calculated using the following formula:

$$\text{BTS} = \text{volume performance} \times \text{mix performance} \times \text{sequence performance}$$

The calculation for determining volume performance is as follows:

$$\text{volume performance} = \frac{\text{actual number of units produced}}{\text{scheduled number of units}}$$

Where "actual number of units produced" is the number of units of a given product to come off the end of the line on a given day, and "scheduled number of units" is the number of units of a given product scheduled to be produced. The result of the calculation is a percentage.

The calculation for determining mix performance is as follows:

$$\text{mix performance} = \frac{\text{actual number of units built to mix}}{\text{actual units produced or units scheduled to be produced}}$$

Where "actual number of units built to mix" is the number of units built that are included in the daily production schedule (i.e., no overbuilds are counted). You can use either the number of actual units produced or the number of units scheduled to be produced, whichever is lower.

The calculation for determining sequence performance is as follows:

$$\text{sequence performance} = \frac{\text{actual number of units built to mix schedule}}{\text{actual units built to mix}}$$

Where “actual number of units built to schedule” equals the number of units built on a given day in the scheduled order.

**Case example: ABC Company calculates its BTS performance**

ABC Company was painfully aware of its schedule mix-ups , overproduction, and inability to consistently match its production schedules to the ship dates that had been promised to its customers. The company decided to use BTS as a measure to ensure compliance to the scheduling and production requirements. What follows is a description of how ABC Company calculated its BTS performance.

The company had scheduled three types of Yarn Cones for one day's production.

The table below shows the three Yarn Cone types and their build sequences.

Yarn Cone Types and Build Sequences		
Yarn Cone Type I	Build Sequence	Scheduled
R56T	1	7,240
45TS	2	12,500
37CTS	3	3,450
Total		23,190
Yarn Cone Type	Actual Sequence	Built
R56T	1	6,250
37CTS	2	3,375
45TS	3	
Total		23,525

$$\text{Volume} = \frac{23,525}{23,190} \quad 0.954, \text{ or } 95.4\%$$

- No credit is given for overproduction Using the formula shown on the previous page

ABC Company calculated its mix performance as follows:

Mix Performance	
Yarn Cone Type	Type Built to Mix
R56T	6,250
37CTS	3,375
45TS	12,500
Total	22,125

$$\text{Mix} = \frac{22,125}{23,190} \quad 0.954, \text{ or } 95.4\%$$

ABC Company's sequence performance is as follows:

Sequence Performance			
Yarn Cone Type	Scheduled Sequence	Actual Sequence	Built to Sequence
R56T	1	1	6,250
37CTS	3	2	3,375
45TS	2	3	0 (37CTS built before 45TS)
Total			9,625

$$\text{Sequence} = \frac{9,625}{22,125} = 0.435, \text{ or } 43.5\%$$

This day's performance, then, was as follows:

$$\text{BTS} = 100\% \times 95.4\% \times 43.5\% = 41.5\%$$

Thus, ABC Company succeeded in making its volume goal; however, it did not produce the correct quantities in the correct sequence. Instead, it overproduced— and, because of schedule mix-ups, it missed customer delivery windows.

## 8. Overall equipment effectiveness (OEE)

Overall equipment effectiveness (OEE) is a metric that measures the availability, performance efficiency, and quality rate of your equipment. It is especially important to calculate OEE for your constraint operation.

### Why use it?

- A higher throughput rate reduces the time your equipment spends in process, thereby decreasing your total DTD time.
- More stable processes improve your production predictability, thereby improving your BTS.
- Higher throughput and lower rework and scrap costs lead to improved total costs.

OEE is calculated using the following formula:

$$\text{OEE} = \text{equipment availability} \times \text{performance efficiency} \times \text{quality}$$

The calculation for determining equipment availability is as follows:

$$\text{Equipment availability} = \frac{\text{Operating time}}{\text{net available time}}$$

"Operating time" is the net available time minus all other downtime (i.e., breakdowns, setup time, and maintenance). "Net available time" is the total scheduled time minus contractually required downtime (i.e., paid lunches and breaks).

### Case example: ABC Company calculates its OEE performance

ABC Company calculated its Yarn Cone-Spinning Machine's equipment availability as follows:

Equipment Availability	
Machine #5127	Calendar Week: 35
A. Total scheduled time minutes	6,000 minutes
B. Required downtime	500 minutes
C. Net available time (A-B)	5,500 minutes
D. Other downtime(C-D)	850 minutes
E. Operating time	4,650 minutes

$$\text{Equipment availability} = \frac{4,650 \text{ minutes}}{5,500 \text{ minutes}} = 0.845, \text{ or } 84.5\%$$

The calculation for determining performance efficiency is as follows:

$$\text{performance efficiency} = \frac{\text{total parts run} \times \text{ideal cycle time}}{\text{operating time}}$$

where "total parts run" equals the total number of parts produced (regardless of quality), and "ideal cycle time" equals the greatest of the following: the normal expected cycle time (in seconds per part) for the equipment; the best cycle time ever achieved and sustained for that piece of equipment; and an estimate based on experience with similar equipment. ABC Company calculated the performance efficiency of its Yarn Cone-Spinning Machine as follows:

$$\text{performance efficiency} = \frac{0,0167 \text{ minutes} \times 250,500}{4,650} = 0.898, \text{ or } 89.8\%$$

The calculation for determining quality is as follows:

$$\text{quality} = \frac{\text{total parts run} - \text{total defects}}{\text{total parts run}}$$

Where "total defects" equals the number of rejected, reworked, or scrapped parts. ABC Company calculated the quality of its Yarn Cone Spinning Machine as follows:

$$\text{quality} = \frac{250,500 - (4,450 + 0 + 4,318)}{250,500} = 0.965, \text{ or } 96.5\%$$

ABC Company then calculated the OEE performance for its Yarn Cone-Spinning Machine as follows:

$$\text{OEE} = 84.5\% \times 89.8\% \times 96.5\% = 73.2\%$$

Do not compare OEE results for non-identical machines or processes. An OEE comparison should be done only at time intervals for the same machine or the same process; otherwise, it is meaningless.

