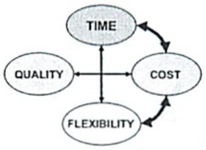
4/5

Announcements

1. Simulation assignment and data will are out. Live game, April 10-15
2. Goal report is due Thursday, April 7
3. Guest lecture on April 13, 11.30-1 (E51-345), Gavin DeNyse, HP

Production Control and SC Coordination

Production Control/SC Coordination is what determines:



- When work is performed
- What work is performed
- Who performs work

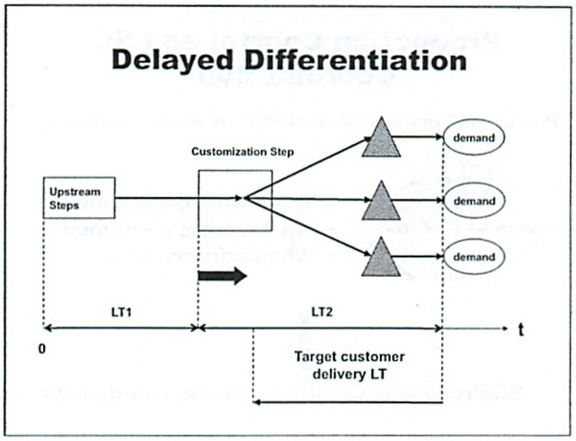
SC/Production Control = process coordination

Key Definitions

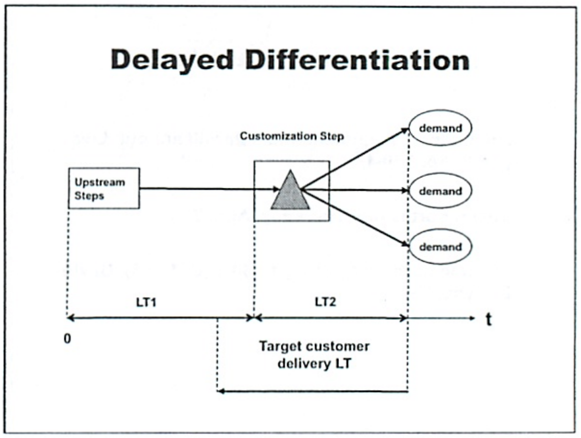
- Pull:
  Work triggered by actual downstream (possibly internal) demand
- Push:
  Work triggered by a forecast of demand
- Make-To-Order:
  Work performed towards an existing (external) customer order
- Make-To-Stock:
  Work performed for a yet unknown customer

Production/SC Control Methods

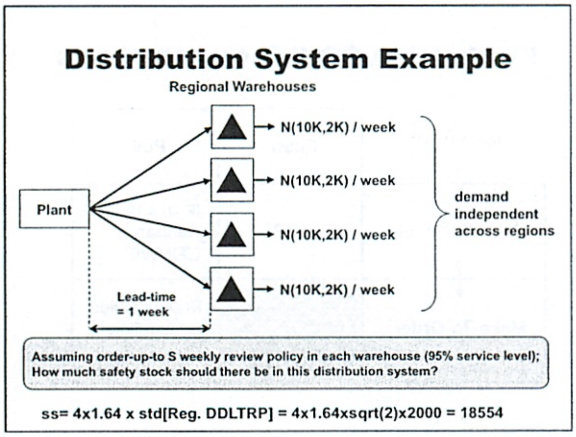
(this lecture)	Push	Pull
Make-To-Stock	MRP	(R,Q) & Up-to-S Kanban CONWIP
Make-To-Order	▨	Priority Rules Scheduling



Delayed Differentiation



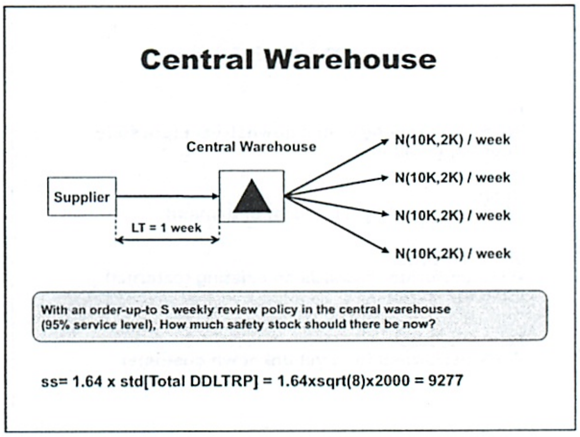
Delayed Differentiation



Distribution System Example

Assuming order-up-to S weekly review policy in each warehouse (95% service level); How much safety stock should there be in this distribution system?

ss= 4x1.64 x std[Reg. DDLTRP] = 4x1.64xsqrt(2)x2000 = 18554

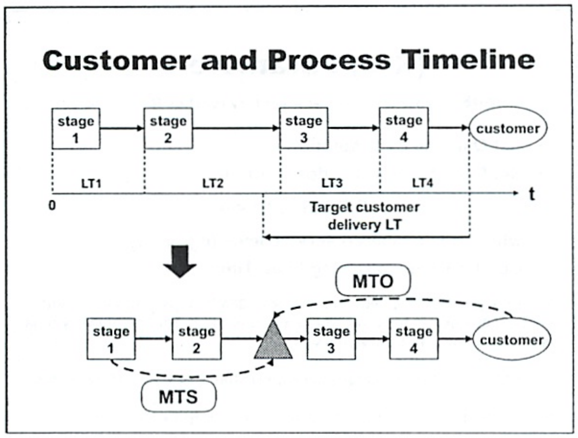


Central Warehouse

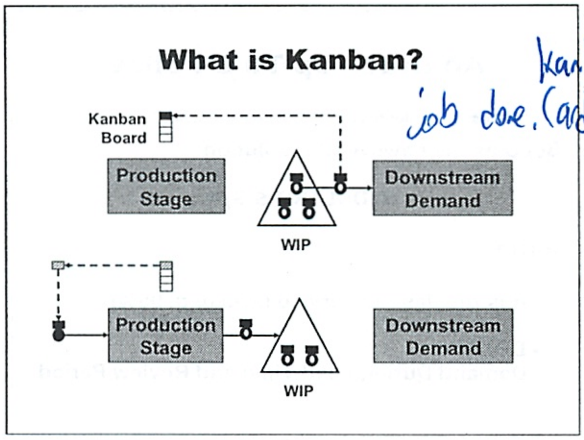
With an order-up-to S weekly review policy in the central warehouse (95% service level), How much safety stock should there be now?

ss= 1.64 x std[Total DDLTRP] = 1.64xsqrt(8)x2000 = 9277

Customer and Process Timeline

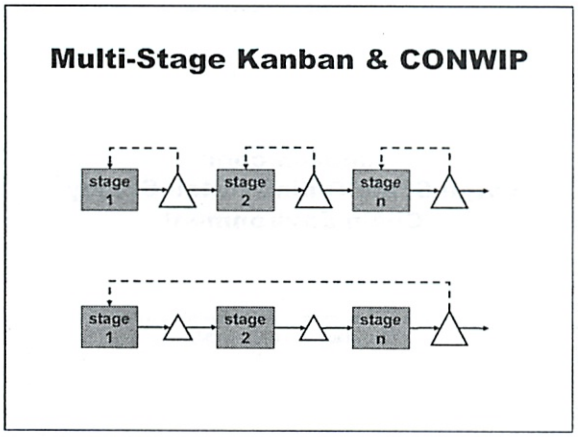


What is Kanban?

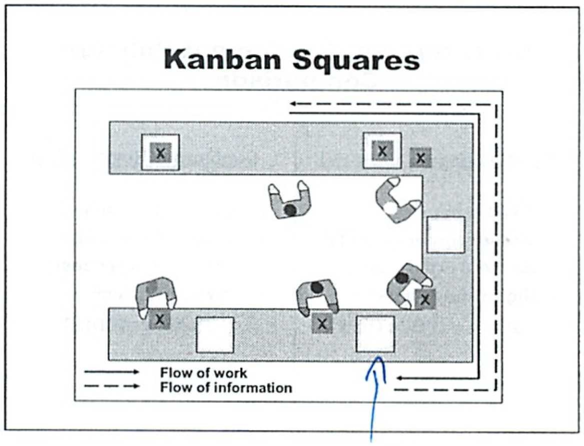


Kanban
job done. Card goes back on rack

Multi-Stage Kanban & CONWIP



Kanban Squares



Work queues
capacity = 1

An Order-Up-To S Policy

➡ "order back to S every review period"

Set S as the newsvendor solution:

$$P(DDLTRP \leq S) = \alpha$$

where:

- α is the desired service level (e.g. 95%)
- DDLTRP = Demand During Lead-Time and Review Period

(R,Q) Parameters

➡ "order Q whenever inventory reaches R"

- Set Q as the EOQ solution
- Set R as the newsvendor solution:

$$P(DDLT \leq R) = \alpha$$

where α is a desired service level (e.g. 95%)

DDLT = Demand During Lead Time

Example (cont'd): if weekly demand for 128Mb chips, each shipment costs $500 custom fees, weekly demand is N(400,80) and delivery time is 2 weeks, for a 95% service level:

Q = 1,013 units (use EOQ formula with D=400, C=45, H=0.45/52, F=500)

R = E[DDLT] + 1.64 x σ[DDLT] = 800 + 1.64 x sqrt(2) x 80 = 986

Inventory Replenishment Policies Comparison

Periodic Review (Up-to-S):	Continuous Review (R,Q):
Fixed order time	Variable order time
Variable order quantity	Fixed order quantity
No fixed order costs	High fixed order costs
High safety stock	Low safety stock
SS = k x σ[DDLTRP]	SS = k x σ[DDLT]

Amazon.com: Large-Scale Online Retail Supply Chain Environment

The Slides on Amazon.com are borrowed from Jack Muckstadt, Cornell University

Amazon.com Brief Profile

- $8.5 billion in worldwide sales in 2005; $4.7 billion in North America
- Over 40 million unique products sold on U.S. website
- Shipped over 100 million units to U.S. customers in 2005
- International websites and fulfillment networks serve the UK, Canada, Germany, Japan, China, and France

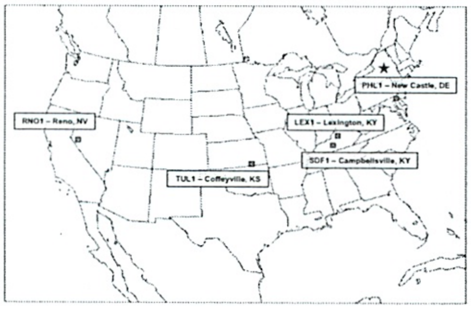
Strategic Goals

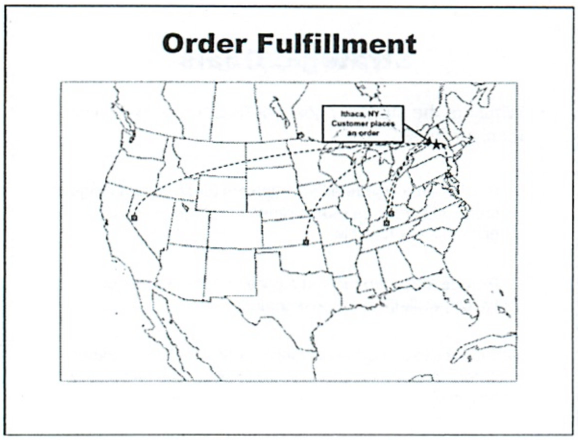
- What are the strategic goals of Amazon.com's online retail business?
  - Provide an online retail environment for as wide a range of products across as wide a range of categories as is economically feasible
  - Provide these products at a price at or below that of a typical "walk-in" retail environment
  - Offer reliable short-lead shipping (for a fee) of customer orders for as many of these products as is economically possible

Amazon.com Sortable FCs

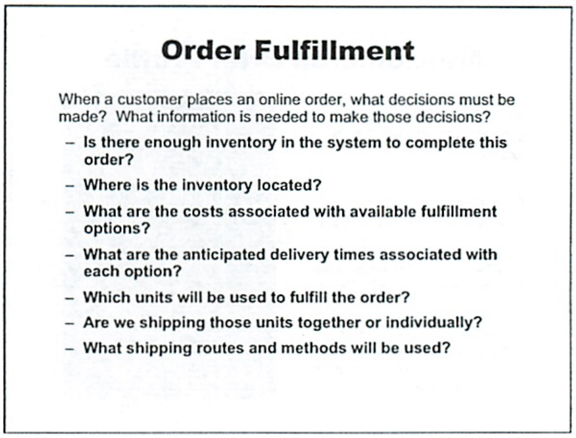
- Five major Fulfillment Centers (FCs) for "sortable" products.
  - Sortable products are within certain size restrictions.
  - Sortable products can be sent to customers in multi-item shipments.

Amazon.com Fulfillment Network





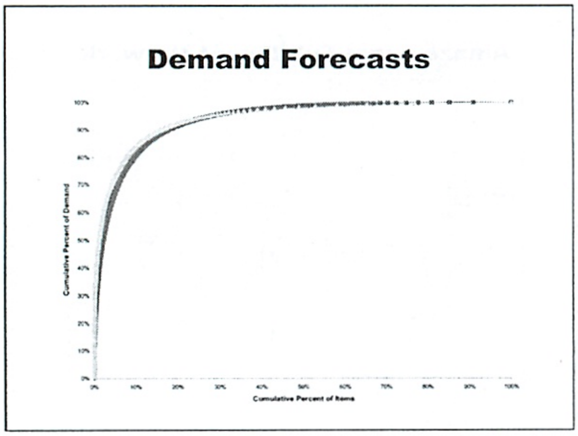
Order Fulfillment



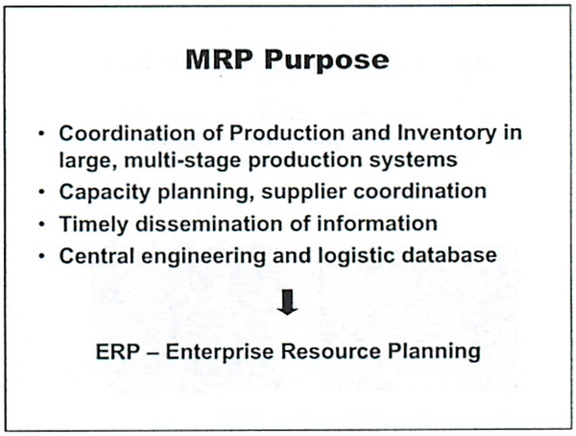
Order Fulfillment

When a customer places an online order, what decisions must be made? What information is needed to make those decisions?

- Is there enough inventory in the system to complete this order?
- Where is the inventory located?
- What are the costs associated with available fulfillment options?
- What are the anticipated delivery times associated with each option?
- Which units will be used to fulfill the order?
- Are we shipping those units together or individually?
- What shipping routes and methods will be used?



