15.760 Introduction to Operations Management

Professor Jérémie Gallien
Operations Management Group,
MIT Sloan School of Management

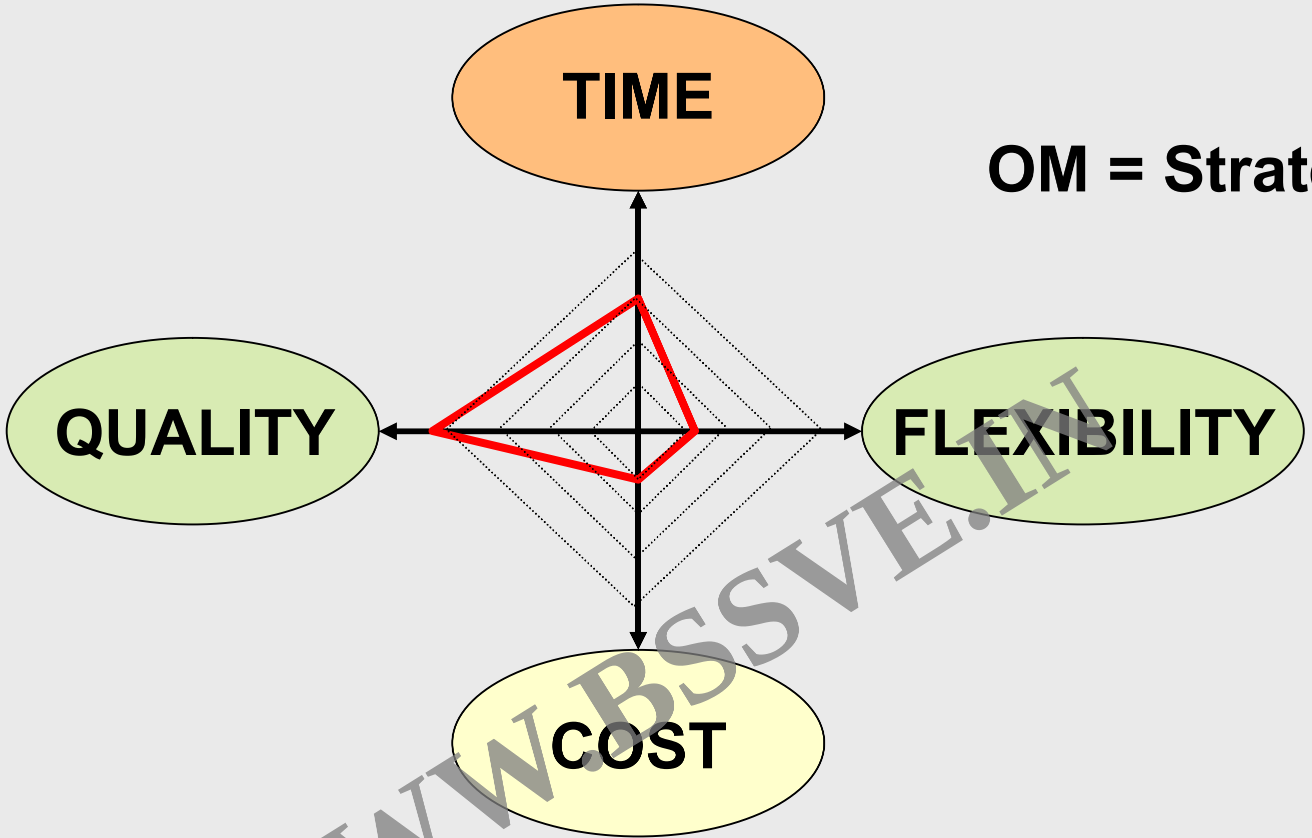
Bio

- French, Eng.D in Production Systems from Ecole des Mines de Paris
- PhD (2000) in Operations Research from MIT
- Research: Online sales channels, dynamic pricing, e-procurement, manufacturing revenue management, order fulfillment, product introduction
- Experience in Electronics, Aeronautics, Transportation and Software

Class Outline

- Class Introduction: Concepts & Outline
- Organization
  - Material
  - Assignments/Grading

What is Operations Management?



OM = Strategy Execution!

2002 - Jérémie Gallien

Why Study OM (1)?

Dell Vs. Compaq, HP

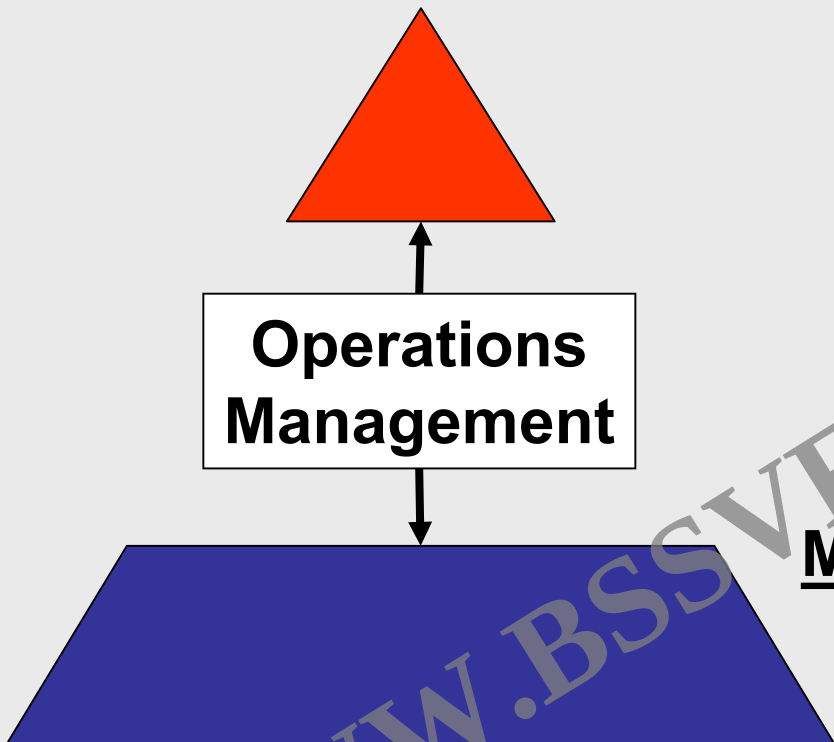
Toyota Vs. Ford, GM

Amazon Vs. Barnes & Noble

JetBlue, Southwest Vs. American Airlines

Why Study OM (2)?

Corporate Structure



<u>Top Management</u>
speaks the language of
MONEY

<u>Mid-Mgt., Associates, Workers</u>
speak the language of
THINGS

OM merges physical and financial analyses, and requires great care to people issues!

2002 - Jérémie Gallien

Why Study OM (2) ?

Set of responsibilities:

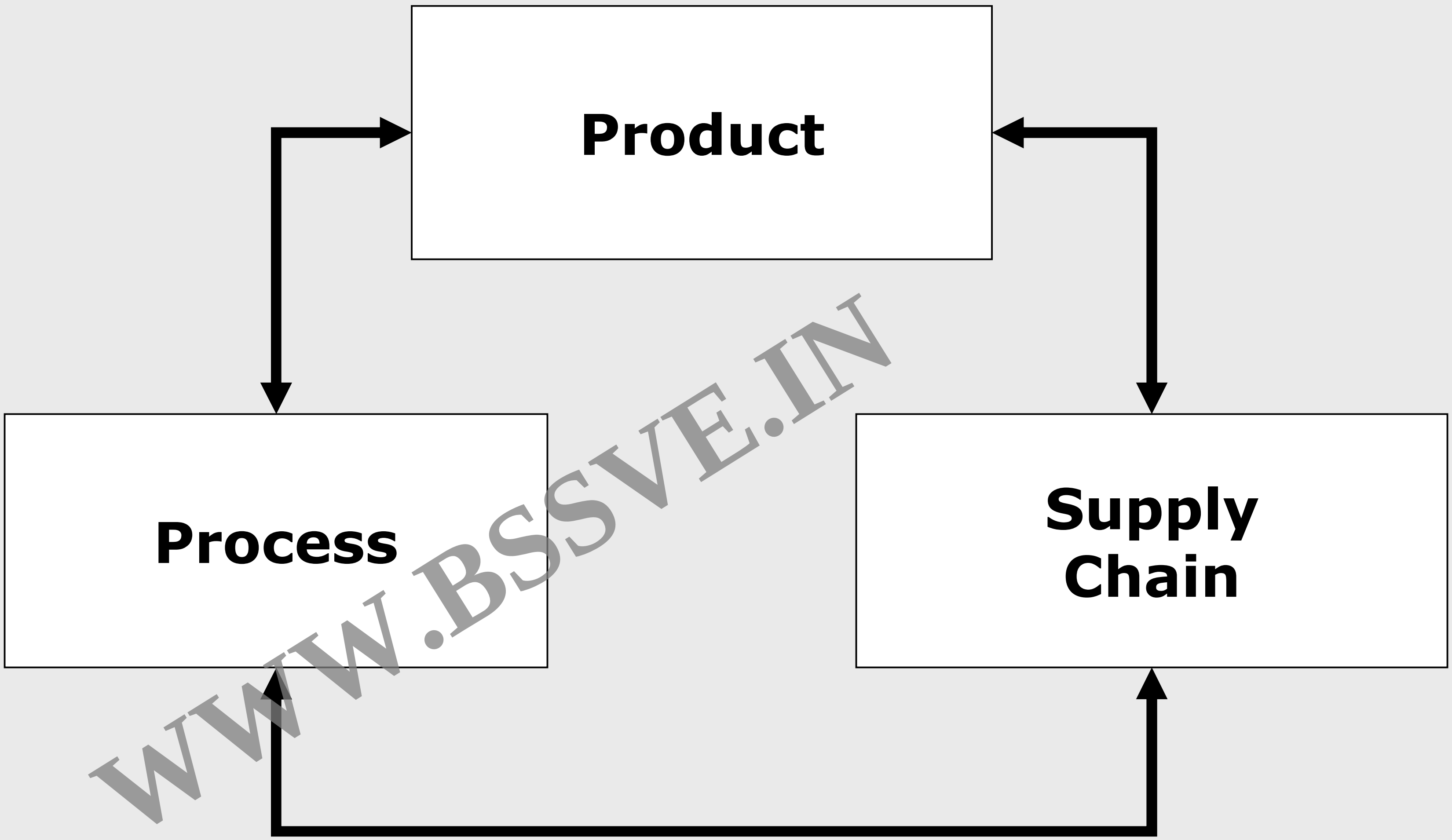
1. DESIGN
2. PLANNING
3. CONTROL
4. IMPROVEMENT

2002 - Jérémie Gallien

Why Study OM (3) ?

- Boeing
- Microsoft
- Intel
- Massport
- Johnson & Johnson
- Southwest
- Lucent Technologies
- Amazon
- United Technologies
- AT Kearney
- Dell
- PRTM
- McKinsey & Company

Components of Operations Management



2002 - Jérémie Gallien

Product Definition

- Product Type (Good or Service)
- Strategic Positioning
- Product Architecture

Service Vs. Manufacturing Operations

- **Intangibility** (Explicit and Implicit)
  - "We manufacture perfume; we sell Hope"
  - PERCEPTION Vs. EXPECTATION, ADVERTISE & MATERIALIZE
- **Perishability** (no inventory buffer)
  - Can't inventory seating room!
  - CAPACITY PLANNING/FLEXIBILITY, PREVENTION/CULTURE
- **Heterogeneity** (supply and demand variability)
  - Consider medical service delivery!
  - HIRING, TRAINING, PLANNING, CUSTOMIZATION
- **Simultaneity** (of production and consumption)
  - No safety nets for quality problems…
  - HIRING, TRAINING, HR, PLANNING, CONCURRENT ENGINEERING

Slide courtesy of Prof. Charles Fine, MIT.

Process Definition

- Type (Discrete or Continuous)
- Process Architecture
  - Technology
  - Physical Flow
  - Information Flow

} Process Flow Diagram (Physical Flow and Information Flow)

Supply Chain Definition

- Supply Chain Architecture
  - Physical & Information Flow
  - Integral/Modular Relationships
  - Incentives
- Coordination
  - Delivery
  - Inventory
  - Information Systems

2002 - Jérémie Gallien

Class 1 Wrap-Up

1. Operations Management = Strategy Execution

2. Strategic Product Definition:
Quality + Cost + Time + Flexibility

3. Operations Management Components:
Product Devlpt. + Process + Supply Chain

4. Operations Management Activities:
Design + Planning + Control + Improvement

5. Service Operations Features:
Intangibility + Perishability + Heterogeneity + Simultaneity

Course at-a-glance

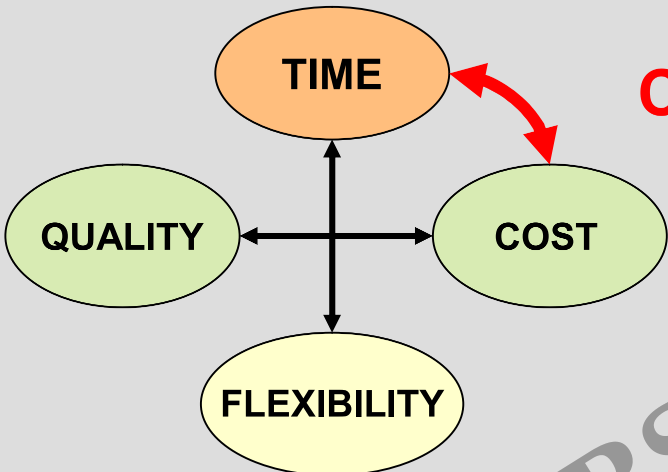
#	Day	Date	Contents	Readings	Assignments	Sim
1	Mon	29-Mar	Course Introduction	Course Syllabus		
2	Wed	31-Mar	Case: Burger King + McDonald's	Types of processes		
3	Fri	2-Apr	Lecture: Capacity	Wait-in-line blues	1 Ex. Buildup, 1 Ex. Queueing	
4	Mon	5-Apr	Case: National Cranberry			
5	Wed	7-Apr	Case: Webvan			
6	Fri	9-Apr	Lecture: Inventory	Automate or Die	1 Ex. EOQ, 1 Ex. Newsboy	
7	Mon	12-Apr	Case: Barilla	Managing Supply-Chain Inventory		
8	Wed	14-Apr	Case: Sport Obermeyer	Rocket Science Retailing	Case Write-up	
9	Fri	16-Apr	Lecture: Production Control	Growth in MRP, Control of JIT	1 Ex. Kanban, 1 Ex. Commonality	
10	Wed	21-Apr	Case: Hewlett-Packard			
11	Fri	23-Apr	Book: The Goal	The Goal	Book Review	
12	Mon	26-Apr	Lecture: Quality	Hank Kolb case	1 Ex. SPC, 1 Ex. 6 Sigma	
13	Wed	28-Apr	Case: Toyota			
14	Fri	30-Apr	Lecture: Process Design	Reengineering Work, ERP Tech. Note		
15	Mon	3-May	Case: Global Financial Corporation			
16	Wed	5-May	Lecture: Supply Chain Design	Chapter 8 Clockspeed		
17	Fri	7-May	Lecture: Product Design			
18	Mon	10-May	Case: Sega Dreamcast		Simulation Write-up	
19	Wed	12-May	Simulation & Course Wrap-up			

2002 - Jérémie Gallien

Organization

- Course uses Sloan's class server (15.760 BC H2)
- Course Materials:
  - Course Packet (Cases and Readings)
  - *The Goal: A Process of Ongoing Improvement,* E. Goldratt and J. Cox
- Grading
  - Class participation 30% } individual
  - Book review 10% } individual
  - Case write-up 30% } in teams of 3
  - Simulation 30% } in teams of 3
- Professional Standards

Class 3: Capacity Lecture



CAPACITY

too high:

- Capital expenses
- Labor expenses
- Resource waste
- Environmental damage
- Cash flow issues

too low:

- Customer wait / death
- Brand damage
- Customer dissatisfaction
- Lost sales
- Low employee morale
- High turnover

2002 - Jérémie Gallien

Typical Questions

- How many machines should be purchased?
- How many workers should be hired?
- Consequences of a 20% increase in demand?
- How many counters should be opened to maintain customer wait below 10 minutes?
- How many assembly stations are needed to maintain backorders below 20?
- How often will all 6 operating rooms be full?
- How will congestion at Logan change if a 5th runway is built?

2002 - Jérémie Gallien

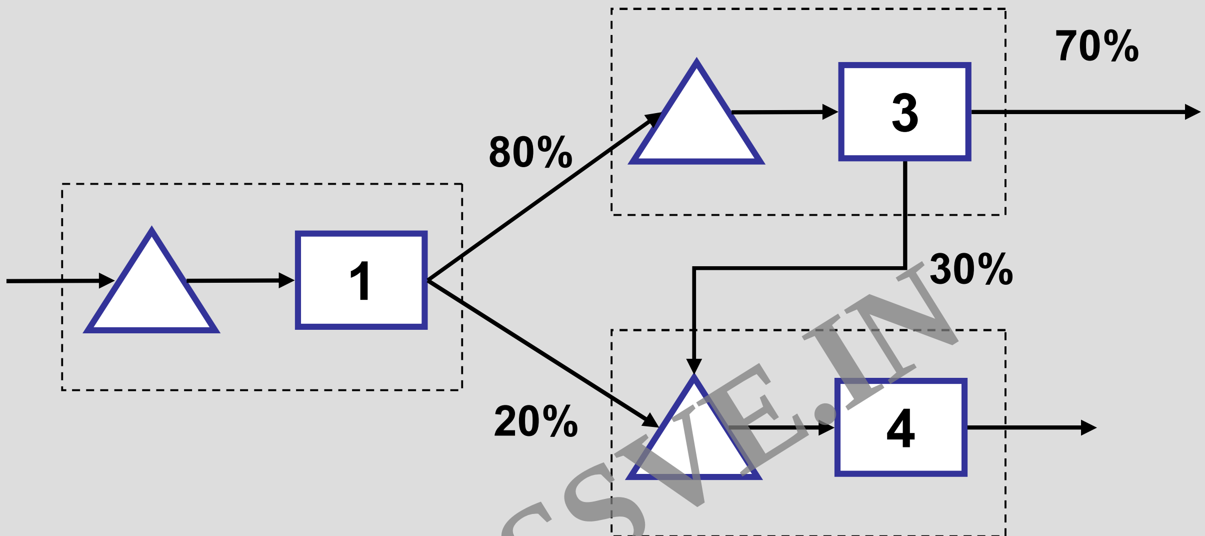
Methodology

This lecture {

Step 1:	Process Flow Diagram
Step 2:	Demand and Capacity Analysis
Step 3:	Congestion Analysis
Step 4:	Financial/Decision Analysis

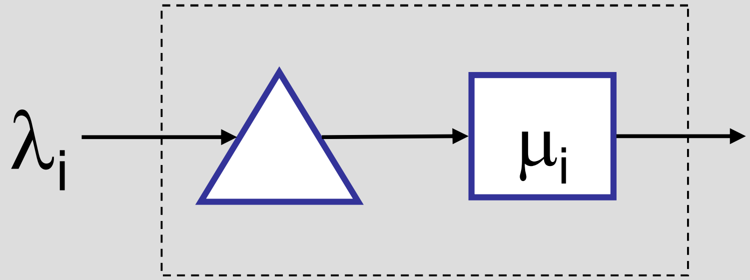
2002 - Jérémie Gallien

Step 1: Process Flow Diagram



2002 - Jérémie Gallien

Step 2: Demand/Capacity Analysis



For each process step i, determine:

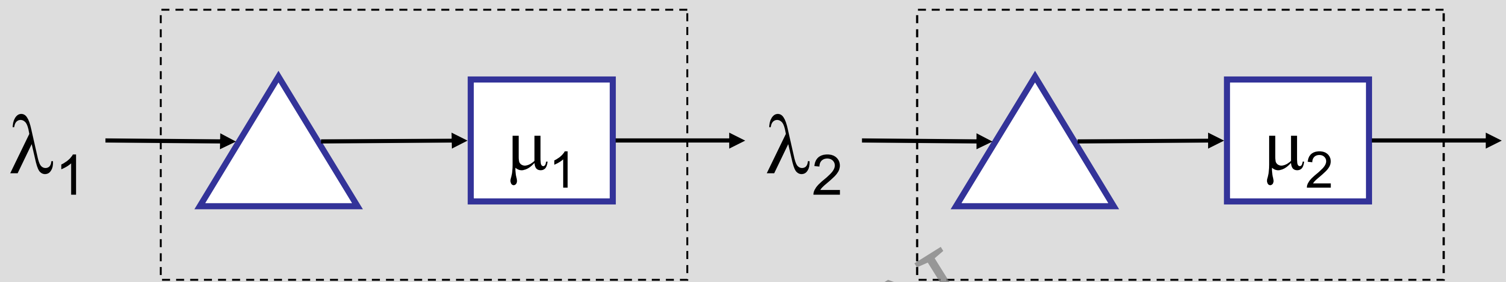
- λ_i : demand or input rate (in units of work per unit of time)
- μ_i : realistic maximum service rate, assuming no idle time (in units of work per unit of time)

$\rho_i = \lambda_i / \mu_i$: capacity utilization

$\lambda_i - \mu_i$: build-up rate

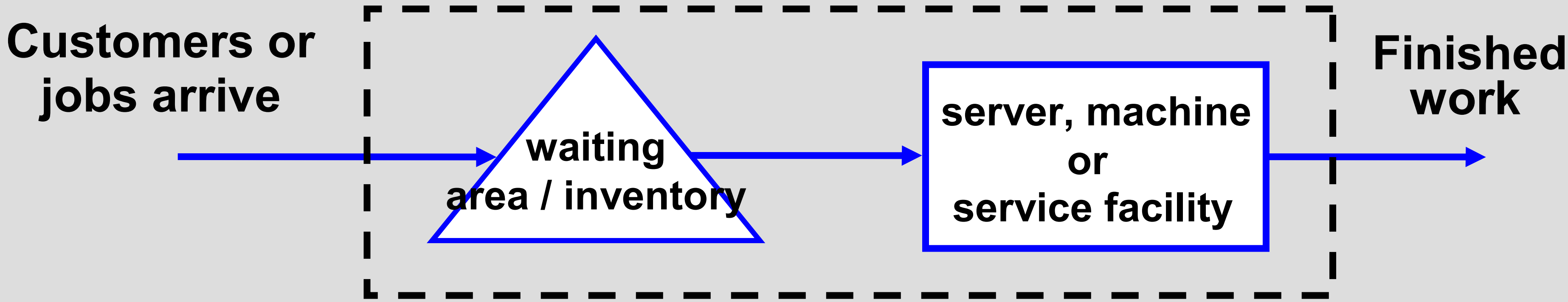
2002 - Jérémie Gallien

Throughput



$$\lambda_2 = \min(\lambda_1, \mu_1)$$

Step 3: Congestion Analysis



System Performance = F(System Parameters)

- **L** Inventory level/Queue size/Line length
- **W** Waiting time
- **C** Cycle time
- **P_{full}** Probability queue is full

- **λ** Arrival rate
- **μ** Service rate
- **A** Inter-arrival time distribution
- **S** Service time distribution
- **N** Number of servers
- **R** Queue/Buffer capacity

Congestion Analysis Tools

Build-Up Diagrams	*Queueing Theory*
• Predictable Variability • Utilization > 1 o.k. • Short Run Analysis • Variable rates o.k.	• Unpredictable Variability • Utilization < 1 only • Long Run Analysis • Fixed rates only
• assumes workflow is continuous and deterministic	• stochastic analysis with inter-arrival and service time distributions

All other cases → ***Simulation / Experiments***

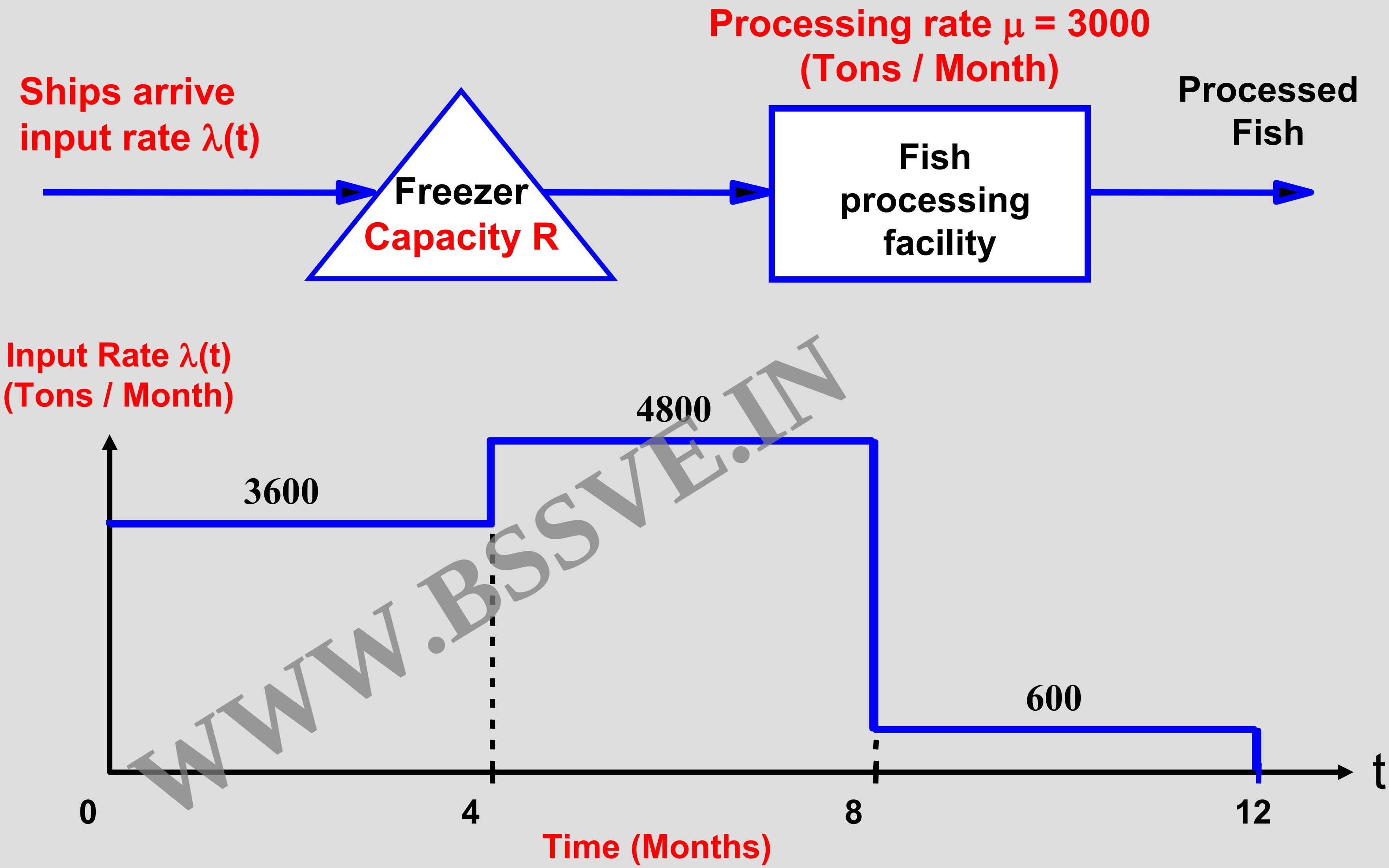
Buildup Diagrams

Think of work as being liquid

- Predictable Variability
- Utilization > 1 ok
- Short Run Analysis
- Variable rates ok

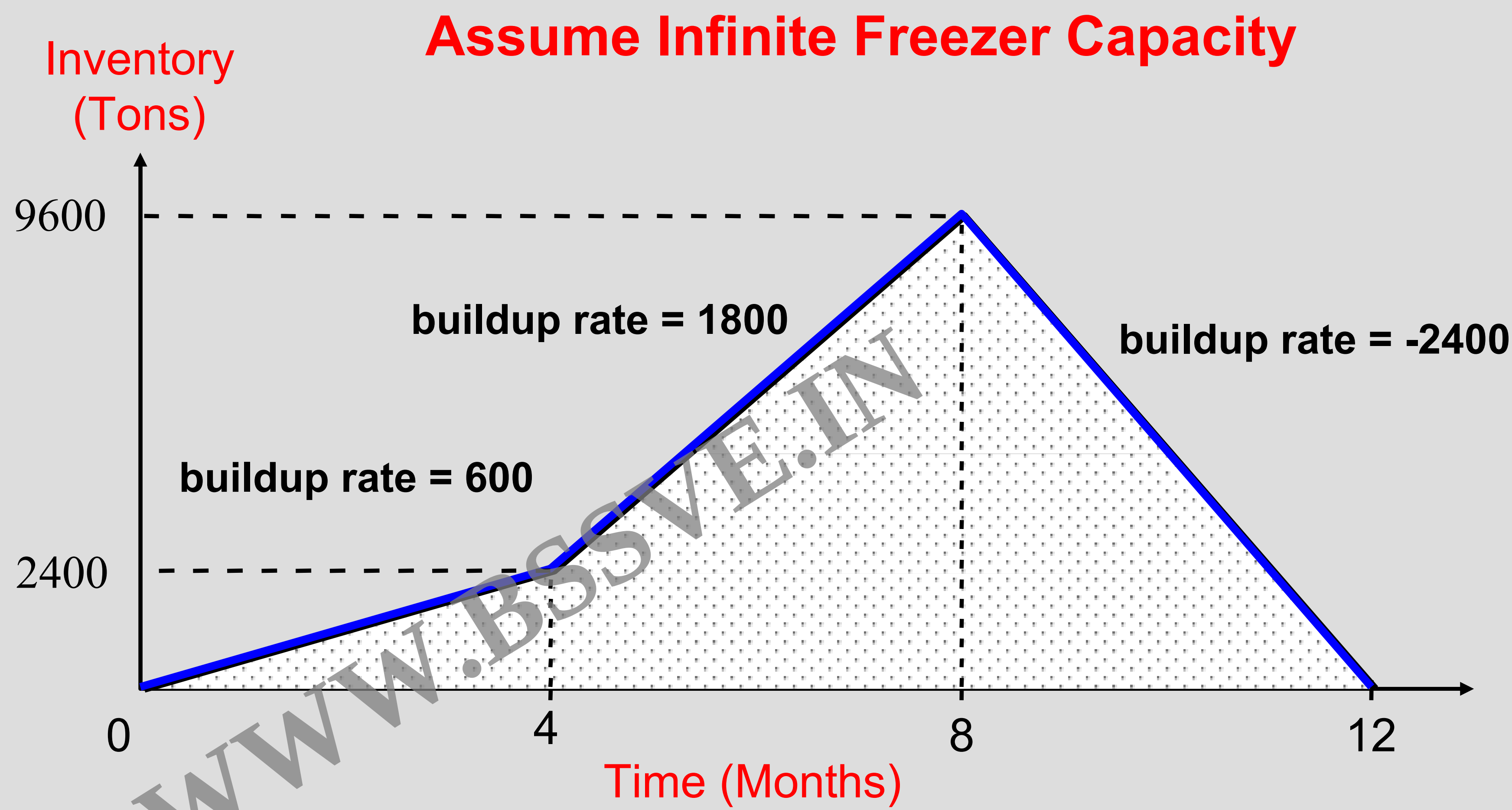
- No rocket science, but requires a little care