## 9. The VA/NVA ratio?

The value-added to non-value-added (VA/NVA) ratios a metric that compares the amount of time in your work process spent on value-added activities to the amount of time spent on non-value-added activities.

### Why use it?

- It makes non-value-added activities evident.
- It focuses your lean improvement efforts on the elimination of waste and the reduction of lead time.
- It provides a common metric for your management, sales, engineering, production, and procurement departments to communicate their priorities to each other and conduct cross functional improvement activities.

VA/NVA ratio is calculated using the following formula:

$$\text{VA/NVA} = \frac{\text{total value - added activities time}}{\text{total OFLT}}$$

### Case example: ABC Company calculates its VA/NVA ratio

To determine their total value-added activities time, the team at ABC Company developed a value stream map of their order-fulfillment process. They observed or calculated times for each activity.

From this map they were able to identify the value-added and non-value-added activities. From these results, the ABC Company team considered only their order-entry and manufacturing activities as value-added. Because all other activities were necessary but did not add value to the product, they were considered to be non-value-added activities.

ABC Company's weekly production hours included three daily shifts for five days, for a total of twenty hours per day (100 hours per week). The team at ABC Company calculated their VA/NVA performance as follows. (See the section on OFLT for details on the meaning of the letters used in the equation below.)

$$\text{VA} = \text{SO} + \text{PS} + \text{M} + \text{S} + \text{I}$$

$$\text{VA} = 10 + 0 + 235 + 0 + 0 = 245 \text{ minutes}$$

Recall that the ABC Company team calculated their OFLT as follows:

$$\text{OFLT} = \text{SO} + \text{PS} + \text{M} + \text{S} + \text{I}$$

$$\text{OFLT} = 1 + 2 + 5 + 2 + 2 = 12 \text{ days}$$

$$\text{VA/NVA} = \frac{245 \text{ minutes} / 60 \text{ minutes per hour}}{8 \text{ hours} + 16 \text{ hours} + 100 \text{ hours} + 16 \text{ hours} + 16 \text{ hours}} = 0.026, \text{ or } 2.6\%$$

The result of 2.6% was an eye-opener for the team at ABC Company. They conducted a benchmarking study and found that most companies that perform this calculation do so for their manufacturing processes only. Their manufacturing-only



VA/NVA percentages ranged from about 15% to 35%. However, adding their sales, production-planning, shipping, and invoicing times significantly reduced their VA/NVA ratio.

To focus your efforts, consider breaking the VA/NVA ratio into discrete measures within each functional area of your company (e.g., sales, engineering, scheduling, procurement, and accounting). Have each functional area develop value stream maps and focus its improvement efforts on waste elimination and lead-time reduction.

#### **d. How do I decide what performance metrics to use?**

Your goal is to select the metrics that accurately portray your company's performance. The best approach is to balance the metrics you use among the three categories (financial, behavioral, and core-process) and to use a mix of in-process and end-of-process metrics.

You should also consider the total number of metrics you use. Using too many can confuse employees and slow your performance-improvement efforts. Using too few might not provide you with enough detail to properly focus your improvement efforts.

When deciding which metrics to use, consider the following points:

- What are you measuring?
- What will be the frequency of measurement?
- How long will data be collected?
- Who will measure it?
- How will it be measured?
- How will it be charted?
- What action will be taken after the data is interpreted?
- Who will be responsible for follow-up action?

## An Example of A Balanced Measurement Selection

Yarn Cone Types and Build Sequences				
Measurement	Freq.	Who Measures?	How Measured?	How Charted
Cost reductions	Monthly	improvement teams	Hard- and soft-cost transactional cost analysis	Bar chart indicating monthly and Cumulative totals by location
Cost increases	Monthly	improvement teams	Hard- and soft-cost transactional cost analysis	Bar chart indicating monthly and Cumulative totals by location
Category: Behavioral				
Customer satisfaction	Yearly	Quality department	Customer survey— questions weighted by satisfaction and importance	Bar chart
Employee satisfaction	Yearly	Steering team	Employee Survey questions weighted by satisfaction and importance	Bar chart
Lean improvement initiative completions	Monthly	improvement teams	Number of lean improvement initiatives completed with desired results	Bar chart indicating monthly and Cumulative totals by location
Category: Core: Process				
On-time delivery	Monthly	Sales and manufacturing	OTD % at line-item level, by ship-to locations	Pareto Chart
BTS	Monthly	Production planning	Volume x mix x sequence	Chart of individuals and moving range
OEE	Monthly	Manufacturing	Availability performance efficiency x FTT quality for constraining operation and Lowe stave ail ability assets	Chart of individuals and moving range
ITO rate	Monthly	Finance	Inventory turns (cost of goods sold x average inventory value)	Chart of individuals and moving range
OFLT	Monthly	Aggregated by functions submitted to lean enterprise	Average OFLT by product family	Chart of individuals and moving range

- As you complete your measurement selection, set specific performance objectives to drive your evaluation and improvement efforts.