Demand Forecasts



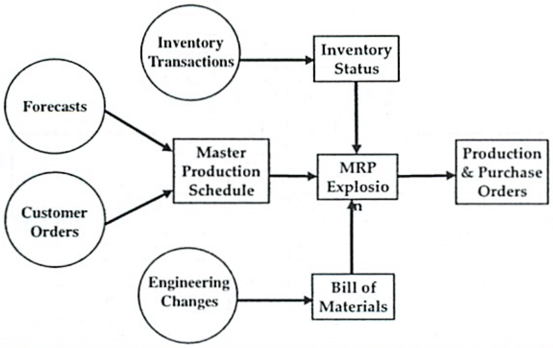
MRP Purpose

- Coordination of Production and Inventory in large, multi-stage production systems
- Capacity planning, supplier coordination
- Timely dissemination of information
- Central engineering and logistic database

⬇

ERP – Enterprise Resource Planning

Structure of MRP



Inventory Transactions

Inventory Status

Forecasts

Master Production Schedule

MRP Explosion

Production & Purchase Orders

Customer Orders

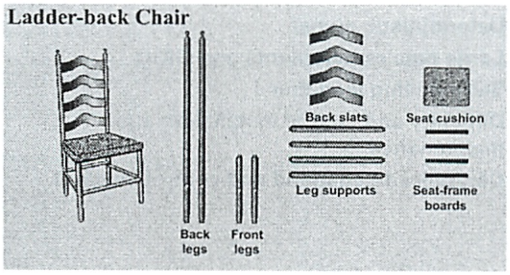
Engineering Changes

Bill of Materials

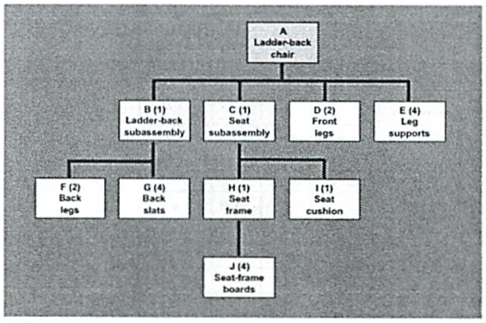
Master Production Schedule

	April				May			
	1	2	3	4	5	6	7	8
Ladder-back chair	150					150		
Kitchen chair				120			120	
Desk chair		200	200		200			200
Aggregate production plan for chair family	670				670			

Bill of Material



Bill of Material Structure



A Ladder-back chair

B (1) Ladder-back subassembly

C (1) Seat subassembly

D (2) Front legs

E (4) Leg supports

F (2) Back legs

G (4) Back slats

H (1) Seat frame

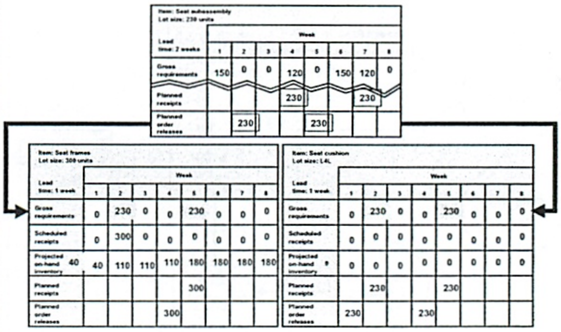
I (1) Seat cushion

J (4) Seat-frame boards

MRP Net Requirements

Item: Seat subassembly Lot size: 230 units	Week							
Lead time: 2 weeks	1	2	3	4	5	6	7	8
Gross requirements	150	0	0	120	0	150	120	0
Scheduled receipts	230	0	0	0	0	0	0	0
Projected on-hand inventory 37	117	117	117	227	227	77	187	187
Planned receipts				230			230	
Planned order releases		230			230			

MRP Demand Explosion 1

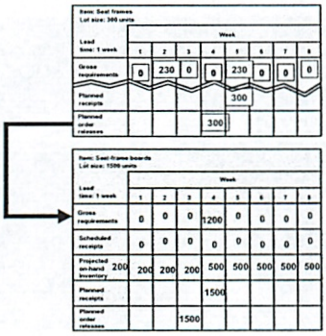


Item: Seat subassembly Lot size: 230 units	Week							
Lead time: 2 weeks	1	2	3	4	5	6	7	8
Gross requirements	150	0	0	120	0	150	120	0
Planned receipts				230			230	
Planned order releases		230			230			

Item: Seat frames Lot size: 300 units	Week							
Lead time: 1 week	1	2	3	4	5	6	7	8
Gross requirements	0	230	0	0	230	0	0	0
Scheduled receipts	0	300	0	0	0	0	0	0
Projected on-hand inventory 40	40	110	110	110	180	180	180	180
Planned receipts					300			
Planned order releases				300				

Item: Seat cushion Lot size: L4L	Week							
Lead time: 1 week	1	2	3	4	5	6	7	8
Gross requirements	0	230	0	0	230	0	0	0
Scheduled receipts	0	0	0	0	0	0	0	0
Projected on-hand inventory 0	0	0	0	0	0	0	0	0
Planned receipts		230			230			
Planned order releases	230			230				

MRP Demand Explosion 2



Item: Seat frames Lot size: 300 units	Week							
Lead time: 1 week	1	2	3	4	5	6	7	8
Gross requirements	0	230	0	0	230	0	0	0
Planned receipts					300			
Planned order releases				300				

Item: Seat-frame boards Lot size: 1500 units	Week							
Lead time: 1 week	1	2	3	4	5	6	7	8
Gross requirements	0	0	0	1200	0	0	0	0
Scheduled receipts	0	0	0	0	0	0	0	0
Projected on-hand inventory 200	200	200	200	500	500	500	500	500
Planned receipts				1500				
Planned order releases			1500					

MRP Problems

- Deterministic model
- Large data requirements and GIGO
- Self-fulfilling lead-times
- Difficulty and cost of installation and maintenance
- Centralized command and control mindset

Production/SC Control Wrap-Up

1. Production Control, Push, Pull, MTS, MTO
2. MRP, Kanban, CONWIP
3. MTS/MTO and Lead-Time Target
4. Risk Pooling and Delayed Differentiation

15.761

4/5

Fill out web survey tonight!

Goal report

- summary
- related to opps
- pull that info out

Suppy Chain coordination + production control

- entire process
- choices firms make
- how to implement
- Coordination mechnisms

- pull - downstream triggers (possibly internal)
- push - forcast controls production
- made-to-order - have an order (external)
- made-to-stock - cust still unknow

- Zara: watch 20 min video before hand

- when work perfored?
- what work " ?
- who perfoms work?

②

table of production/SC control methods

	Push	Pull
Made Stock		
Made to order	▨	

decisions how to work

Many are a mix of this

Burger King

Kanban + CONWIP are control/coordination mechanisms

MTO - lead times long, ~~d~~ supply chain disruptions devistating, surges not handled, Custom possible

MTS - inventory higher, has costs, forecasting errors

- obsilencense
- can only have fewer SKUs
- opp cost of inventory
- inventory listed as asset - but really liability - not revenue yet
- storage room for inventory

- easier to forecast for something with high demand
  - risk pooling!
- delay differentiation
  - do localication in DC

③

Can do a cross

Like only differentiating when have an order in DC

Pooling comes in diff forms

- but should ↓ costs
- b/c ↓ uncertainty

Kanban

- Pull system
- Cards attached to WIP
- # cards limited
- order must be shipped before new product started
- can do for each station
- or whole process

- need to balance line - so all cycle times are similar
- but also need to decide # cards active
  - match flow to demand

⑨

Other policies: Order up to S

- coordination mechanism

(R, Q) parameters

- only care abaut lead time
- continous vs periodic reviews

Amazon

- risk pooling
- strategy: cheap, ~~the~~
  fast shipping
- "fufilment centers" - not warehouses

15% of items = 90% of sales

So put less used items in back of warehouse

Stack related items near each other

Put high volume items in multiple DCs
So can save on shipping

Collect data to forecast better

Incentie Issues

- diff depts / diff companies in supply change have diff incentives

ERP/MRP

Planning system

Schedule production or purchasing

Bill of Materials - product components

Get master production schedule

Plan at how much inventory you have/will have

For each sub piece

But no variability /uncertanity

Garbage in → garbage out

4/5

43/50

The Goal

Michael Plasmeier

The Goal is the story of Alex Rogo and his plant owned by UniCo. Mr. Rogo is the manager of the plant. At the beginning of the story, the plant is out of control. A focus to keep everyone busy hides true high-priority orders, until the customer calls to demand the job immediately. Work in progress inventory is stacked everywhere, but not much seems to ship without a "drop everything" intervention. Mr. Rogo meets one of his old professors, Jonah, who gets him to focus on the bottlenecks of his plant and building actual customer orders. Jonah teaches him that making the plant look busy by building to inventory does nothing for the bottom line. After this and several other improvements, Alex is able to turn the plant around and he is promoted to district manager as a reward.

1. A bottleneck is any process which is processing less than the demand put on it by outside sales. At first, Ralph, the computer guy, tries to find the bottlenecks by going through computer print outs. However, he quickly finds that these are out of date. Next Alex's team talks to the expediters to see where they often saw problems. Finally, the team decides to just go out on the shop floor and look for what step had the highest WIP inventory pile in front of it. They find two: the NCX-10 and the heat treatment machine. 5
2. Jonah believes that a bottleneck should be solved at almost any cost. The cost of the bottleneck is equal to the hourly cost of the entire plant, because it is constraining the capacity of the plant. Almost any steps should be taken to increase capacity. For example, setting up a second machine or process, even if it is less efficient, would help relieve the bottleneck. In addition, if the resource is sitting idle, dedicate additional personal so that the machine is never idle. If necessary, reschedule lunch so that lunch is taken when the machine is running. At the heat treat machine, Mr. Rogo stations dedicated employees at the machine all three shifts. In addition, one of the employees figures a way to stage the parts so that they can be loaded quickly. The employee also realizes that he can load lower priority parts that need the same temperature in excess space in the furnace. Lastly, if one is very behind, one can use an outside firm to catch up on a large batch of items. As long as the cost of the improvement is less than the cost of running the entire plant, the improvement to the bottleneck is necessary. 15
3. Two part question:
    a. We have worked with *dependent events* and *statistical fluctuations* in class before. We know that certain events take a pre-determined amount of time. For example, a robot's production is 25 items an hour. Period. It can't move any faster. However, some events may take a random amount of time. Humans sometimes have a good day and sometimes have a bad day, where they work slower. In addition, some events may not occur every day, for example, your supplier in Japan is hit with a tsunami. Calculating how long a dependent event will take is easy, but predicting statistical fluctuations is much harder. Both need to be taken into account when managing a system, as is shown

in chapter 17 where a team manages to their step on time, only to have the robot backed up and they can't ship the entire order.

b. 5 2 What Jonah said is that a factory that tries to balance capacity with demand will go bankrupt. We learned in the class that we should try to make all steps take an equal amount of time to have the factory be most efficient. Jonah feels that this cannot be done in real life. Capacity takes some time to ramp up and down. Hiring and training a worker takes weeks. A worker cannot be fired without problems from the union and lower morale for the employees. On the other hand, workers can leave at any time, leaving the system in a lurch. All of these things will quickly break a carefully balanced a plant. However, Jonah believes that once should try to balance the flow of product through a plant with the demand from the market. There is little point in making stuff just to stay busy. Even if you are making something to stock, it should be to meet a certain safety stock target, and then it should be lower priority.

4. How I understood it, smaller lot sizes allow the factory to be more responsive to the demand, giving quicker response times and lower lead times. These lead to an advantage in the marketplace, as it is one of the things customers look for when deciding where to purchase from. However, smaller lot sizes also require multiple set up times. Obviously there is a sweet-spot where the tradeoff between the two effects is equal. Smaller lot sizes also does not force the plant to make a bunch of items for stock at the same time as a customer order, tying up capital in finished inventory. A large stock of finished inventory also discourages the introduction of new products. In addition, smaller lot sizes also reduces the wait time that parts face at non-bottleneck stations, further reducing WIP inventory and saving capital and space. 4.

5. 4 x✓ Optimally, the market should be the bottleneck. Any step or process in the plant should be able to be scaled up to reach the new order. That way the factory can take all of the orders that it can, in order to make the most money.

6. I really liked how the book tied the operational issues in with an interesting story. I would perhaps make the example plant more specific, by providing more data on this plant. I realize that the authors wanted to make the plant sound like a generic plant, so that managers from any industry could apply the lessons. However, I would like to see more of the details, like were shared during the hike, to study this plants old and new performance more in-depth. 3.

3.

4/7

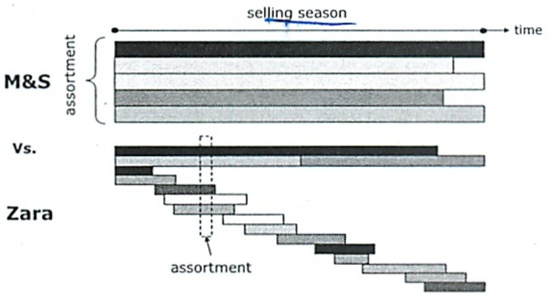
Zara Vs. Marks & Spencer

1. What are the key differences between M&S (or GAP) and Zara from a customer standpoint?
2. Discussion of M&S's supply chain and design-to-shelf cycle
3. Discussion of Zara's supply chain and design-to-shelf cycle
4. What are the relative benefits of Zara's business model?

M&S Vs. Zara For Customers

Issue	M&S	Zara

Fast-Fashion Assortment Rotation



➡ Zara's average number of customer store visits per year (Spain)?

Zara/Inditex Background

- Flagship brand of Inditex group (operates 2,800 stores, sales € 6.74 B in 2005, net income € 803 M, annual growth rate 25%)
- Zara: 900 stores in 62 countries, sales € 4.44 B in 2005, 200 designers

Sources: Inditex Group Press Dossier (2006), Freiman et al. (2002)

Zara's Store Display Policy

remaining sizes			action
S	M	L	Keep on display
	M	L	Keep on display
S	M		Keep on display
	M		Keep on display
S		L	Move to backroom
S			Move to backroom
		L	Move to backroom

remaining sizes				action
S	M	L	XL	Keep on display
	M	L	XL	Keep on display
S	M	L		Keep on display
S	M		XL	Keep on display
S		L	XL	Keep on display
S	M			Keep on display
	M	L		Keep on display
		L	XL	Move to backroom
S		L		Move to backroom
	M		XL	Move to backroom
S			XL	Move to backroom
S				Move to backroom
	M			Move to backroom
		L		Move to backroom
			XL	Move to backroom

Not all combinations of sizes are displayed:
  - Sales vs. brand perception
  - Key to inventory distribution

M&S Supply Chain and Design Cycle

Zara Supply Chain and Design Cycle

Zara Business Model: Costs and Benefits

Wrap-Up

1. Newsvendor model and the trade-offs of ordering under uncertainty (= $)
2. Costs and revenues should not be optimized separately
3. Shorter design-to-shelf lead times is a big advantage but costs money (capacity, labor, transportation)

477

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Marks + Spencer Vs Zara

- did not read/watch video

M-S	Zara
Conservitive	trendy
assortment, seasonal	fast, rolling - one month
older cust	younger cust
food + supermarket + Clothes	fashion
quality	cheap
less international	more scessful international
store owners more free	standardized
lots of sizes	3 sizes
marketing	word-of-mouth, store-design
?	prime locations
markdowns	stuff sells out quickly
buricratic	?, Communicates better

②

1

Employees not as important	Employees engaged
?	Many employees per store
items there for season	items turn over freq
perhaps not that often	Cust visit freq ~once a week
avg ~5 ~~pra~~ visits/year	Avg 17 ~~purchases~~ visits/year
Company	just a brand