Buildup Example: Fish Processing



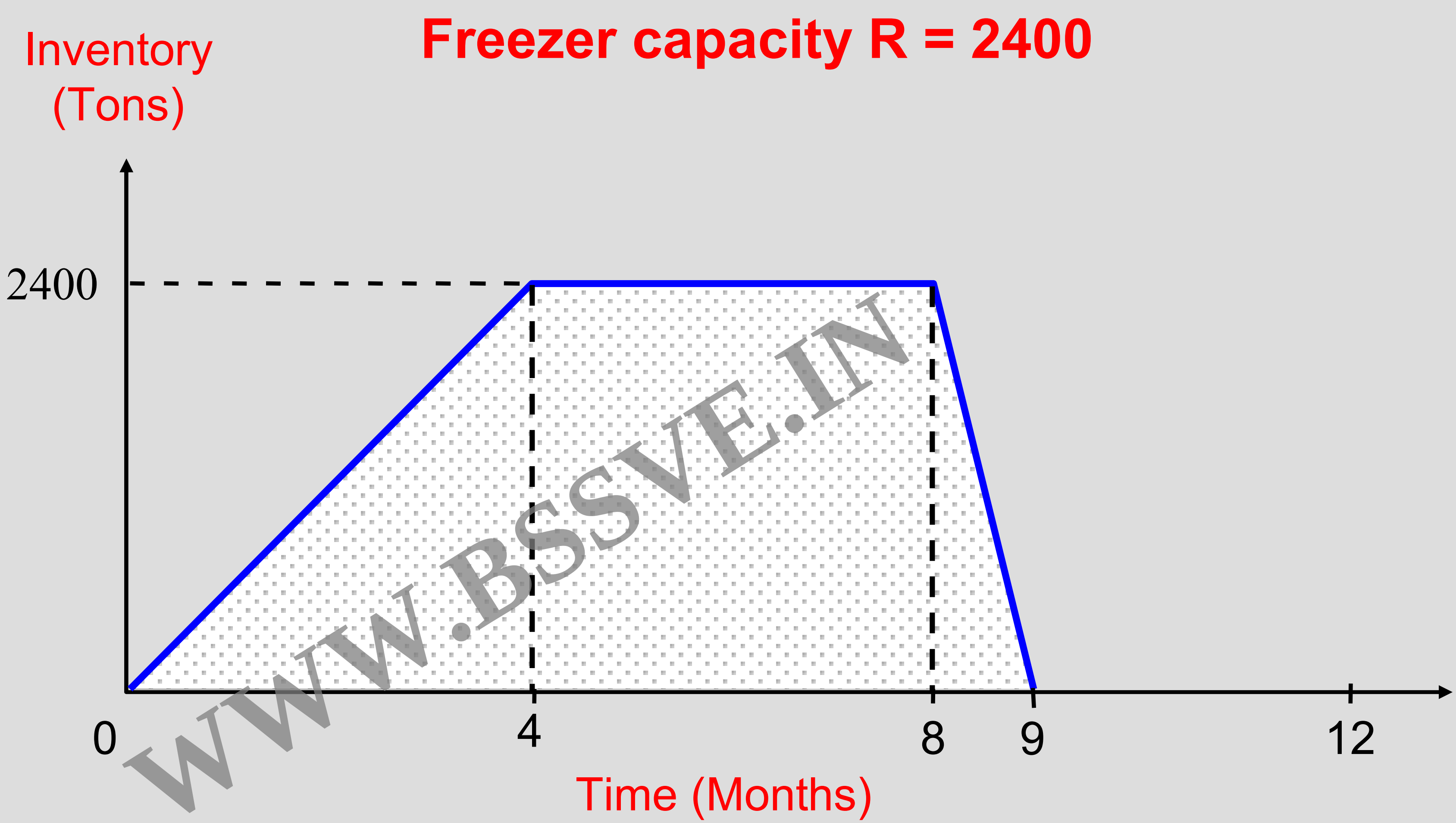
2002 - Jérémie Gallien

Freezer Inventory Diagram



2002 - Jérémie Gallien

Limited Storage Capacity



Queueing Theory

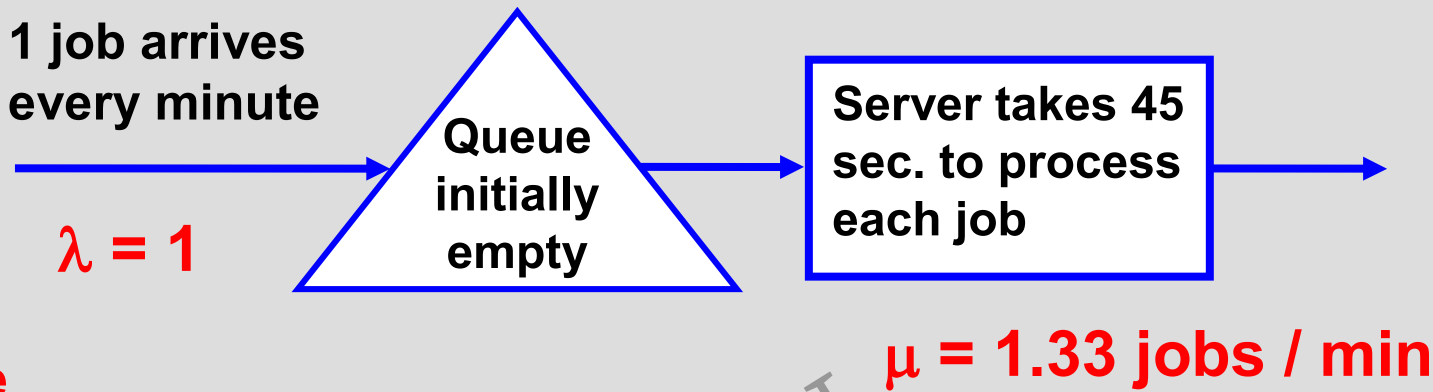
Sophisticated analysis (but easy formulas) predicting long-term impact of unpredictable variability on congestion.

- Unpredictable Variability
- Utilization < 1 only
- Long Run Analysis
- Fixed rates only

COVERED

- G/G/N queueing formula
- Little's law (flow balance)
- Managerial insights

A Deterministic Queue

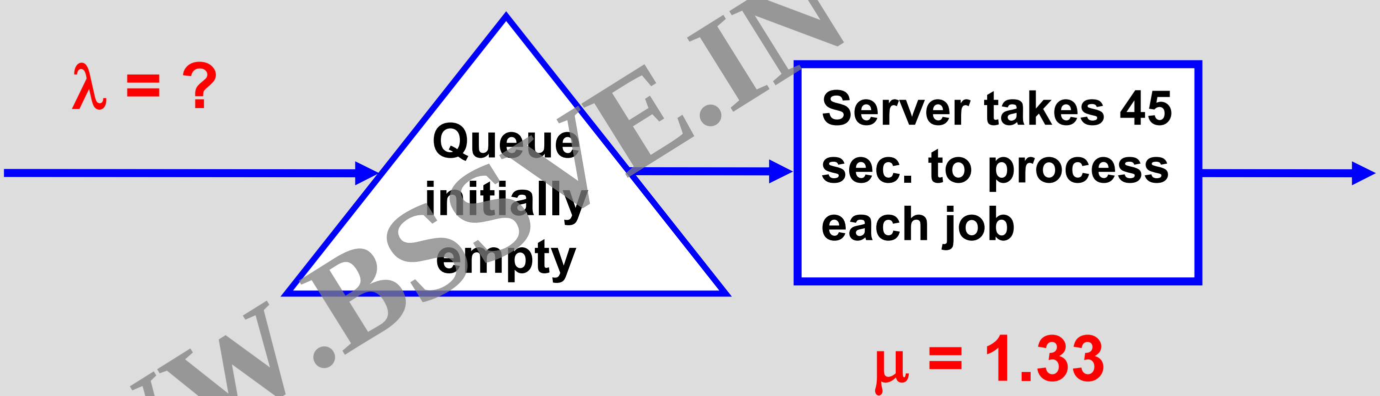


2002 - Jérémie Gallien

A Queue with Bursty Arrivals

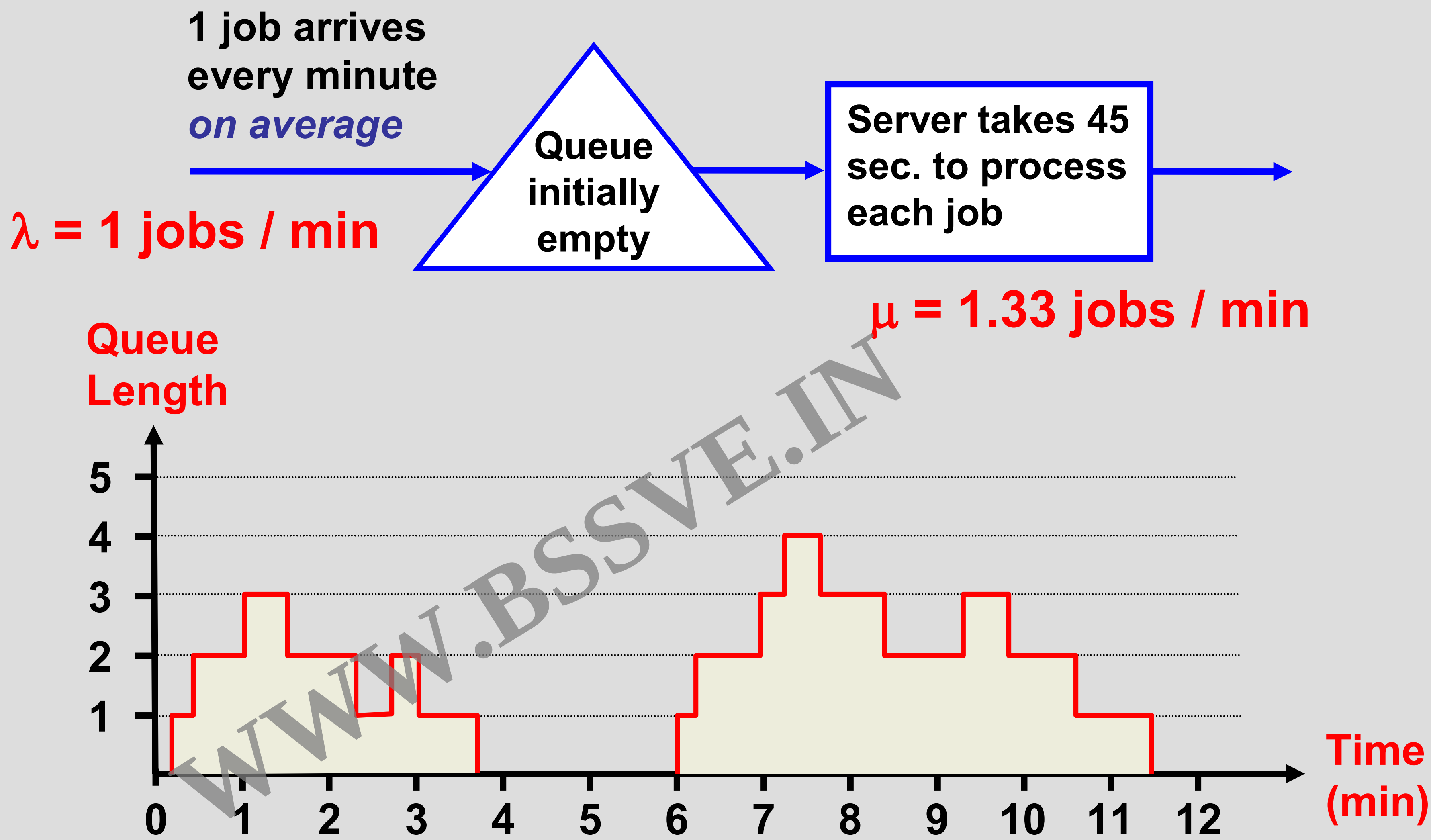
Next job arrives:

- after 15 sec. with probability 1/2
- after 1 min 45 sec. with probability 1/2



- This model captures unpredictable variability

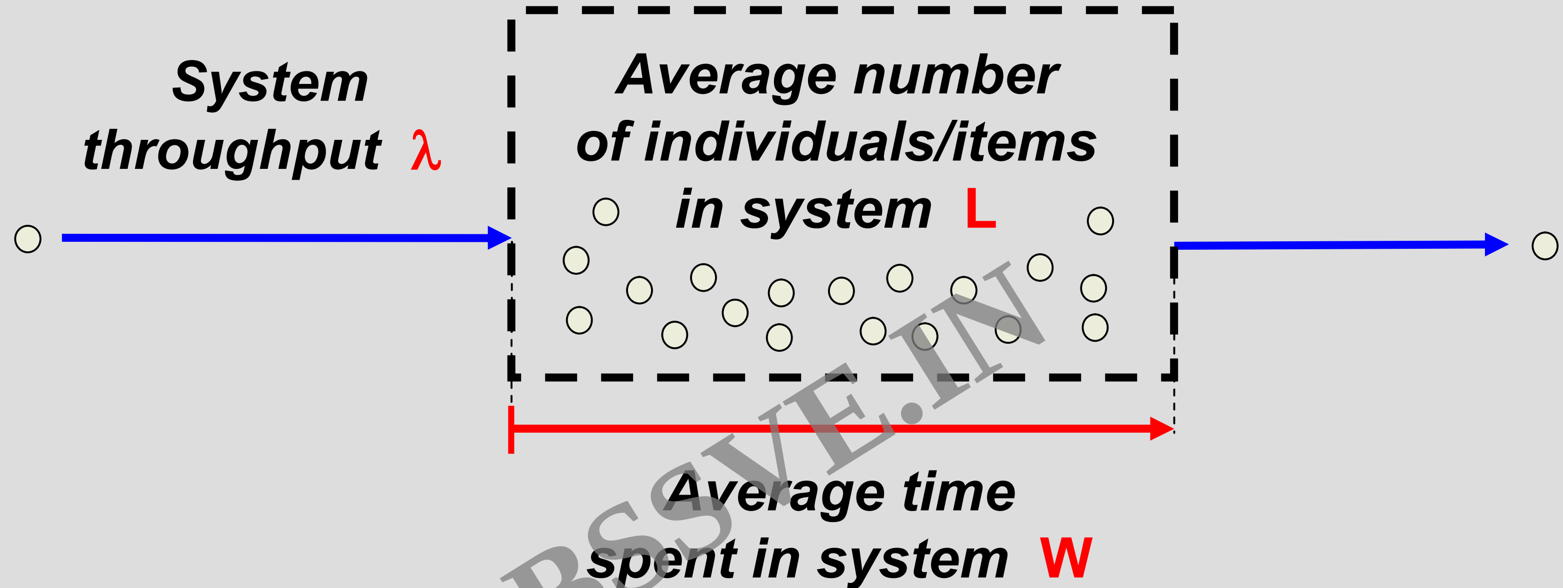
A Queue with Bursty Arrivals



2002 - Jérémie Gallien

Little's Law

- 300 new MBA's/Year x 2 Years MBA = 600 students in Sloan



- Conservation of Flow (equilibrium):

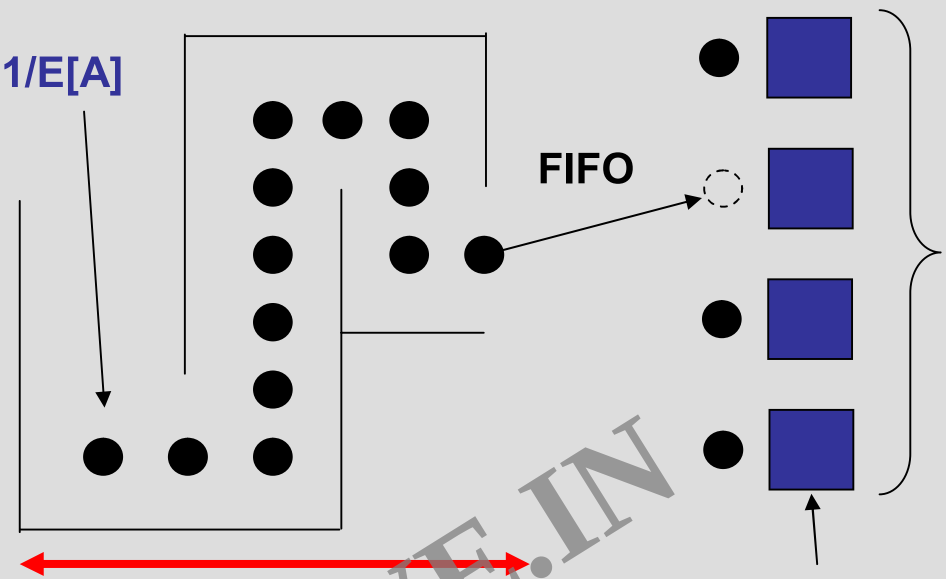
$$L = \lambda \times W$$

2002 - Jérémie Gallien

G/G/N Queueing Model

arrival
rate $\lambda = 1/E[A]$

inter-arrival time
distribution A
$C_A = \sigma[A] / E[A]$



N servers,
capacity utilization
$\rho = \lambda / (N \times \mu)$

Average queue length L

individual
service rate $\mu = 1/E[S]$

service time
distribution S
$C_S = \sigma[S] / E[S]$

Examples:

- Airline check-in counters
- Bank ATMs
- Retail cashiers
- Computer processing
- Manufacturing
- Call centers
- 911 response
- …

2002 - Jérémie Gallien

G/G/N Queueing Formula

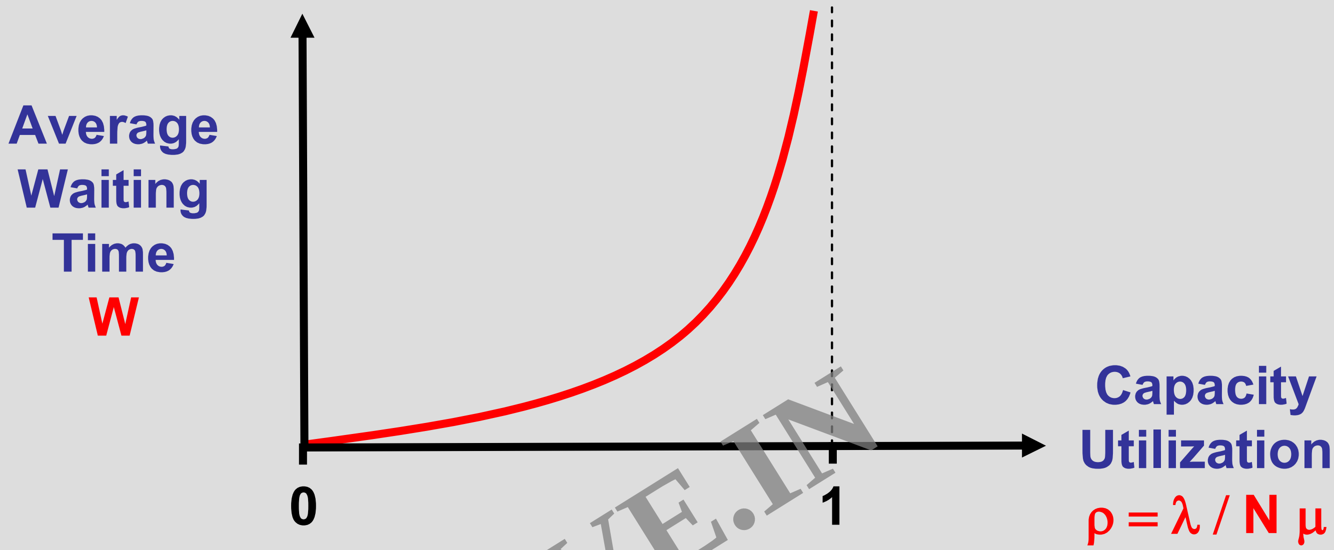
Approximation with an infinite buffer size:

$$L = \frac{\rho^{\sqrt{2(N+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

L	average number waiting
ρ	capacity utilization ($= \lambda / N\mu$)
C_A	coefficient of variation: inter-arrival times
C_S	coefficient of variation: service times
N	number of servers

2002 - Jérémie Gallien

Main Queueing Insight



- The relationship between waiting time and capacity utilization is strongly non-linear!

Managing the Psychology of Queueing

1. Unoccupied time feels longer than occupied time
2. Process waits feel longer than in process waits
3. Anxiety makes waits seem longer
4. Uncertain waits seem longer than known, finite waits
5. Unexplained waits are longer than explained
6. Unfair waits are longer than equitable waits
7. The more valuable the service, the longer the customer will wait
8. Solo waits feel longer than group waits

Class 3 Wrap-Up

1. Inventory buildup diagrams and predictable variability

2. Little's law (systems in equilibrium) $L = \lambda \times W$

3. Queueing theory and unpredictable variability

4. Non-linear relationship between W or L and ρ

5. Queue Psychology Management

Exercise 1 Name: ______________________

Draw an inventory buildup diagram for the fish processing example (from the lecture) when freezer capacity is 2400 tons, demand pattern is the same, but processing capacity is instead 3300 tons/month:

Exercise 2

Compute the long-term average of customer waiting time for the example "A Queue with Bursty Arrivals" (from the lecture), when the service time of each customer is instead (exactly) 50 seconds:

Hint: recall from DMD/Stat that $\sigma[X] = sqrt(E[X^2]-E[X]^2)$

(R,Q) Parameters

→ "order Q whenever inventory reaches R"

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

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

where α is a desired service level (e.g. 95%)
DDLT = Demand During Lead Time

<u>Example (cont'd):</u> if weekly demand for 128Mb chips is in fact N(400,80) and delivery time is 2 weeks, for a 95% service level:

Q = 1,013 units (as before),
R = E[DDLT] + 1.65 x σ[DDLT] = 800 + 1.65 x sqrt(2) x 80 = 986

(S,T) Parameters

→ "order back to S every T time units"

- Set T as the EOQ solution divided by the demand rate
- Set S as the newsboy solution:

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

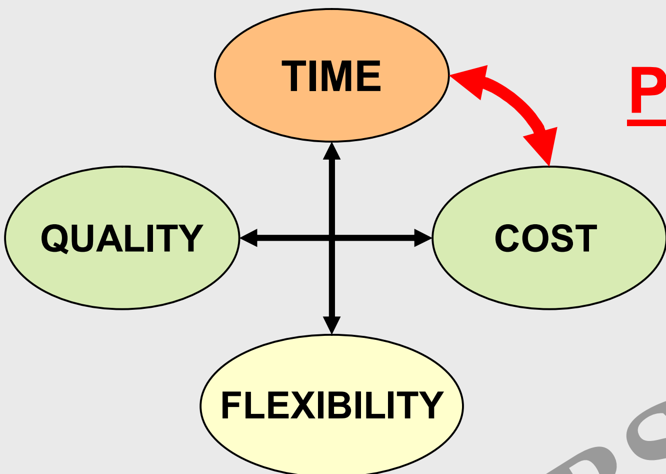
where: - α is the desired service level (e.g. 95%)
- DDLTRP = Demand During Lead-Time and Review Period

Example (cont'd): For the 128Mb chips example (from slides 12 & 23):

T = Q / D = 1,013 / 400 = 2.5 weeks,
S = E[DDLTRP] + 1.65 x σ[DDLTRP]
= (400 x 4.5) + 1.65 x sqrt(4.5) x 80 = 2080 units

2002 - Jérémie Gallien

Class 6: Inventory Lecture



Design Decision:
CAPACITY (cf. Class 3)

Planning/Control Decision:
INVENTORY

(Oct 2001: $1.16 trillion in US!)

Trade-off: Inventory Cost Vs. Service Level

2002 - Jérémie Gallien

From the Trenches...

Too much:

- Liz Claiborne experiences "unexpected earnings decline as a consequence of 'higher-than-expected excess inventories'" – Agins, Teri. "Liz Claiborne Seems to Be Losing Its Invisible Armor," *The Wall Street Journal*, July 19 1993.

- "On Tuesday, the network-equipment giant Cisco provided the grisly details behind its astonishing $2.25 billion inventory write-off in the third quarter" – Barrett, Larry. "Cisco's $2.25 Billion Mea Culpa," *News.com*, May 9 2001, http://cnet.news.com (accessed June 3, 2004).

Too little:

- IBM struggles with shortages in ThinkPad line due to ineffective inventory management – Hays, Laurie. "IBM to Slash Prices Up to 27% on Business PCs," The Wall Street Journal, August 24 1994.

- "Since 1990 we have designated the Department of Defense's management of its inventory, including spare parts, as high risk because […] its management systems and procedures were ineffective." – US General Accounting Office. "Army Inventory: Parts Shortages Are Impacting Operations and Maintenance Effectiveness," August 2001.

2002 - Jérémie Gallien

Why Inventory Costs Money

- Cost of (stuck) capital
- Obsolescence
- Storage
- Insurance
- Security
- Theft (Shrinkage)

→ Typical per annum inventory holding cost:

Financial Inventory Metrics

$$\text{Inventory Turns} = \frac{\text{COGS}}{\text{Inventory Value}}$$

COGS ← Earnings or P & L

Inventory Value ← Balance sheet

$$\text{Inventory Cost / Unit} = \frac{\text{Inventory Value x Holding Cost}}{\text{COGS}} = \frac{\text{Holding Cost}}{\text{Inventory Turns}}$$

Example: 10k filings, 2002 ($M)

	Wal Mart Stores Inc.	*Kmart Corp.*
Inventory	$22,749	$4,825
C.O.G.S	$171,562	$26,258

Why Hold Inventory? How Much?

Type of Inventory	*Decision Tool*
Safety Inventory	Newsboy Model
Cycle Inventory	EOQ Model
Seasonal Inventory	Buildup Diagram
Speculative Inventory	Finance
In-Process/Pipeline Inventory	Little's Law
Marketing/Shelf Inventory (Retail)	Experience

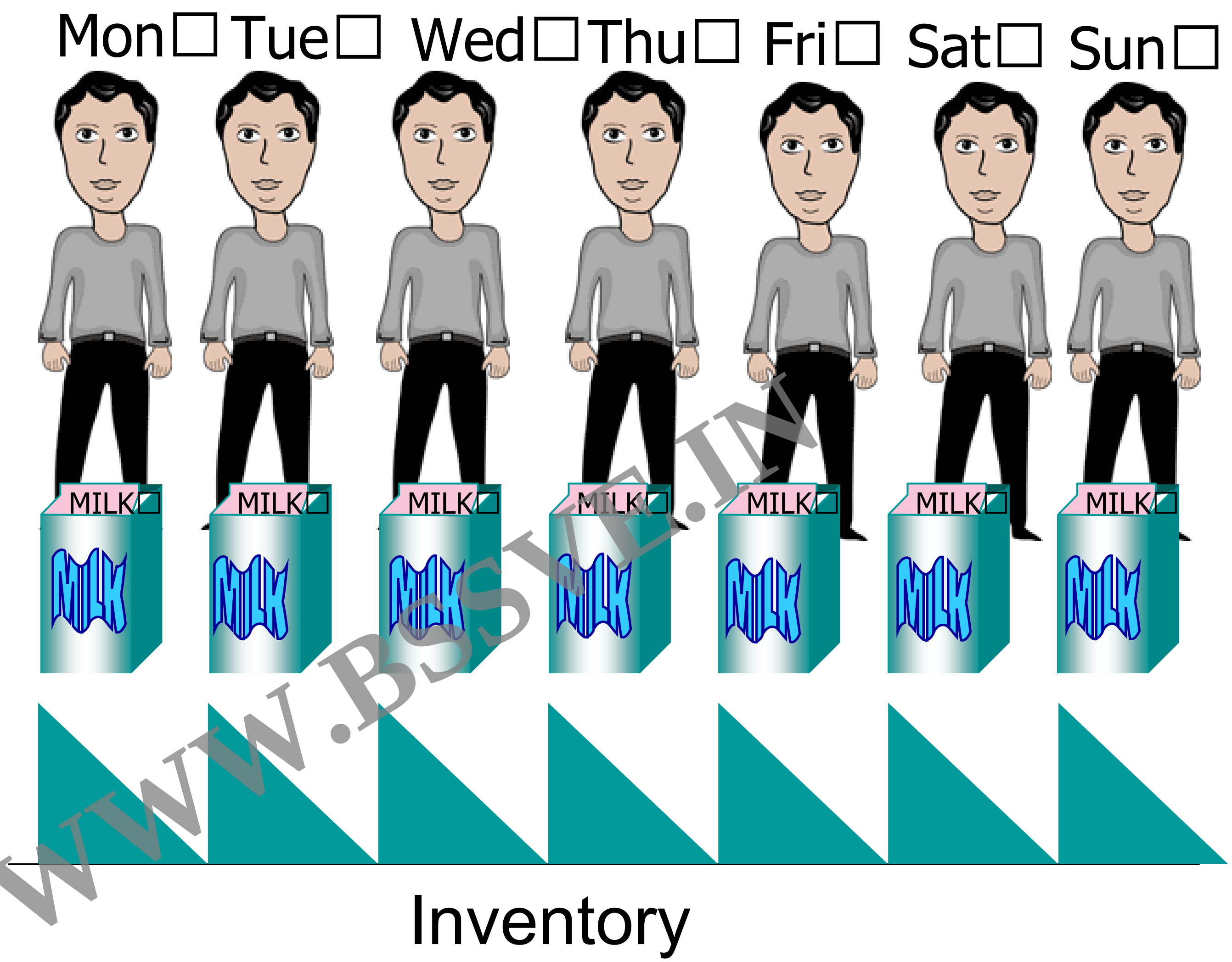
Economic Order Quantity Model

- **Set order size for repetitive ordering process with fixed order cost**

- **Trade-off:**
  - **Order size too large (too much average inventory) versus**
  - **Order size too small (too much ordering cost)**

- **Examples:**
  - **Ordering/Inventory replenishment policy;**
  - **Batch size on machine with setup time…**

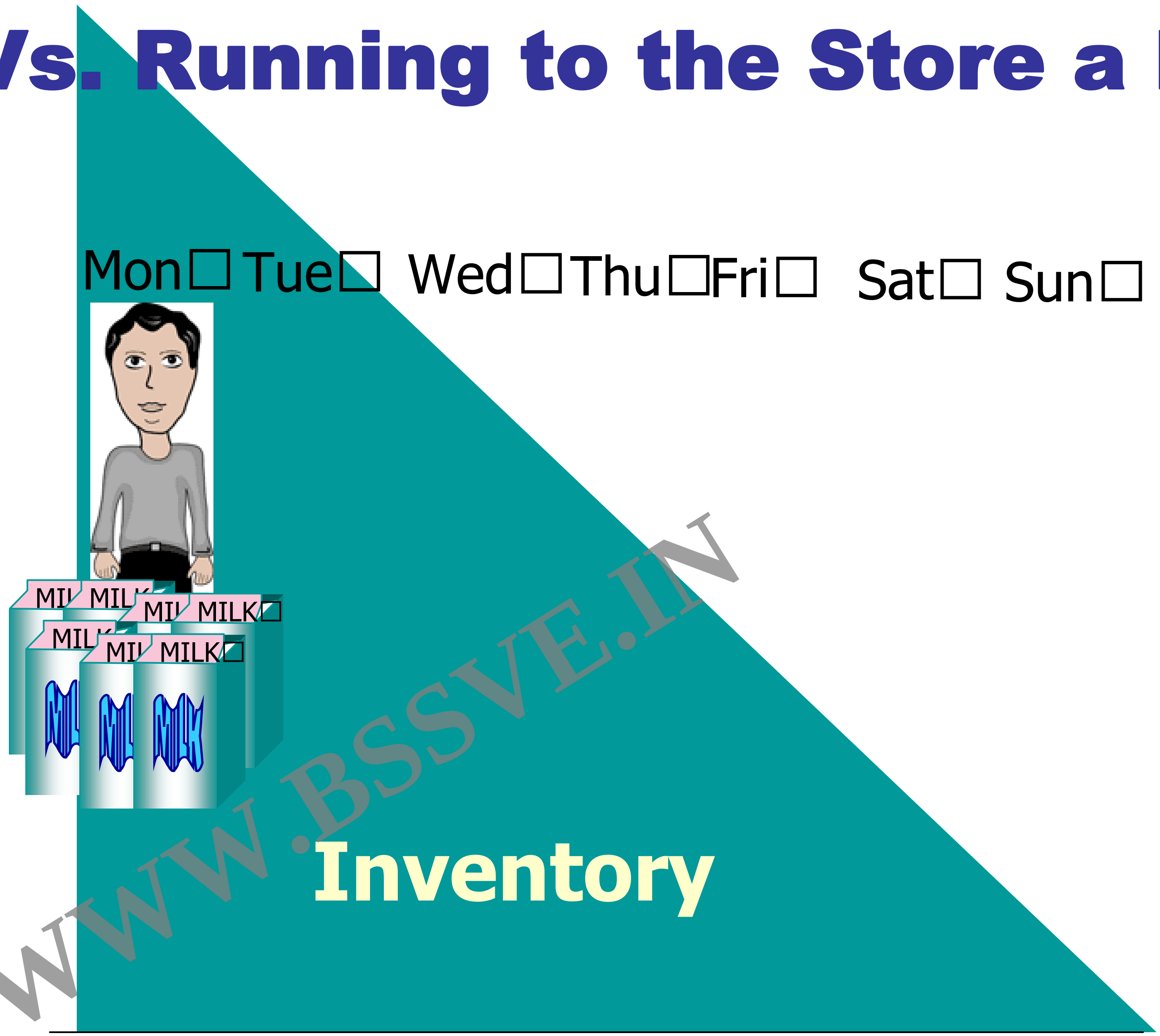
Running to the Store a Lot...