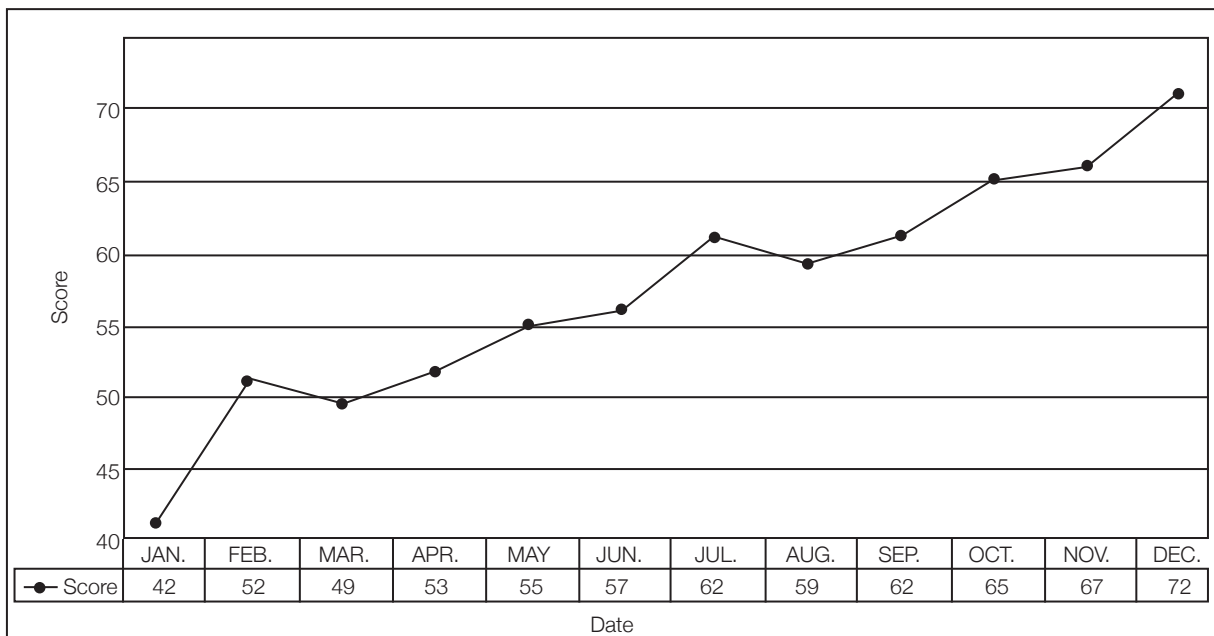
## Lean enterprise scorecard

A lean enterprise scorecard is a technique for comparing your actual results to your performance objectives Below is ABC Company's scorecard. It shows how the company used scoring to gauge its overall progress toward its goals.

monthly Performance by Site: May

Category	Site A			Site B		Site C	
	Goal	Actual	Score	Actual	Score	Actual	Score
1. Monthly cost reductions (% of operating budget)	0.5%	0.45%	6	0.6%	10	0.4%	4
2. percentage of products having undergone a lean transformation	12%	15%	10	10%	4	9%	2
3. Improvement suggestions	25	21	4	17	0	12	0
4. FTT quality	100%	92%	6	81%	4	78%	2
5. OTD (based on line items shipped)	98%	97% (of 128)	8	94% (of 124)	8	99% (of 198)	10
6. DTD	10 days	12	6	14	2	15	0
7. BTS	100%	75%	2	90%	6	85%	4
8. OEE for constraining operation	Per target: no less than 85%	Target =95% 89%	8	Target =94% 79%	4	Target =93% 88%	6
9. ITO rate	5	4.6	6	4	4	3.9	2
10. OFLT	5 days	5 days	10	7 days	6	6 days	8
Totals (out of a possible 100 points)			66		48		38

ABC Company's Lean Scorecard for One Calendar Year



Scoring Guide	
Percentage of Goal	Days to Complete Goal
100%: 10 points	< 0 days: 10 points
95–98%: 8 points	+ 1 days: 8 points
90–94%: 6 points	+ 2 days: 6 points
80–89%: 4 points	+ 3 days: 4 points
70–79%: 2 points	+ 4 days: 2 points
<69%: 0 points	+ 5 days: 0 points

## 4.2-Lean Organization

### 4.2.1 Building lean organization

Successful transformation to a continuous process improvement culture is arduous. It requires an enterprise approach that engages the entire organization and challenges its norms. It requires knowledge of new tools and methodologies, and a level of internal discipline beyond that in which most organizations operate, While Lean may seem like a radical shift, the dynamics of successful Lean transformation rely on continuous small pushes on the flywheel of change, creating momentum and a cultural movement.