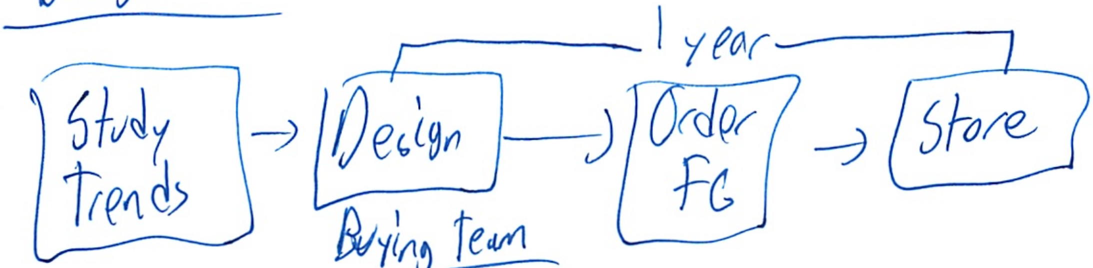
Zara

Does not leave leftover sizes on display
- moves to backroom

③

M+S

Design Chain



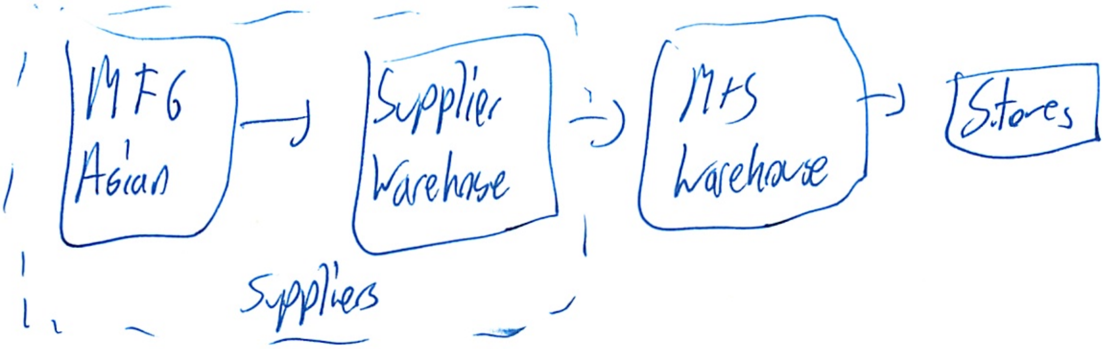
Try to forecast from previous seasons

Buying team

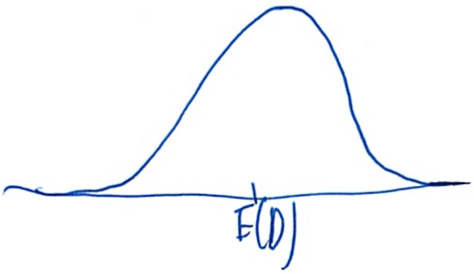
- stylists
- selectors
- merchandizers
- Technologists

Why does it take 1 year?

- Order from Asia



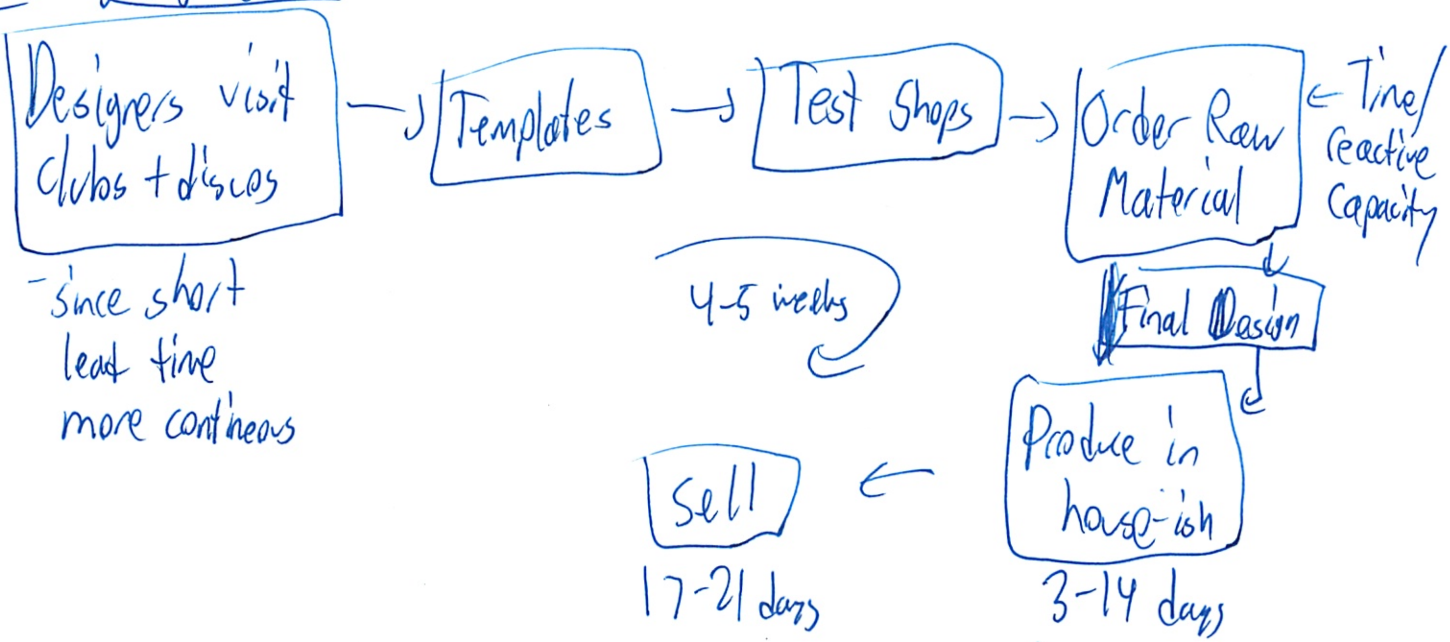
Newsvendor model



①

At end of season - markdown time

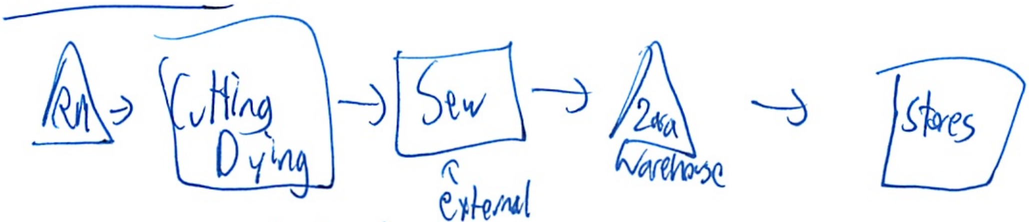
Zara Design Chain



- since short lead time more contineous

- have external sewing cooperatives

Supply Chain



most in house
in spain
- faster, but more expensive
Ok - 12,000 items/year SKUs

New styles are kinda different

Can react quickly - so forecasting is not that important

⑤

Send out orders 2-3/week   deliveries ~ 4/week
- truck optimization

Communication b/w store managers

Can take advantage of ~~yo~~ knowing customers

Do have to forecasting RM
- risk pooling

Don't care about stock-out

Zara Pros + Cons

~~Lead time~~

Can you still do this supply chain but diff product?

Announcements

1. Goal report is due Now!
2. Guest lecture on April 13, 11.30-1 (E51-345), Gavin DeNyse, HP
3. Simulation assignment and data will are out. Live game, April 10-15. Recitations will cover material relevant for the game

Zara Vs. Marks & Spencer

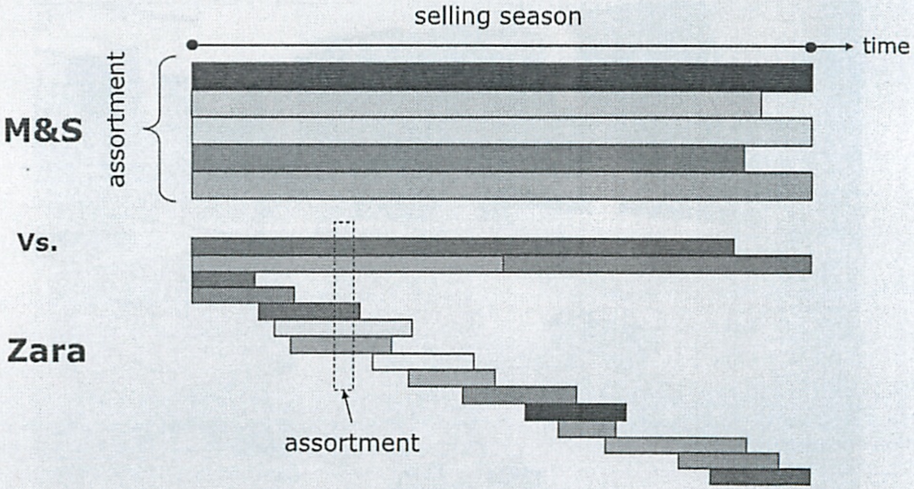
1. What are the key differences between M&S (or GAP) and Zara from a customer standpoint? (Wattana Kulkolakan)
2. Discussion of M&S's supply chain and design-to-shelf cycle (Suhail Ahmad)
3. Discussion of Zara's supply chain and design-to-shelf cycle (Natalia Baryshnikova)
4. What are the relative benefits of Zara's business model? (Ankit Jain)

Solutions

M&S Vs. Zara For Customers

Issue	M&S	Zara

Fast-Fashion Assortment Rotation

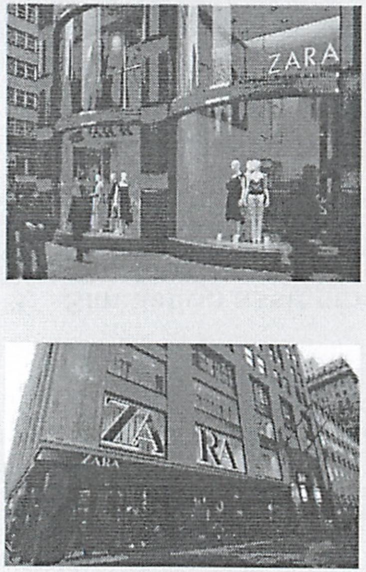


➡ Zara's average number of customer store visits per year (Spain)?

Zara/Inditex Background

- Flagship brand of Inditex group (operates 2,800 stores, sales € 6.74 B in 2005, net income € 803 M, annual growth rate 25%)
- Zara: 900 stores in 62 countries, sales € 4.44 B in 2005, 200 designers

Sources: Inditex Group Press Dossier (2006), Freiman et al. (2002)



Zara's Store Display Policy

remaining sizes			action
S	M	L	Keep on display
	M	L	Keep on display
S	M		Keep on display
	M		Keep on display
S		L	Move to backroom
S			Move to backroom
		L	Move to backroom

remaining sizes				action
S	M	L	XL	Keep on display
	M	L	XL	Keep on display
S	M	L		Keep on display
S	M		XL	Keep on display
S		L	XL	Keep on display
S	M			Keep on display
	M	L		Keep on display
		L	XL	Move to backroom
S		L		Move to backroom
	M		XL	Move to backroom
S			XL	Move to backroom
S				Move to backroom
	M			Move to backroom
		L		Move to backroom
			XL	Move to backroom

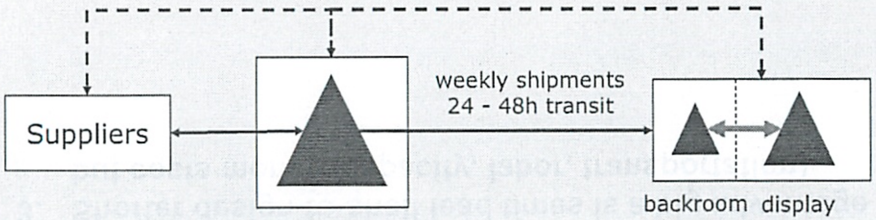
Not all combinations of sizes are displayed:

- Sales vs. brand perception
- Key to inventory distribution

M&S Supply Chain and Design Cycle

Zara Supply Chain and Design Cycle

Zara's Supply Chain



2 warehouses:
Arteixo and
Zaragoza

900 Stores:
45.4% → Spain
37.3% → R. Europe
10.5% → America
6.7% → R. World

Source: Freiman, N., M. Singh, L. Arrington and C. Paris, "Zara," Columbia Business School Case, 2002.

Zara Business Model: Costs and Benefits

Wrap-Up

1. Newsvendor model and the trade-offs of ordering under uncertainty (= $)
2. Costs and revenues should not be optimized separately
3. Shorter design-to-shelf lead times is a big advantage but costs money (capacity, labor, transportation)

4/12

Announcements

1. Simulation now running!
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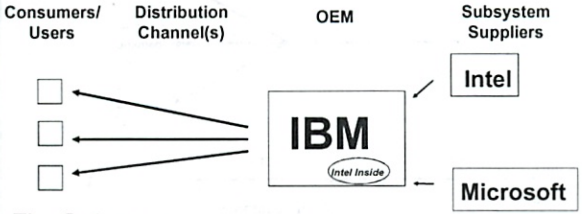
Some of the slides in this lecture are based on slides of Professor Charlie Fine

HP vs. Dell

1. History of the PC/computing industry
2. Dell's supply/value chain – design and operations
3. HP vs. Dell – comparative supply chain perspective
4. How HP reacted

IBM Enters the PC Market

1980: IBM designs a product, a process, & a value chain

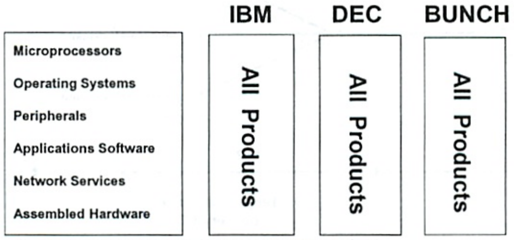


The Outcome:

A phenomenally successful product design
A disastrous value chain design (for IBM)

Vertical Industry Structure with *Integral* Product/System

Computer Industry Structure, 1975-85



(A. Grove, Intel; and Farrell, Hunter & Saloner, Stanford)

Horizontal Industry Structure With *Modular* Product/System Architecture

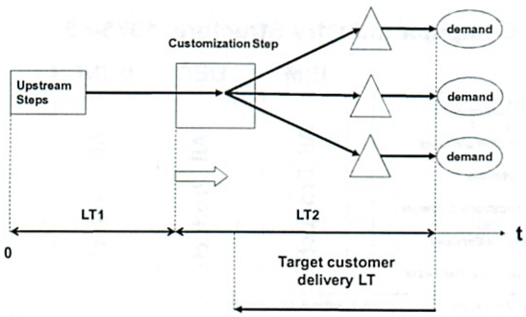
Computer Industry Structure, 1985-99

Microprocessors	Intel	Moto	AMD	etc	
Operating Systems	Microsoft	Mac	Unix		
Peripherals	HP	Epson	Seagate	etc	etc
Applications Software	Microsoft	Lotus	Novell	etc	
Network Services	AOL/Netscape	Microsoft	EDS	etc	
Assembled Hardware	HP	Compaq	IBM	Dell	etc

(A. Grove, Intel; and Farrell, Hunter & Saloner, Stanford)

Dell's Supply Chain

Delayed Differentiation



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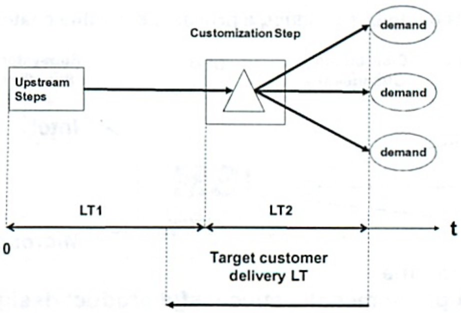
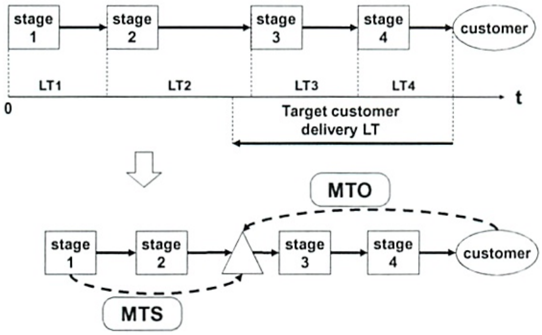