2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

...Vs. Running to the Store a Little



2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT

EOQ Model Parameters

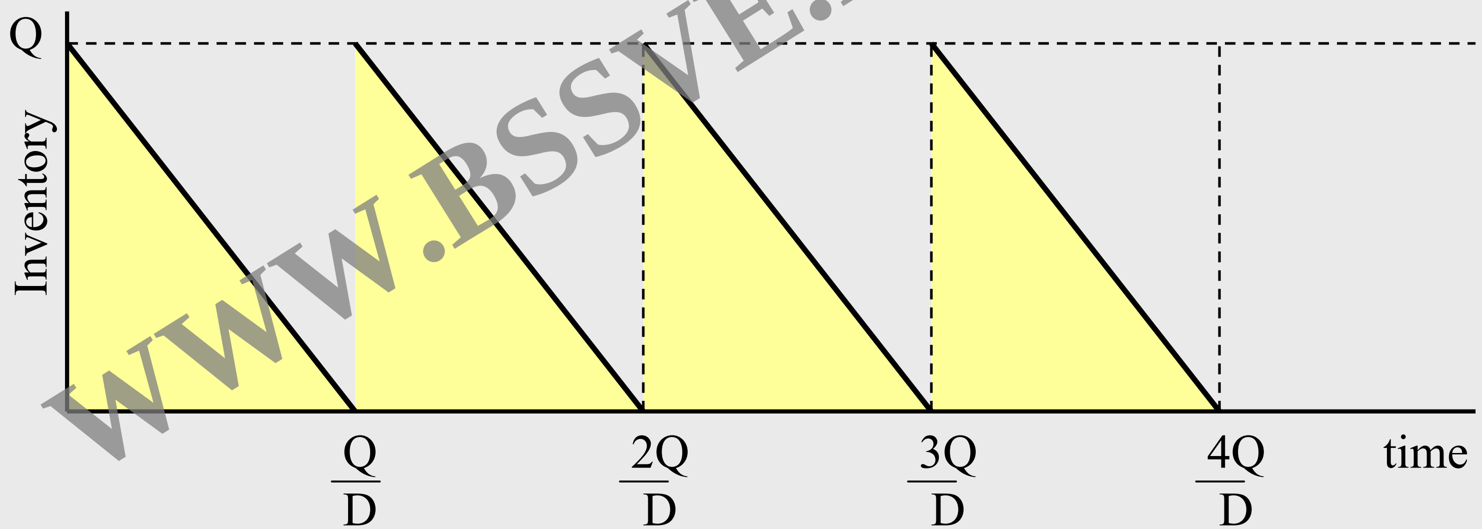
- Q = Order Quantity *decision*

- D = Demand Rate (units/time)
- C = Purchasing Cost ($/unit) *parameters*
- F = Fixed Order Cost ($)
- H = Inventory Holding Cost (% p.a.)

Assumptions: - constant, deterministic demand
- instantaneous replenishment

EOQ Model Derivation

- **Inventory Cost** $H \cdot \frac{C \cdot Q}{2}$ **; Order Cost** $F \cdot \frac{D}{Q}$ **;**
- **Total Cost** $V = F \cdot \frac{D}{Q} + C \cdot H \cdot \frac{Q}{2}$



2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

EOQ Formula

- **Set first derivative to 0:** $$\frac{\partial V}{\partial Q} = -\frac{DF}{Q^2} + \frac{CH}{2} = 0$$
- **This yields:**

$$Q^* = \sqrt{\frac{2 \cdot DF}{CH}}$$

2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

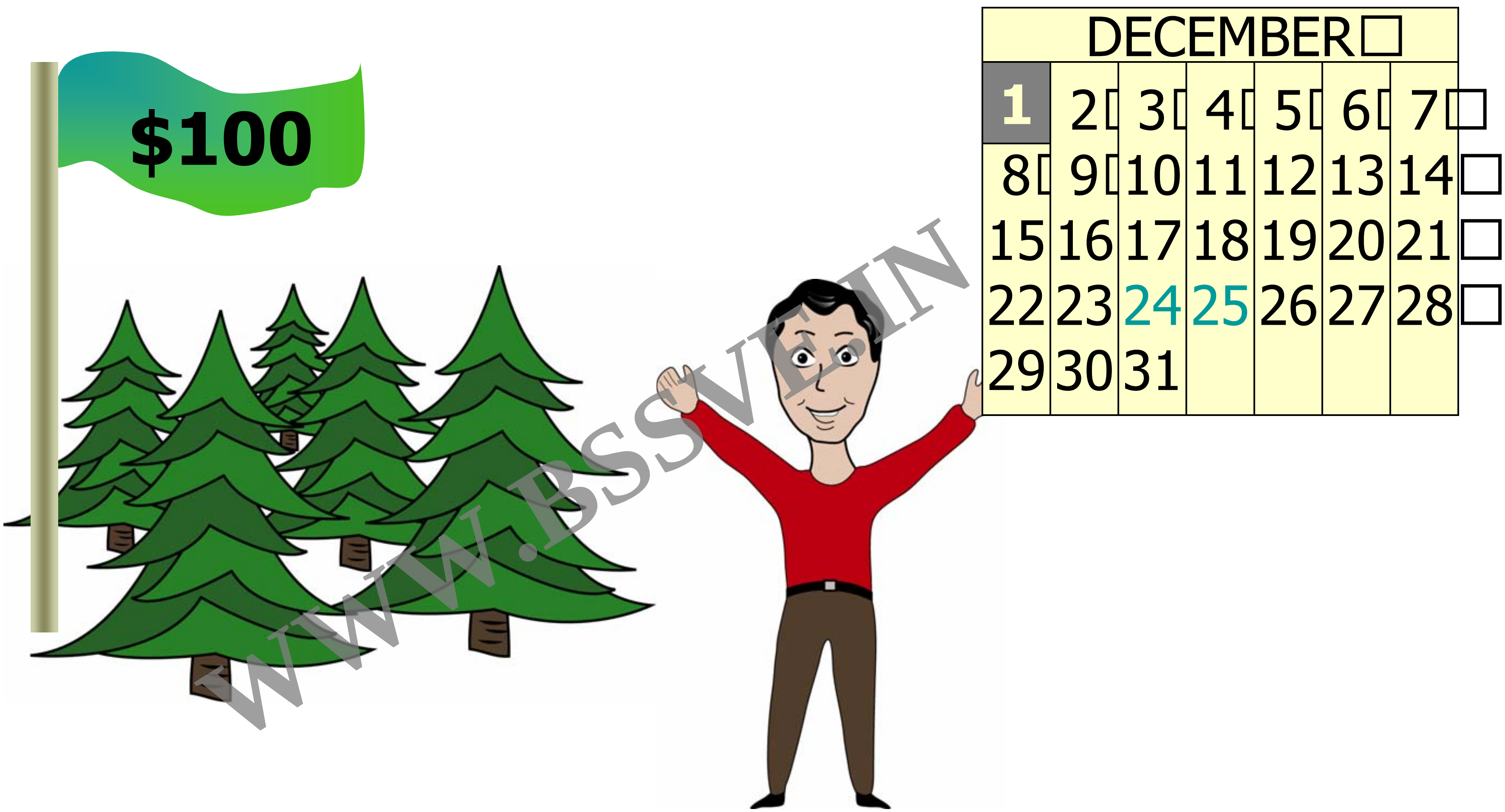
EOQ Example

A PC assembly operation procures its 128Mb memory chips at $45 each (purchase + shipment cost) from a foreign vendor; in addition each order also costs $500 in customs fees. Assuming a constant demand of 400 chips per week and an inventory holding cost of 45%, how often would you order?

Newsvendor Model

- One time decision under uncertainty
- Trade-off:
  - Ordering too much (waste, salvage value < cost) versus
  - Ordering too little (excess demand is lost)
- Examples:
  - Restaurant;
  - Fashion;
  - High Tech;
  - Inventory decisions…

Christmas Tree Problem



2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

Ordering Too Many...

DECEMBER						
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

...Versus Ordering Too Few

DECEMBER						
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

Newsvendor Model Parameters

- q = Order Quantity — *decision*

- c = Unit Cost
- r = Unit Revenue
- b = Unit Salvage Value

} *parameters* (r > c > b)

- d = Demand (unknown) — *random variable*

Newsboy Objective

IF d > q

(demand > quantity ordered)

Opportunity cost:

$(r - c) \times (d - q)$

IF q > d

(quantity ordered > demand)

Disposal cost:

$(c - b) \times (q - d)$

Objective:

minimize expected opportunity + disposal cost

Model Derivation

	• IF d > q (demand > order qty)	• IF d < q (demand < order qty)
Profit:	$q \cdot (r - c)$	$d \cdot (r - c) + (q - d) \cdot (b - c)$
Incremental Analysis: $q \rightarrow q + 1$:		
Δ Profit:	$r - c$	$b - c$
EAP:	$P(d > q) \cdot (r\text{-}c) + P(d \le q) \cdot (b\text{-}c)$	

As long as the *Expected Additional Profit* [EAP] is positive, it is lucrative to increase *q* to *q + 1 !!!*

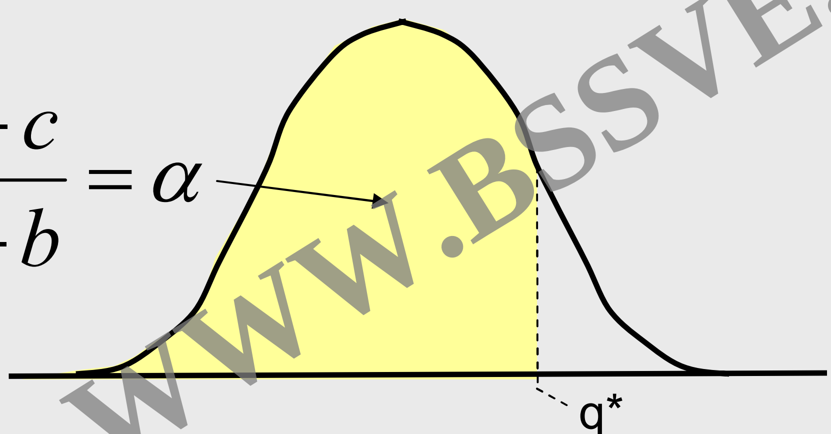
2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

Newsvendor Formula

$$P(d < q^*) = \frac{r-c}{r-b} = \frac{r-c}{\underbrace{(r-c)}_{\text{cost of under-stocking}} + \underbrace{(c-b)}_{\text{cost of over-stocking}}} = \frac{u}{u+o}$$

$$\frac{r-c}{r-b} = \alpha$$



Demand Distribution

<u>Remark:</u> If d is Normal(μ,σ),

q* = μ + k.σ with

α = 95% → k = 1.64
α = 99% → k = 2.32
α = 99.9% → k = 3.09

2002 - Jérémie Gallien

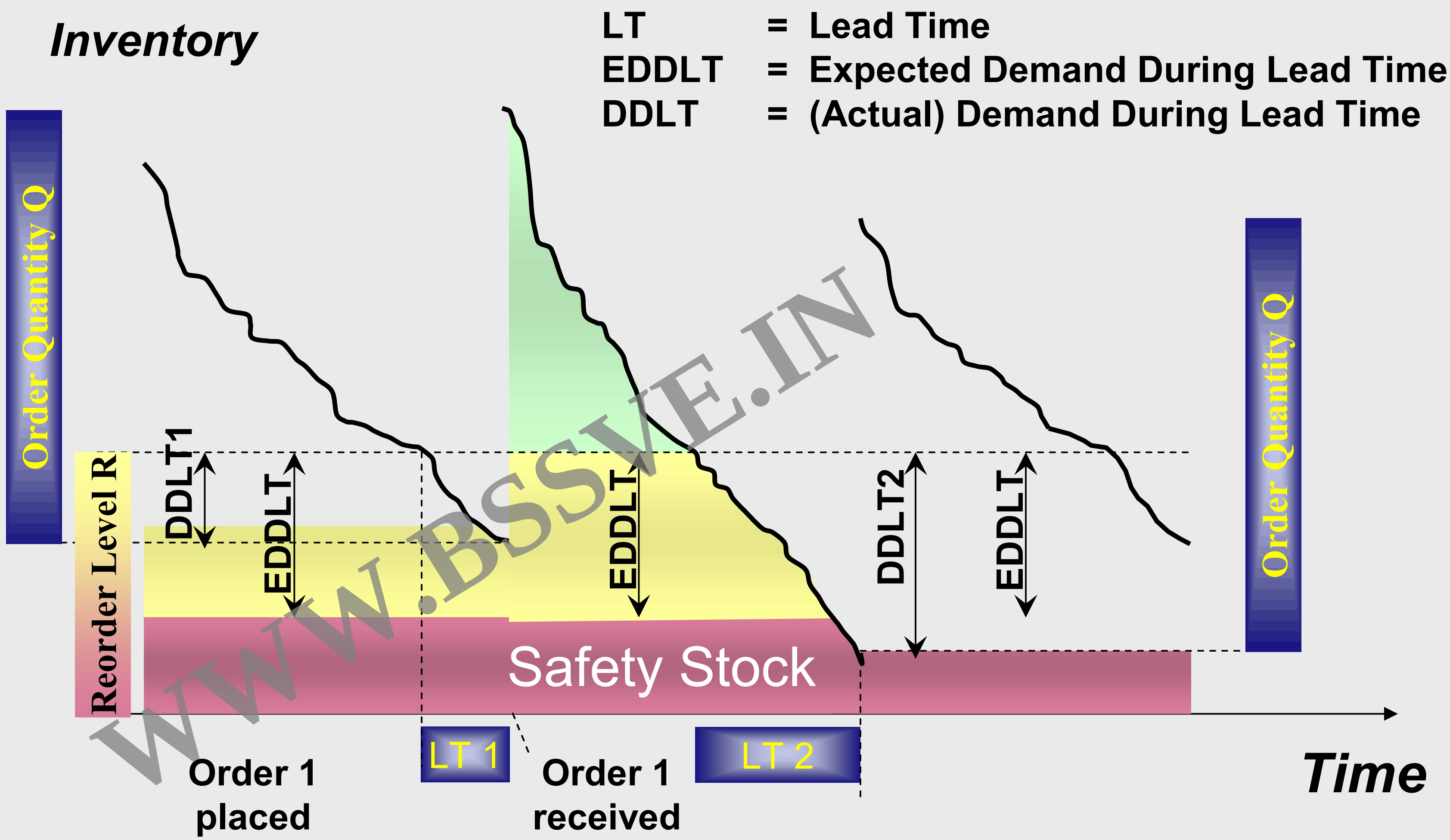
Slide courtesy of Prof. Thomas Roemer, MIT

Newsvendor Example

Based on forecasts and marketing studies you are expecting a total lifecycle demand N(60,000;20,000) for a new product due to launch in the future. The product has a gross margin of $750 and a liquidation/disposal cost (for unsold inventory) of $250. Because of long lead-times you must commit orders to supplier for the entire product life-cycle now. How much should you order?

Continuous Review System

"order Q whenever inventory reaches R"



2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT

(R,Q) Parameters

➡ "order Q whenever inventory reaches R"

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

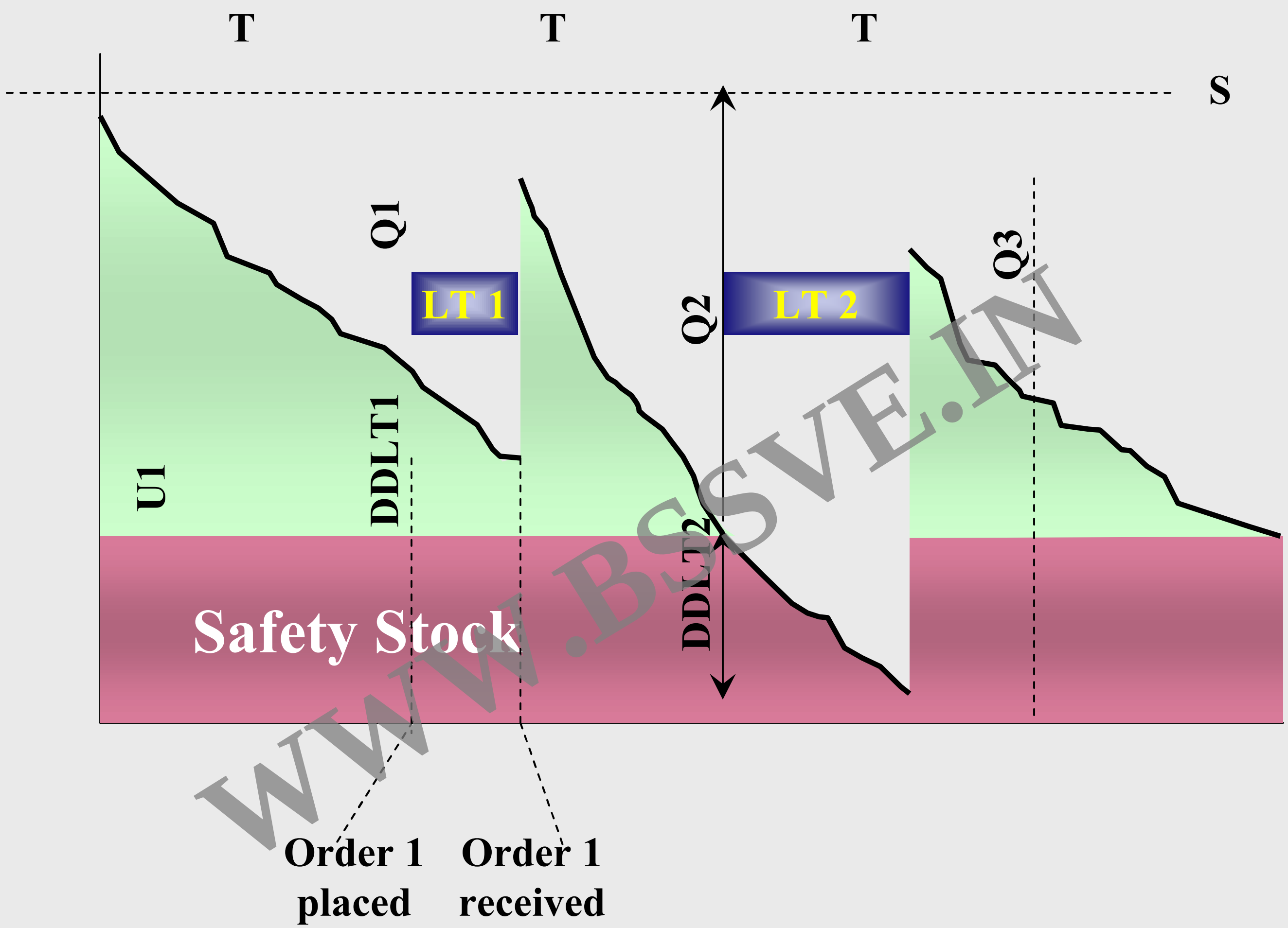
$$P(DDLT < R) = \alpha$$

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

Example (cont'd): if weekly demand for 128Mb chips is in fact N(400,80) and delivery time is 2 weeks, for a 95% service level:

Periodic Review System

"order back to S every T time units"



LT = Lead Time
T = Cycle Time or Review Period
DDLT = Actual Demand During Lead Time
Qi = Order Size
S = Order Up To Level

2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT

(S,T) Parameters

➡ "order back to S every T time units"

- Set T as the EOQ solution divided by the demand rate
- Set S as the newsboy solution:

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

where: - α is the desired service level (e.g. 95%)

- DDLTRP = Demand During Lead-Time and Review Period

Safety Stock Formula

- Under periodic and review systems, safety stock SS (under normally distributed demand) is given by:

$$SS = k\,\sigma$$

fractile depending on service level, e.g.
95% → k = 1.64
99% → k = 2.32
99.9% → k = 3.09

standard deviation of DDLT or DDLTRP

2002 - Jérémie Gallien

Class 6 Wrap-Up

1. Financial inventory metrics: inventory turns, per unit inventory cost
2. Functions of inventory: seasonal, cyclical, safety, speculative, pipeline, shelf
3. EOQ & newsboy models
4. Continuous and discrete replenishment policies, safety stock formula

Exercise 3 Name: ______________________

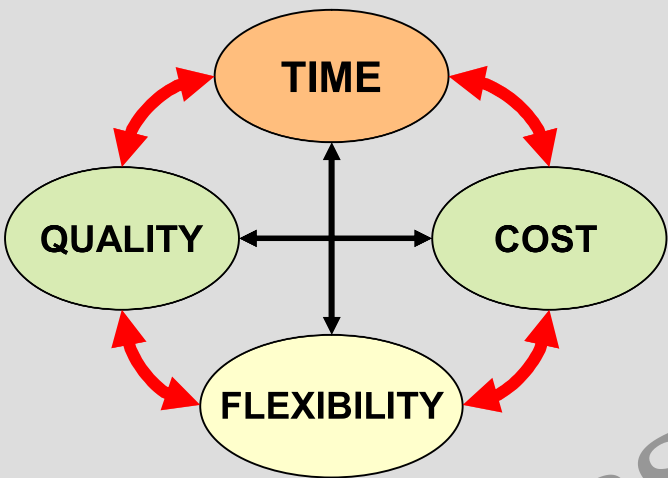
You need 50,000 units per year of a given part, and that part costs you $4 per unit. In addition to purchasing cost, every order for that part has a fixed administrative cost of $800 (regardless of order size). Assuming an inventory holding cost of 30% per annum, what is the optimal number of inventory turns per year?

Exercise 4

A warehouse facing a weekly customer demand N(100,20) replenishes its stock every month from a vendor with a 2 week delivery lead-time. What is the order-up-to level required to achieve a service level of 99%?

Class 9: Production Control

Production Control determines:



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

Production Control is the nervous system of a business process

2002 - Jérémie Gallien

Key Definitions

- **Pull:** Work triggered by 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 Control Methods

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

MRP Purpose

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

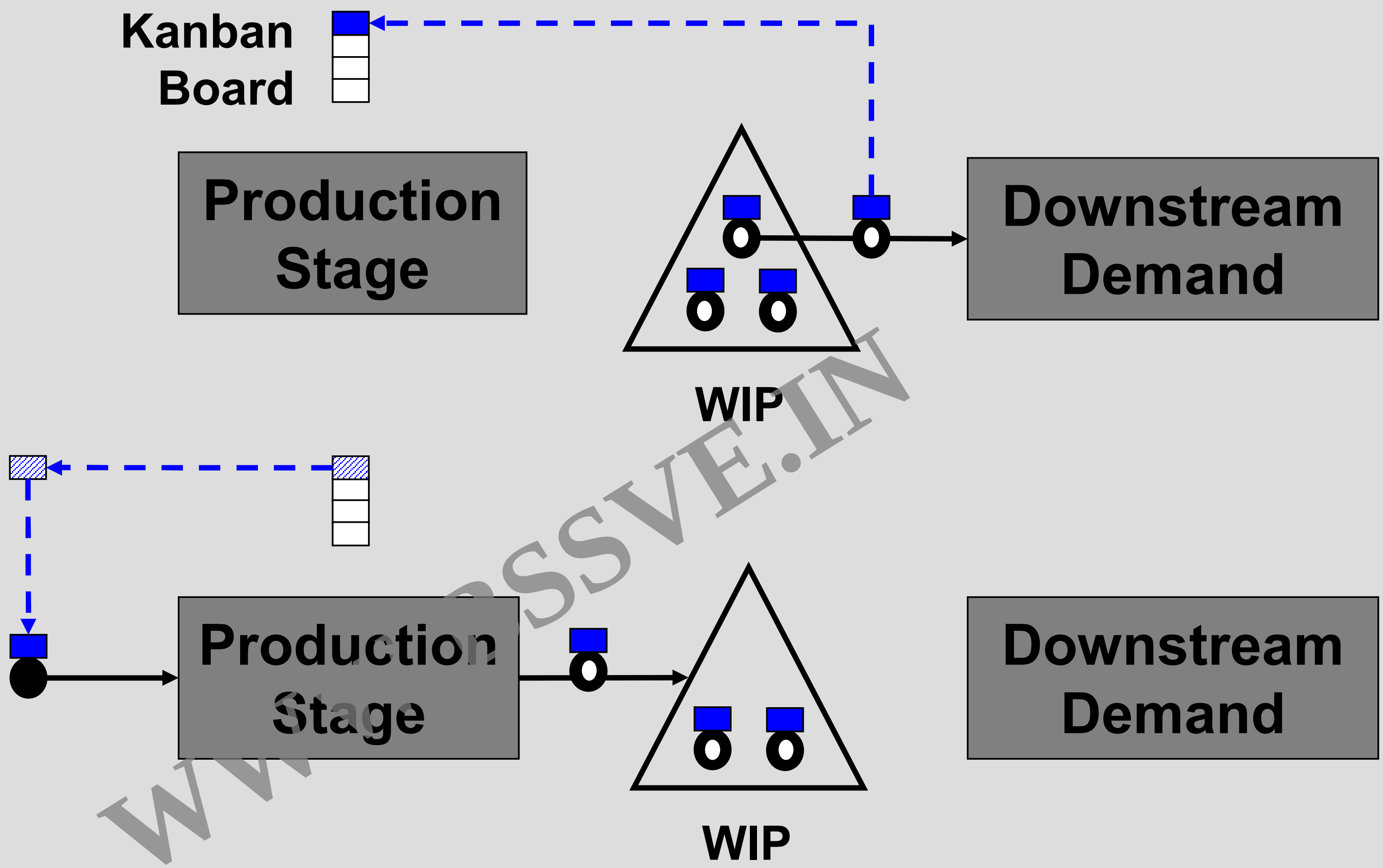
↓

ERP

MRP Problems

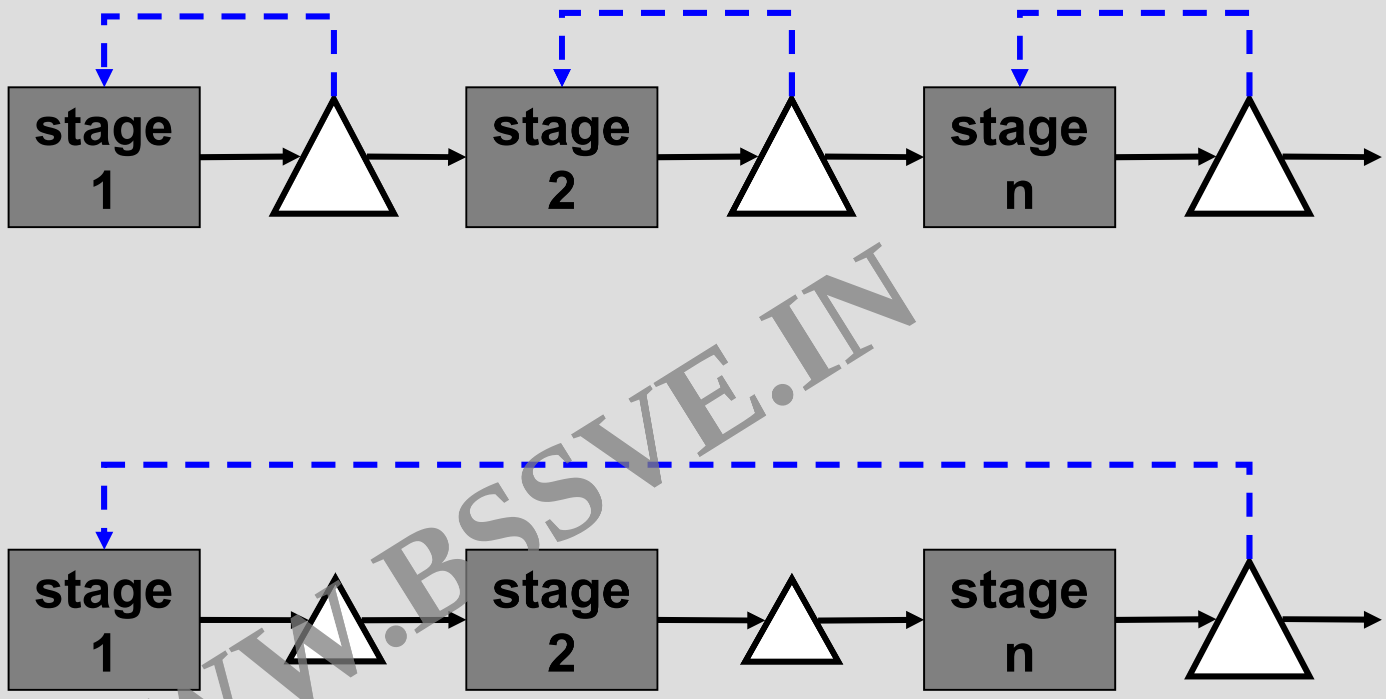
- Deterministic model
- Large data requirements and GIGO
- Self-fulfilling lead-times
- Difficulty and cost of installation and maintenance
- Centralized command and control mindset

What is Kanban?