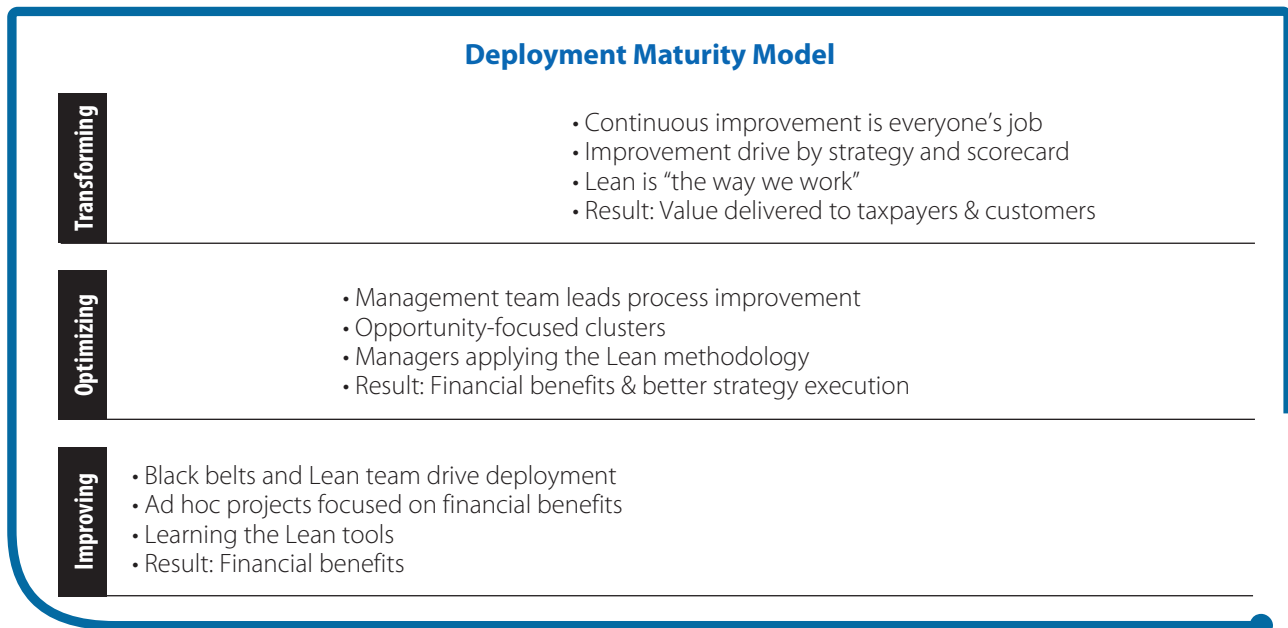


### 4.2.2 Deployment steps:

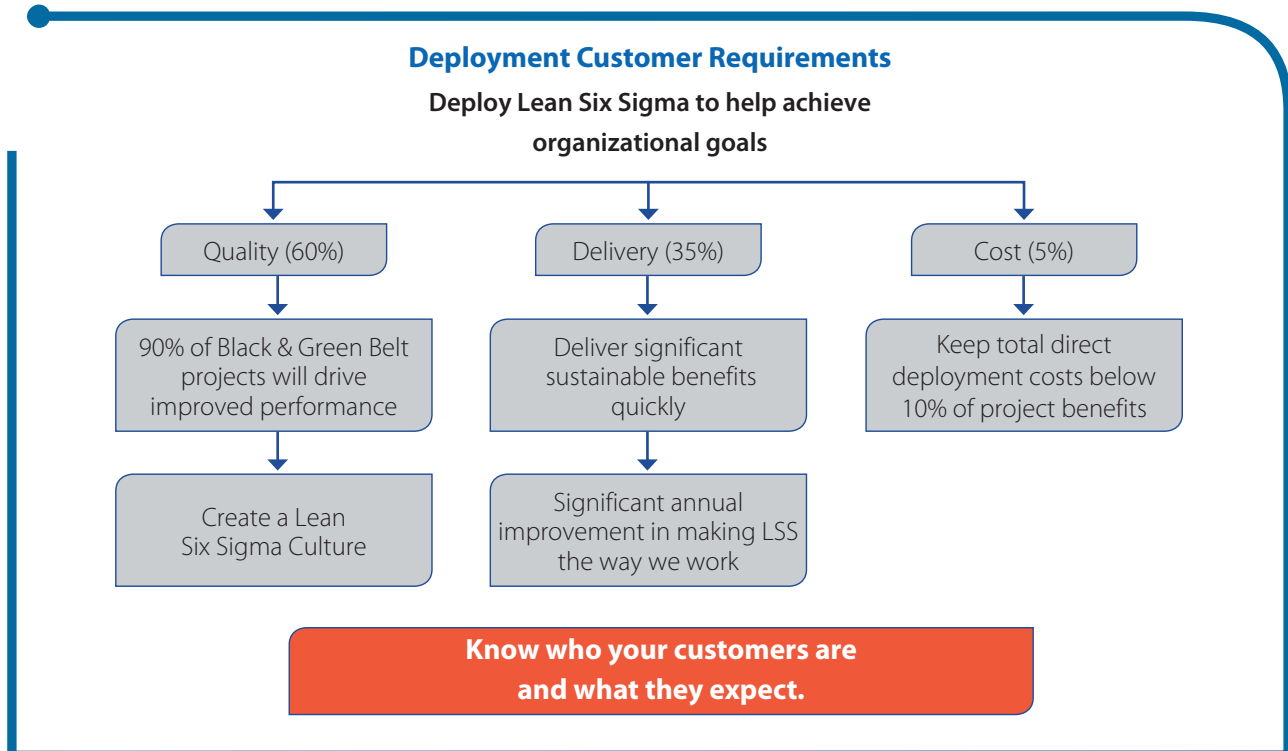
#### 4.2.2.1 Unrelenting focus on what matters most.

- Fully engage leaders in Lean Program
  - Require leaders to be highly visible in leading Lean Program
  - Structure engagement in key deployment activities
- Lean Program goal setting
  - Identify the most serious business problems
  - Set explicit Lean Program goals
  - Link to pay and job performance appraisals
- Understand the business goals and the major organization drivers
  - Get leaders to understand their customer requirements
- Put deployment accountability where it belongs
  - Executives and managers need to own Lean Program
  - The deployment strategy needs to get executive ownership quickly.

#### 4.2.2.2 Adopting a deployment maturity model



#### 4.2.2.3 Understanding deployment customer requirements



#### 4.2.2.4 Roles and Responsibilities

- Project specific support
- Resource allocation
- Project focus
- **Project leader**
  - Trains and mentor.

- Technical resource.
- Coaches deployment champions and managers.
- Manages project clusters.
- **Kaizen team leader**
  - Leads projects.
  - Mentors green belts.
  - Lead smaller projects.
  - Key team member on larger projects.
- **Functional Champions**
  - Support for deployment in key areas such as finance, HR and IT.
  - Policies and procedures.
- **Process Owners**
  - Project team member.
  - Ownership of the process.
  - Cross functional coordination.
  - Sustain the project gains.

#### 4.2.2.5 Organization Structure Options

- Modify structure for scale of deployment.
- Contract for training.
- Functional champions may not be needed.
- Consolidate deployment leadership.