Customer and Process Timeline



HP vs. Dell

1. The concepts of Push, Pull, MTS, MTO are connected to goals and capabilities of the value chain
2. Product, Process and Supply chain designs are all interrelated!
3. Different players in market have different tradeoff balance

15.761 Dell vs HP

4/12

(3 min late)

IBM started personal computer revolution
- did lots of stuff inside
- Smaller margins in consumer so not focused on
- Intel + MS big suppliers later on
- In very begining - companies did everything
- Then market much more modalized

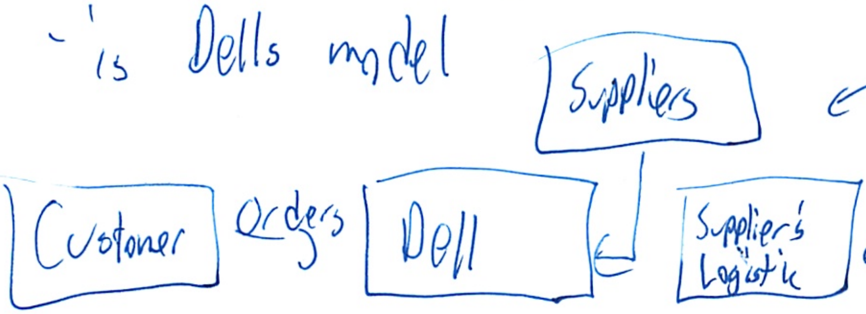
Value of PC

- typewriter
- replaced mundane office tasks
- data collection
- Commodity
- more of a nessity than a car
- PCs more personalized now
  - more branding/design today
  - not much in 1990s
- more choosing components
  - less so in laptop
  - brand more important in laptop

②

Less standardization in 1990s

Get rid of extra steps in dist. chain
- is Dells model



← Virtual integration

← Vendor managed inventory (VMI)

No distributer in middle

Will see Thur why VMI better
- Shifts cost to vendor of interview
- couldn't many answers besides this

<u>Made to Order</u>

- less forcasting
- long lead times
- low inventory cost
- fast feedback
- direct relationship w/ cust

[illegible] ③

- Making custom - labor costs slightly higher?
- less availibility
- won't be stuck w/ old parts
- more dependency on suppliers
- higher margin?
- can hard to switch suppliers
- quality check harder
- cust service harder
    - config not standard

    (But I don't agree w/ this - this works w/ Dell
    - others change rapidly too
    - standard config over years
- process overhead of having all these parts
- managing orders
- can it easily be copied?
- transportation costs

Parts special to fit together in laptops

People wanted to see laptops - kiosks

④

Supplier Logistic Center (SLC)

- long term relationship
- shorter lead times
- shift risk to supplier
    - Since Dell is so big can destroy supplier
        - like WalMart
    - supplier has risk anyway
        - compacting it

w/ large cust their cust IT dept handle tech support
- talk to tech people

HP focused more on institutions
- more of fashion accessory
- special software
- TouchSmart
- better relationship w/ suppliers - like BBY
- less models

Fashion
- Cloud / Services model

Announcements

1. Simulation now running!
2. Guest lecture on April 13, 11.30-1 (E51-345), Gavin DeNyse, HP
3. More feedback lunches

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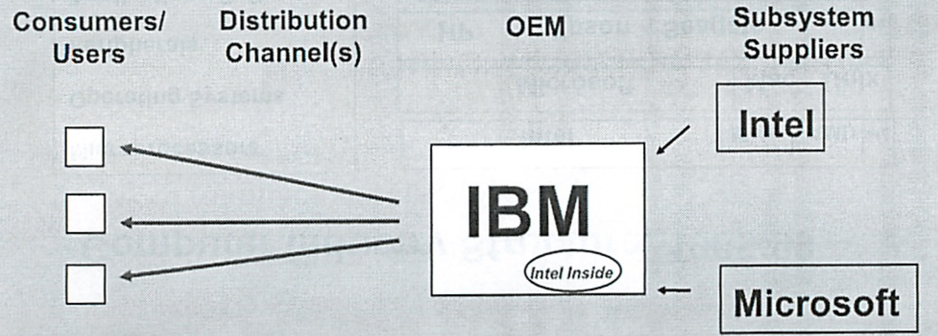

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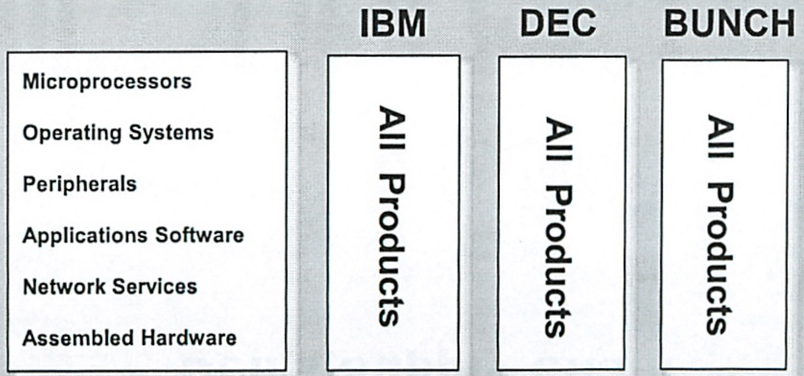

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4/13 SYN

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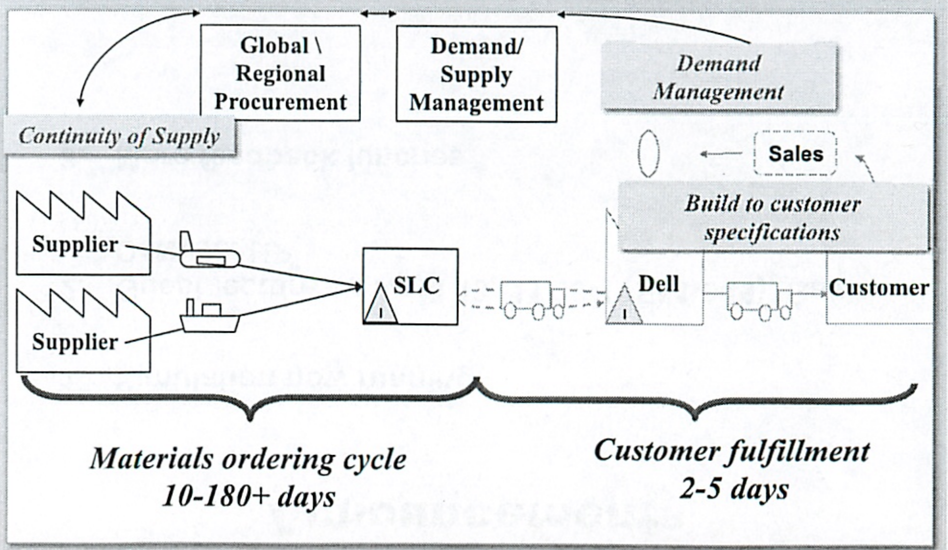
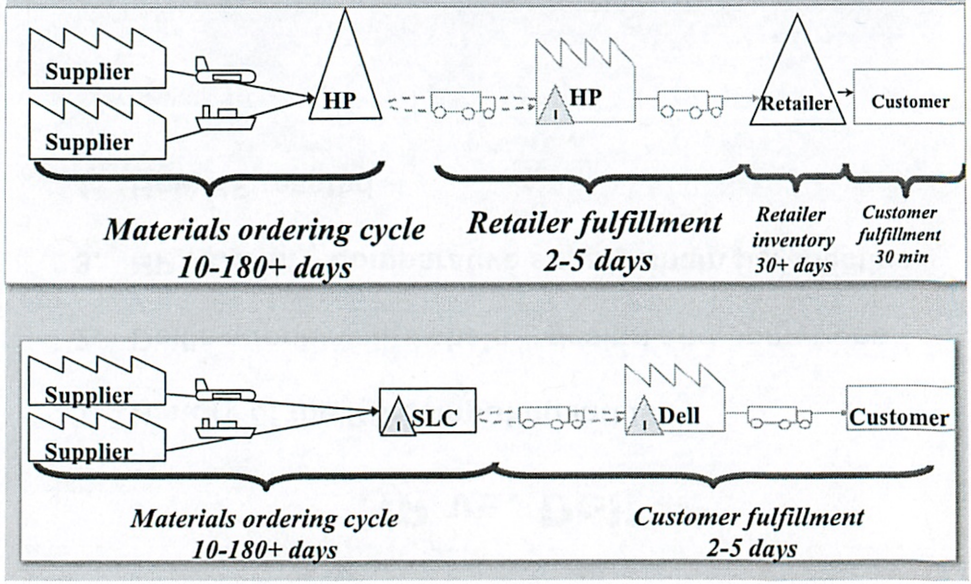
Dell's Supply Chain

Dell's Supply Chain

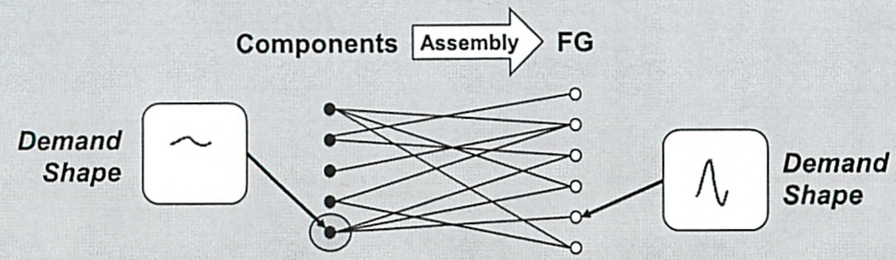


Modular Product Architecture enables Modular Supply Chain

Dell vs. HP Supply Chains



Component Commonality



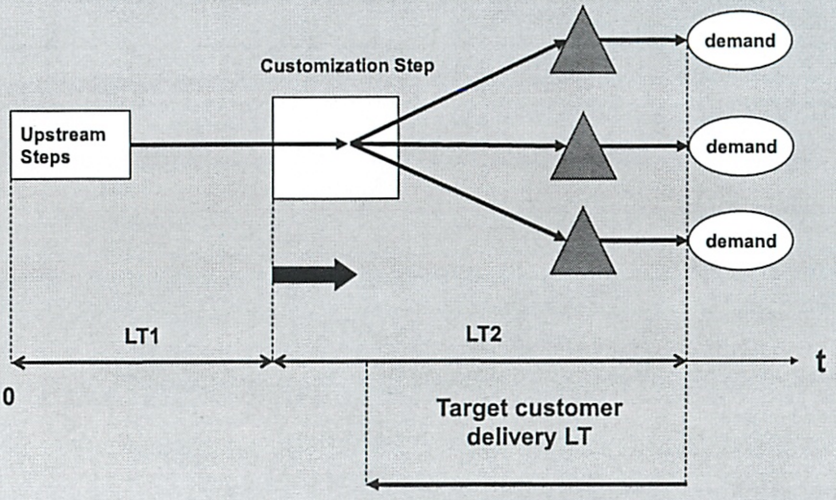
Components
Assembly
FG

Demand Shape

Demand Shape

- Instead of geographic differentiation, this is an assembly differentiation

Delayed Differentiation



Customization Step

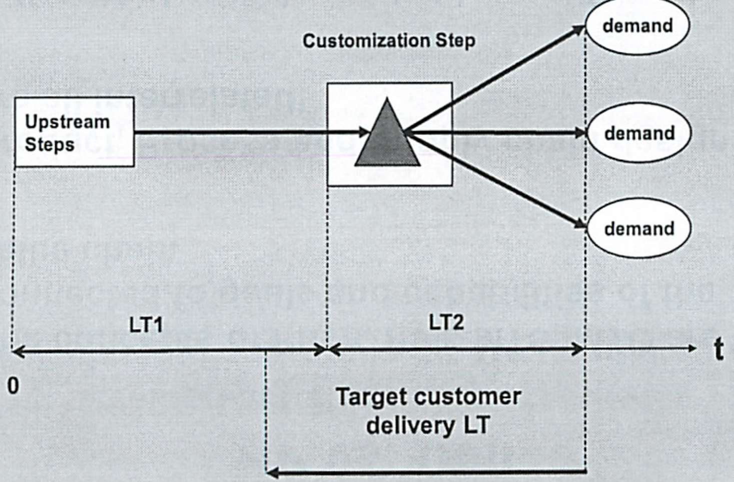
Upstream Steps

demand
demand
demand

LT1
LT2
t
0

Target customer delivery LT

Delayed Differentiation



Customization Step

Upstream Steps

demand
demand
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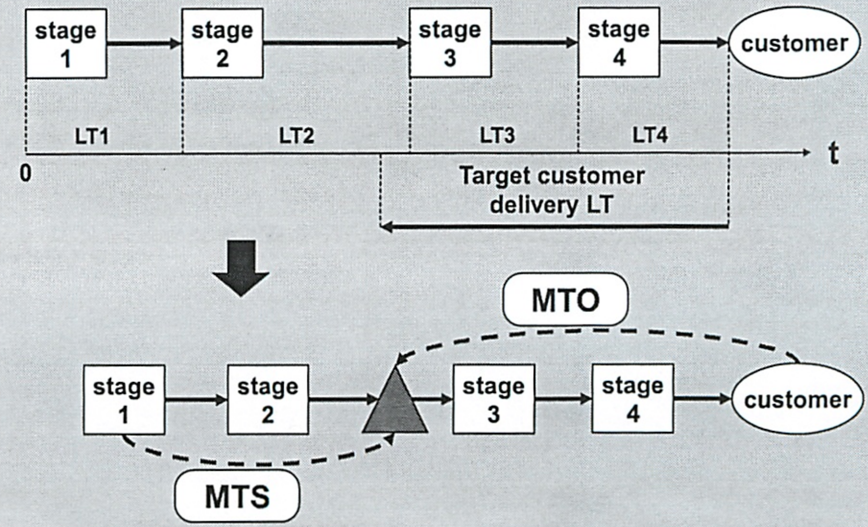
Target customer delivery LT

Customer and Process Timeline



stage 1
stage 2
stage 3
stage 4
customer

LT1
LT2
LT3
LT4
t
0

Target customer delivery LT

MTO

stage 1
stage 2
stage 3
stage 4
customer

MTS

HP vs. Dell

1. The concepts of Push, Pull, MTS, MTO are connected to goals and capabilities of the value chain
2. Product, Process and Supply chain designs are all interrelated!
3. Different players in market have different tradeoff balance

Announcements

1. No recitations this week
2. Guest lecture TODAY, 11.30-1 (E51-345), Gavin DeNyse, HP

Barilla Case

1. What problem was JITD designed to solve? What are its underlying causes?
2. What is the principle of JITD? Why is it supposed to be effective?
3. What are the sources of resistance to this program?
4. How can Barilla implement this program?