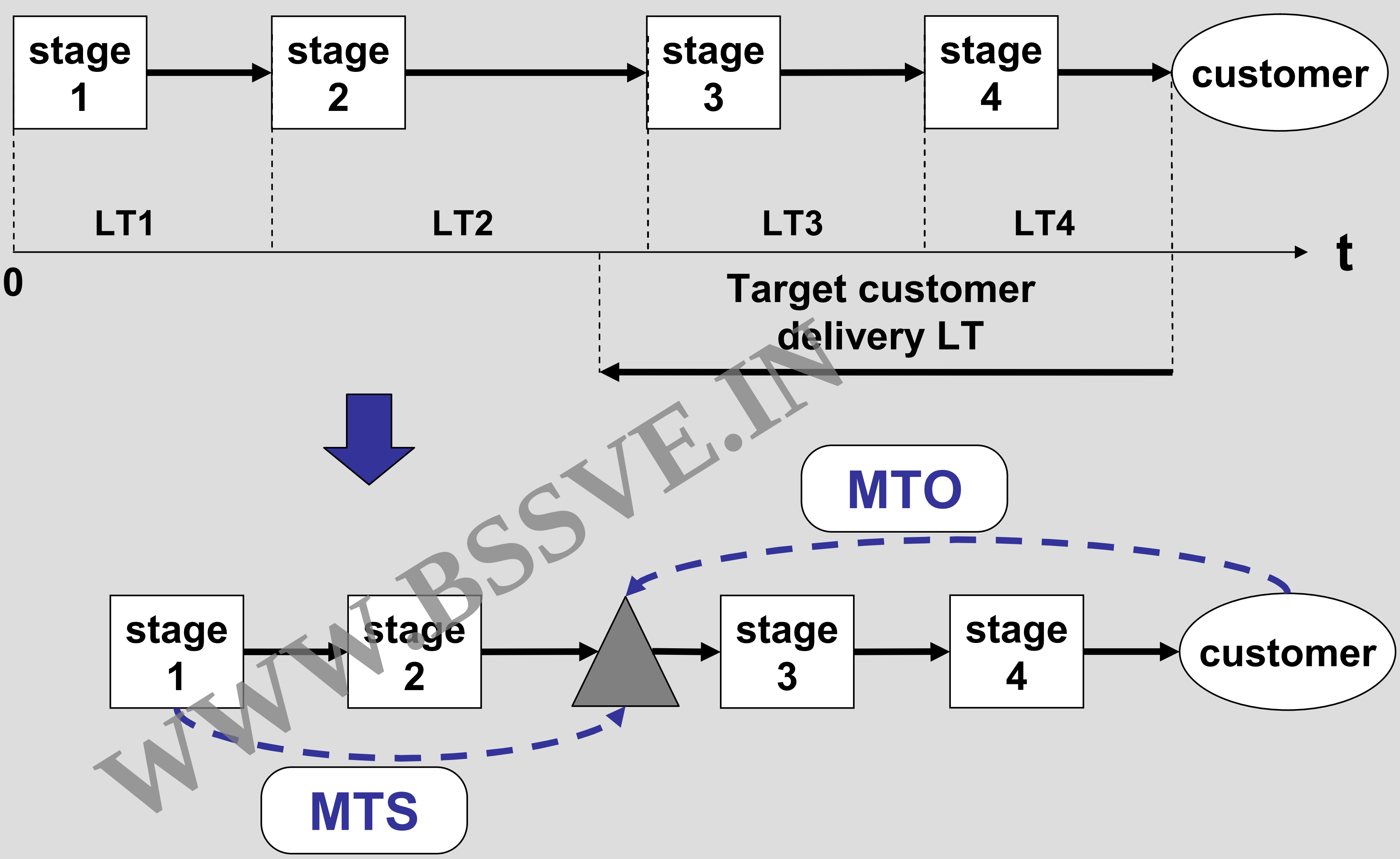
2002 - Jérémie Gallien

Multi-Stage Kanban & CONWIP



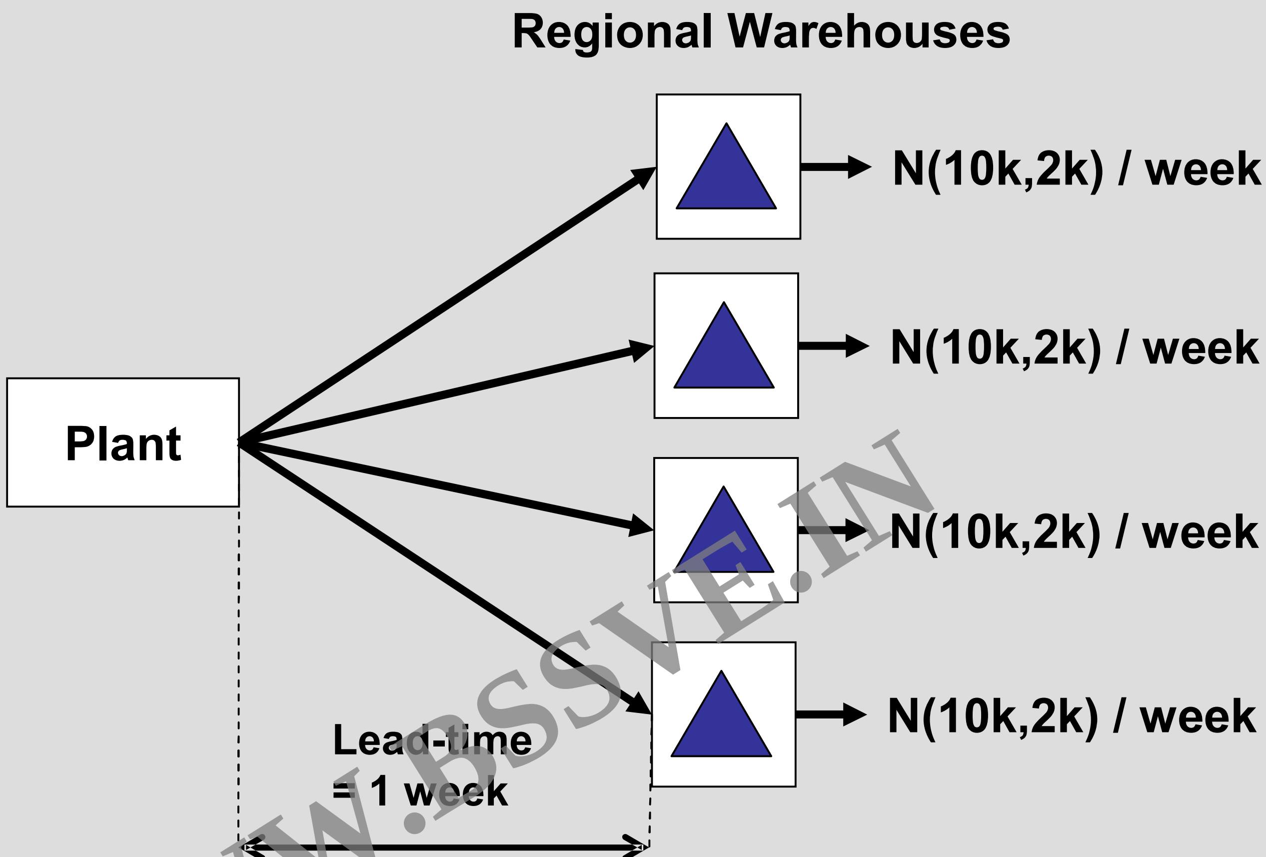
2002 - Jérémie Gallien

Customer and Process Timeline



2002 - Jérémie Gallien

Distribution System Example



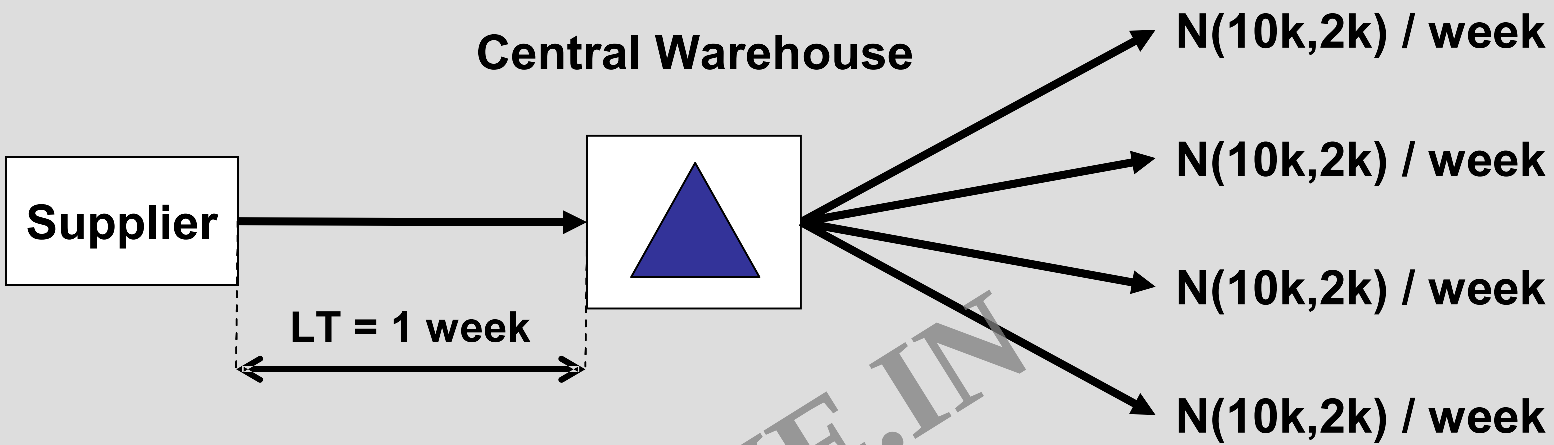
Assuming a (S,T) weekly review policy in each warehouse (95% service level, T=1), How much safety stock should there be in this distribution system?

2002 - Jérémie Gallien

Work out your answer here

2002 - Jérémie Gallien

Central Warehouse

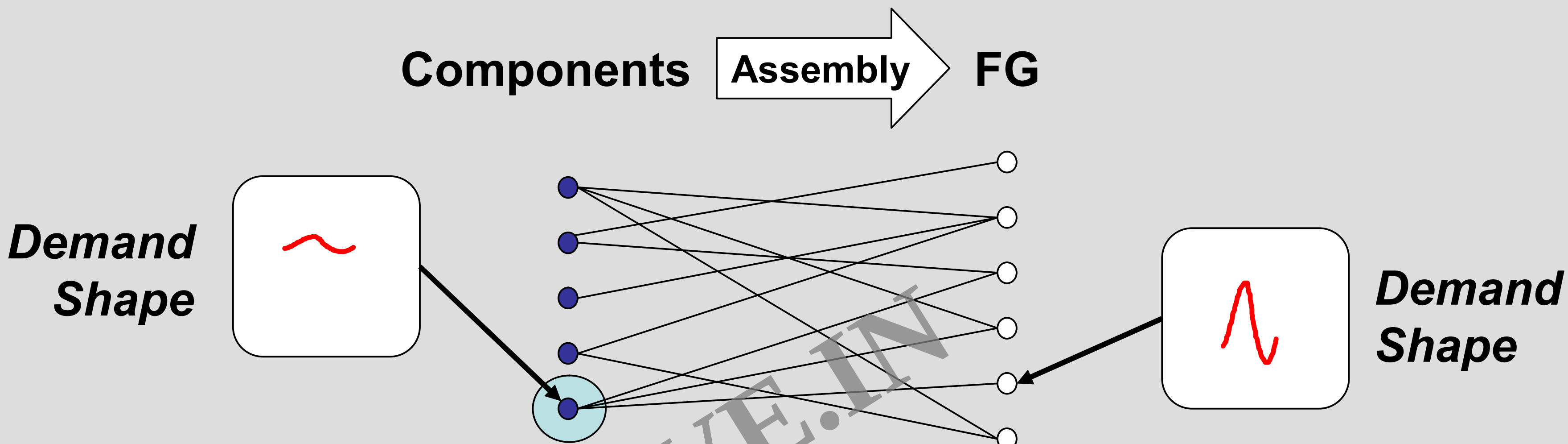


With a (S,T) weekly review policy in the central warehouse (95% service level, T=1), How much safety stock should there be now?

Work out your answer here

2002 - Jérémie Gallien

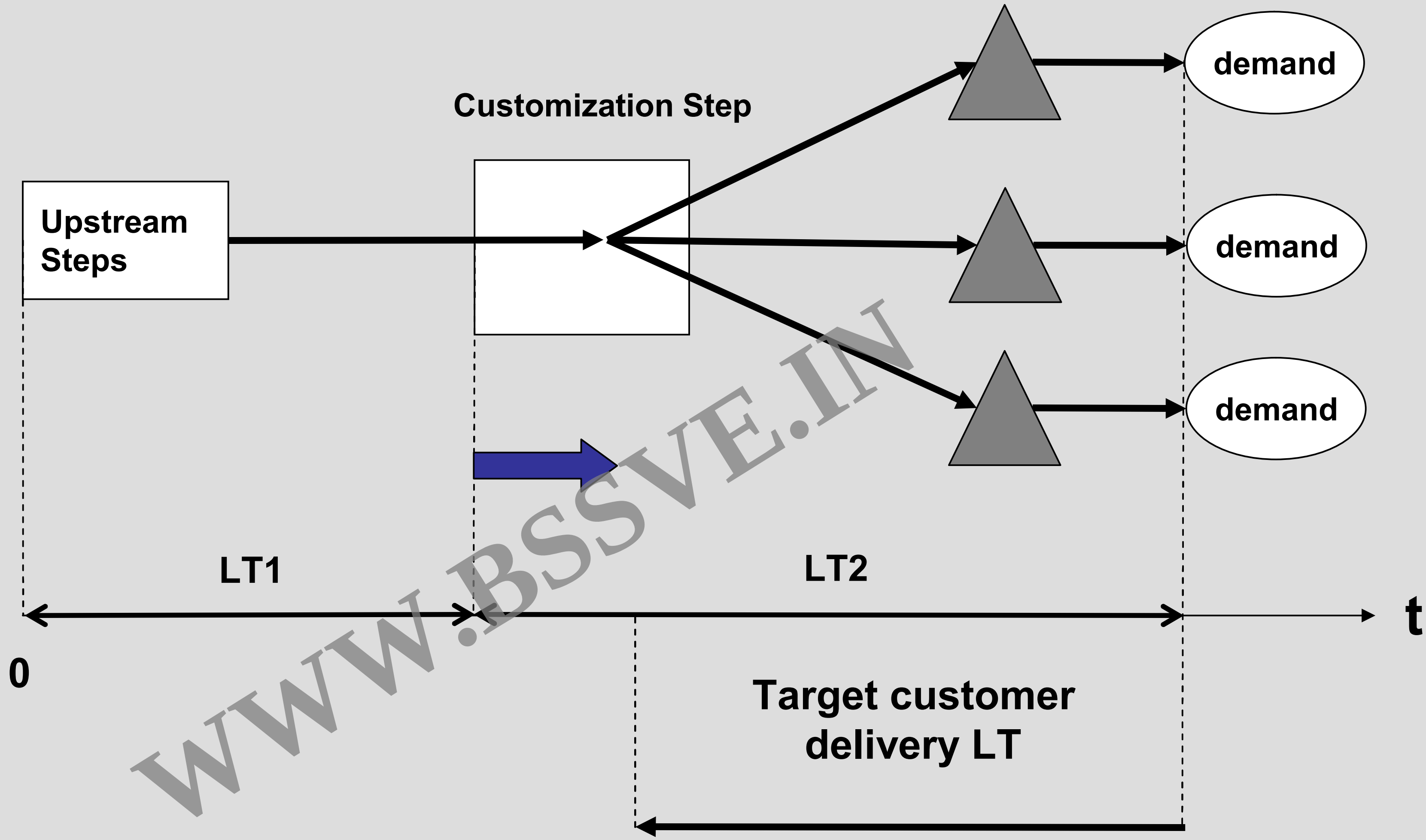
Component Commonality



- Instead of geographic differentiation, this is an assembly differentiation

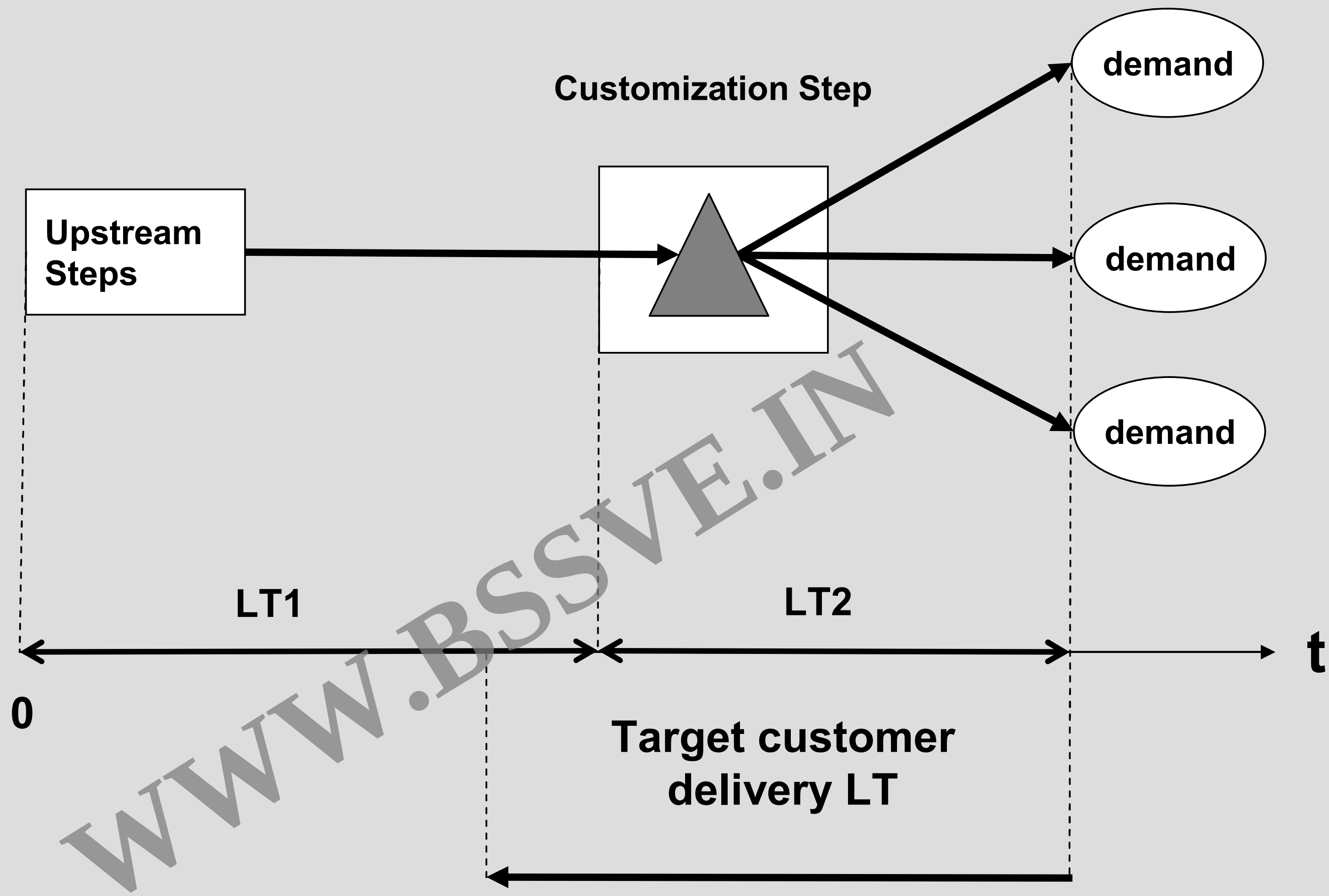
2002 - Jérémie Gallien

Delayed Differentiation



2002 - Jérémie Gallien

Delayed Differentiation

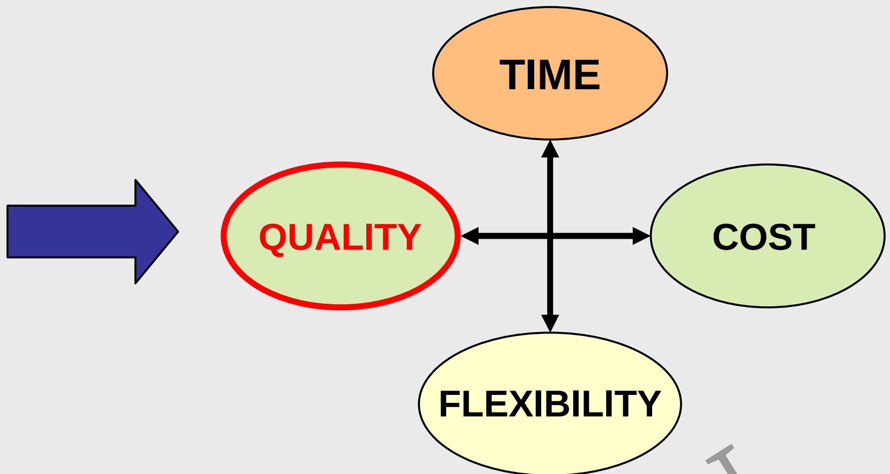


2002 - Jérémie Gallien

Production Control Wrap-Up

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

Class 12: Quality Lecture



1. What are the causes of quality problems on the Greasex line?

2. What should Hank Kolb do?

3. Overview of Total Quality Management (TQM)

2002 - Jérémie Gallien

The 3 Components of TQM

Goal: Quality
1. Fitness to Standards
2. Fitness to Use
3. Fitness to Market

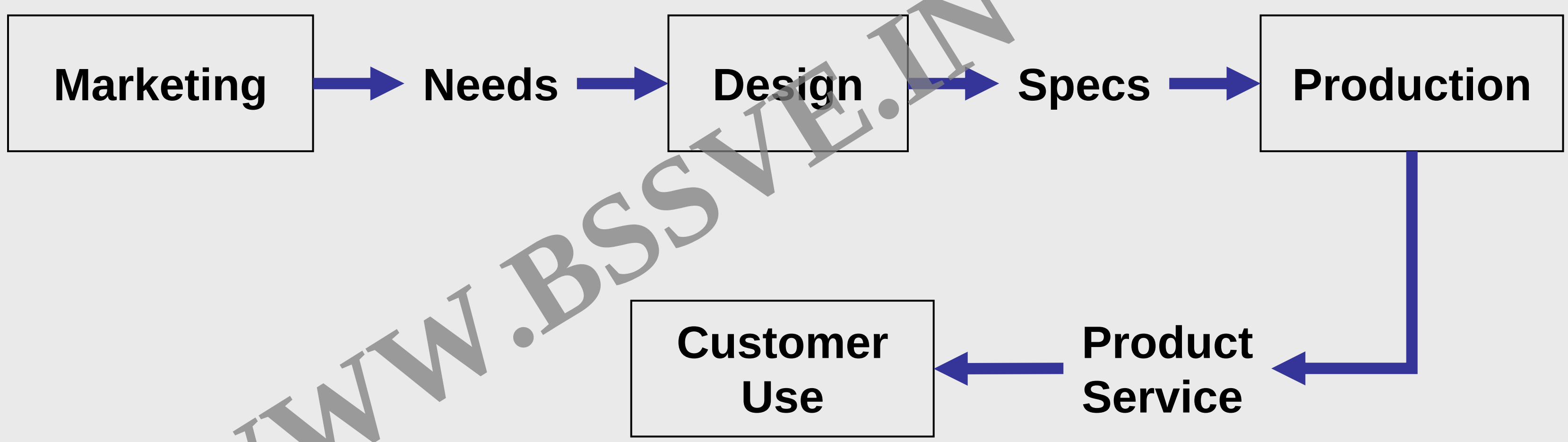
Tools
1. Measurement Systems
2. Education
3. Incentives
4. Organizational Change

Principles
1. Customer First
2. Continuous Improvement
3. Total Participation
4. Societal Learning

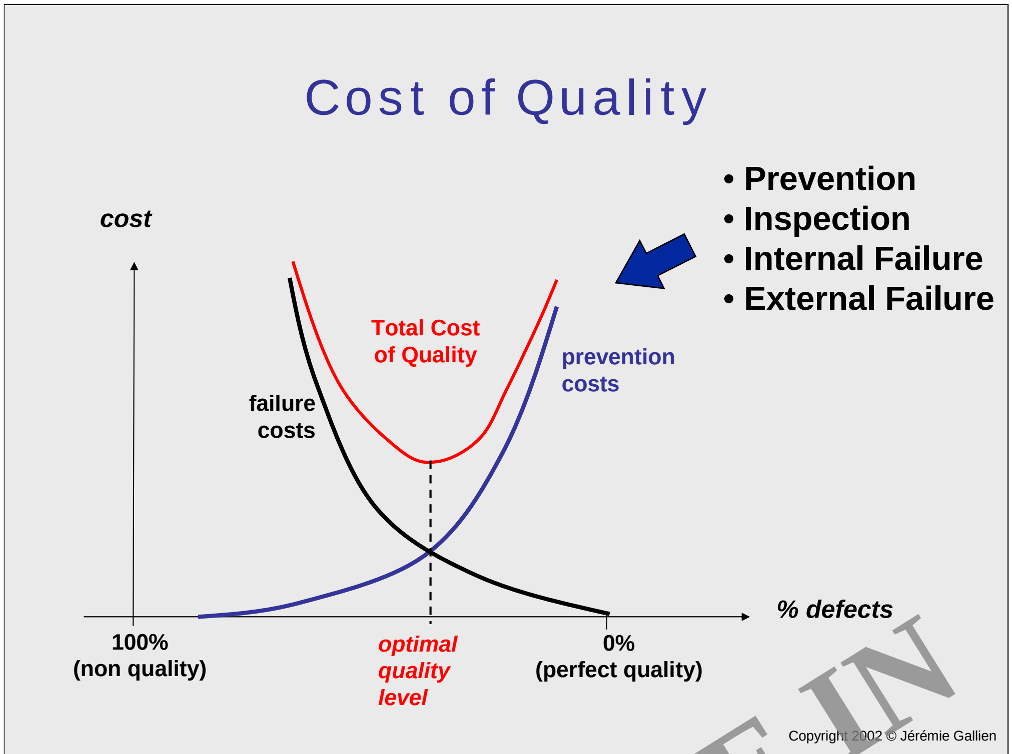
What is Quality?

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

result from:



2002 - Jérémie Gallien



•It is important to understand the rationale for this graph, presenting the concept of a (less than perfect) optimal quality level resulting from optimizing the sum of the cost of quality (prevention, inspection, etc.) and the cost of non quality (internal and external failures). It is in particular very relevant in a number of settings where the cost of quality and non-quality is fairly technical in nature (in semiconductor fabs for example, cost components of yield on one hand and atmosphere purity on the other side)

•It is also important to understand the limitations of this reasoning:

- •The failure costs are easily underestimated, particularly the external failures (think of brand/reputation, lawsuit settlements…);
- •The notion that the cost of quality increases as quality becomes near-perfect is debatable: when quality is very high, there may not be a need for inspection anymore;
- •It is also hard to estimate the part of the cost of quality resulting from market response, both positive (impact on brand and desirability of product) and negative (think of the cost for Microsoft of postponing the release of a software product to get some time to work out the bugs: they are clearly making the conscious calculation that this is not worth it);
- •This picture is static and for example does not show clearly what the competition's reaction could become (this would drastically increase the cost of non-quality);
- •The notion of an accepted level of defects may also have perverse incentive effects and cultural impact on the organization;
- •Finally, unlike the EOQ which is a robust model (change in the values of the input data have relatively little effect on the output), this one does not seem to be robust – the cost of non-quality may for example abruptly jump up by several million dollars for a very little reduction in quality level, if that reduction happened to result in a catastrophic external failure (Firestone tires of the Ford explorer, Challenger & Columbia shuttles, etc…).

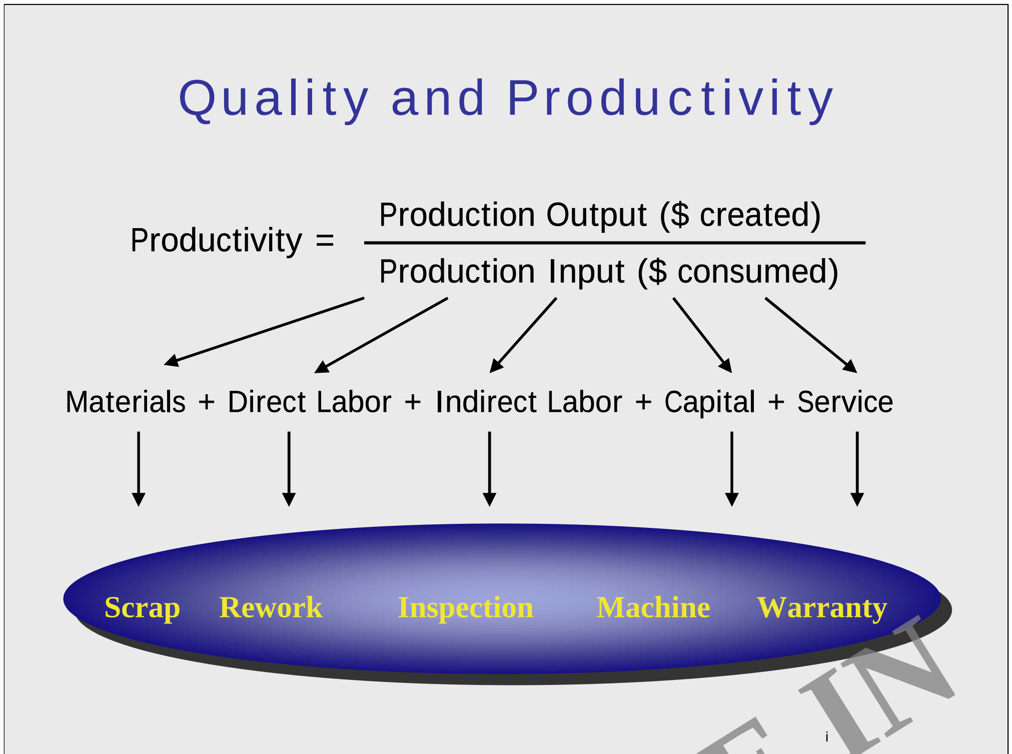
Slide courtesy of Prof. Thomas Roemer, MIT.