#### 4.2.2.6 Talent Management

- Rotate top performers through 2 year assignments as lean project manager
- Lean Program is an outstanding management development experience
- Problem identification
- Systematic problem solving
- Managing using data
- Leadership
- Select the best and brightest for black belts
- Don't compromise on talent
- Plan repatriation
- Make Lean Program experience a requirement for advancement
- Skip talent management if culture change is not a deployment goal

#### 4.2.2.7 Change management

- **Manage change from the start**
  - The biggest deployment risk is not technical.
  - Create a formal change management plan.
- **Lean Program fundamentally changes an organization**
  - Anticipate the impact that Lean Program will have.
  - Address problems in the related management systems.
- **The legacy of enterprise initiatives is a common barrier**

- Many will wait it out if given a chance
- Skepticism should be expected
- **Get to critical mass quickly**
  - Window for change is often very short
  - Take advantage of momentum, start-up good will and leadership enthusiasm.
- **Leadership counts**
  - Leadership needs to be consistent, visible and constant
  - Change is hard - don't do it if you are not committed
- **Address the people issues early**
  - Layoffs
  - Pay
  - Job changes
- **Understand what helps people change**
  - What's in it for me?
  - Certainty
  - Knowledge
- Communicate, communicate, communicate

### 4.2.2.8 Deployment Execution

- Understanding the core process and critical Ys
- Kaizen Team selection
- Selecting projects
- Supporting infrastructure
- Training
- Mentoring and project support
- Project execution
- Leadership engagement
- Metrics

### 4.2.2.9 Supporting Infrastructure

- Projects
- Project idea charter



Project Charter		
Project Title		
Project Leader	Site	
<b>Objective</b>		
Start Date:	Completion Date:	
Project Sponsor	Title	
Team Members	Function	
<b>Problem Description and Scope</b>		
<b>Customer Impact</b>		
<b>Business Impact. including saving</b>		
Key Metrics	Baseline	Target
Authorisation	Signature	Date
Champion/ Manager		
Finance Representative		

- Project financial validation process
- Project selection process
- Project management process
- Audit results process
- Project database

Lean kaizen projects	Assigned kaizen teams											T12-Teachinal office	KPI's Before and After Audit
	T1 JS	T2 Belloy	T3 HM	T4 Dalic	T5-over	T6-Finsh	T7-Store	T8-Planing	T9-quality	T10 Admin	NT11 - MAINTENANCE		
Improving productivity & reduceing process LT	X	X	X	X	X	X	X			X	X		P-CR-DT-D-COST/UNIT
Reducing machine down time	X	X	X	X	X	X	X			X	X	X	CT-D
Improving process work place orgnization and safety	X	X	X	X	X	X	X						OEE- Q-P-DT
Reducing machine QCO	X	X	X	X	X				X		X		Change over time
reducing Material consumption	X	X	X	X	X	X		X	X				P/AP srape %
Improving planning process LT					X	X							Process LT
Improveing material ordering system													shoratge %
Reduceing lead time ( pattern design and maintenance	X	X	X	X	X	X	X		X	X		X	Process LT -Defect % Patterns
<b>Quality projects</b>													
Improving process product quality											X		PPM- SCRAP% REWORK%
<b>Production management system</b>													PPM- SCRAP% REWORK%
reducing LT respoting kpis - production performance system	X	X	X	X	X	X							
<b>Engineering projects</b>													
Construct products BOM	X	X	X										
Constuct planning and scheduling process system	X	X	X	X	X								
<b>Lean kaizen training</b>													
<b>COURSE NAME ( LEAN KAIZEN )</b>													
What is Lean	X	X	X	X	X	X	X	X	X	X	X	X	
6s visualization	X	X	X	X	X	X	X	X	X	X	X	X	
standarization	X	X	X	X	X	X	X	X	X	X	X	X	
TPM-OEE-PLM											X		
PLM- OPL- ERROR PROF	X	X	X	X	X	X					X		
Deatiled process- std -standarization - vsm	X	X	X	X	X	X							
material management								X	X				
<b>COURSE NAME ( Quality training )</b>													
MBF- LEAN KPI's	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL		
7Basic managent tool	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL		
introduction to iso -	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL	TL		
introduction to six sigma - SPC	TL	TL	TL	TL	TL	TL	TL	TL	TL		TL		

- **People**
  - Selection process
  - Certification process
  - Repatriation for Lean kaizen team leaders
  - Development plans
  - Rewards and recognition
  - Organizational structure
  - Engagement

#### 4.2.2.10 Training

- Kaizen teams
- Directors and Administrators
- Deployment
- Awareness
- Delivery Methods
  - Contracted training
  - Open enrollment
  - In-house

#### 4.2.2.11 Mentoring & Project Support

- Require monthly 1:1 between Lean project program and assigned Lean kaizen team leaders to review projects.
- Encourage Lean kaizen team leader program and project sponsor monthly touch points to eliminate barriers.
- Hold weekly “study halls” for project help.
- Assign Lean project program manager to mentor team leader.
- Measure customer satisfaction from project sponsors and project teams.

#### 4.2.2.12 Mentoring & Project Support Lessons Learned

- Keep process owners/sponsors involved in the projects and communicate often.
- Have discipline in conducting the monthly project reviews.
- Identify and address issues early.
- Review checklist.
- Recognize the critical leadership development role the kaizen team leaders play.
- Know who is doing well and who isn't.

#### Project Execution Lessons Learned

- Scope projects appropriately.
- Use a formal project management methodology.
- Track project progress monthly.
- Be willing to stop poor projects early.
- Use project cluster management for related projects.

#### Leadership Engagement

- Annual goal setting.
- Monthly staff meeting agenda item.
- Project sponsorship / barrier removal.
- Training attendance.