Was absent

Barilla's Supply Chain

Demand Variability

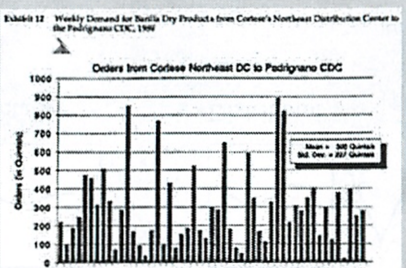
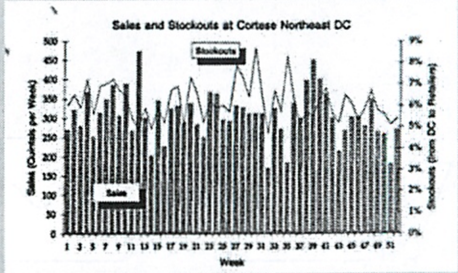
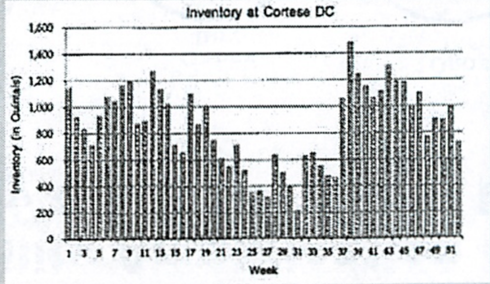


Exhibit 12 Weekly Demand for Barilla Dry Products from Cortese's Northeast Distribution Center to the Pedrignano CDC, 1989

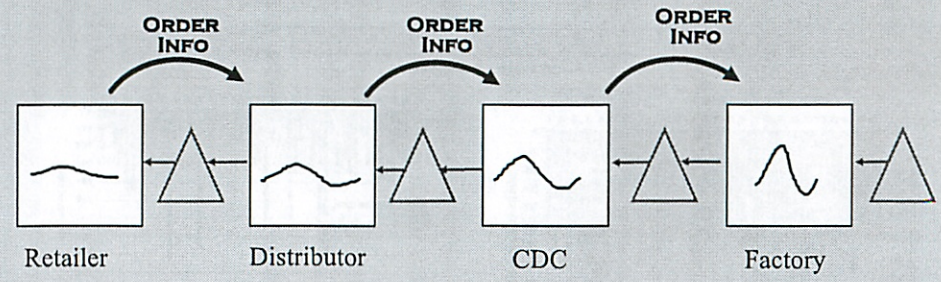




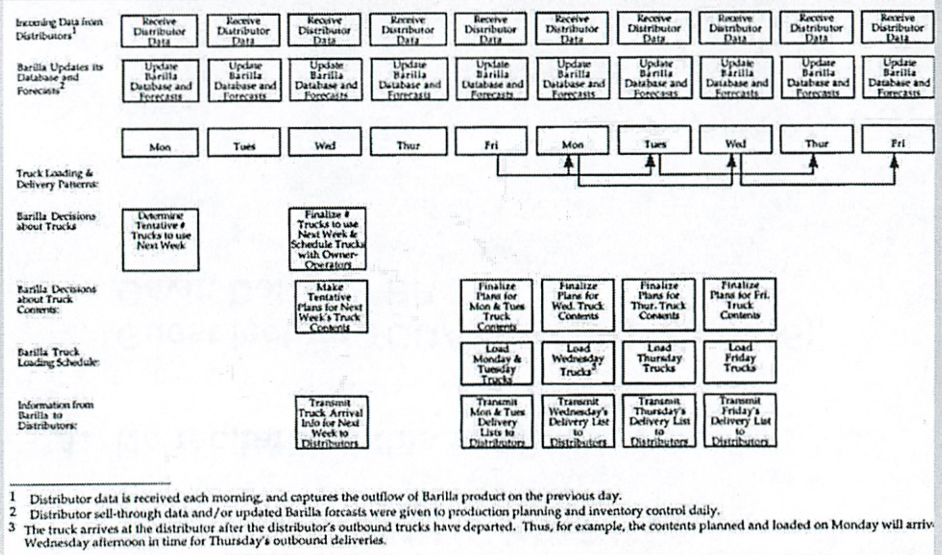
4/15

Sources and Costs of Order Variability

Volatility Amplification in the Supply Chain: Bullwhip Effect



JITD Timeline Description



Incoming Data from Distributors[1]	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data	Receive Distributor Data
Barilla Updates its Database and Forecasts[2]	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts	Update Barilla Database and Forecasts
	Mon	Tues	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri
Truck Loading & Delivery Patterns:										
Barilla Decisions about Trucks	Determine Tentative # Trucks to use Next Week		Finalize # Trucks to use Next Week & Schedule Trucks with Owner-Operators							
Barilla Decisions about Truck Contents:			Make Tentative Plans for Next Week's Truck Contents		Finalize Plans for Mon & Tues Truck Contents	Finalize Plans for Wed. Truck Contents	Finalize Plans for Thur. Truck Contents	Finalize Plans for Fri. Truck Contents		
Barilla Truck Loading Schedule:					Load Monday & Tuesday Trucks	Load Wednesday Trucks[3]	Load Thursday Trucks	Load Friday Trucks		
Information from Barilla to Distributors:			Transmit Truck Arrival Info for Next Week to Distributors		Transmit Mon & Tues Delivery Lists to Distributors	Transmit Wednesday's Delivery List to Distributors	Transmit Thursday's Delivery List to Distributors	Transmit Friday's Delivery List to Distributors		

---

[1] Distributor data is received each morning, and captures the outflow of Barilla product on the previous day.

[2] Distributor sell-through data and/or updated Barilla forcasts were given to production planning and inventory control daily.

[3] The truck arrives at the distributor after the distributor's outbound trucks have departed. Thus, for example, the contents planned and loaded on Monday will arriv Wednesday afternoon in time for Thursday's outbound deliveries.

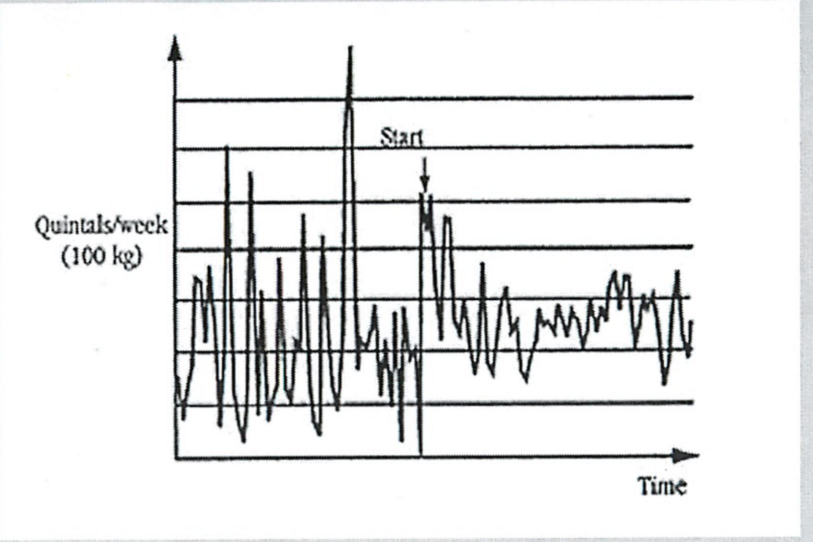
Periodic Review Parameters

Main idea: set target level S such that:

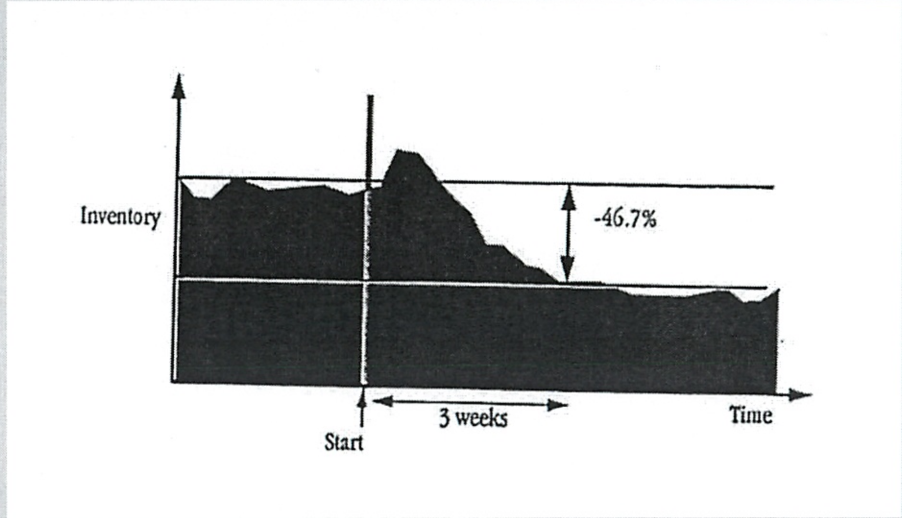
$$P(\text{DDLTRP} \leq S) = \alpha \quad \text{(ex: 95\%)}$$

- **Target Level:** $S = E[\text{DDLTRP}] + k\sigma[\text{DDLTRP}]$
- **Safety Stock:** $SS = k\sigma[\text{DDLTRP}]$
- **Cycle Stock:** $CS = E[\text{DDRP}] / 2$
- **Pipeline Inventory:** $PS = E[\text{DDLT}]$
- **Total Stock:** $TS = S - CS$

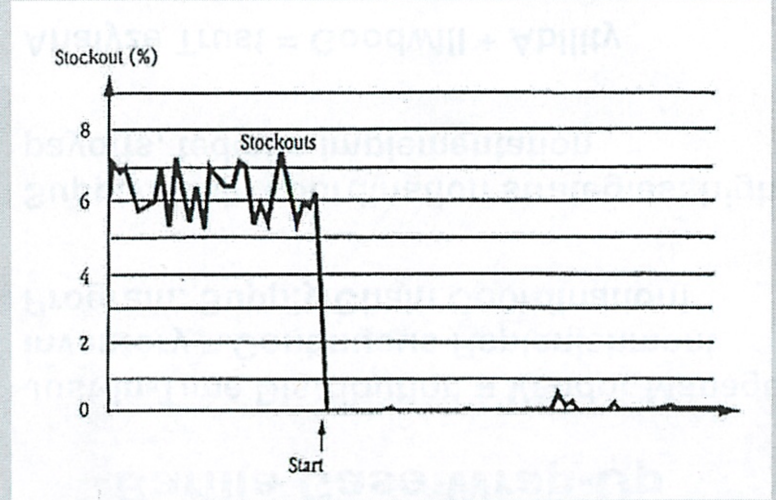
Shipments from Barilla to the Marchese Distribution Center, Before and After Start of JITD Program



Inventory of Barilla Products in Marchese DC, Before and After Start of JITD Program



Stockout Rate from Marchese DC to Retailers, Before and After Start of JITD Program



What Happened

- 1988: Maggiali appointed as Director of Logistics (JITD concept already formulated)
- 1988-1990: Unsuccessful attempts to convince 2-3 external distributors
- Late 1990: Pilot program starts with Florence depot
- Late 1993: Convinced distributor (Marchese) to start 6 month simulation + pilot implementation
- 1994: Program implementation scaled up

Barilla Case Wrap-Up

1. Just-In-Time Distribution = Vendor Managed Inventory = Continuous Replenishment Program: Supply Chain Coordination!
2. Supply chain coordination strategies: high payoffs, tedious implementation
3. Analyze Trust = Goodwill + Ability

MSD 8 Variability

4/19
Car

- Variability leads to Throughput losses
- with no buffers

- averages don't work
- flow rate = min(demand, capacity)
- can't make up for losses where constrained by capacity
  - "buffer or suffer"
- emergancy rooms same
  - can onto diversion

$$\text{Capacity} = \frac{\#\text{ of resources}}{\text{Activity time}}$$

- But most exponential arrival times → $CV_{arrival} = 1$
- Hardest part is finding P_m = Prob(m people in clinic)

  ↑ m = # of patients in clinic

  - depends on 2 variables:
    - implied utilization - can be >100 u

      $\frac{\text{demand}}{\text{capacity}}$ NOT $\frac{\text{flow rate}}{\text{capacity}}$

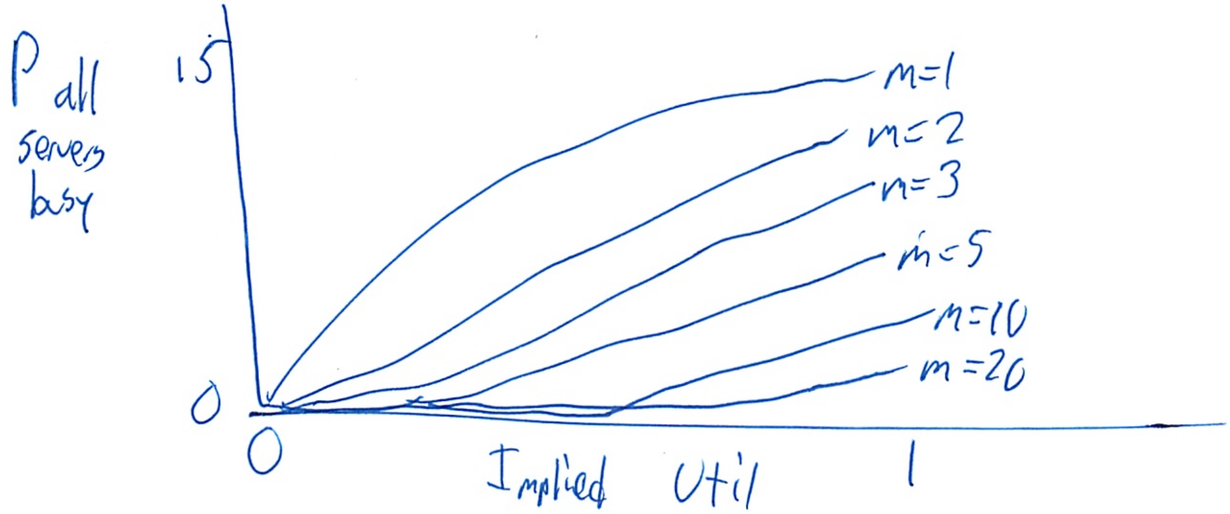
    - # of resources m

②

Use Erlang Loss Table to look up P(all resources in use)
(how is this diff than earlier?)