Industry Benchmark

For this graph of labor hours / vehicle vs. assembly defects for various countries, please see:

"World Assembly Plant Survey 1989" by MIT-IMVP (International Motor Vehicle Program).

2002 - Jérémie Gallien



•The point made of this slide (and the previous one with the automotive industry benchmark) is that there is not necessarily an inverse relationship between productivity and quality.

•The numerator of the ratio defining productivity tend to increase with quality, because of positive market response.

•The denominator may actually decrease with higher quality, because all of its terms (materials, direct labobr, etc. as listed above) have a cost component (scrap, rework, etc…) that increases with poor quality.

•This type of reasoning along with the critique of the optimal quality level illustrated in the slide “Cost of Quality” gives rise to the motto “Quality is Free” (the title of a book written by Crosby, one of the recognized american quality “gurus”).

Slide courtesy of Prof. Thomas Roemer, MIT.

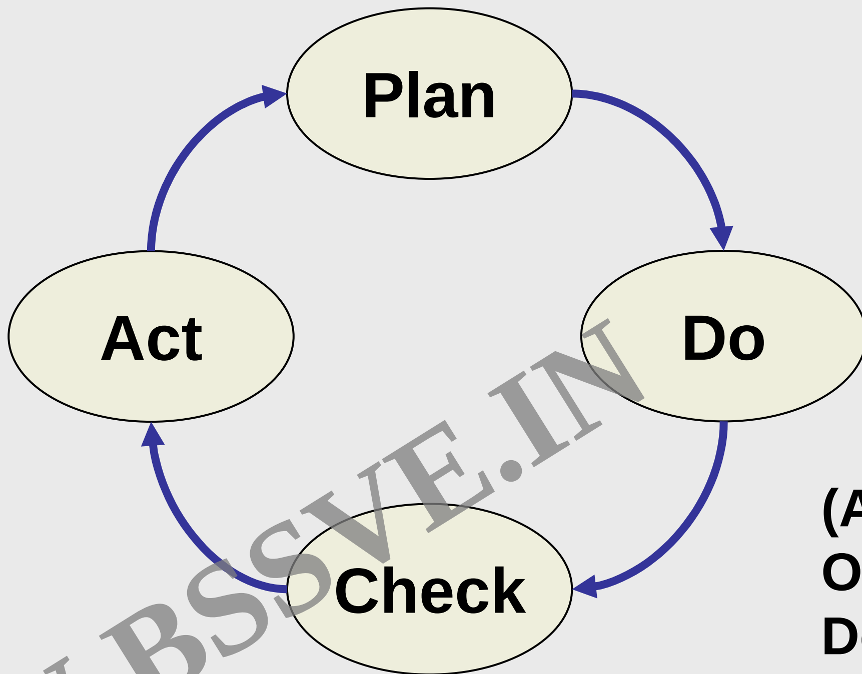
Quote from Dr. W. E. Deming

"The prevailing system of management has destroyed our people."

2002 - Jérémie Gallien

Continous Improvement

Philosophy: “A defect is a treasure”



(Also known as Observe - Assess Design – Intervene)

“In God We Trust; All Others Bring Data”

2002 - Jérémie Gallien

Measurement Systems

W. E. Deming advocated that the SQC tools be known by everybody in the organization:

1. Pareto Analysis
2. Process Flow Chart
3. Fishbone Diagrams
4. Histograms
5. Control Charts
6. Scatter Plots

2002 - Jérémie Gallien

Statistical Process Control

1. **Is the Process *In Control*?**

→ **Control Chart or X bar Chart**

2. **Is the Process *Capable*?**

→ **SQC Histogram**

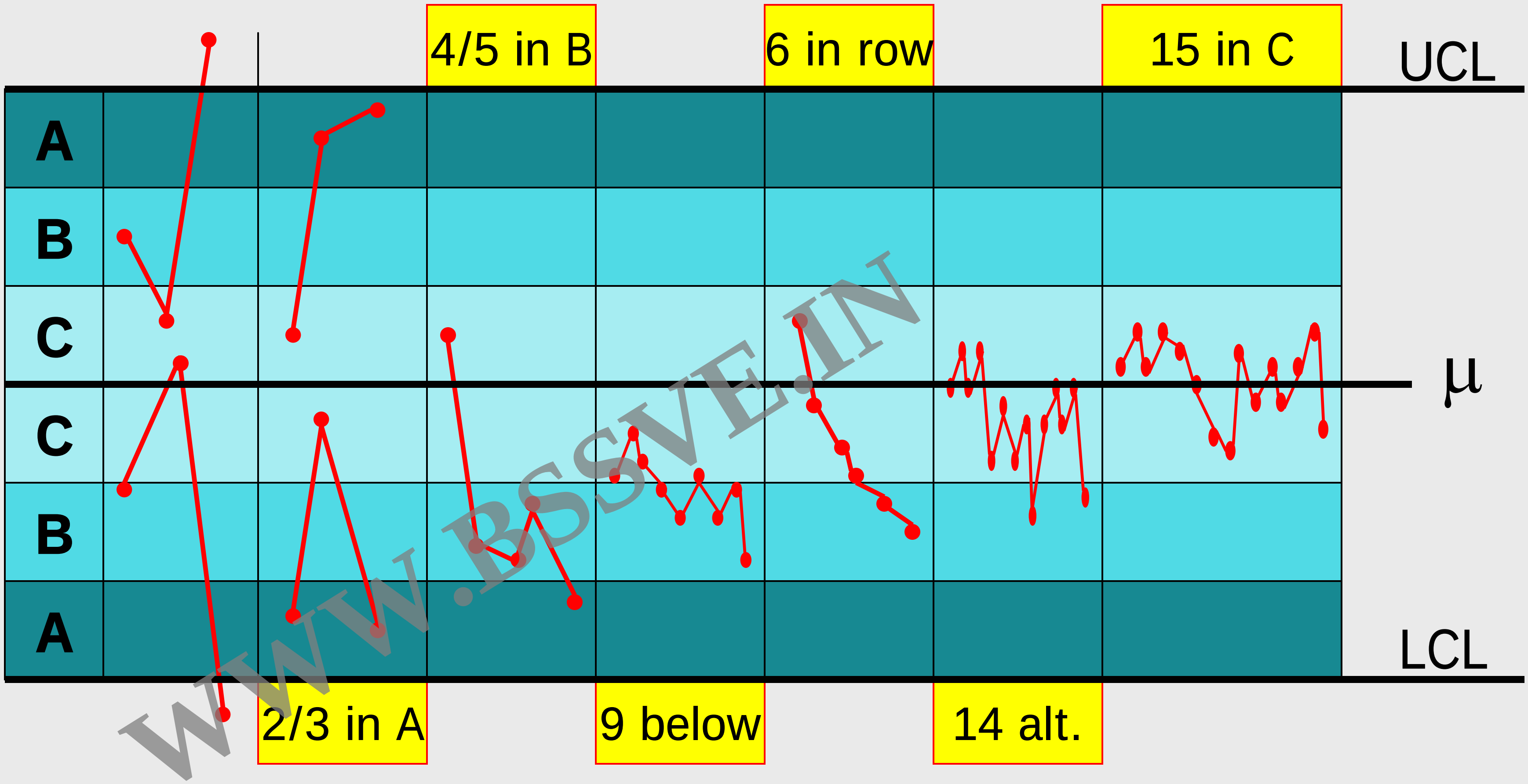
$\overline{X}$ Charts (*"X bar Chart"*)

1. Periodical Random Samples x_i of n items
2. $$\overline{x} = \frac{x_1 + x_2 + ... + x_n}{n}$$
3. Once μ, σ are known $\Rightarrow \sigma_{\overline{x}} = \frac{\sigma}{\sqrt{n}}$
4. $\textbf{UCL} = \mu + 3 \cdot \sigma_{\overline{x}}$ $\textbf{LCL} = \mu - 3 \cdot \sigma_{\overline{x}}$
5. Plot $\overline{x}$'s
6. Is Process out of Control ?

2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT.

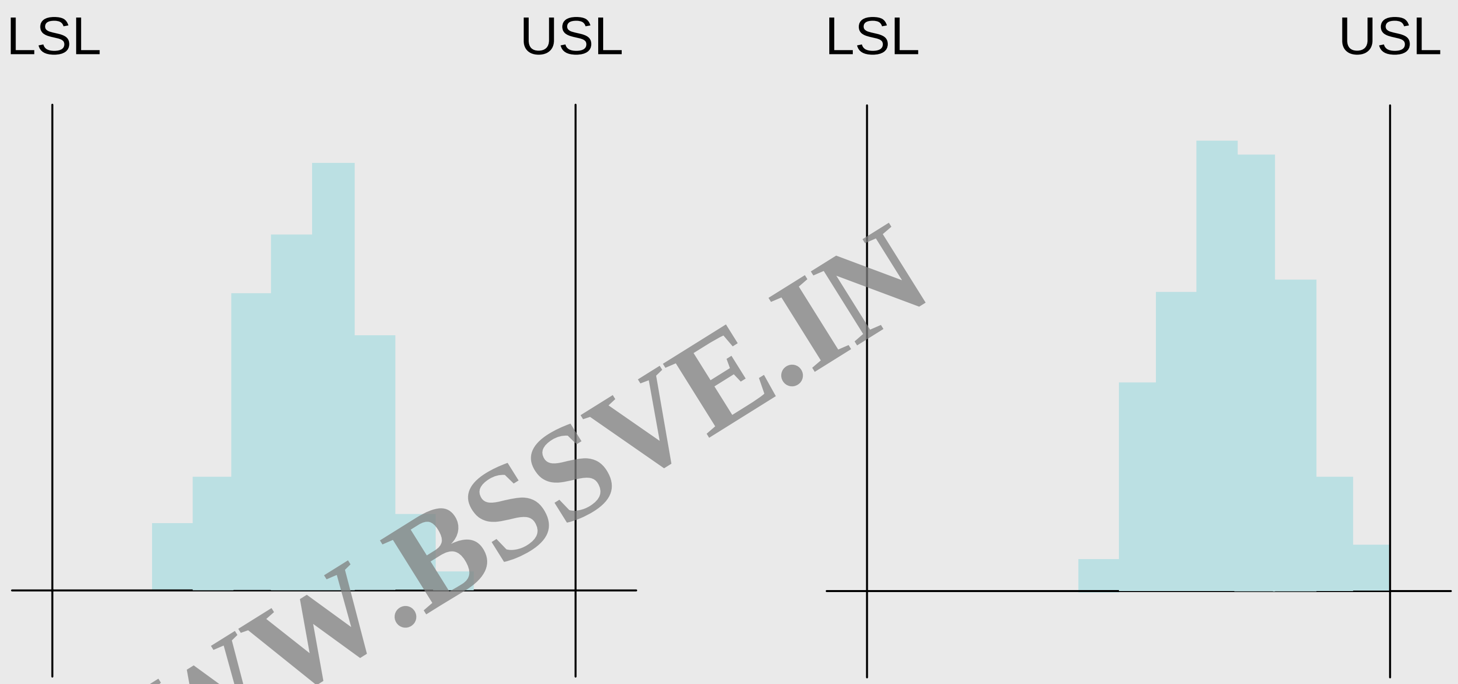
Tests For Control



2002 - Jérémie Gallien

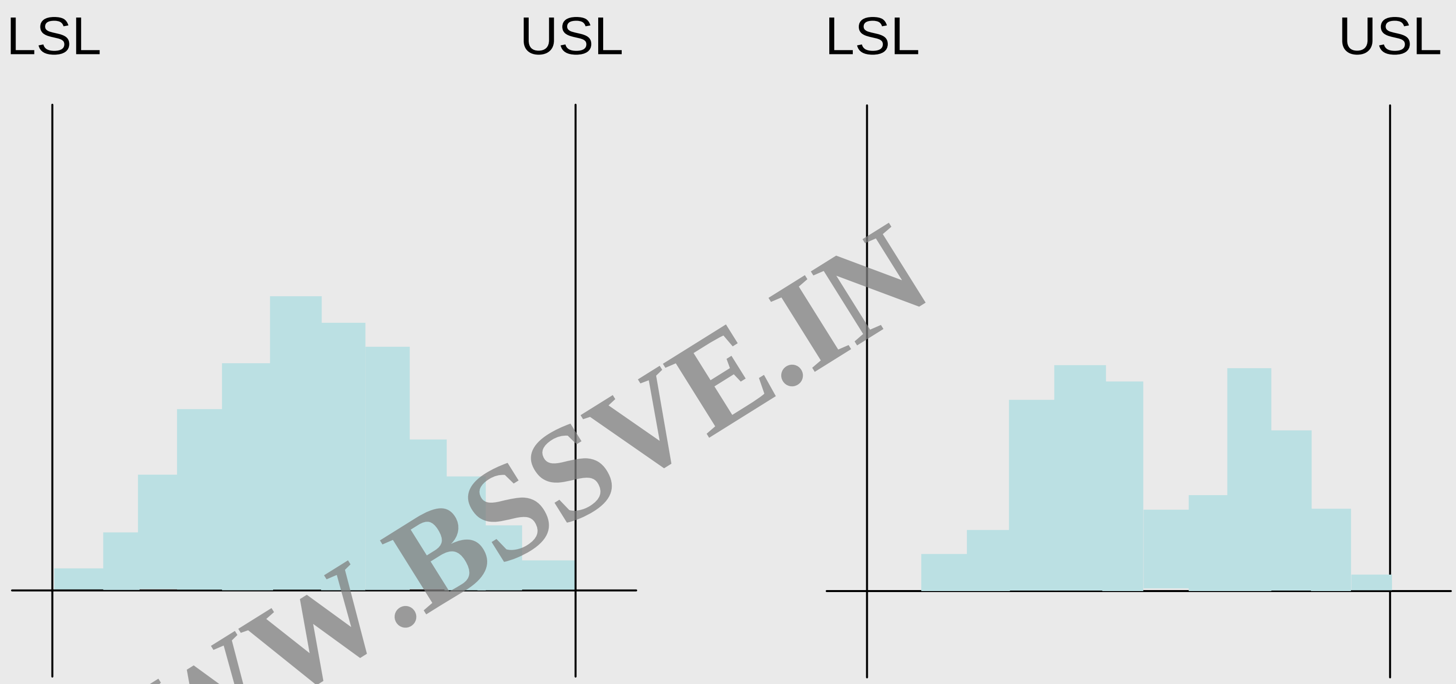
Slide courtesy of Prof. Thomas Roemer, MIT

SQC Histograms



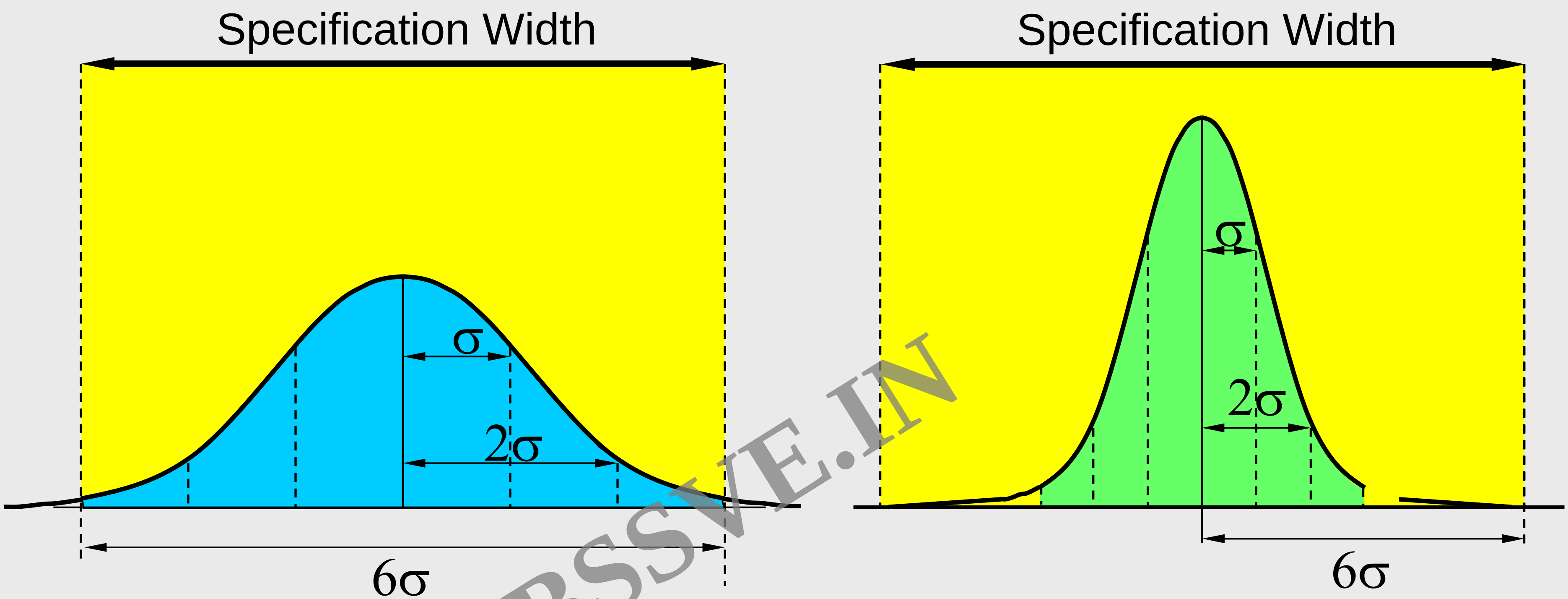
2002 - Jérémie Gallien

SQC Histograms



2002 - Jérémie Gallien

Process Capability



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

$$c_p = \frac{\text{Specification Width}}{\text{Process Width}\left[6\sigma\right]} = 2$$

2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT

Companies Implementing Six Sigma

- Motorola
- Texas Instruments
- ABB
- AlliedSignal
- GE
- Bombardier
- Nokia
- Toshiba
- DuPont
- American Express
- BBA
- Ford
- Dow Chemical
- Johnson Controls
- Noranda

2002 - Jérémie Gallien

Why 6σ?

99% Good (3.8 Sigma) → **99.99966% Good (6 Sigma)**

2002 - Jérémie Gallien

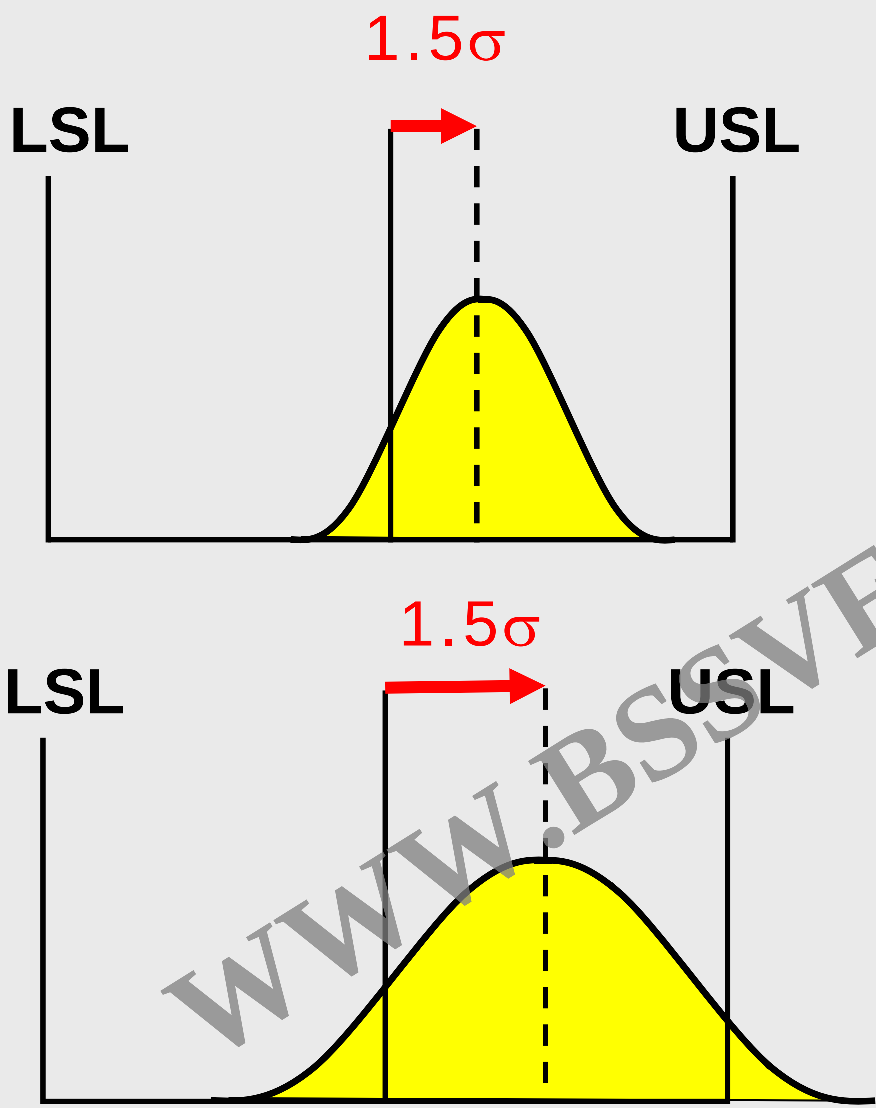
6σ and Dependent Components

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

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

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

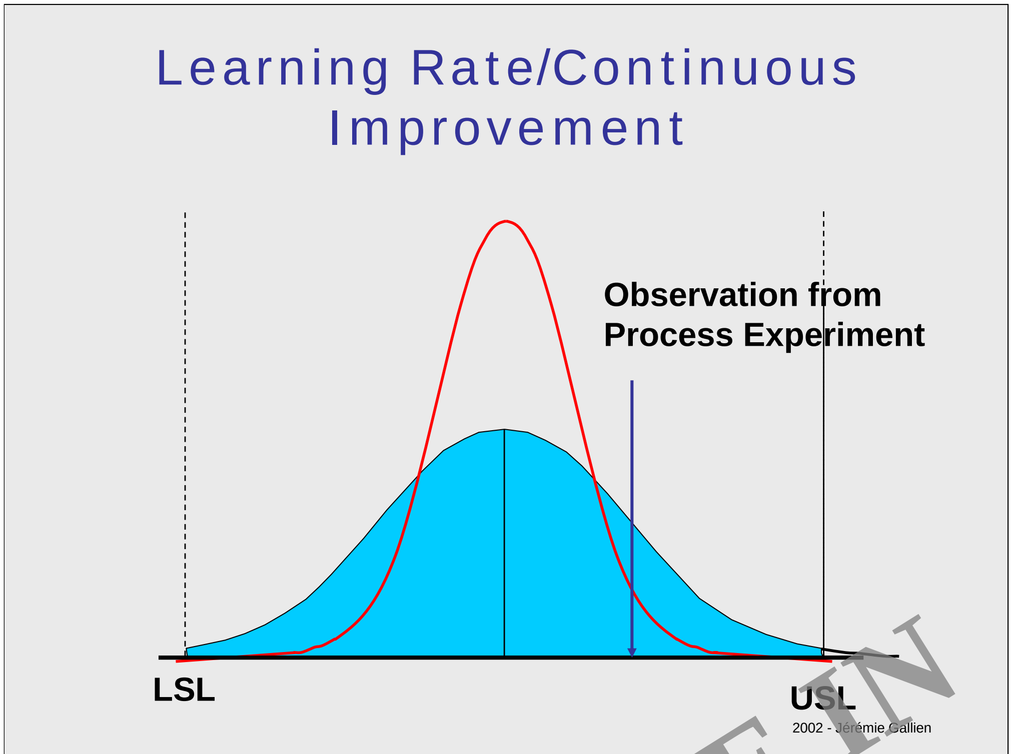
Robustness To Process Shift



6σ: 3.4ppm defective

3σ: 7% defective

2002 - Jérémie Gallien



•This slide illustrates the result obtained when an experiment was performed in order to improve a process, say by varying one of the control levers or input.

•When the process capability is tight, it is much easier tell apart a special cause (in this case the variation of the input or process control value) from a random fluctuation that could have occurred regardless of the change in the input.

•So performing continuous improvement and process learning is much quicker when the capability is high.

Slide courtesy of Prof. Thomas Roemer, MIT.

Why 6σ?

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

2002 - Jérémie Gallien

Quality Lecture Wrap-Up

1. Quality is very systemic in nature –remember Hank!

2. Defining Quality, Setting Quality Goals

3. Principles of TQM: Customer First
   Cont. Improvement
   Total Participation

4. Tools of TQM: Measurement (SQC, 6σ)
   Education
   Incentives
   Organizational Change

Process In Control?
Process Capable?

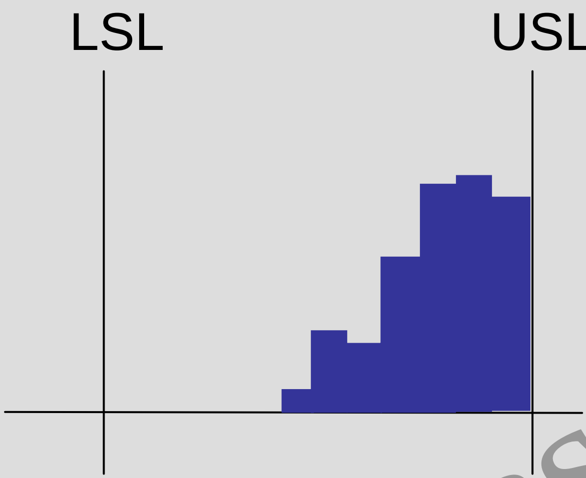
2002 - Jérémie Gallien

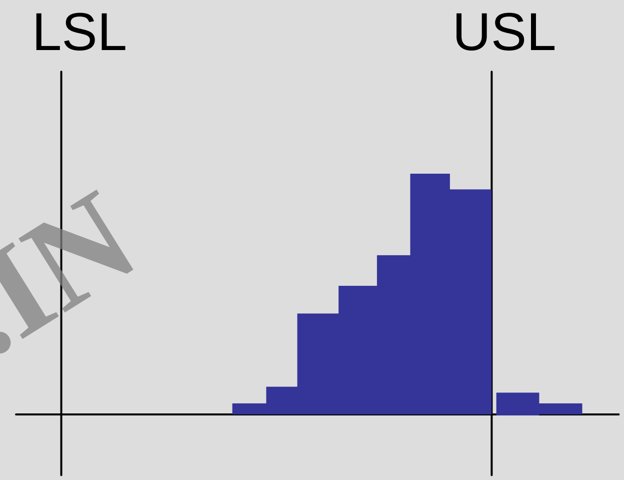
Quality

Exercise 7

Name: ____________________

The two following quality control histograms represent the distribution of the number of dead pixels per square inch in a LCD display component received by a cell phone manufacturer from a supplier. From an operational standpoint, what is likely to have produced such results? Note: we are NOT asking for an engineering or technical answer.





Quality
Exercise 8

What is the capability of a centered process that would produce 1 part per million outside of the upper and lower specification limits?

Hint: in Excel, the function giving the fractiles of the standard normal distribution is NORMSINV(probability).

Value Chain Dynamics

Professor Charles Fine
Massachusetts Institute of Technology
Sloan School of Management
Cambridge, Massachusetts 02142

May 2004

Some material in this presentation is based on: Fine, Charles. *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*. Perseus Publishing, 1999. ISBN: 0-7382-0153-7.