- Training kick off speeches.
- Attendance at LSS functions.

#### **4.2.2.13 Leadership Engagement Lessons Learned**

- Leadership wants to help but may not know how to help. Provide training and hand holding as necessary.
- Create and reinforce the expectation that management must lead Lean programs:
  - Identify projects.
  - Provide resources.
  - Remove barriers.
- Measure leadership engagement.
- Metrics
- Outcome measures
- Lean Program project financial benefits.
- Culture change.
- Deployment management measures:
  - Projects completed.
  - Project cycle time.
  - Projects on-track.
  - Active and completed projects per Black Belt and Green Belt.
  - Benefits per project.
  - Charters written.
  - Charter inventory.
  - Lean kaizen team leader program per employee.
  - Projects per employee.

#### **4.2.2.14 Sustaining the Gains**

- Create a Lean Program control plan.
- Build a data and performance driven management culture.
- Organization performance.
- Process performance.
- Lean Program performance.
- Strengthen management accountability.
- Maintain the Lean Program focus on the most important organization goals and performance gaps.
- Tighter integration between Lean Program and the enterprise's management systems

## 5. Glossary

**5S:** Derived from the Japanese words seiri, seiton, seiso, seiketsu, and shitsuke, which have been translated into English as sort, straighten, scrub, systematize, and standardize.

**5 Whys:** A method of root-cause analysis that entails the progressive asking of “Why?” at least five times or until the root cause is established. 5 Ws and 1 H: A tool of inquiry in which you ask, “Who?”, “What?”, “When?”, “Where?”, “Why?”, and “How?”

**Affinity Diagram:** An organization of individual pieces of information into groups or broader categories.

**Andon:** A signal to alert people of problems at a specific place in a process; a form of visual management.

**A3:** A one-page reporting format, named for the international paper size. It contains, on one page, critical information about an issue, such as description, cost, timing, data, planned solution, and planned resolution.

**Autonomation:** Automation with a human touch. Autonomation is related to jidoka. Intelligence is added to equipment to prevent the production of defective products, eliminate overproduction, and automatically stop the process when abnormalities are detected. This type of automation frees people to perform more valuable activities. See also jidoka.

**Backflow:** The return of a “product” to an earlier step, usually to the source of the issue, for reprocessing or repair.

**Balanced Scorecard:** A framework for identifying business metrics beyond the basic financial measures normally used. The framework includes customer, internal, people, and financial measures, and ties together strategic goals with operational metrics.

**Bar Chart:** A graphical method of depicting data, grouped by category. The values are depicted in vertical or horizontal bars.

**Batch and queue:** A method of processing where

material is accumulated into a lot (batch) and pushed through the process independent of demand or requirements. This is also known as mass production or traditional manufacturing.

**Bottleneck:** A process that constricts or limits the flow of the overall process.

**Buffer stock:** An amount of inventory accumulated between processes to protect a process from starving due to uneven capacities. Buffers are a form of inventory, one of the seven forms of waste. See also inventory; seven forms of waste.

**Bull-whip effect:** The progressive magnification of demand upstream from the customer in the value stream.

**Cause-and-Effect Diagram:** A pictorial diagram that shows the variable causes that can affect a given process or output. Also known as a C&E Diagram.

**Cell:** See work module.

**Check Sheet:** Any standard way you can gather data and view an activity as it happens, normally on a piece of paper or chart on which someone indicates an activity and checks it as it occurs.

**Changeover:** Elapsed time between one activity or product and a new one. In a production environment, changeover is the time between the production of the last part of one type to the production of the first good part of the next type. Another example is a racing pit crew: The time between the moment the car rolls into the pit for tires and fuel to its entrance back into the racecourse is changeover.

**Consumer:** The person or entity who obtains goods and services for his or its own use. In Star bucks, the person drinking the Venti half-caf, nonfat White Chocolate Mocha Frappuccino with extra whipped cream is the consumer. See also customer.

**Continuous Dow:** The ideal state where products

move through a manufacturing process - or people move through a service process - one at a time, without stopping or waiting.

**Control Chart:** The most powerful tool of statistical process control, the control chart is a time-series run chart, with statistically determined upper and lower control limits and a centerline.

**Current-State Map:** A Value Stream Map that depicts things as they currently exist within the value stream. See also Value Stream Map.

**Customer:** The person or entity who is the recipient of what you produce, either within your organization or outside your organization. For Starbucks suppliers, the customer is the retail store that receives the espresso beans, milk, syrup, and blender, in order to make that Venti half-caf, nonfat White Chocolate Mocha Frappuccino for the consumer. See also consumer.

**Cycle time:** The total amount of elapsed time from the time a task, process, or service is started until it is completed.

**Defects:** The output of a process that fails to meet the required specification or performance standard. One of the seven forms of waste. See also seven forms of waste.

**Demand amplification:** See bull-whip effect.

**Deming Cycle:** See Plan-Do-Check-Act (PDCA) or Plan-Do-Study-Act (PDSA).

**Downtime:** The stoppage of a process due to planned or unplanned causes, such as equipment maintenance or failure, material or quality issues, training or staffing constraints, and so on.

**Effectiveness:** The utilization of the minimum number of resources, with the least amount of waste, to create a defined value for the customer.

**Efficiency:** The optimization of a process that results in minimum resource use. Efficiency is not necessarily tied to customer value. A process can be efficient but not effective.

**Error-proofing:** See poka-yoke.

**Excess processing:** work being performed beyond what is required to satisfy the customer standards or requirements. See seven forms of waste.

**Failure Mode Effects Analysis (FMEA):** The method used to identify, assess, and mitigate risks associated with potential failure modes in a product, process, or system.