- Does not depend on service time variation

- Flow rate = Demand rate × P(not all servers busy)
- Divert rate = " × P(all servers busy)



8.4 Cust Impatience + Throughput Loss

- Usually there is a queue, but its size is limited
  - # phone circuits
  - lenght of drive-through line
  - or custs unwilling to wait after a certain point
- adding buffers adds capacity quickly
- Custs can balk at joining the queue
- or leave the line after waiting some time
  ↑ seperate thing to think about

Can do a few things to ↓

- Some ↓ wait times
  - add capacity
  - ↓ variability
- ↑ max units in buffer
- but worst is when custs leave after doing some waiting
  - So tell them wait time at start
  - So can do other errands or decide not to wait
  - give people something to do

8.5 Several Resources in Seq

- where outflow process 1 = inflow of process 2
- called tandem queues
- resource is blocked if unable to release the flow unit it just completed, if no space in next buffer
- resource is starved if it is idle and buffer feeding resource is also empty

decoupling inventory - by adding buffers - reduces dependencies b/w steps

horizontal pooling - combining multiple steps into 1
  - removes blocking + starving

Watch for exploding inventories ↑ in size

9 MSD Quality Management

4/19
Car

- Many processes suffer from quality problems

9.1 Controling Variation

Variation is at root of all quality problems

Use statistical process control (SPC) to check for quality problems

Variation is bad b/c then product might not work

9.2 2 types of variation:

Common causes - from pure randomness of the process
- no 2 things exactly alike
- Form a normal distribution

assignable causes - changes in underlying stat. distribution of process
- Only affects a subset of parts

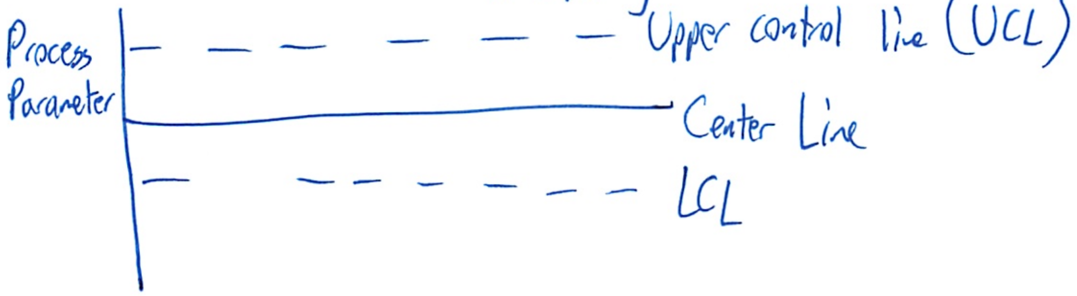
distinction b/w two kinda merky
- and in eye of the beholder

Want to
- alert management to assignable cause variations
- measure amt of variation in process
- assign causes to variation that is percieved as pure random to try to ↓

②

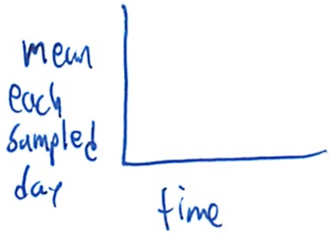
9.3 Control Charts

- graphic tools to distinguish b/w the 2 types of variation
- Started in 1930s, back again w/ 6-σ
- product, component, or service
- pull random samples from ~~Control~~ line
  - can't check everything



2 types of charts

$\overline{X}$ (x-bar)



to see drifts/jumps

← find mean of day's sample

R (range)

← find range of day's sample

$R = max(x_1, ... x_n) - min(x_1, ..., x_n)$

Could also do σ

Avg across all $\overline{X}$s is $\overline{\overline{X}}$

Set UCL and LCL to have stuff fall inside w/ certain confidence

9.5 Design Specs

- has a target value
- and tolerance level
- these are seperate from the "in control" lines
- get variation from range

$$\hat{\sigma} = \frac{\bar{R}}{d_2}$$

from table

- or via ~~other~~ standard means to find σ

Merge into single score: Process Capability Index

$$C_p = \frac{USL - LSL}{6\hat{\sigma}}$$

- measure tolerances vs actual variation of process
- when $C_p = 1$ that means project ~~always~~ meets quality specs at target confidence
- typically wanted $C_p = 1.33$
- but 6σ means want $C_p = 2$ on every step
  - so USL is 6σ above mean

9.6 Attribute Control Charts

- often track % defective
  - can make lots of rules about stuff being defective or not
  - Sample sizes must be larger (~50 - 200)
  - $\bar{p}$ is avg across averages
    - is our center line

$$\text{Estimated } \sigma = \sqrt{\frac{\bar{p}(1-\bar{p})}{\text{Sample size}}}$$

$$UCL = \bar{p} + 3 \cdot \text{estimated } \sigma$$

$$LCL = \bar{p} - 3 \cdot \text{estimated } \sigma$$

- If a single measurable variable - use variable chart
- Can't tell how close to defective you are w/ attribute chart

Pareto Diagram

- Want to find root cause of defects
- bars height indicate rel. freq of each occurance
- also plot cumulative contribution as a line
  - up to 100%

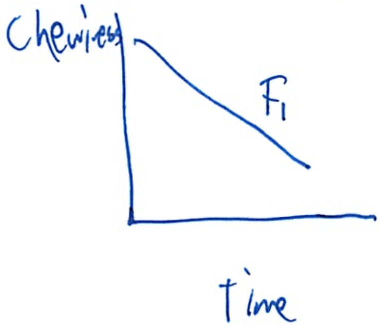
9.7 Robust Process Design

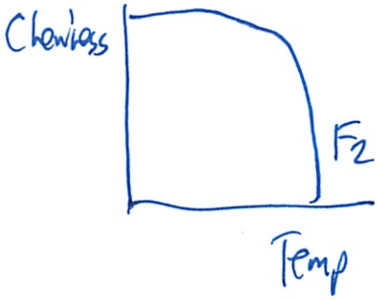
- eliminating variation is not always possible
- so accomodate it

⑤

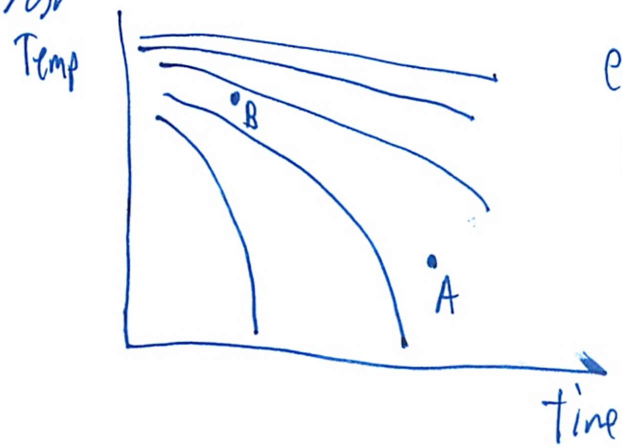
Say process outcome is controlled by 2 factors

$$\text{Chewiness} = F_1(\text{Bake time}) + F_2(\text{Oven temp})$$





- So 2 ways to get same chewiness
  - identical for cust
- But one outcome is far more risky
  - getting the temp slightly wrong is far more likly
- So pick other process = more robust



each line = same chewiness
more tolerance around A

9.8 Impact of Yields + Defects

- must either scrap or rework defective product

$$\text{Yield of resources} = \frac{\text{Flow rate of sucessful units at resource}}{\text{Flow rate}}$$

$$= 1 - \frac{\text{Flow rate of defective units at resource}}{\text{Flow rate}}$$

$$\text{Process yield} = \frac{\text{Flow rate sucessful units}}{\text{Flow rate}}$$

$$= 1 - \frac{\text{Flow rate defective units}}{\text{Flow rate}}$$

Cutting something out is not always a failure
- like eliminating canidates while recruiting

Rework
- items taken out of main production line to be redone
- it always has cost implications
- but much worse if it is a bottleneck

Scrap

Sometimes throw out

$$\text{\# units started to get 100 good units} = \frac{100}{\text{Process yield}}$$

Then for multiple ~~items~~ step processes

$$\text{Process yield process} = \text{Yield}_{\text{step 1}} \times Y_2 \times \ldots \times Y_n$$

⑦ Cost + Economics of Test pts

- what is value of good unit in process?

if demand - constrained

- Value of good n, even if no material added
- Y_n = yied at nth stage
- So value = $\frac{1}{Y_n}$ • Sum of value + Variable Costs at n

if capacity constrained

- before bottleneck - just value of the parts
- after bottleneck - selling price of good
  - since losing 1 finished good that could be sold
  - can never make that slot back

So have inspection step prior to bottleneck
(just like The Goal!)

Or even better find defect at the source
- so employee knows why they had a defect + fixes it

* remember yied = P(defect occurs) *

9.4 Process for Improvement

- need to collect data
  - many firms don't do
- Use VW model
  - go from left to right over model

⑧ 0. Select Theme

1. Focus on Problem
2. Collect data
3. Idetify Assignable Causes
4. Eliminate Causes/ Redce Variability
5. Evaluate Results
   - same as collect date
6. Monitor Conformance

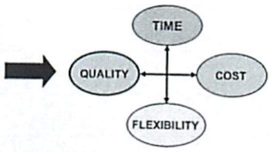
Quality

4/22

Announcements

1. Schedule changes next week and beyond
2. Break.Com individual assignment is cancelled (still have to prepare for the case). Retailer game report is due on May 3
3. Sport Obermeyer case reports are now back
4. Simulation game debrief

Quality Lecture

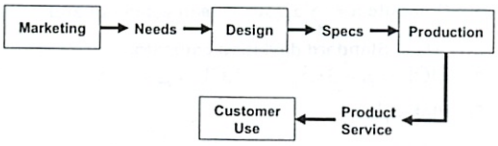


1. What are the causes of quality problems on the Greasex line?
2. What should Hank Kolb do?
3. Overview of Quality Management Approaches

What is Quality?

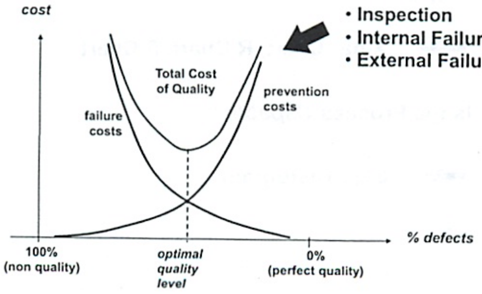
1. Fitness to Standards
2. Fitness to Use
3. Fitness to Market

} result from:

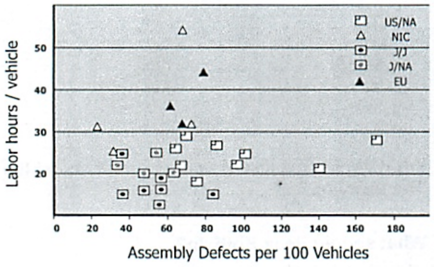

Marketing → Needs → Design → Specs → Production → Product Service → Customer Use

Cost of Quality

- Prevention
- Inspection
- Internal Failure
- External Failure



Industry Benchmark

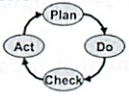


MIT-IMVP: World Assembly Plant Survey 1989

Four Common Principles of (Good) Quality Management Approaches

1. Customer First
2. Total Participation
   Leadership, Education, Incentives
3. Continuous Improvement

"A defect is a treasure"



(Observe - Assess
Design - Intervene)

4. Data-driven
   "In God We Trust; All Others Bring Data"

Statistical Process Control

1. Is the Process *In Control*?

   ➡ X bar Chart, R Chart, P Chart

2. Is the Process *Capable*?

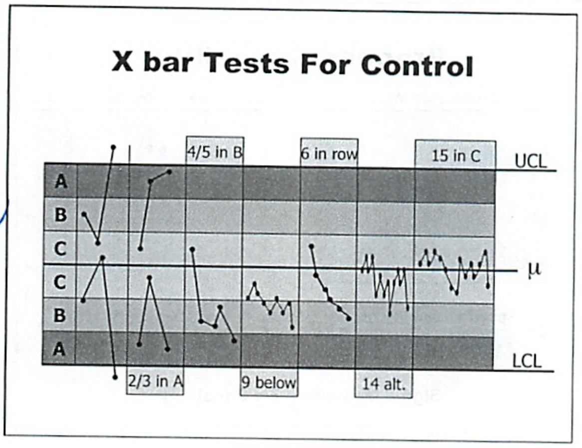
   ➡ SQC Histogram

$\overline{X}$ Charts (*"X bar Chart"*)

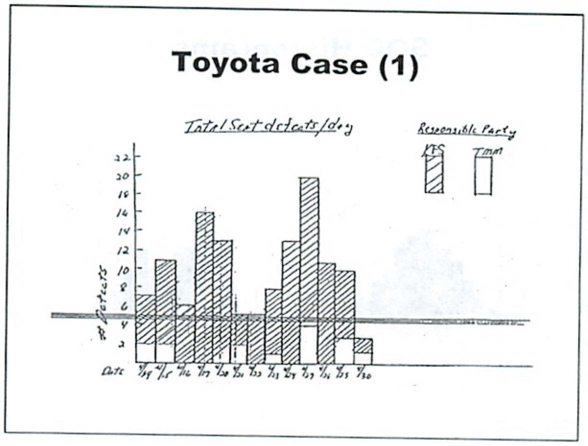
1. Periodical Random Samples x_i of *n* (= 4) items
2. $\overline{x}_i = \frac{x_{i1} + x_{i2} + x_{i3} + x_{i4}}{4}, i = 1,......,50$
3. Compute $\mu = \sum_{i=1}^{50} \overline{x}_i / 50$ - mean estimator and
   $\sigma_{\overline{x}}$ - Standard deviation estimator
4. $\mathrm{UCL} = \mu + 3 \cdot \sigma_{\overline{x}}$ $\quad$ $\mathrm{LCL} = \mu - 3 \cdot \sigma_{\overline{x}}$
5. Plot $\overline{x}_i$'s
6. Is Process out of Control ?

Clocks

[reverse letters since A is better :)]



X bar Tests For Control



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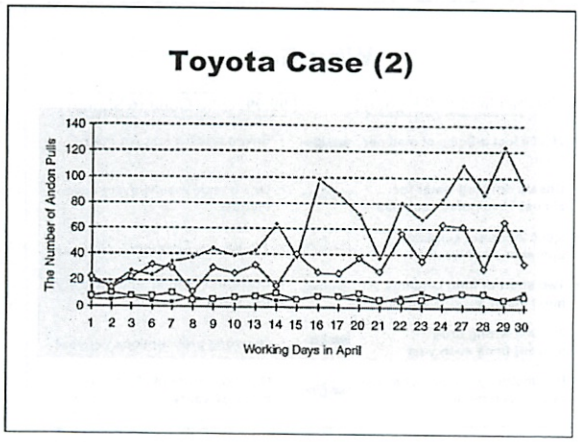
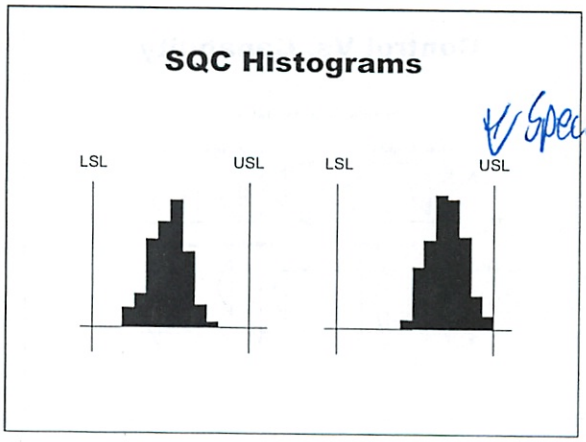
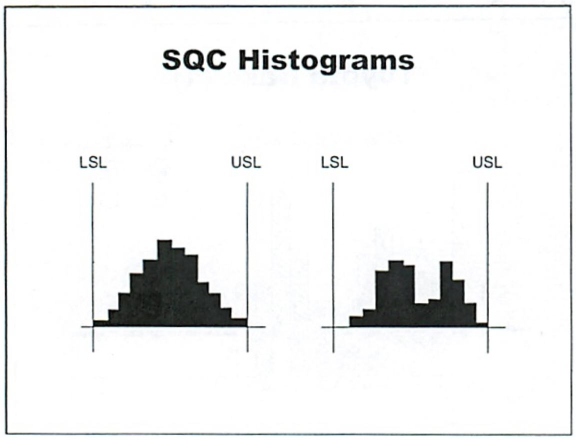


Toyota Case (2)