Value Chains and Supply Chains

Supply Chains

Order fulfillment

-Inventory
-Quality, cost & service
-Flexibility
-Response times
-Logistics
-Distribution
-Procurement
-Forecasting
-Transportation
-Quantity accuracy
-Timing accuracy

"The Physics of Flow"

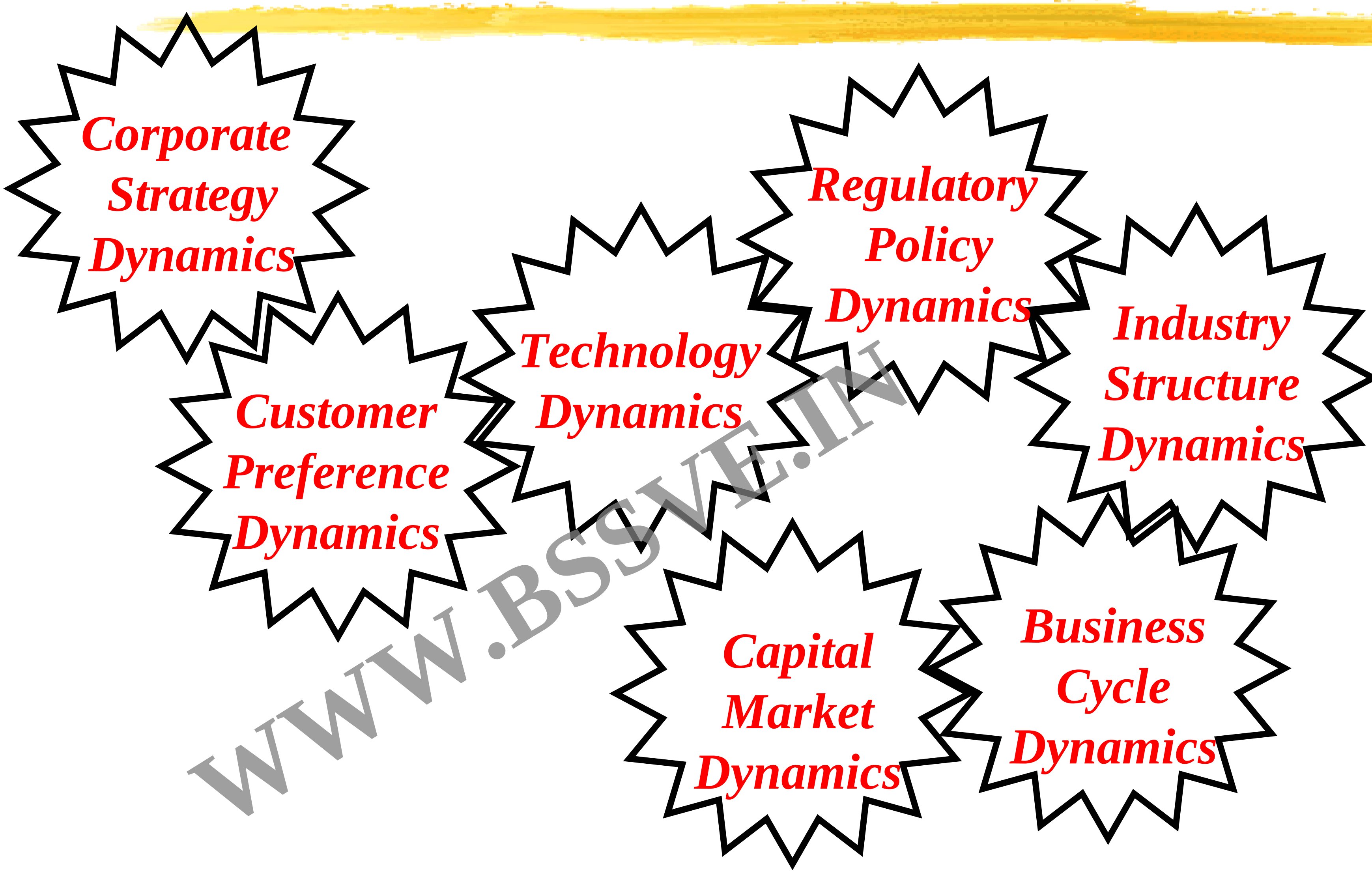
Value Chains

System Design

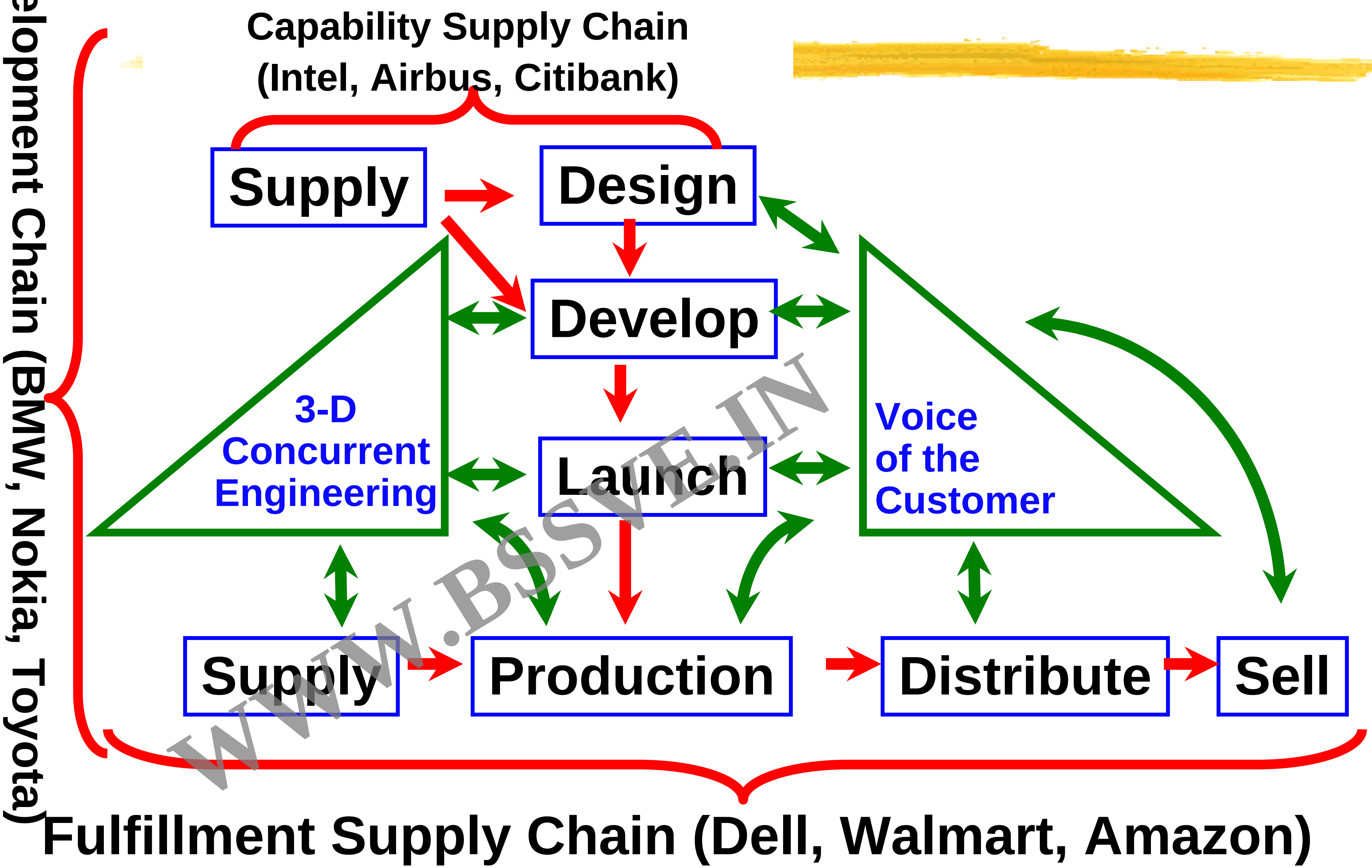
-Core competences
-Make/Buy
-Relationship Design
-Strategic Intent
-Clockspeed
-Dynamics of
  -Disintermediation
  -Disintegration
  -Dependence
  -Capability development

"The Biology of Evolution"

Dynamic Analysis to Support Industry & Technology Roadmapping



The Three Chains of Enterprise Design: *Fulfillment, Development, & Technology Chains*



Supply Chain Design in a Fast-Clockspeed World: Study the Industry Fruitflies

Evolution in the natural world:

FRUITFLIES
evolve faster than
MAMMALS
evolve faster than
REPTILES

THE KEY TOOL:

Cross-SPECIES Benchmarking of Dynamic Forces

Evolution in the industrial world:

INFOTAINMENT is faster than
MICROCHIPS is faster than
AUTOS evolve faster than
AIRCRAFT evolve faster than
MINERAL EXTRACTION

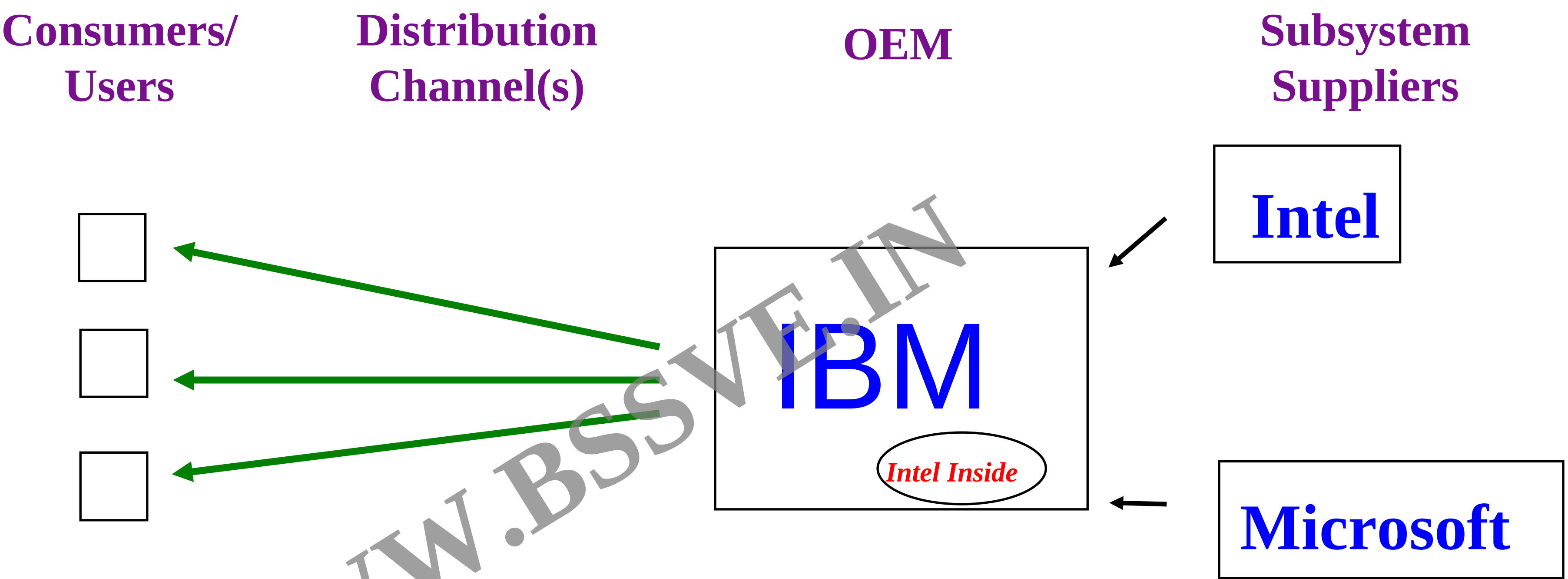
THE KEY TOOL:

Cross-INDUSTRY Benchmarking of Dynamic Forces

The Strategic Impact of Project Design:

(Who let Intel Inside?)

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



The Outcome:

A phenomenonally successful product design

A disastrous value chain design (for IBM)

LESSONS FROM A FRUIT FLY:
THE PERSONAL COMPUTER

1. BEWARE OF *INTEL INSIDE*
   (Regardless of your industry)
2. MAKE/BUY IS NOT ABOUT WHETHER IT IS *TWO CENTS CHEAPER* OR *TWO DAYS FASTER* TO OUTSOURCE VERSUS INSOURCE.
3. DEVELOPMENT PARTNERSHIP DESIGN CAN DETERMINE THE FATE OF COMPANIES AND INDUSTRIES, AND OF PROFIT AND POWER
4. THE LOCUS OF VALUE CHAIN CONTROL CAN SHIFT IN UNPREDICTABLE WAYS

VALUE CHAIN DESIGN:
Three Components

1. Insourcing/OutSourcing
(The Make/Buy or Vertical Integration Decision)

2. Partner Selection
(Choice of suppliers and partners for the chain)

3. The Contractual Relationship
(Arm's length, joint venture, long-term contract, strategic alliance, equity participation, etc.)

Buzz Groups

When have you seen sourcing decisions have a significant impact on a key innovations in the value chain?

What are the strengths and weaknesses of how sourcing strategy works at your company?

Vertical Industry Structure with *Integral* Product Architecture

Computer Industry Structure, 1975-85

For this diagram, see:

A. Grove, Intel; and Farrell, Joseph, Hunter Monroe, and Garth Saloner. "The Vertical Organization of Industry: Systems Competition versus Component Competition." *Journal of Economics & Management Strategy* 7, no. 2 (1998): 143-182.

Horizontal Industry Structure with *Modular* Product Architecture

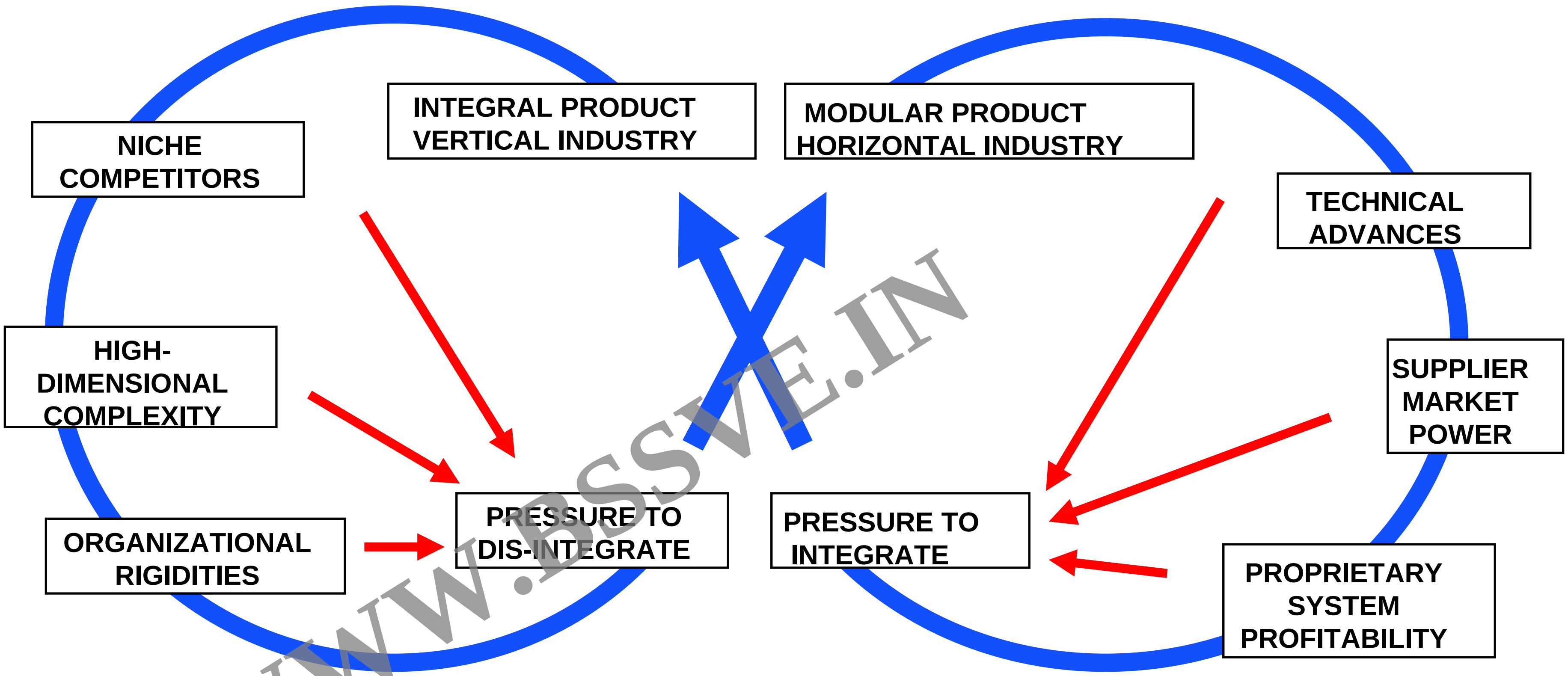
Computer Industry Structure, 1985-95

For this diagram, see:

A. Grove, Intel; and Farrell, Joseph, Hunter Monroe, and Garth Saloner. "The Vertical Organization of Industry: Systems Competition versus Component Competition." *Journal of Economics & Management Strategy* 7, no. 2 (1998): 143-182.

THE DYNAMICS OF PRODUCT ARCHITECTURE AND VALUE CHAIN STRUCTURE:

THE DOUBLE HELIX



Source: Fine, Charles, and Daniel Whitney. "Is the Make-Buy Decision Process a Core Competence?" MIT Center for Technology, Policy, and Industrial Development, February 1996. Used with permission.

BUZZ GROUPS: THE *DOUBLE HELIX* IN OTHER INDUSTRIES

1. HOW HAS THE DOUBLE HELIX AFFECTED A VALUE CHAIN THAT YOU ARE FAMILIAR WITH?
2. WERE THERE ANY "EARLY WARNING SIGNALS" AS TO THE COMING INTEGRATION OR DISTINTEGRATION?
3. WHAT DO YOU THINK MIGHT BE SOME HELPFUL "EARLY WARNING SIGNALS?"

THE *DOUBLE HELIX* IN OTHER INDUSTRIES

- ***TELECOMMUNICATIONS--***
  - **"MA BELL" was Vertical /Integral**
  - **BABY BELLS & LONG LINES & CELLULAR are Horizontal/Modular**
  - **Today's Verizon is going back to Vertical /Integral**
- ***AUTOMOTI VE--***
  - **Detroit in the 1890's was Horizontal/Modular**
  - **Ford & GM in the mid 1900's were Vertical /Integral**
  - **Today's Auto Industry is going back to Horizontal/Modular**
- ***TELEVISION--***
  - **RCA was Vertical /Integral**
  - **1970'S THROUGH 1990'S were Horizontal/Modular**
  - **Today's media giants are going back to Vertical /Integral**
- ***BICYCLES--***
  - **Safety Bikes to 1890's boom to Schwinn to *Shimano Inside***

INDUSTRY CLOCKSPEED IS A COMPOSITE:

OF PRODUCT, PROCESS, AND ORGANIZATIONAL CLOCKSPEEDS

Mobile Phone INDUSTRY CLOCKSPEED

THE
Mobile Phone
product technology

THE
Mobile Phone
PRODUCTION PROCESS
process technology

THE
Mobile Phone
MANUFACTURING COMPANY
organization

16

Mobile Phone System CLOCKSPEED is a mix of Transmission Standards, Software and Handsets

Mobile Phone System

TRANSMISSION STANDARD
slow clockspeed

OPERATING SYSTEM
slow clockspeed

SOFTWARE APPLICATIONS
medium clockspeed

SERVICES
fast clockspeed

HAND SET
fast clockspeed

ISSUE: THE FIRMS THAT ARE FORCED TO RUN AT THE FASTEST CLOCKSPEED ARE THE MOST LIKELY TO STAY AHEAD OF THE GAME.

Automobile CLOCKSPEED IS A MIX OF ENGINE, BODY & ELECTRONICS

Automobile

ENGINE
slow clockspeed

BODY
medium clockspeed

ELECTRONICS
fast clockspeed

ISSUE: MOST AUTO FIRMS OPERATE AT ***ENGINE OR BODY CLOCKSPEEDS***; IN THE FUTURE THEY WILL NEED TO RUN AT ***ELECTRONICS CLOCKSPEED.***

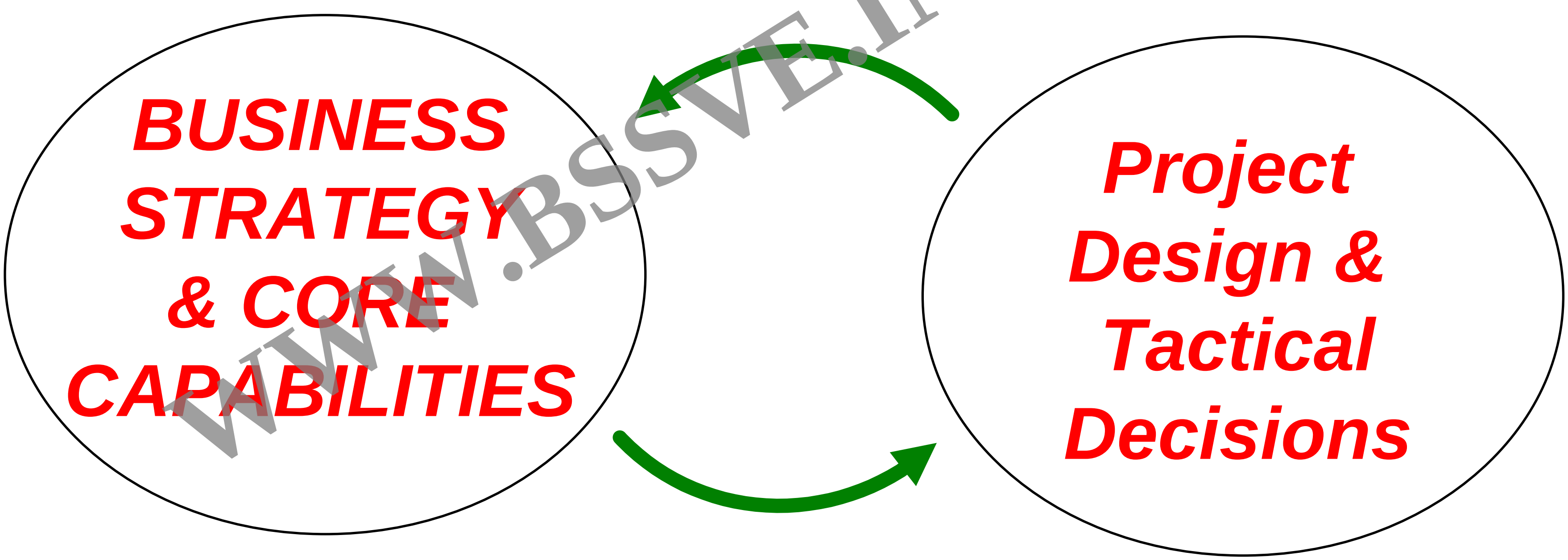
Buzz Groups

What's the fastest clockspeed component of your company's value chain?

How is your company responding to the speed of this fast-moving component?

Clockspeed drives *Business Strategy Cadence*

Dynamics between New Projects and Core Capability Development: PROJECTS MUST MAKE MONEY AND BUILD CAPABILITIES



3-D Concurrent Engineering & the imperative of concurrency

Product (Deliverable

Process (Project Plan)

Supply Chain (Partners/Suppliers)

Detailed Design
Specs
Materials
Functions

Product/ System Architecture
Modular/ Integral Life Cycles

Unit Processes
Technology
Equipment

Production System
Objectives
Systems
People
Capacity

Supply Chain Architecture
Sourcing
Selection
Relationship

Logistics & Coord System
Information
Inventory
Integration

Development & Tech. Chains

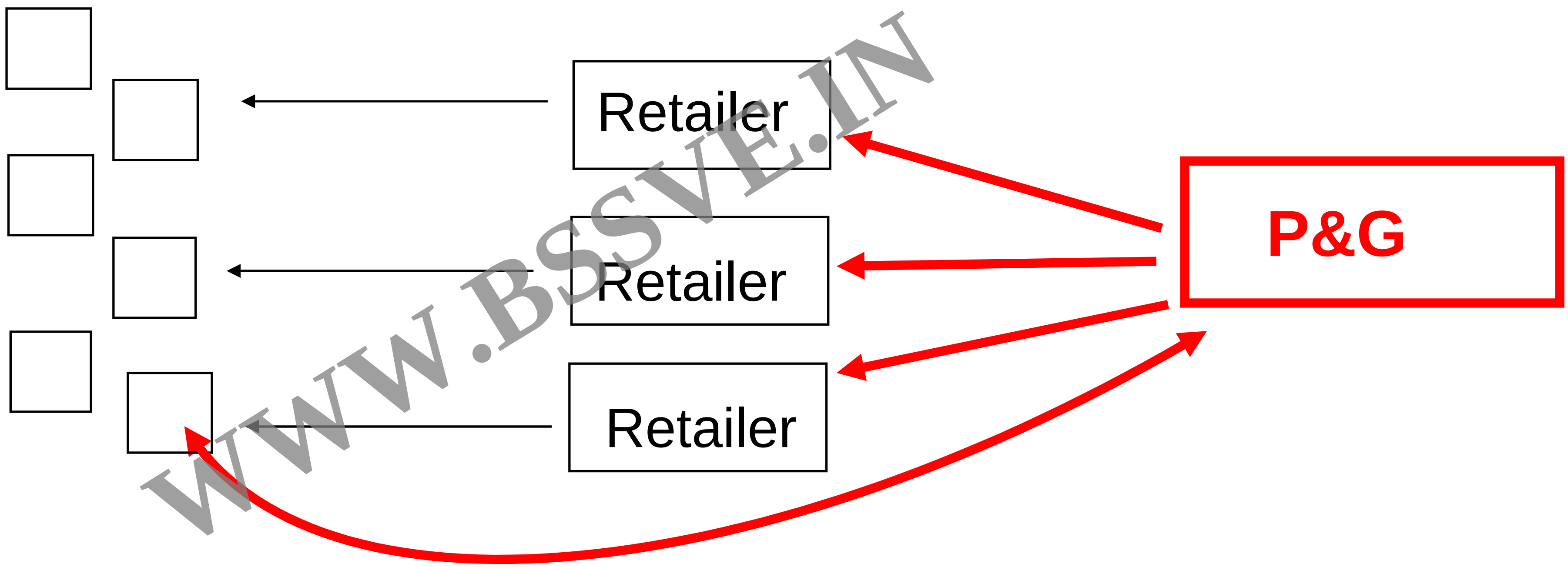
Fulfillment Supply Chain

Fulfillment Architecture Technology

Controlling the Chain Through Distribution:
The End of *P&G Inside* ?

- *Controlling the Channel Through Closeness to Customers:*
- *consumer research, pricing, promotion, product development*

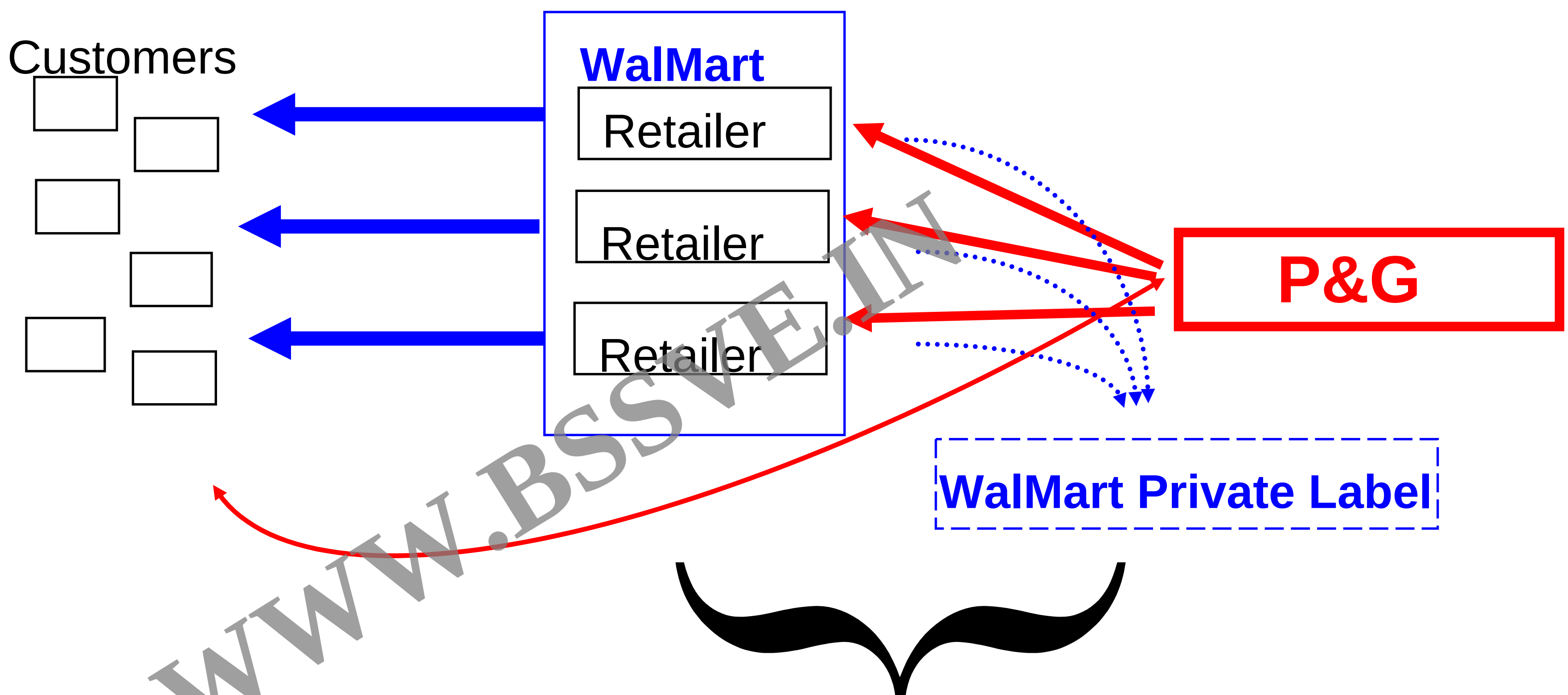
Customers



Controlling the Chain Through Distribution:

Beware of *Walmart Outside*

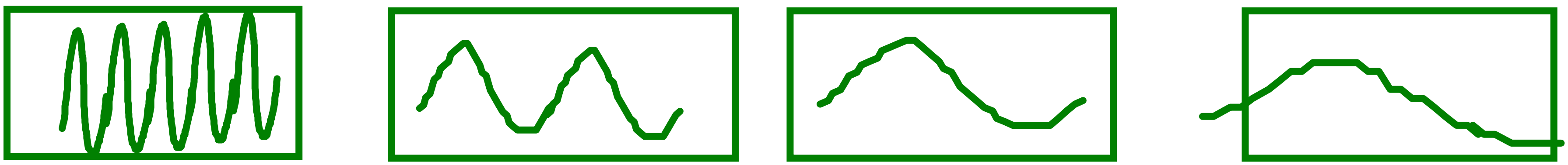
Controlling the Channel Through Closeness to Customers: Chain Proximity



Vertical Growth on the Double Helix

lockspeeds accelerate as you head downstream closer to the final customer ;

Clockspeed = f(technology push, customer pull, system complexity)



New Phone Applications	Handset Platforms	Telecom Equipment	Optical Components
Web Site Developer	PC Maker	Chip maker	Semiconductor Equipment Maker
In-Vehicle Services	Automobile	Telematics System	Vehicle Electronics Architecture

ALL COMPETITIVE ADVANTAGE IS TEMPORARY

Autos:

Ford **in 1920,** ***GM*** **in 1955,** ***Toyota*** **in 1990**

Computing:

IBM **in 1970,** ***DEC*** **in 1980,** ***Wintel*** **in 1990**

World Dominion:

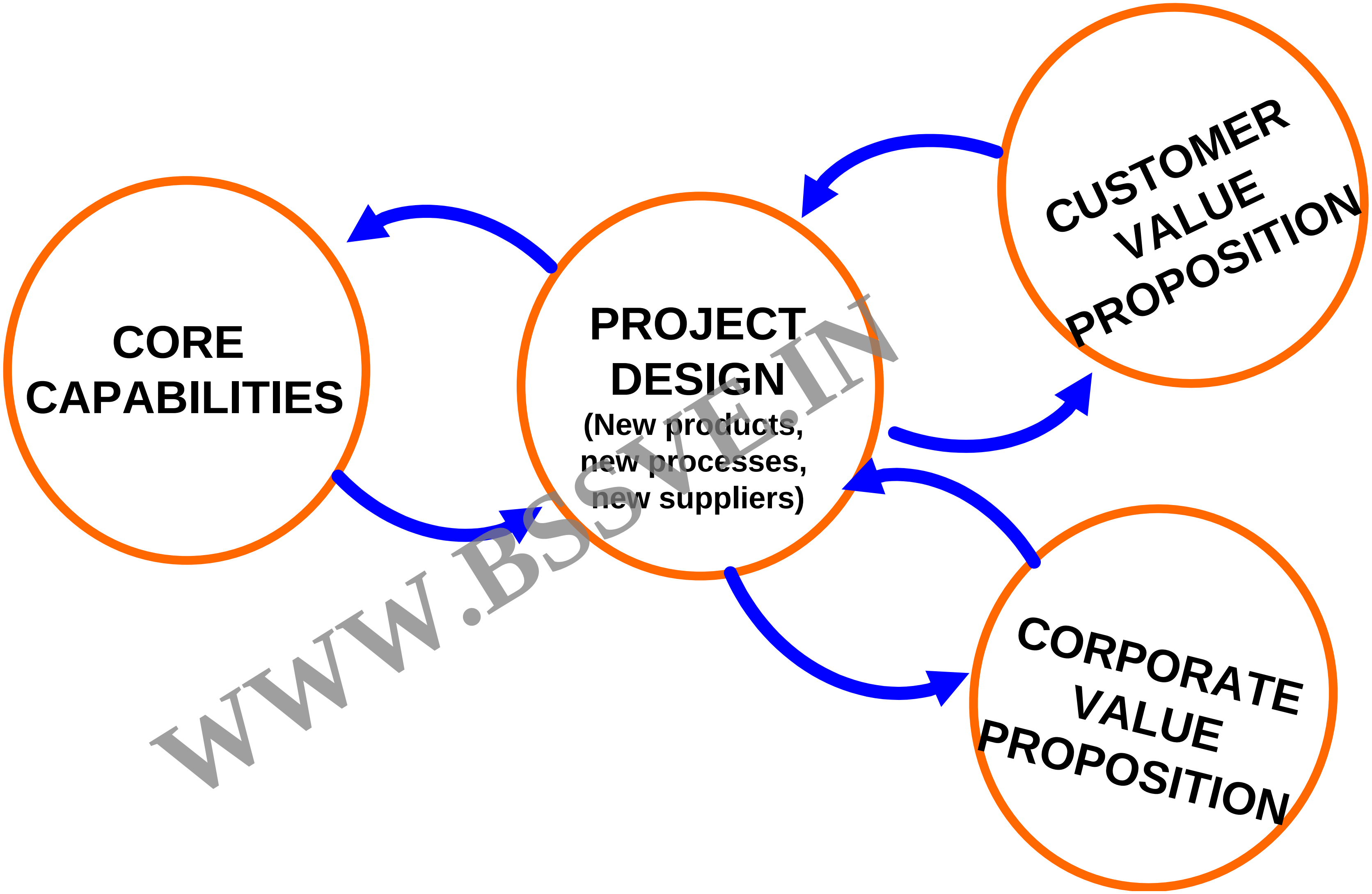
Greece **in 500 BC,** ***Rome*** **in 100AD,** ***G.B.*** **in 1800**