**FIFO:** See first in first out (FIFO).

**Finished goods:** An inventory of products in a completed state awaiting shipment or sale.

**First in first out (FIFO):** A process to manage orders or inventory so that the oldest is processed first. The goal of FIFO is to prevent earlier orders from being delayed unfairly in favor of new orders.

**Fishbone Diagram:** See Cause-and-Effect Diagram.

**Flow:** The movement of a product or service along the value stream, from its inception to the customer.

**Flowchart:** The graphical representation of all activities in a process including tasks, delays, decisions, movement, and so on.

**Flow production:** See continuous flow.

**FMEA:** See Failure Mode Effects Analysis (FMEA).

**Freed up:** Resources or floor space made available through continuous improvement or Kaizen efforts.

**Future-State Map:** A Value Stream Map that depicts an improved view of the Value stream. See also Value Stream Map.

**Gemba:** Where the action occurs.

**Genchi genbutsu:** Go and see.

**Group technology:** The process of analyzing and categorizing products, parts, and assemblies in order to simplify design, manufacturing, purchasing, and other

business processes. The resulting categories form the basis of work-module development.

**Heijunka:** The technique of smoothing or leveling schedules.

**Heijunka box:** A tool used to control the volume and mix of production through the controlled distribution of kanban at standard, fixed intervals of time.

**Histogram:** A Bar Chart that depicts the frequency of occurrence - by the height of the bars - of numerical or measurement categories of data.

**Hoshin:** A system of planning, forms, and rules that engages everyone in addressing business at both the strategic and tactical levels. It is also known as policy deployment or hoshin kanri.

**Hoshin kanri:** See hoshin.

**Ideal-State Map:** A Value Stream Map that depicts a value stream comprised of only value-added activities. See also Value Stream Map.

**Information flow:** The uninterrupted progression of supporting data and instructions along the value stream.

**Inspection:** The act of comparing a product to a predefined performance standard. Inspection is a non-value-added activity, especially when it occurs after the transformational step in the process.

**Inventory:** The raw materials, purchased parts, work-in-process components, and finished goods that are not yet sold to a customer. Inventory is one of the seven forms of waste, when the amounts exceed the minimum level to maintain the pull system. See also seven forms of waste.

**Inventory turns:** Financial measure of the Cost of Goods Sold (COGS) in a given period (annually) divided by the Average Inventory for the same period.

**Ishikawa Diagram:** See Cause-and-Effect Diagram.

**jidoka:** Transference of human intelligence to machines via automation. The automation enables the equipment

to detect defects and stop until someone comes to fix the problem. This supports quality at the source and the prevention of defects from progressing along the value stream. Additionally, the person in charge of the step in the value stream is responsible to resolve the issue or stop the flow to get outside assistance.

**just-in-time:** Providing what is needed, when it is needed, in the quantity needed, and the quality level needed.

**Kaikaku:** Radical improvement activity to reduce waste.

**Kaizen:** Incremental continuous improvement that increases the effectiveness of an activity to produce more value with less waste.

**Kanban:** A signal that triggers replenishment or withdrawal in a pull system. Kanban is often in the form of a card on a container in production environments. The signal regulates the production flow in the value stream.

**Lead time:** The elapsed time from the initial stage of a project or policy and the appearance of results. In the case of a product environment, the time from order receipt to shipment to the customer for one product.

**Lean:** An improvement methodology based on a customer-centric definition of value, and providing that value in the most effective way possible, through a combination of the elimination of waste and a motivated and engaged workforce.

**Left I hand/right I hand analysis:** A method to analyze the motion of an operator's hands to perform a process step. The analysis is then used to eliminate the waste caused by unnecessary motion. level production: See heijunka.

**Level scheduling:** The practice of averaging out both the volume and mix of products in the production schedule. Leveling allows a consistent workflow, reducing the fluctuation of customer demand with the eventual goal of being able to produce every product every day according to demand.

**Level selling:** A sales method characterized by the



elimination of artificial demand spikes, created by sales incentives and promotions. The resulting sales process coupled with a Lean production process can respond to real fluctuations caused by customer demand.

**Line balance:** The process of aligning the cycle times and operator staffing of a process to takt time. See also takt time.

**Mass production:** See batch and queue.

**Material flow:** The movement of raw materials and product through the process steps of a value stream.

**Metric:** A measure that is considered to be a key indicator of performance.

**Milk run:** A method of consolidating material shipments that includes the routing of trucks to collect materials from various suppliers based on kanban signals, fixed routes, and fixed times. Milk runs help to control the incoming flow of materials into a facility.

**Module:** See work module.

**Monument:** A unit or piece of equipment that cannot or should not be moved due to process constraints.

**Motion:** Any movement of people's bodies that does not add value to the process. One of the seven forms of waste. See also seven forms of waste.

**Muda:** Any activity that consumes resources, but creates no value. Muda is categorized in two forms: Type-1 muda is necessary for the process, but nonvalue-added; type-2 muda is both unnecessary and non-value-added.

**Mura:** Waste due to unevenness or variation.

**Muri:** Waste or stress on the system due to overburdening or unreasonableness.

**Non-value-added:** Any activity, product, or process that does not meet the value-added criteria. See also value-added.

**OEE:** See Overall Equipment Effectiveness (OEE).

**Overall Equipment Effectiveness (OEE):** The measurement of how effectively equipment is being used. It is calculated as a percentage. The formula is  $OEE \% = Availability \times Performance Rate \times Quality$ .

**Overproduction:** Producing more than the customer requires. One of the seven forms of waste. See also seven forms of waste.

**Pacemaker process:** The operation that establishes the pace of the production of a product or service; its rate of production should be equal to or close to takt time. See also takt time.

**Pareto Chart:** A bar chart where the categories are presented in descending order of frequency. The Pareto principle states that 80 percent of the data will fall in 20 percent of the categories.