SQC Histograms

✓ Specified



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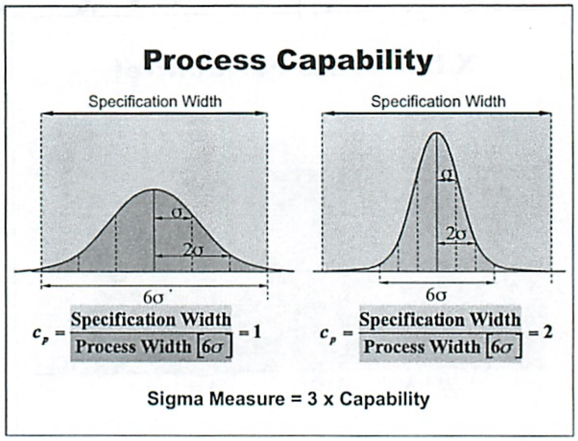
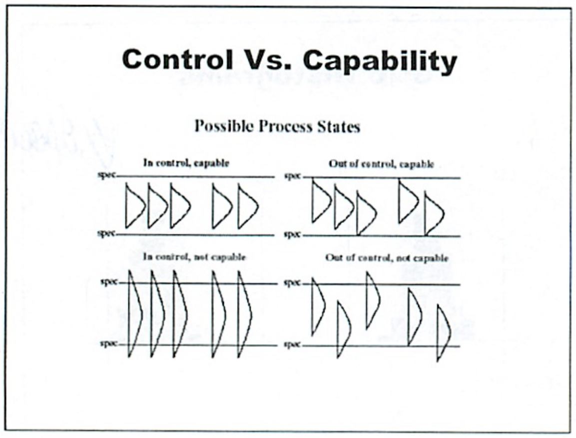


Process Capability

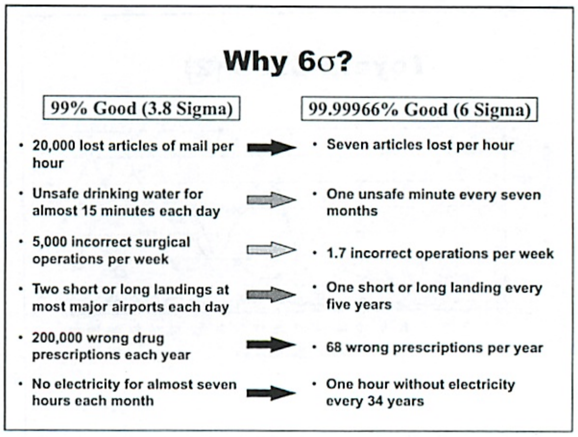
$$c_p = \frac{\text{Specification Width}}{\text{Process Width } \boxed{6\sigma}} = 1 \qquad c_p = \frac{\text{Specification Width}}{\text{Process Width } \boxed{6\sigma}} = 2$$

Sigma Measure = 3 x Capability



Control Vs. Capability

Possible Process States



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99% Good (3.8 Sigma)	99.99966% Good (6 Sigma)
20,000 lost articles of mail per hour	Seven articles lost per hour
Unsafe drinking water for almost 15 minutes each day	One unsafe minute every seven months
5,000 incorrect surgical operations per week	1.7 incorrect operations per week
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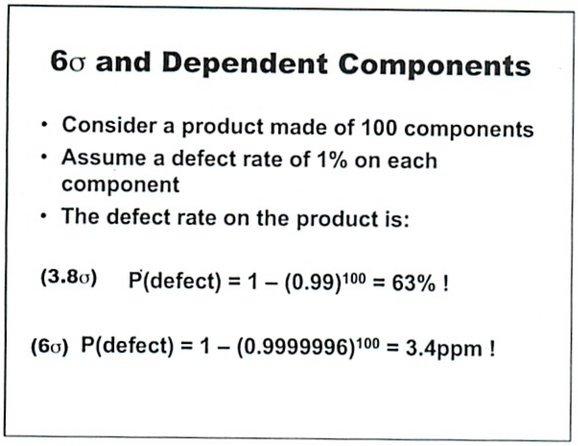
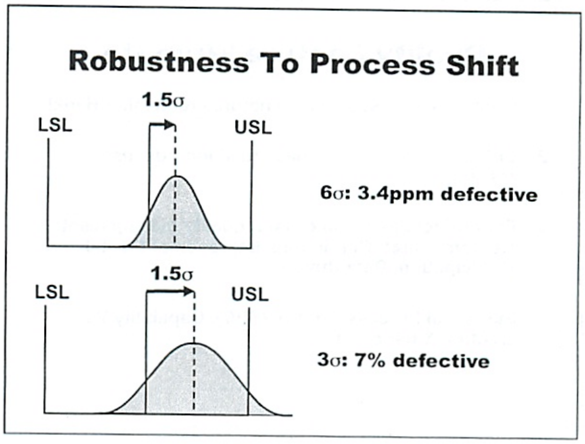


6σ and Dependent Components

- Consider a product made of 100 components
- Assume a defect rate of 1% on each component
- The defect rate on the product is:

(3.8σ) $P(\text{defect}) = 1 - (0.99)^{100} = 63\%$!

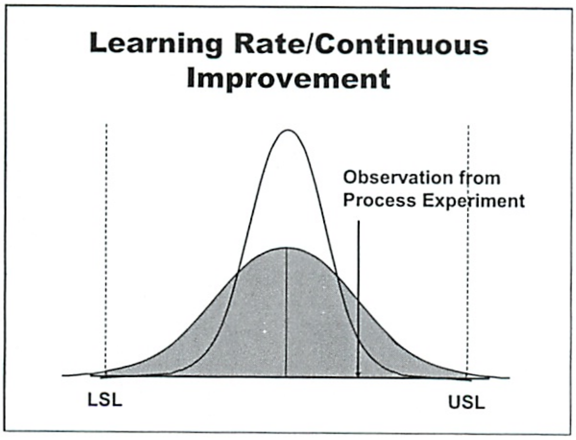
(6σ) $P(\text{defect}) = 1 - (0.9999996)^{100} = 3.4\text{ppm}$!



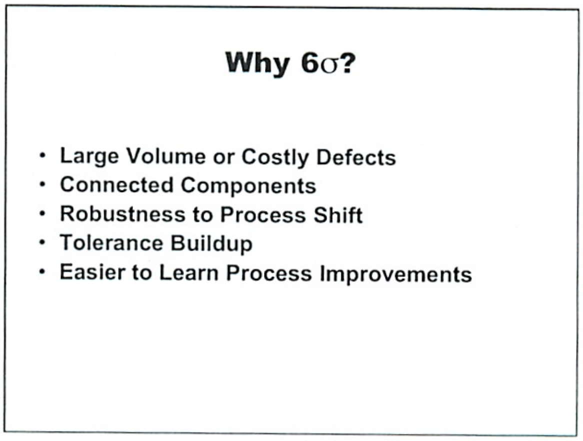
Robustness To Process Shift

6σ: 3.4ppm defective

3σ: 7% defective

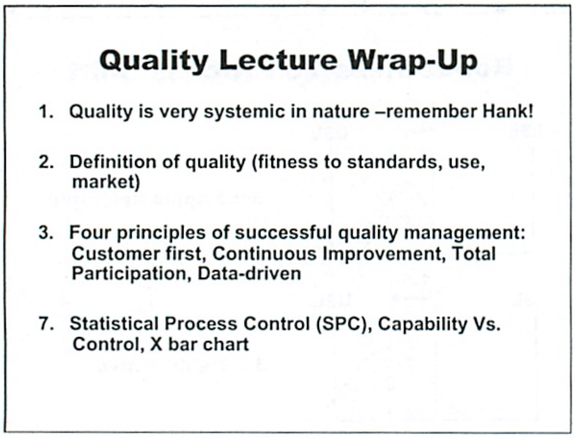


Learning Rate/Continuous Improvement



Why 6σ?

- Large Volume or Costly Defects
- Connected Components
- Robustness to Process Shift
- Tolerance Buildup
- Easier to Learn Process Improvements



Quality Lecture Wrap-Up

1. Quality is very systemic in nature –remember Hank!
2. Definition of quality (fitness to standards, use, market)
3. Four principles of successful quality management: Customer first, Continuous Improvement, Total Participation, Data-driven
7. Statistical Process Control (SPC), Capability Vs. Control, X bar chart

15.761 4/22

Pick up Sport Obermeyer case in folders

Break.com assigment cancled
  - still have to read for case

Sim game report

>21 - very well
18-21 - missed 1-2
<18 - missed 2-3 concepts

Quality

- How do we approach?
- Greasex case
  - What do we mean by quality?
  - How to measure
- How to improve?

Quality appears almost everywhere

Need to get people to understand why quality ↑

In many cases doing things right 1st time costs less $

Greasex

design changes w/o testing
- cap (supplier)
- can deisgn - grippy
- new machine adapted

②

Training / personell issue

Rushing orders
- expediency 1st
- incentives for volume, not correctness

No real reprecussions for not following protocal
- no enforced protocals

Seperate quality dept
- people take them seriously?
- do they have power

Management's heart in it
- But sending contridicting messages
- Promoted wrong person?

Not inspecting soon enough

No awareness of what defects mean
- what is the motivation
- esp for front-line workers

Any one accountable for quality

Understand each group's motivation

Incentives unified?

Get top management buy in - quality is critical

Understand quality is everyone's problem

If want to manage something - we need to measure it

- No measurement for quality
- Need to define quality measurement

Quantify benefits to get investment / buy-in

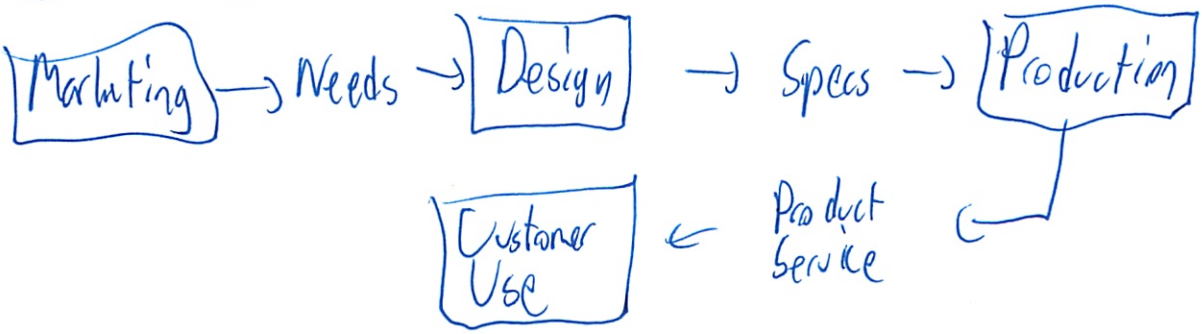
Given name: Top Quality Management

Need to measure / collect data

What is Quality?

1. Fitness to standards
2. Fitness to use
3. Fitness to market

) result from



④

Where do standards come from?

- laws/regs
- customers
- competition
- saftey

Process itself should meet standard

- Not just product itself
- like Toyota

What do you think about seperate QA department?

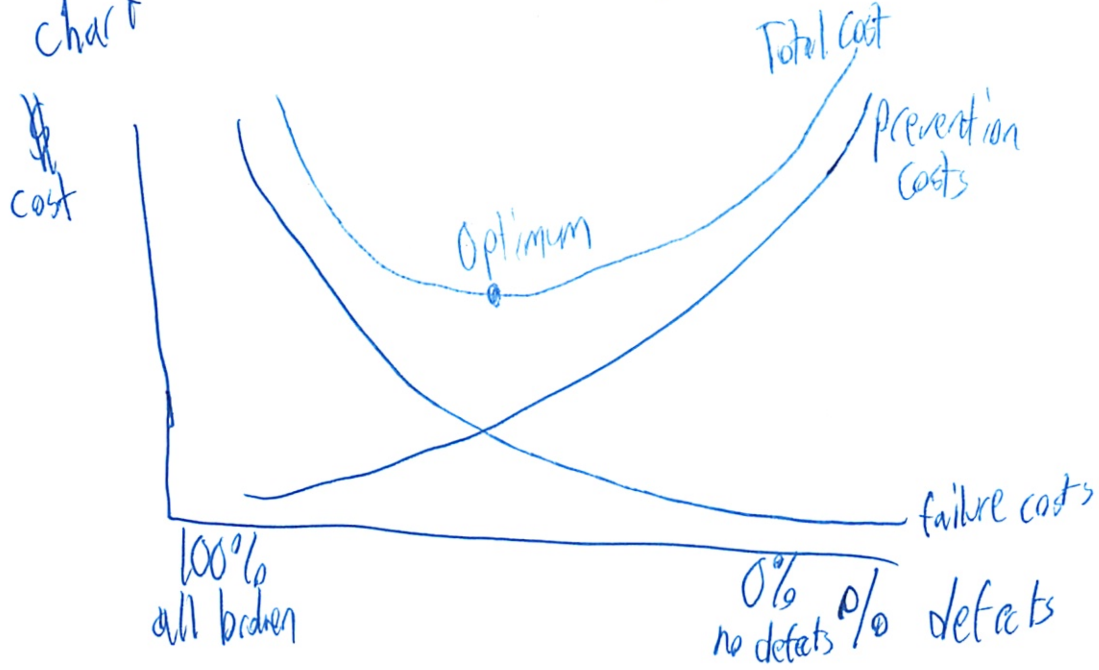
- Need quality culture 1st
- Everyone's job?
- Is it testing department?
- Also sometimes it is integration testing
- User acceptance testing
- How is it in software dev?

* Want part of system itself

- Does it depend on cost of failure
  - in Nuclear ~~[illegible]~~ are seperate auditors
- But main depts still need to insist on quality
- ~~[illegible]~~ External auditors is legal requirements in some industries/public cos

But there is a cost to quality

Rough chart



What are internal failures?

- Rework
- Lost ~~prod~~ production

External failures?

- Warantee
- Litigation
- Reputation

But costs are hard to calculate - unclear and uncertain

- will there be a lawsuit?
- Short or long horizon

* - How to compare apples + oranges

- What are possibilities of failure?
- How to even estimate what a mistake will cost?

ⓔ

Quality problems cost $

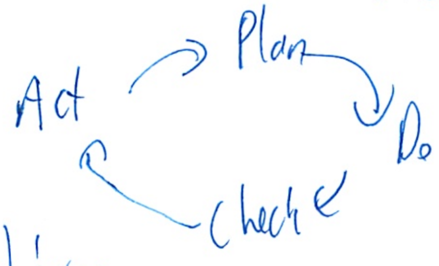
Can save $ from ↑ quality
- if rework cost < failure cost
- at given quality level
- The drop in ~~cost~~ failure cost is larger than increase in prevention/rework cost

---

Car defects in 1989
- Companies w/ less defects have <u>less</u> labor hrs

<u>4 principles</u>

1. Customer first
2. Total participation
   - leadership, edu, incentives
3. Contineous improvement
   - defects are like treasure to hunt



4. Data driven
   - use data

Statistical Process Control

- X-bar chart, R chart, P chart
  - Are we in control?
- SQC Histogram
  - Is the process capable

X Bar Chart

every product is slightly diff
└ normal variation
- within specs

(remember the 2 types of defects)

find avg of samples
- each trial is ind.

X_i s will be distributed normally, around mean

Set upper + lower control limit
- $\mu + 3\sigma$
  ↑ Excel or estimating

Plot X_is - did process go wrong?
- Or predefine the UCL + LCL from spec
(slightly different - I remember from book)

The a thing
- w/ other hand → assignable cause
- w/ letters from same hand → expected random cause

Clocks control test
- each dot is X_i

look at chart
- each column has some diff errors
- can tell you whats' wrong

But events are not really ind - are correlated
- so normal from here
  or ind
- but cor is exactly what you wanted to catch!

Some times mean, limits not from data - but from spec

Announcements

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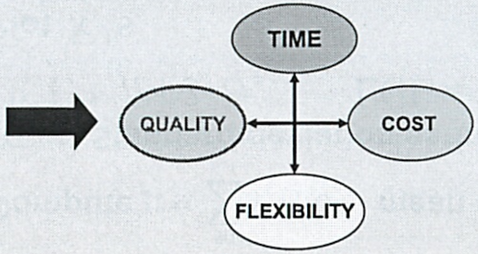
Quality Lecture



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Solutions

What is Quality?