Sports:

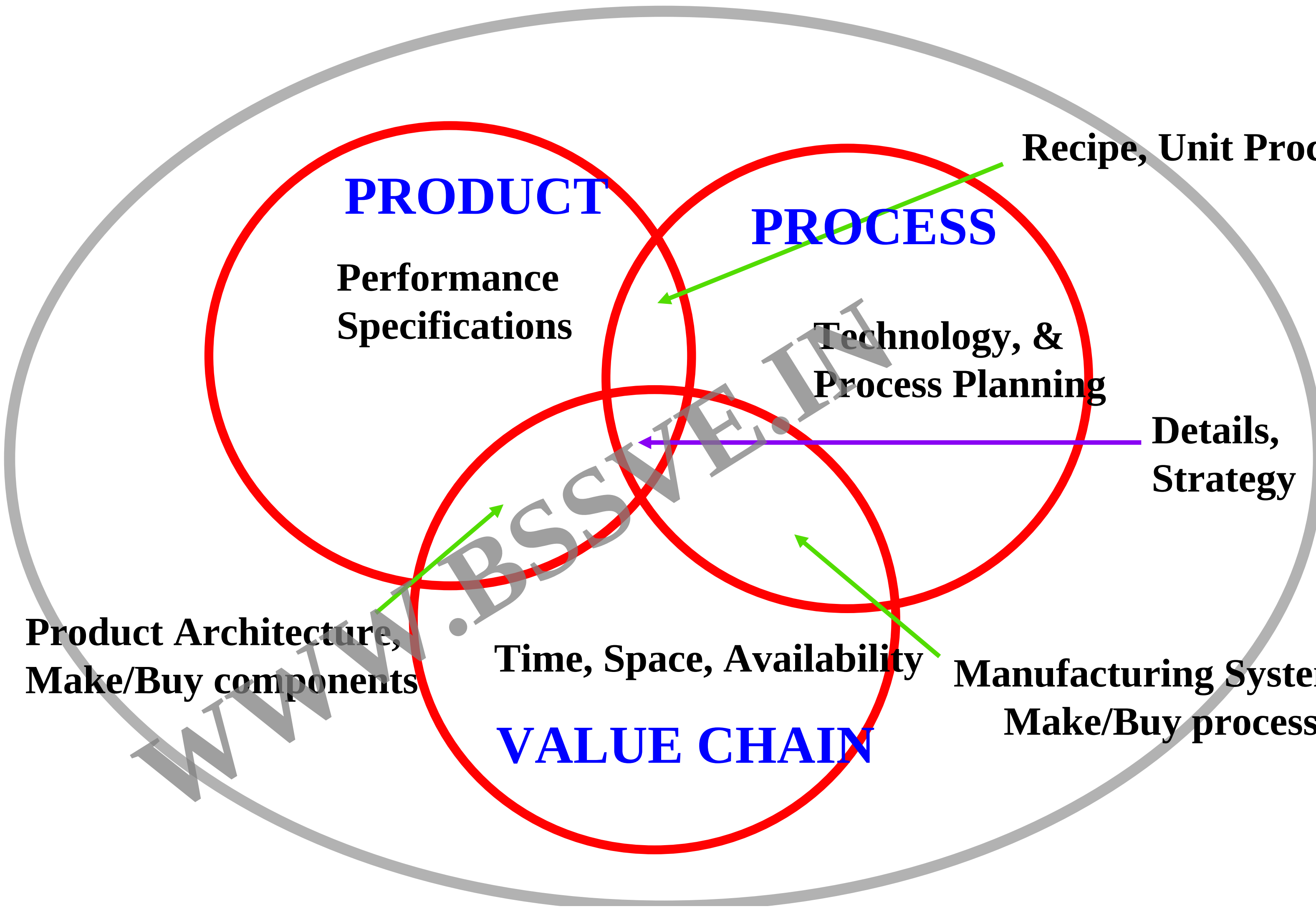
Bruins **in 1971,** ***Celtics*** **in 1986,** ***Yankees*** **no end**

The faster the clockspeed, the shorter the reign

Projects Serve Three Masters: Capabilities, Customers, & Corporate Profit



IMPLEMENTATION OF *PROJECT DESIGN:* FRAME IT AS 3-D CONCURRENT ENGINEERING



ARCHITECTURES IN 3-D
INTEGRALITY VS. *MODULARITY*

Integral product architectures **feature close coupling among the elements**

- **Elements perform many functions**
- **Elements are in close spacial proximity**
- **Elements are tightly synchronized**

- Ex: jet engine, airplane wing, microprocessor

Modular product architectures **feature separation among the elements**

- **Elements are interchangeable**
- **Elements are individually upgradeable**
- **Element interfaces are standardized**
- **System failures can be localized**

- Ex: stereo system, desktop PC, bicycle

VALUE CHAIN ARCHITECTURE

Integral value-chain architecture
features close proximity among its elements
- Proximity metrics: Geographic, Organizational
Cultural, Electronic
- **Example: Toyota city**
- **Example: Ma Bell (AT&T in New Jersey)**
- **Example: IBM mainframes & Hudson River Valley**

Modular value-chain architecture features multiple,
interchangeable supplier and standard interfaces
- **Example: Garment industry**
- **Example: PC industry**
- **Example: General Motors' global sourcing**
- **Example: Telephones and telephone service**

ALIGNING ARCHITECTURES: BUSINESS SYSTEMS & TECHNOLOGICAL SYSTEMS

BUSINESS SYSTEM/SUPPLY CHAIN ARCHITECTURE
(Geog., Organ., Cultural, Elec.)

INTEGRAL ↔ MODULAR

TECHNOLOGY/PRODUCT ARCHITECTURE: INTEGRAL ↕ MODULAR

TECHNOLOGY/PRODUCT ARCHITECTURE \ BUSINESS SYSTEM	INTEGRAL		MODULAR
INTEGRAL	Microprocessors Mercedes & BMW vehicles	Lucent Nortel	Polaroid
	MSFT Windows	Chrysler vehicles	Cisco
MODULAR	Digital Rights/ Music Distribution		Dell PC'S Bicycles

Demand-Supply Chain Management @ Dell

- **Demand Management:**
- **Forecast = Buy = Sell**
- **Buy to Plan, but Build to Order**

- **Inventory Velocity is a wonderful thing …**
  - Customers have immediate access to the latest technology.
  - Suppliers get their products to market quickly
  - Quality is improved with fewer touches.
  - Cash is generated through negative cash cycle.
  - Model efficiencies drive Market Share gain.

Can "Dell Direct" Work for Autos?

- Appealing to OEM's on Many Dimensions
  - Satisfy customer need for Speed
  - Reduce Supply Line Inventories
  - Reduce mismatches and discounting
  - Direct OEM-Customer Relationships (& Data!)
  - Information Transparency

Ideas adapted from Prof. John Paul MacDuffie, IMVP (International Motor Vehicle Program at MIT) and The Wharton School of the University of Pennsylvania

BUT, A Car is not a Computer!!

- **Personal Computer**
- ~50 components
- 8-10 key parts
- 40 key suppliers
- 24 hour burn-in
- 100 design variations
- Modular Architecture

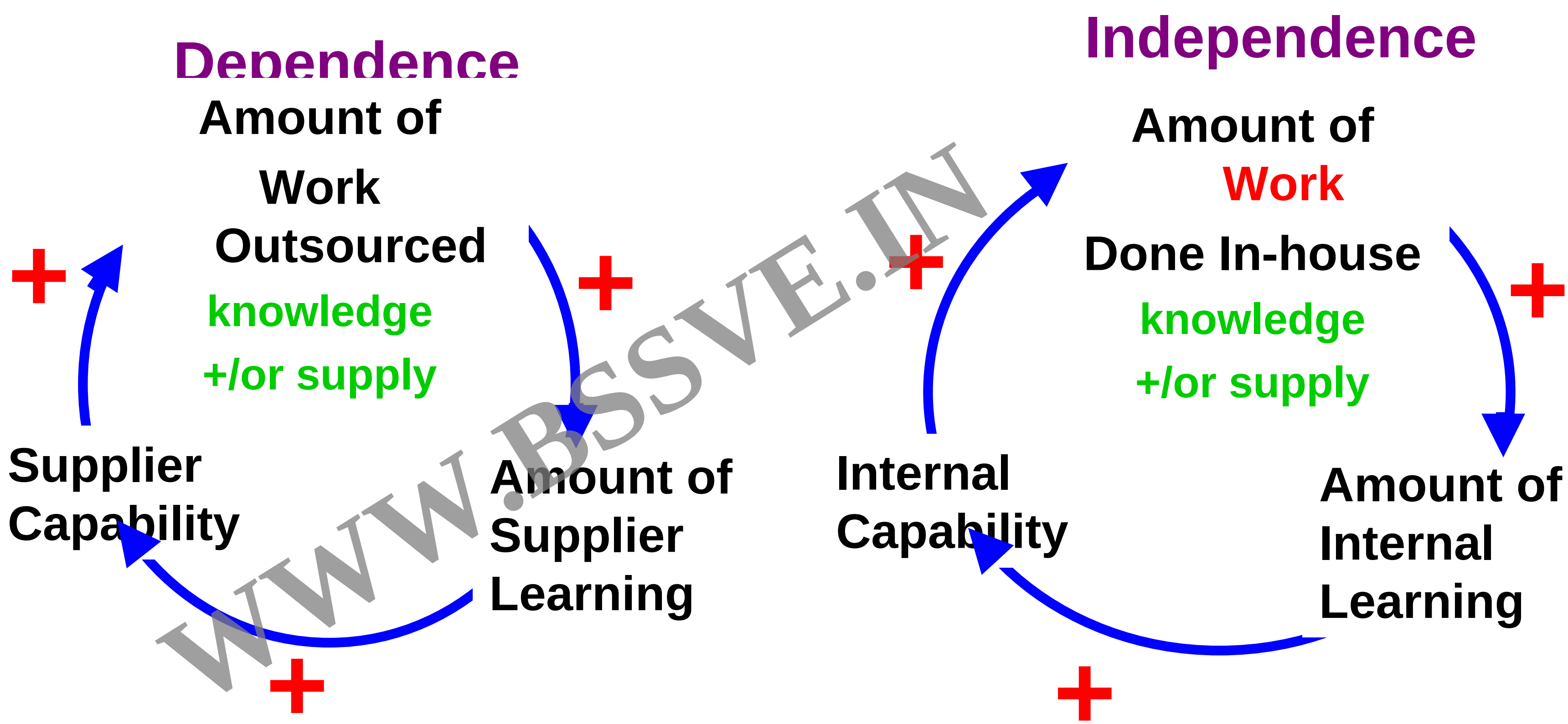
- **Car**
- ~ 4000 components
- 100 key subsystems
- 300 key suppliers
- 12 month validation
- 1,000,000 variations
- Integral Architecture

Ideas adapted from Prof. John Paul MacDuffie, IMVP (International Motor Vehicle Program at MIT) and The Wharton School of the University of Pennsylvania

Strategic Sourcing as a Driver of Dynamic Evolution of Capabilities Along the Value Chain

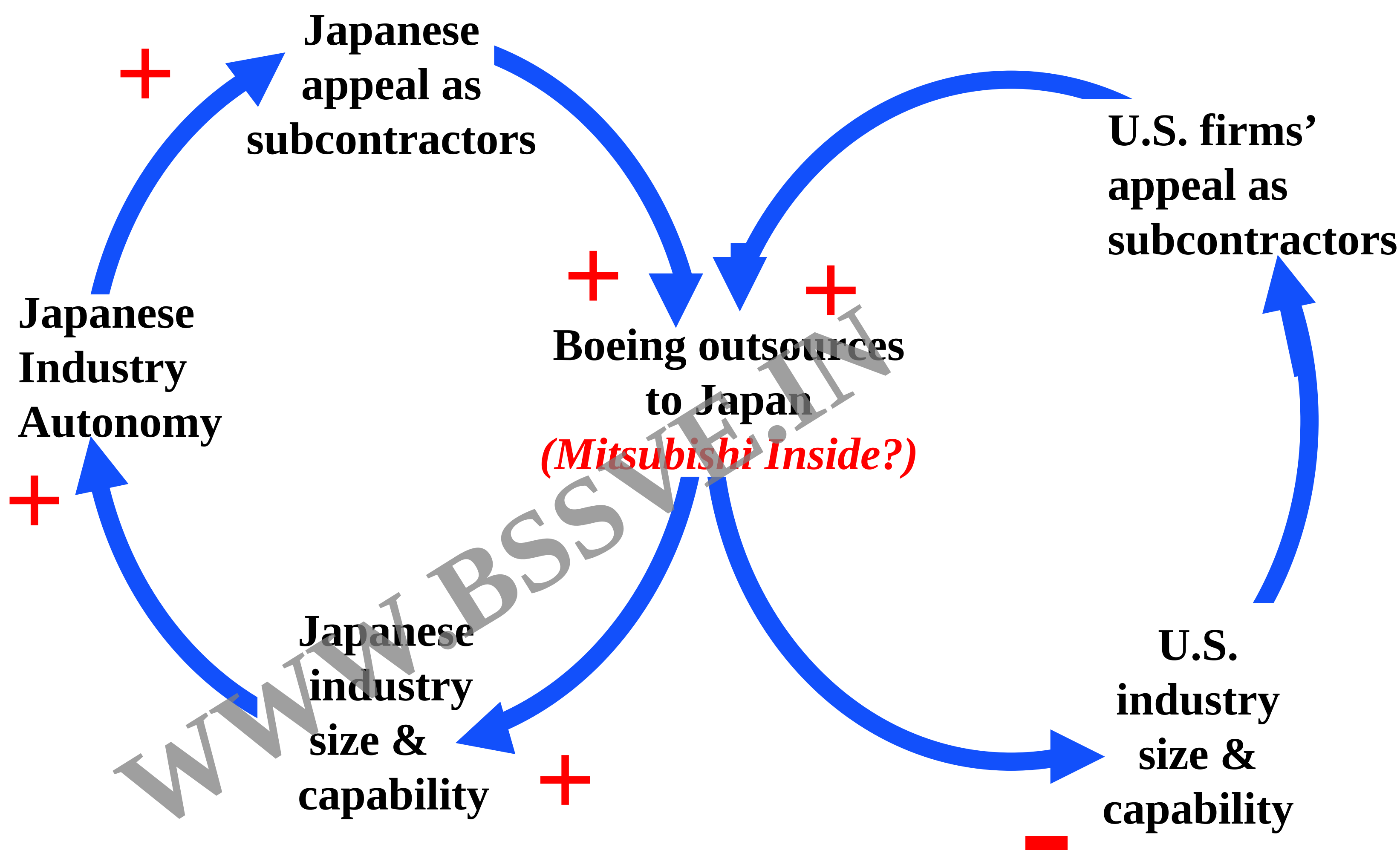
Distinguish between

dependence for knowledge or dependence for capacity

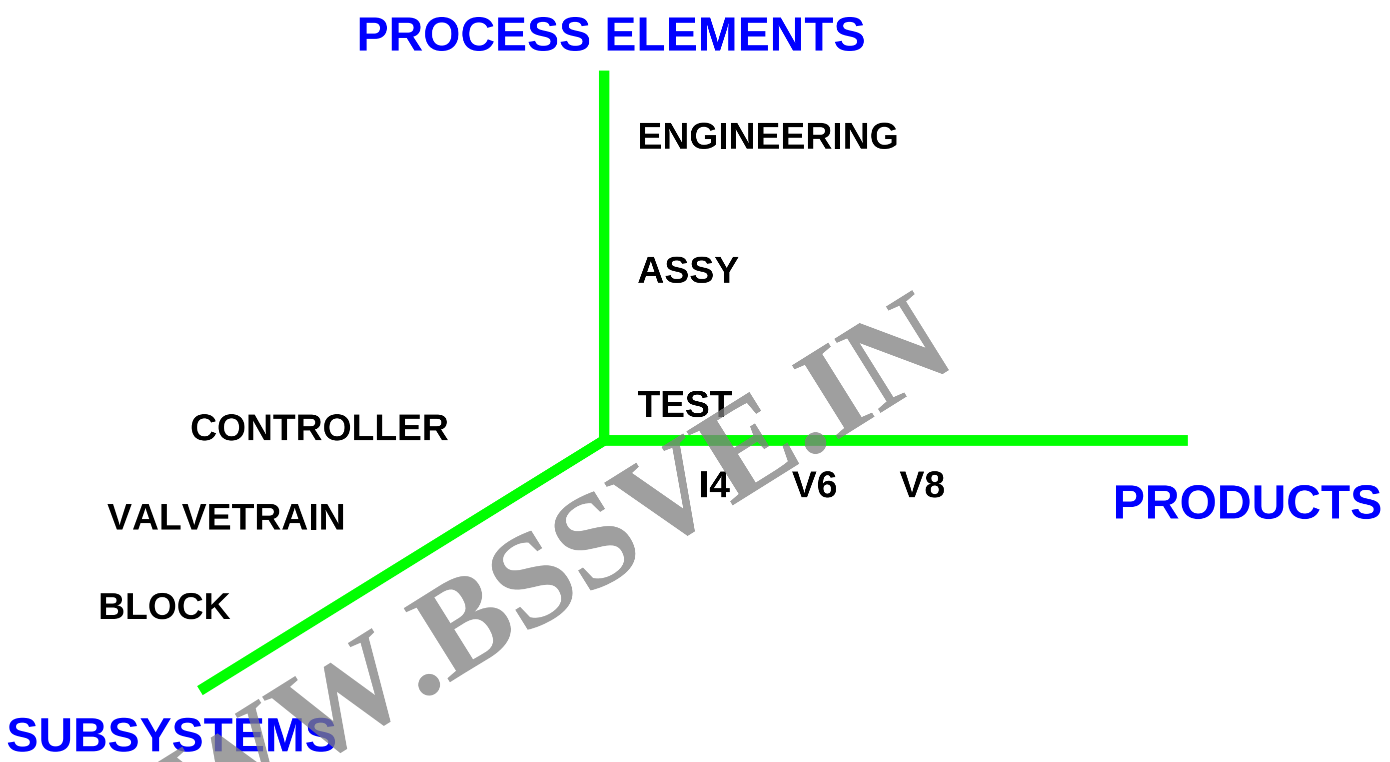


Technology Dynamics in the Aircraft Industry:

LEARNING FROM THE DINOSAURS



SOURCEABLE ELEMENTS



Strategic Make / Buy Decisions: Assess Critical Knowledge & Product Architecture

	DEPENDENT FOR KNOWLEDGE & CAPACITY	INDEPENDENT FOR KNOWLEDGE & DEPENDENT FOR CAPACITY	INDEPENDENT FOR KNOWLEDGE & CAPACITY
ITEM IS MODULAR	A POTENTIAL OUTSOURCING TRAP	BEST OUTSOURCING OPPORTUNITY	OVERKILL IN VERTICAL INTEGRATION
ITEM IS INTEGRAL	WORST OUTSOURCING SITUATION	CAN LIVE WITH OUTSOURCING	BEST INSOURCING SITUATION

Adapted from: Fine, Charles, and Daniel Whitney. "Is the Make-Buy Decision Process a Core Competence?" MIT Center for Technology, Policy, and Industrial Development, February 1996. Used with permission.

Value Chain Mapping

Organizational Supply Chain

Chrysler	Eaton	casting supplier	clay supplier

Technology Supply Chain

engines	valve lifters	casting manufacturing process	clay chemistry

Capability Chain

Supply Chain Management	Quality assurance	NVH engineering	R&D

Underlying Assumption: You have to draw the maps before you can assess their dynamics.

VALUE CHAIN DESIGN IS *THE ULTIMATE* CORE COMPETENCY

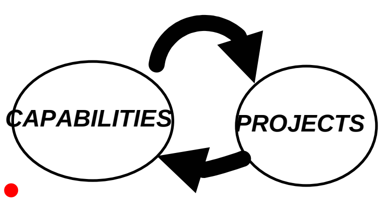
Since all advantages are temporary, the only lasting competency is to continuously build and assemble capabilities chains.

KEY SUB-COMPETENCIES:

1. **Forecasting the dynamic evolution of market power and market opportunities**

2. **Anticipating Windows of Opportunity**

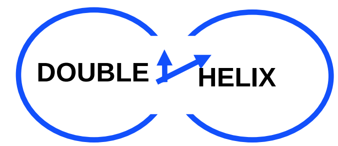
3. **3-D Concurrent Engineering: Product, Process, Value Chain**

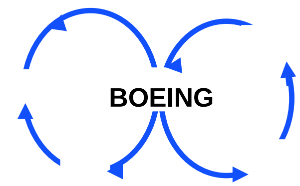


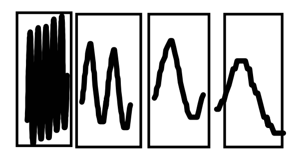
Fortune Favors the Prepared Firm

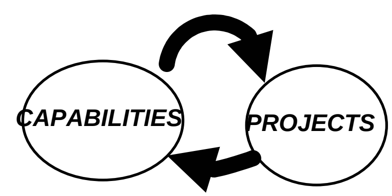
PROCESS FOR VALUE CHAIN DESIGN

1. Benchmark the Fruit Flies
2. Map your Supply Chain
    - -Organizational Value Chain
    - -Technology Value Chain
    - -Competence Chain
3. Dynamic Chain Analysis at each node of each chain map
4. Identify Windows of Opportunity
5. Exploit Competency Development Dynamics with 3-D Concurrent Engineering





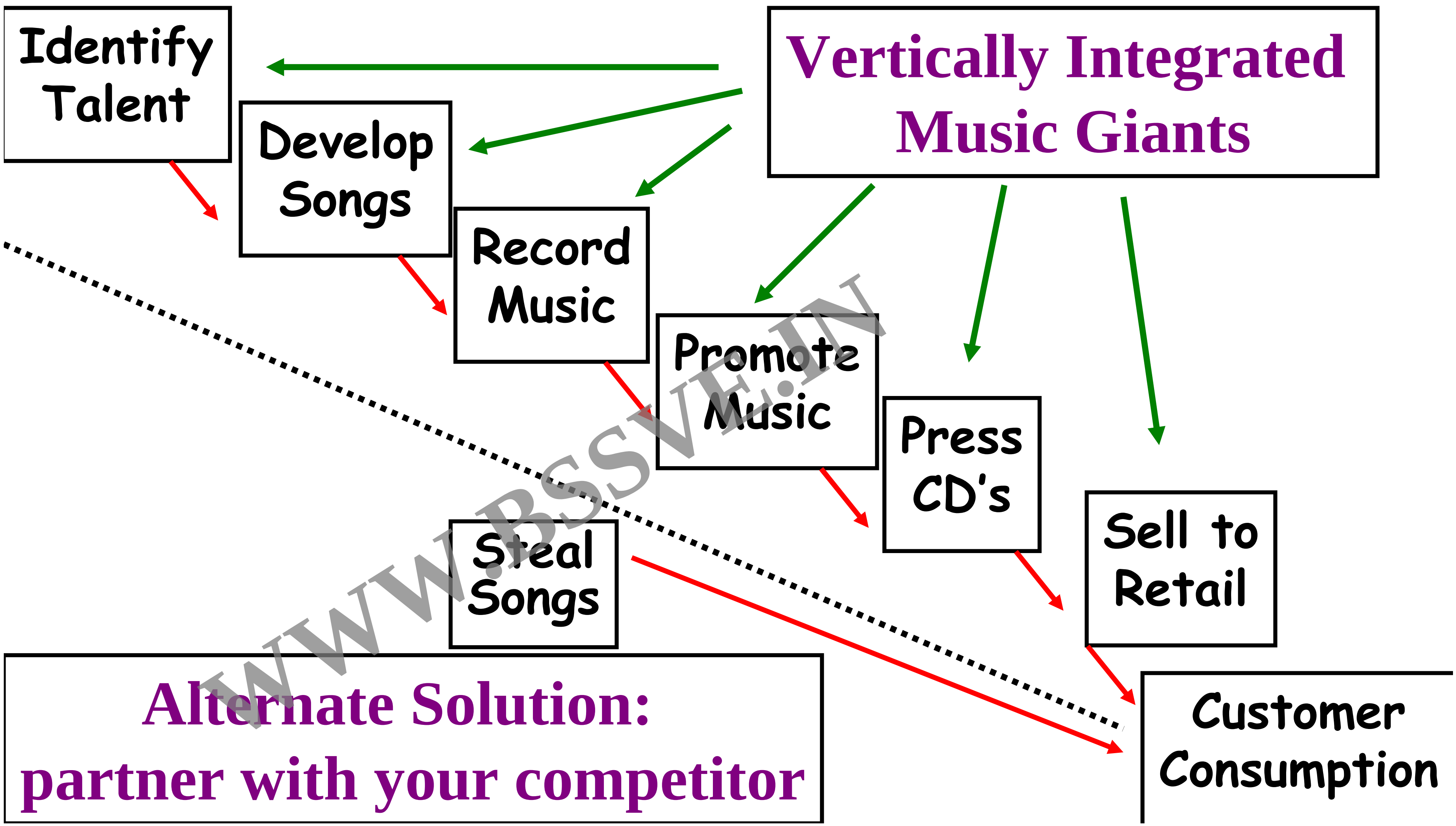




DOT.COM COMPETITION: FOCUS ON THE SUPPLY CHAIN

Napster's New Supply Chain Strategy

(go to the end and steal everything!)



STRATEGY IN 3-D: CASE EXAMPLES

Boeing: Static 3-D in airplane Projects
Dynamic, Strategic Value Chain,
unintegrated w/ Product & Process

Intel: Modular Product vs. Process
Integral Process and Value Chain

Chrysler: Modular Product & Value Chain
(weak on process?)

Toyota: Integral 3-D in Nagoya
(weak on global 3-D?)

Team Exercise:
Value Chain Analysis

Consider one of these five industries (or one of your own):

- -Food
- -Defense aircraft
- -Automobiles
- -Handheld electronic organizers/communicators
- -Music

What are the key elements in the value chain?

What are the key dynamic processes influencing power in the chain?

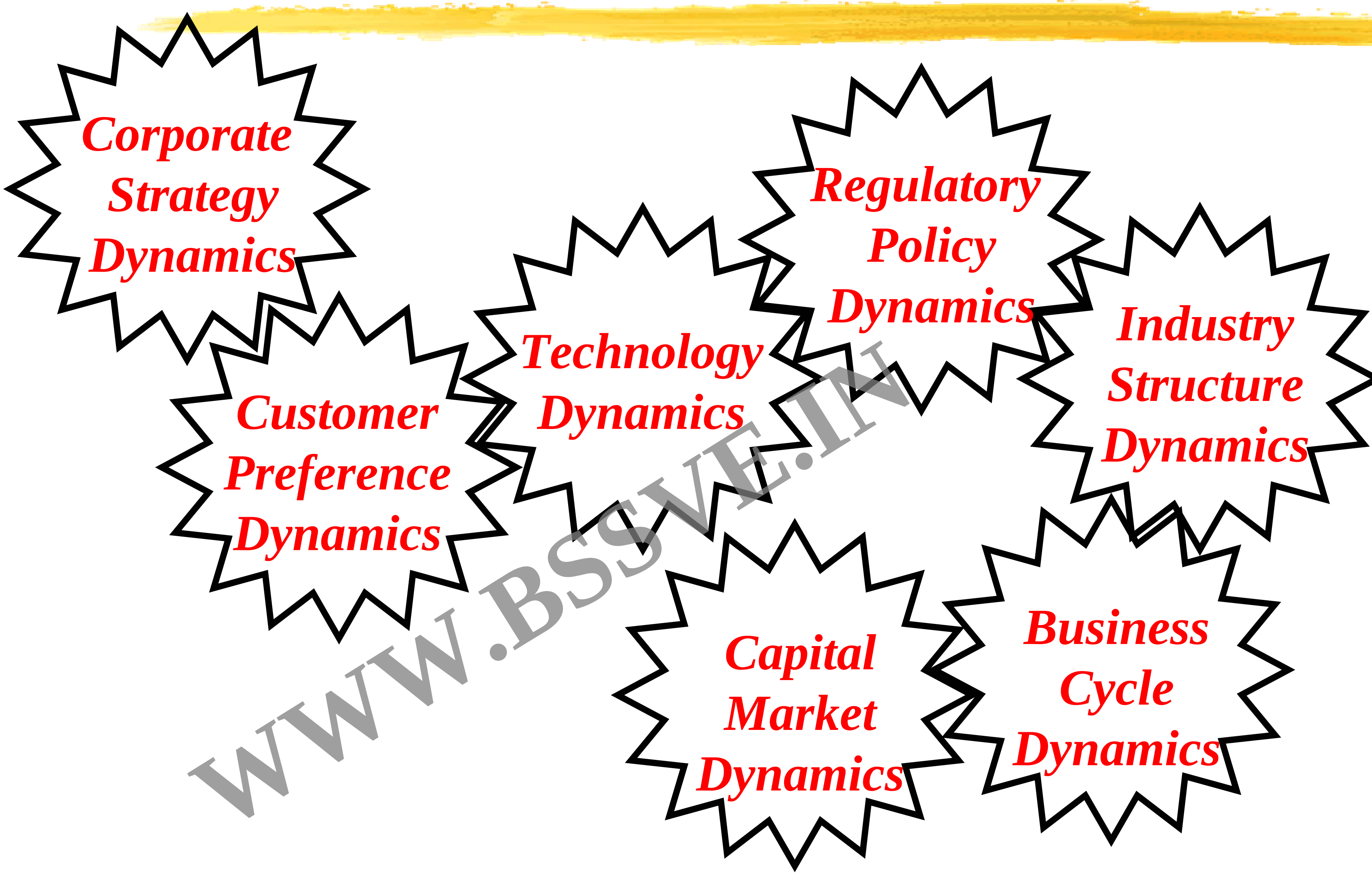
What are the key dependency relationships in the value chain?

What is driving the clockspeed in the chain?