**PDCA:** See Plan-Do-Check-Act (PDCA) or Plan-Do-Study-Act (PDSA).

**PDSA:** See Plan-Do-Check-Act (PDCA) or Plan-Do-Study-Act (PDSA).

**Pitch:** The amount of time required to make one container of product. The formula is  $Pitch = Takt Time \times Container Quantity$ .

**Plan-Do-Check-Act (PDCA) or Plan-Do-Study-Act (PDSA):** A short-cycle iterative improvement scheme at the core of the Kaizen process. This four-step process includes (1) defining the objectives, issues, and potential solution; (2) carrying out the plan in a trial mode; (3) verifying and studying trial results; (4) fully implementing and standardizing the solution. It is also called the Shewhart cycle or Deming cycle.

**Poka-yoke:** A device to prevent defect production.

**Policy deployment:** See hoshin.

**Process:** A set of activities, material, and/or information flow that transforms a set of inputs into defined outputs.

**Process owner:** The individual who has responsibility for process performance and resources, and who provides

support, resources, and functional Expertise to projects. The process owner is accountable for implementing process improvements.

**Product family:** A group of products or services that require all or a majority of the same processing steps for completion.

**Pull:** A system of production that is activated by customer demand, which signals all the upstream activities to build to replenish what has been used. Upstream activities do not do anything until the signal from downstream is received.

**QID:** See Quality Function Deployment (QFD).

**Quality at the source:** A process that ensures the quality level of a product or service before it leaves the transformation station in a process. The implementation of poki-yoke and jidoka are key aspects to creating quality at the source.

**Quality Function Deployment (QID):** A systematic process for identifying and integrating customer requirements into every aspect of the design and Delivery of products and services.

**Rework:** Activities required to correct defects produced by a process.

**Run Chart:** A graphical tool for charting performance of a characteristic over time.

**Scatter Plot:** A chart in which one variable is plotted against another to observe or determine the relationship, if any, between the two.

**Sensei:** Master or teacher, in this context, of Lean.

**Setup reduction:** See single minute exchange of die.

**Seven forms of waste:** Transportation, waiting, overproduction, defects, inventory, motion, and excess processing are the seven forms of waste identified by Taiichi Ohno, one of the pioneers of the Toyota Production System, as waste normally found in mass production. Also known as the seven wastes or the seven mudas.

**Shewhart Cycle:** See Plan-Do-Check-Act (PDCA) or Plan-Do-Study-Act (PDSA). single minute exchange of die (SMED): Term used to describe the compilation of tools and techniques used to dramatically reduce the time required to complete the changeover of production and support of one "product" to another. Think Indy pit-crew tire changes.

**SMED:** See single minute exchange of die (SMED).

**Smoothing:** See level scheduling and heijunka.

**Spaghetti Chart:** A graphical representation of the movement of materials or people in a process. It is used to eliminate wasted motion or transportation. standardized work: The definition of a process step characterized by takt time, a set work sequence and established In-process inventory. Deviations to standardized work constitutes an abnormality, which is then an opportunity for improvement.

**Supermarket:** The location where a predefined amount of inventory is controlled and released into a pull system by kanban.

**Supplier:** An individual or entity that provides an input to a process in the form of resources or information.

**Takt time:** Takt is the German word for "beat." In Lean, takt time is the pace of production based on the rate of customer consumption.

**Therblig analysis:** A method to analyze the motion that an operator performs within a process step based on 18 standardized elements. The analysis is then used to eliminate the waste caused by unnecessary motion.

**Total Productive Maintenance (TPM):** A proactive approach to maintaining equipment. It is divided into three areas: autonomous maintenance, planned maintenance, and predictive maintenance. Its aim is to maximize the overall equipment efficiency (OEE) and minimize production losses due to equipment failure or malfunction.

See also Overall Equipment Effectiveness.

**Toyota Production System (TPS):** A production

system developed by the Toyota Motor Corporation based on the philosophy that the ideal condition for production is created when machines, facilities, and people work together adding value without creating waste. The two pillars of the TPS are just-in-time and jidoka. See also just-in-time and jidoka.

**TPM:** See Total Productive Maintenance (TPM).

**TPS:** See Toyota Production System (TPS).

**Traditional manufacturing:** See batch and queue.

**Transportation:** Unnecessary movement of materials or other items from one place to another, usually to storage or staging areas. See seven forms of waste.

**TWO DIME:** A mnemonic device to remember the seven forms of waste: transportation, waiting, overproduction, defects, inventory, motion, and excess processing. See also seven forms of waste.

**Value:** The worth placed upon goods or services, as defined by the customer. See also customer.

**Value-added:** Defined by the customer and must meet the following three criteria:  
“The customer must be willing to “pay” for it. Payment is generally thought of in monetary terms, but could also include time or other resources.” The product or service must be done correctly the first time. “ The product or service must be transformed.

**Value stream:** The flow of materials and information through a process to deliver a product or service to a customer.

**Value Stream Map:** A graphical representation of how all the steps in any process line up to produce a product or service, and of the flow of information that triggers the process into action.

**VOC:** See voice of the customer (VOC).

**Voice of the customer (VOC):** The collective needs, wants, and desires of the recipient of a process output, a product, or a service, whether expressed or not. The VOC

is usually expressed as specifications, requirements, or expectations.

**Waiting:** People in a process delayed or stopped because of process waste or ineffective process design. See seven forms of waste.

**Waste:** Any activity that uses resources, but creates no value for the customer.

**WIP:** See Work-In-Process (WIP).

**Work-In-Process (WIP):** In-process inventory.

**Work module:** A co-location of all functional steps, in process sequence, to create a product or service. Generally, the work stations in these areas are arranged in a V-shape that flows counterclockwise.