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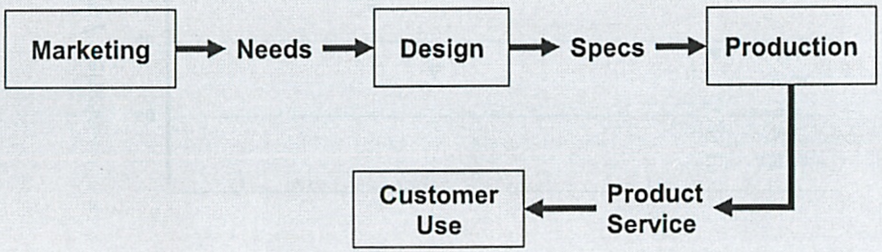
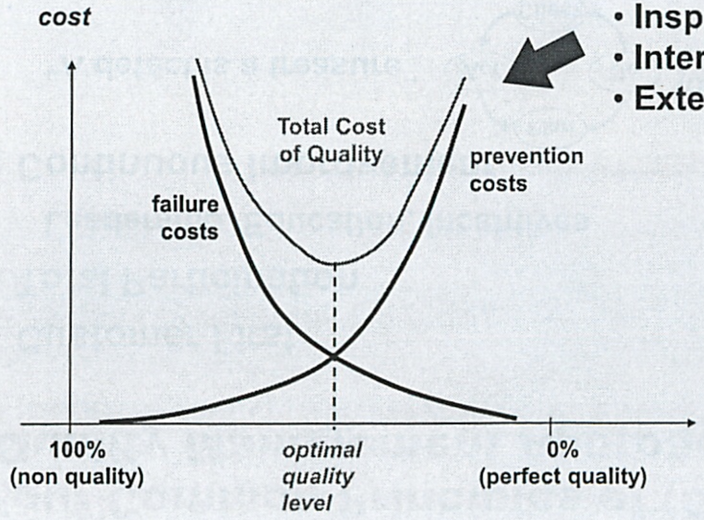
} result from:



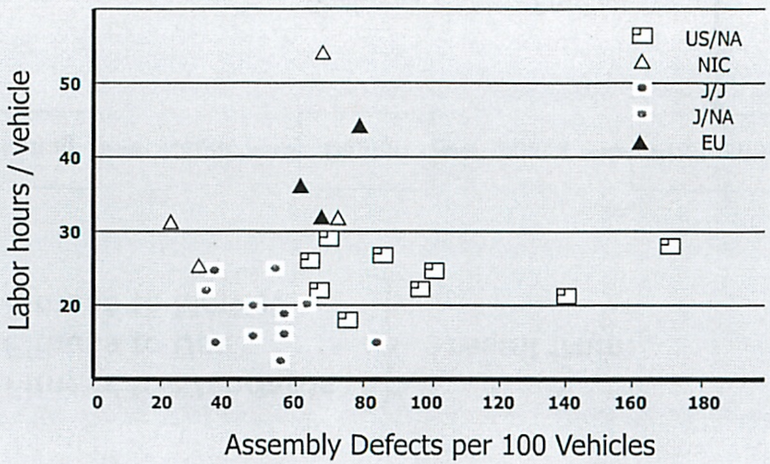
Cost of Quality

- Prevention
- Inspection
- Internal Failure
- External Failure



4/22

Industry Benchmark



MIT-IMVP: World Assembly Plant Survey 1989

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   Leadership, Education, Incentives

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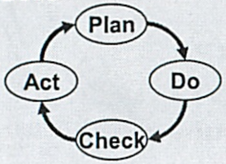

(Observe - Assess Design - Intervene)

4. Data-driven

   "In God We Trust; All Others Bring Data"

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   → SQC Histogram

$\overline{\text{X}}$ Charts (*"X bar Chart"*)

1. Periodical Random Samples x_i of n (= 4) items
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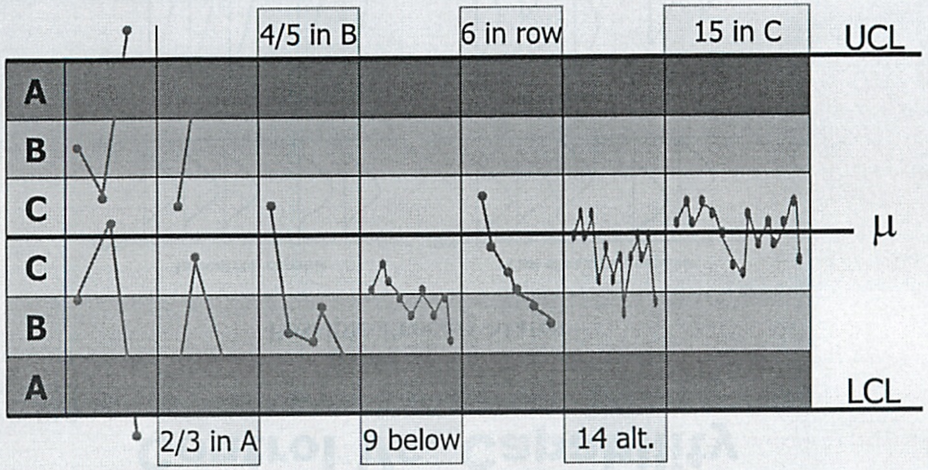
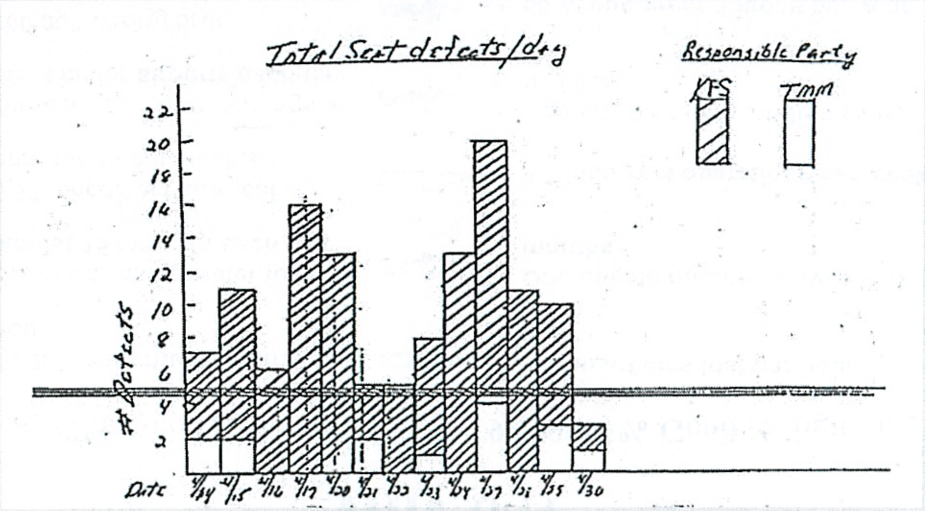
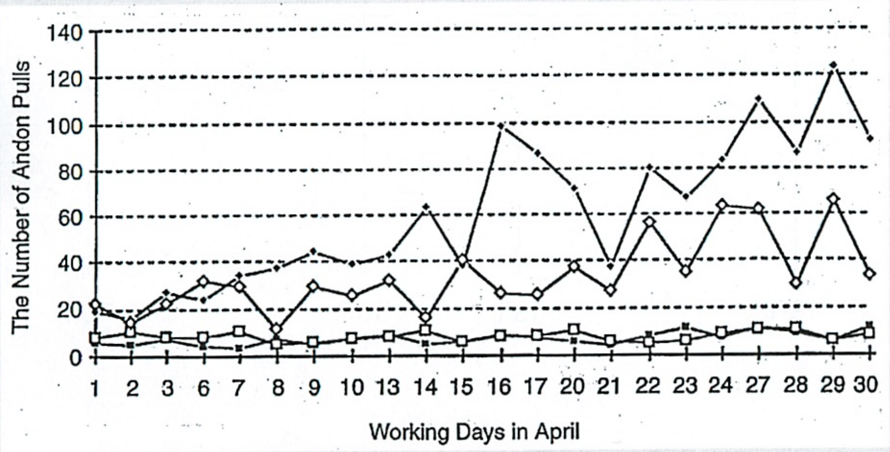
X bar Tests For Control



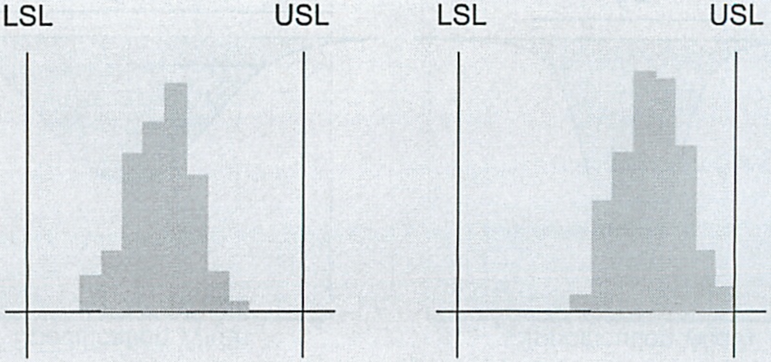
Toyota Case (1)



Toyota Case (2)



SQC Histograms



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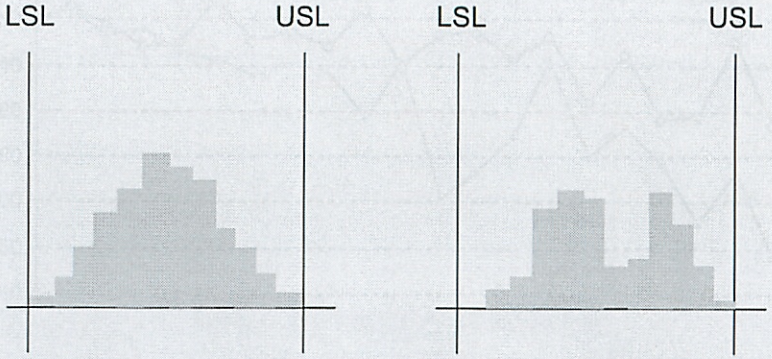
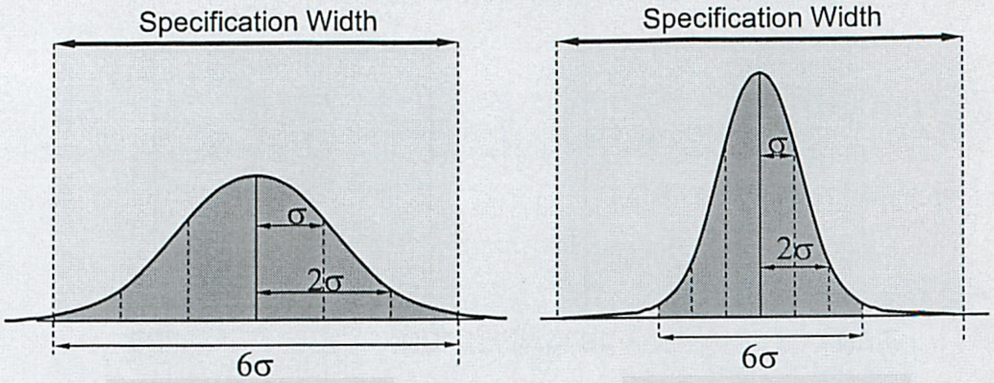


Process Capability



$$c_p = \frac{\text{Specification Width}}{\text{Process Width } [6\sigma]} = 1$$

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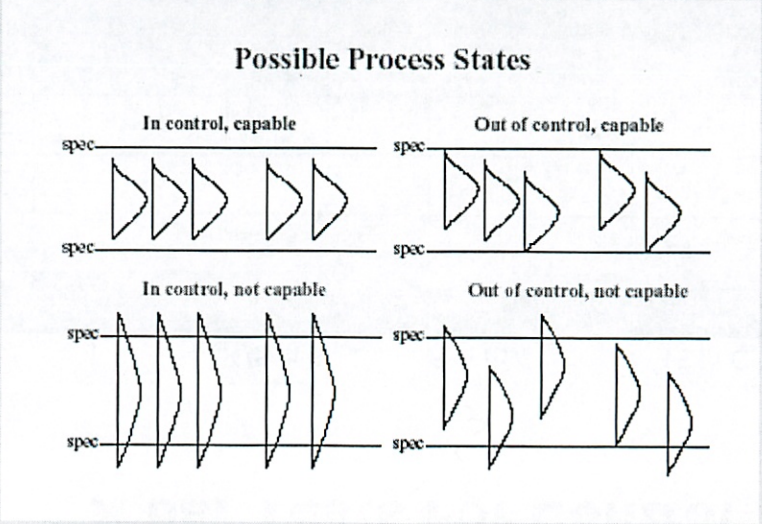
Sigma Measure = 3 x Capability

Control Vs. Capability



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20,000 lost articles of mail per hour	Seven articles lost per hour
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No electricity for almost seven hours each month	One hour without electricity every 34 years

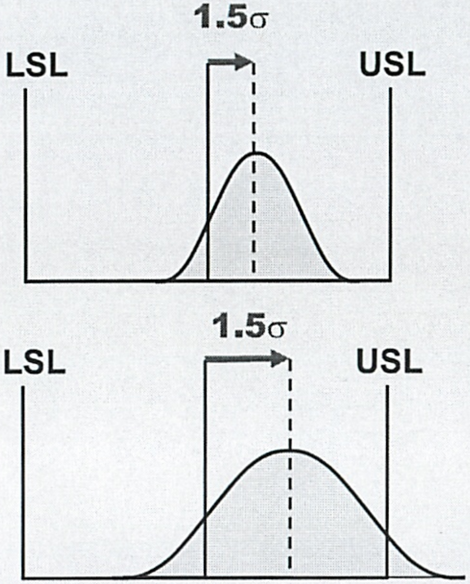
6σ and Dependent Components

- Consider a product made of 100 components
- Assume a defect rate of 1% on each component
- The defect rate on the product is:

(3σ) P(defect) = $1 – (0.997)^{100}$ = 26% !

(6σ) P(defect) = $1 – (0.9999996)^{100}$ = 3.4ppm !

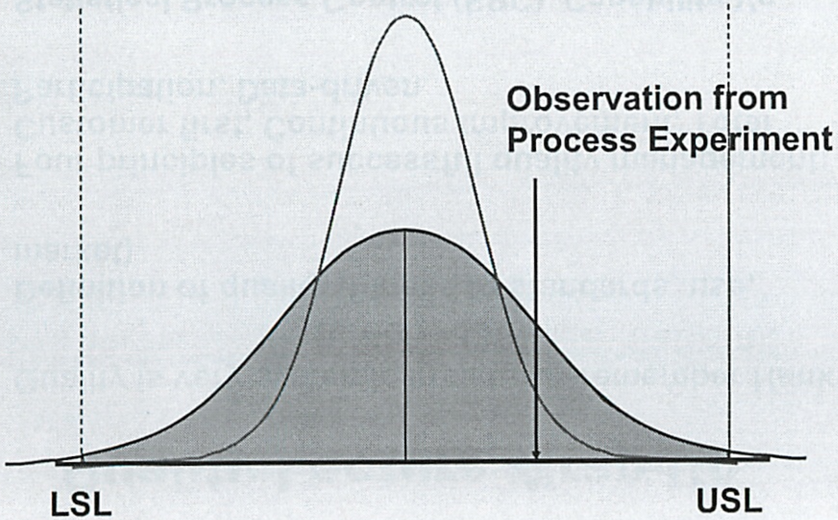
Robustness To Process Shift



6σ: 3.4ppm defective

3σ: 7% defective

Learning Rate/Continuous Improvement



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