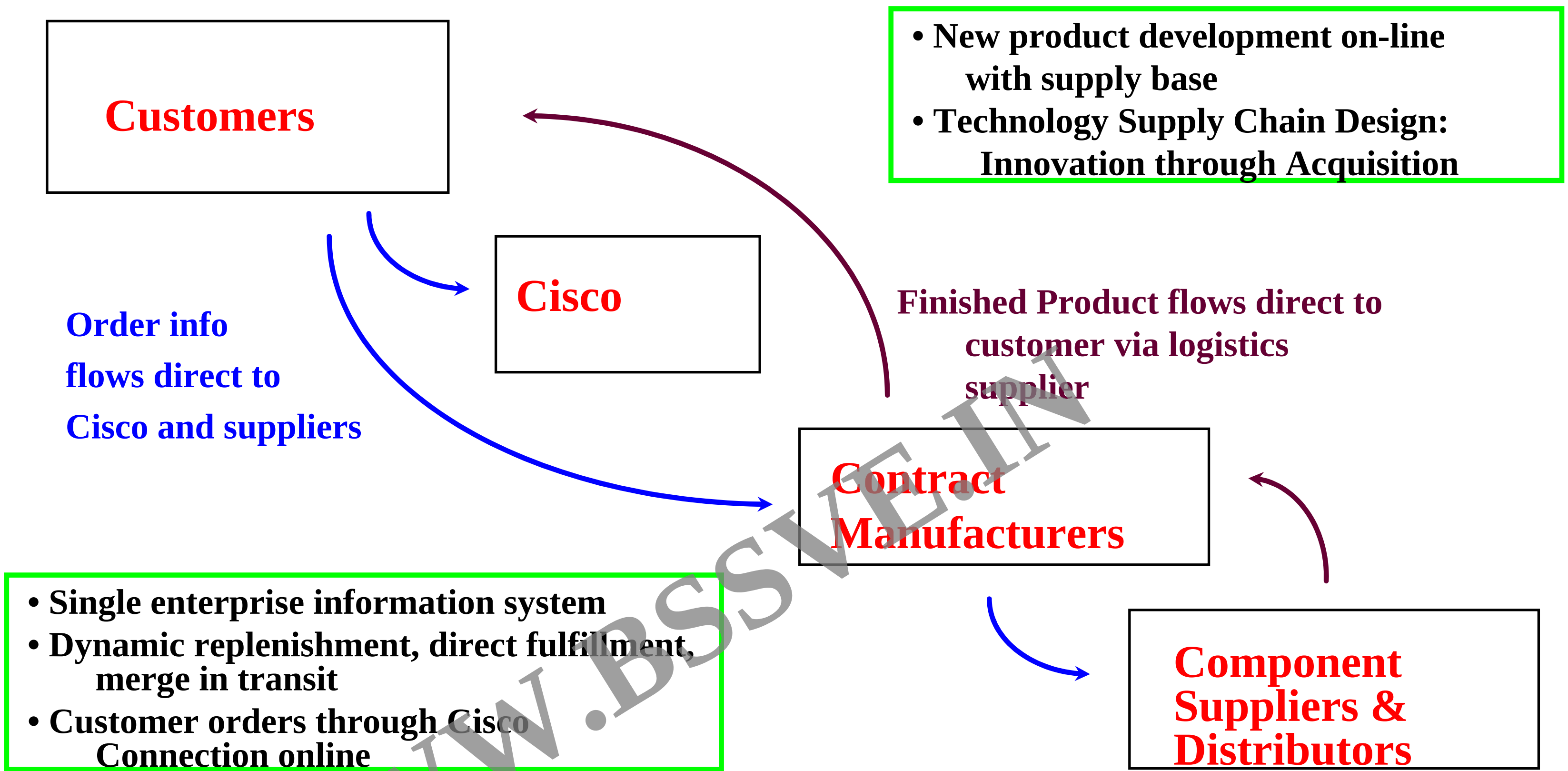
What are the opportunities for outsourcing ?

What are the windows of opportunity in the chain?

Dynamic Analysis to Support Industry & Technology Roadmapping



Cisco's End-to-End Integration for its Fulfillment Supply Chain



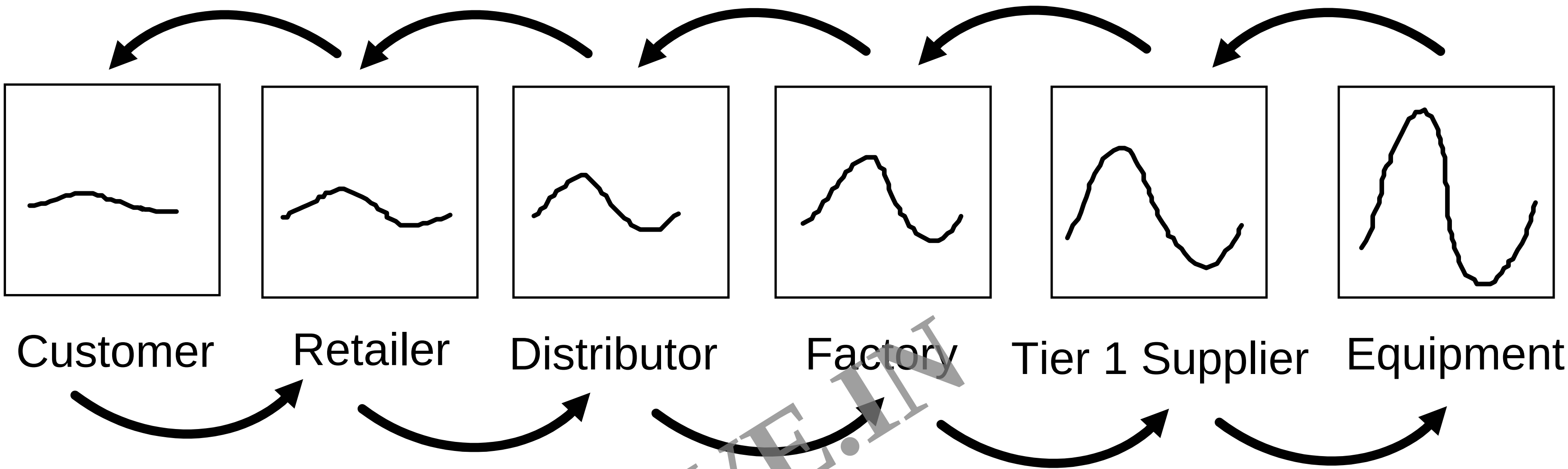
Basic Design Principle: Arm's length Relationship with Fulfillment Chain Partners

Cisco's Strategy for Technology Supply Chain Design

1. Integrate technology around the router to be a communications network provider.
2. Leverage acquired technology with
   - sales muscle and reach
   - end-to-end IT
   - outsourced manufacturing
   - market growth
3. Leverage venture capital to supply R&D

Basic Design Principle: Acquisition Relationship with Technology Chain Partners

Volatility Amplification in the Supply Chain: *"The Bullwhip Effect"*



Information lags
Delivery lags
Over- and underordering
Misperceptions of feedback
Lumpiness in ordering
Chain accumulations

SOLUTIONS:
Countercyclical Markets
Countercyclical Technologies
Collaborative channel mgmt.
(Cincinnati Milacron & Boeing)

Supply Chain Volatility Amplification: Machine Tools at the tip of the Bullwhip

For this chart, see:

Anderson Jr., Edward G., Charles H. Fine, and Geoffrey G. Parker. "Upstream Volatility in the Supply Chain: The Machine Tool Industry as a Case Study." *Production and Operations Management* 9, no. 3 (Fall 2000): 239-261.

LESSONS FROM A FRUIT FLY:
CISCO SYSTEMS

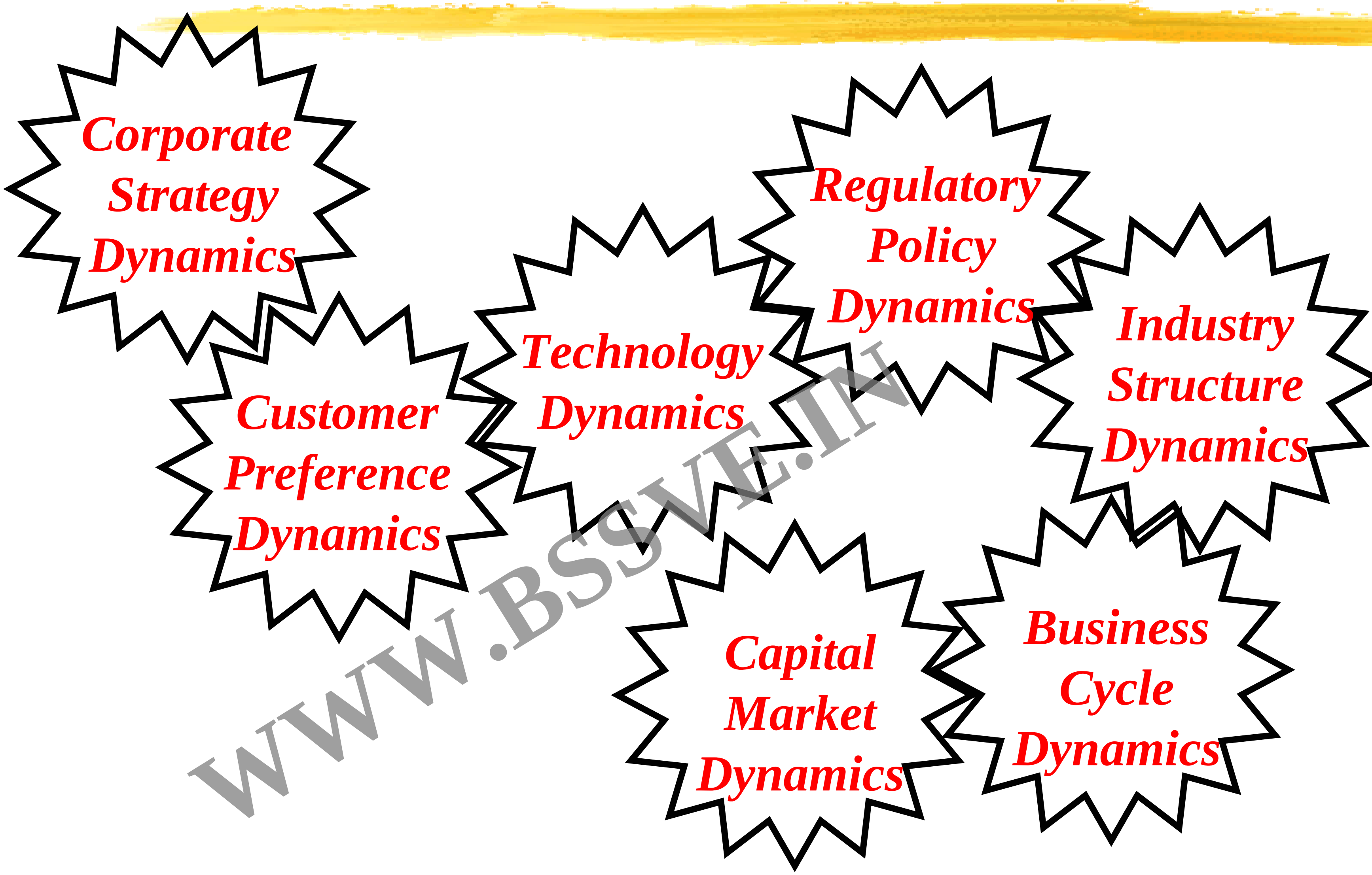
1. KNOW YOUR LOCATION IN THE VALUE CHAIN
2. UNDERSTAND THE DYNAMICS OF VALUE CHAIN FLUCTUATIONS
3. THINK CAREFULLY ABOUT THE ROLE OF VERTICAL COLLABORATIVE RELATIONSHIPS
4. INFORMATION AND LOGISTICS SPEED DO NOT REPEAL BUSINESS CYCLES OR THE BULLWHIP.

Bonus Question:
How does clockspeed impact volatility?

BUZZ GROUPS

1. HOW HAS THE BULLWHIP AFFECTED A BUSINESS THAT YOU ARE FAMILIAR WITH?
2. HOW FAR UPSTREAM OR DOWNSTREAM DID YOU SENSE THE IMPACT OF THE BULLWHIP?
3. WHAT MIGHT HAVE BEEN DONE DIFFERENTLY TO REDUCE THE NEGATIVE IMPACT OF THE BUILLWHIP?

Dynamic Analysis to Support Industry & Technology Roadmapping



All Conclusions are *Temporary*

Clockspeeds are increasing almost everywhere

Many technologies and industries exhibits fast clockspeed & high volatility

Value chain design and service system key competencies

Study of Fruit Flies can help with crafting strategy

Class 19: Course Wrap-up

1. Course Main Concepts and Simulation Debriefing

2. Sloan Evaluation Forms

3. Final Feedback Survey

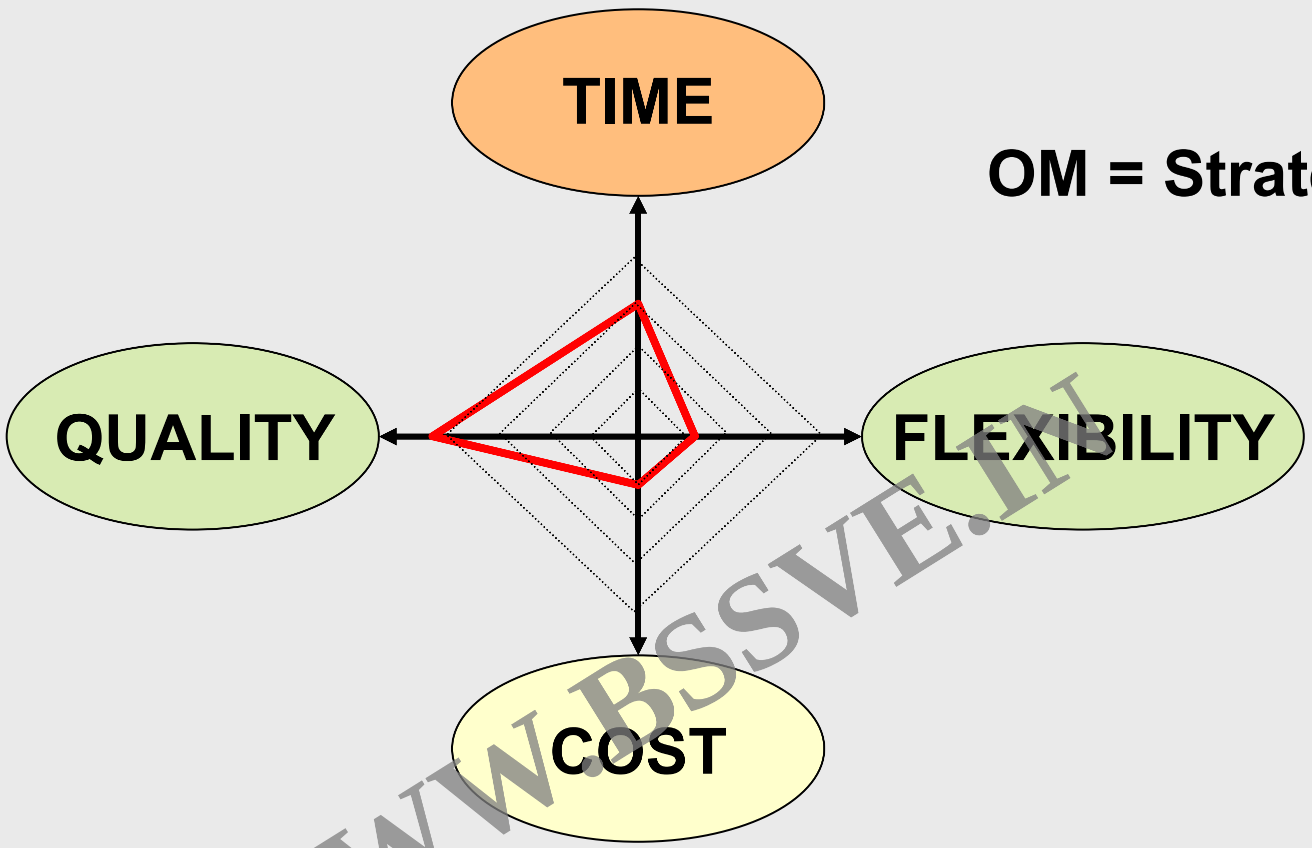
after class

Intro to Ops At-a-Glance

#	Day	Date	Contents	Readings	Assignments	Sim
1	Mon	29-Mar	Course Introduction	Course Syllabus		
2	Wed	31-Mar	Case: Burger King + McDonald's	Types of processes		
3	Fri	2-Apr	Lecture: Capacity	Wait-in-line blues	1 Ex. Buildup, 1 Ex. Queueing	
4	Mon	5-Apr	Case: National Cranberry			
5	Wed	7-Apr	Case: Webvan			
6	Fri	9-Apr	Lecture: Inventory	Automate or Die	1 Ex. EOQ, 1 Ex. Newsboy	
7	Mon	12-Apr	Case: Barilla	Managing Supply-Chain Inventory		
8	Wed	14-Apr	Case: Sport Obermeyer	Rocket Science Retailing	Case Write-up	
9	Fri	16-Apr	Lecture: Production Control	Growth in MRP, Control of JIT	1 Ex. Kanban, 1 Ex. Commonality	
10	Wed	21-Apr	Case: Hewlett-Packard			
11	Fri	23-Apr	Book: The Goal	The Goal	Book Review	
12	Mon	26-Apr	Lecture: Quality	Hank Kolb case	1 Ex. SPC, 1 Ex. 6 Sigma	
13	Wed	28-Apr	Case: Toyota			
14	Fri	30-Apr	Lecture: Process Design	Reengineering Work, ERP Tech. Note		
15	Mon	3-May	Case: Global Financial Corporation			
16	Wed	5-May	Lecture: Supply Chain Design	Chapter 8 Clockspeed		
17	Fri	7-May	Lecture: Product Design			
18	Mon	10-May	Case: Sega Dreamcast		Simulation Write-up	
19	Wed	12-May	Simulation & Course Wrap-up			

2002 - Jérémie Gallien

What is Operations Management?



OM = Strategy Execution!

2002 - Jérémie Gallien

Benchmark Companies

• Toyota	Lean Manufacturing
• FedEx (Webvan)	Hub & Spoke
• Dell	Direct-to-Consumer
	ATO technology
• Walmart (Barilla)	Vendor-Managed Inventory
• Sport Obermeyer	Quick Response
• Zara	Assortment Optimization

2002 - Jérémie Gallien

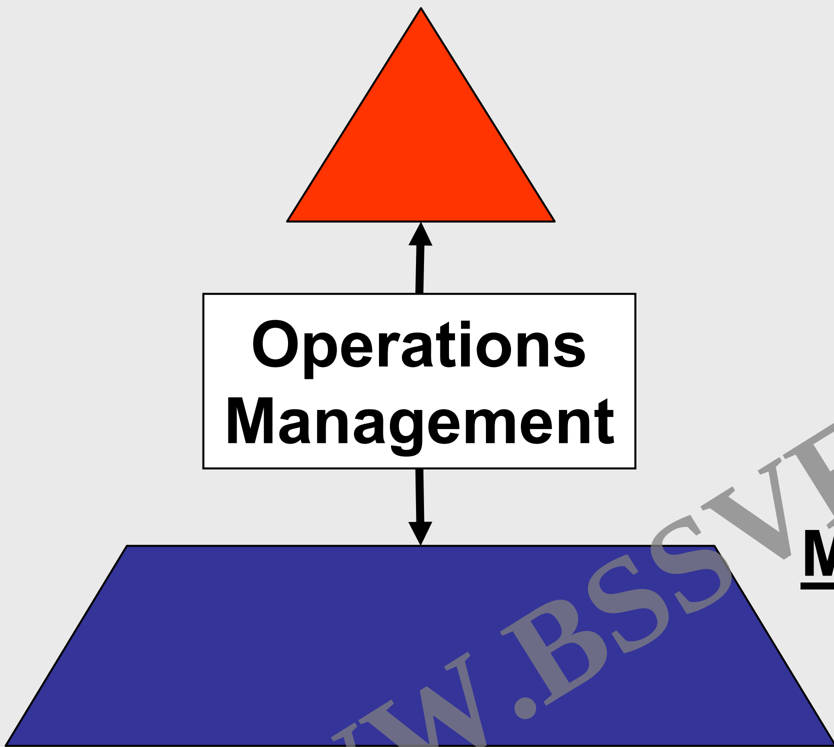
Operations Management History

- 1920's: Ford & Taylor
  Moving Production line and standardized work
- 1930's: Shewhart
  Statistical Control of Quality
- 1960's: Ohno
  Lean Production System
- 1980's: Goldratt
  Theory of Constraints
- 1990's: Hammer
  Reengineering & Process Focus
- 2000's: 15.760 Alumni
  Storytelling

2002 - Jérémie Gallien

A Translation Challenge

Corporate Structure



<u>Top Management</u>
speaks the language of
MONEY

<u>Mid-Mgt., Associates, Workers</u>
speak the language of
THINGS

OM merges physical and financial analyses, and requires great care to people issues!

2002 - Jérémie Gallien

Operations Management Architecture

Product

Integral Vs. Modular:

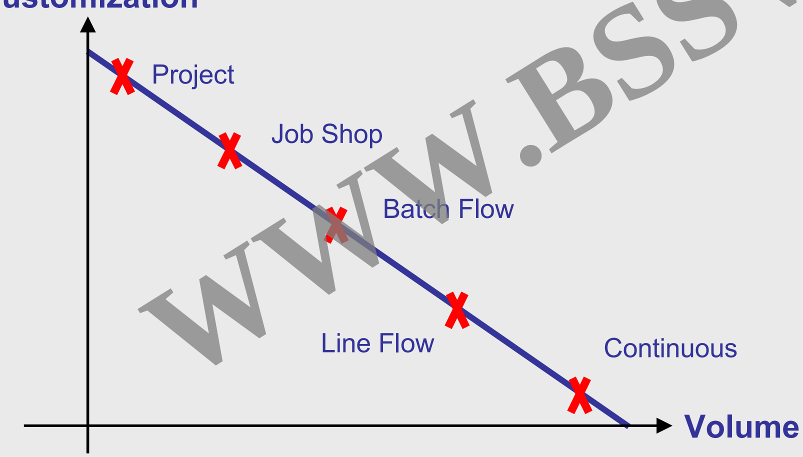
- *Functions*
- *Interface*
- *Interchangeability*

Supply-Chain

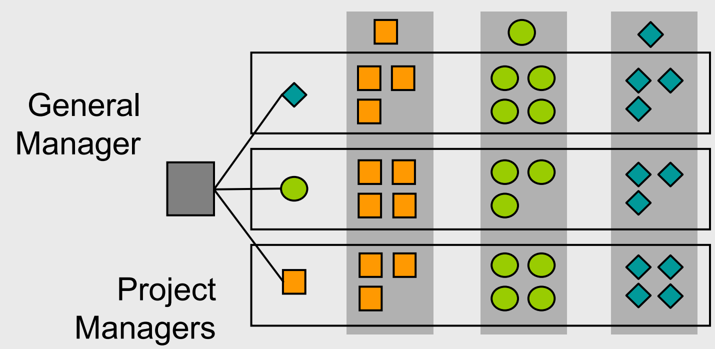
Integral Vs. Modular:

- *Geography*
- *Organization*
- *Culture*
- *Communication*

Process



HR



2002 - Jérémie Gallien

Operations Management Activities

Set of responsibilities:

1.	DESIGN	Product, Process, Supply-Chain, HR
2.	PLANNING	Demand (forecast), Supply (Capacity)
3.	CONTROL	Inventory, Production Control, Suppliers Pricing, LT Quote, Quality, HR
4.	IMPROVEMENT	Time, Cost, Flexibility, Quality

Operations Management Tools

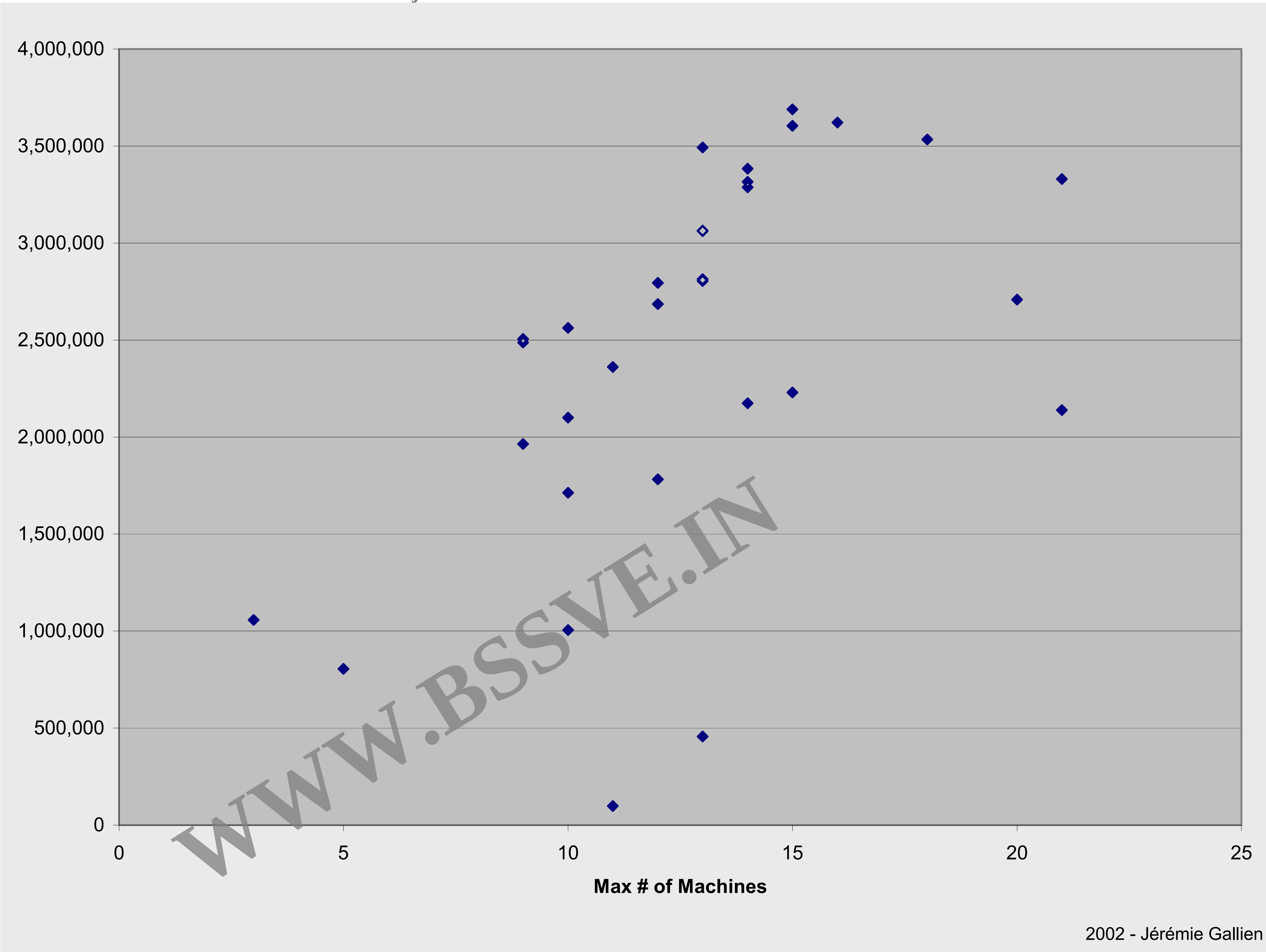
	Product Design & Devlpt.	Process	Supply Chain
Design	Product Architecture Development Process Reengineering Market Positioning	Process Architecture Reengineering	SC Architecture Strategic Sourcing
Planning	CPM DSM	Capacity Analysis ERP, CPM	Quick Response Capacity CPM
Control	CPM Critical Chain	Inventory TOC, CPM, ERP Production Control TQM	Inventory Theory VMI (JITD) Production Control TQM
Improvement	TQM TPS	TOC (The Goal) TQM, TPS & Lean Manufacturing	TPS, Lean Manufacturing

2002 - Jérémie Gallien

Factory Simulation Skills

	Product Design & Devlpt.	Process	Supply Chain
Design		*Process Architecture* *Process Flow Diagram*	
Planning		*Forecasting* *Capacity Analysis* *Cycle Time Analysis*	
Control		*Inventory Control* *Team Organization*	
Improvement		*TOC (The Goal)* *TPS*	

2002 - Jérémie Gallien


4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
0
5
10
15
20
25
Max # of Machines
2002 - Jérémie Gallien

Capacity Analysis

Processing Time (hours):

Step	Station	Set-up time (per lot)	Operation time (per unit)
1	1	0	0.062777
2	2	0	0.02
3	3	1.5	0.001666
4	2	0	0.021388

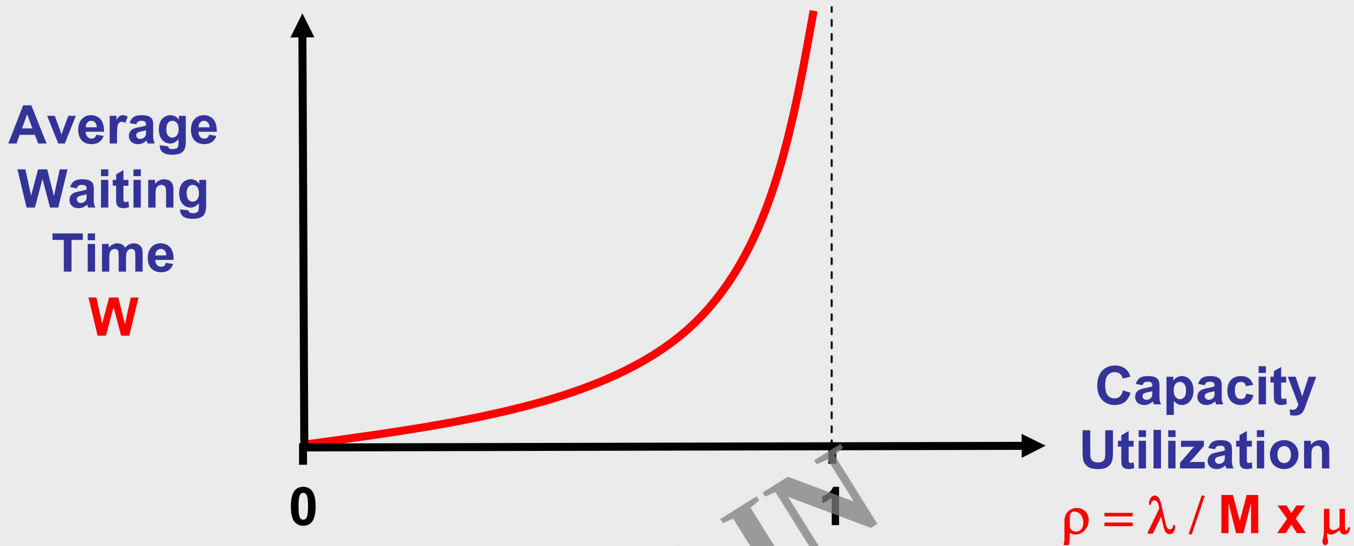
+ ***FORECAST***

Capacity Utilization

$$\rho = \lambda / N \times \mu$$

2002 - Jérémie Gallien

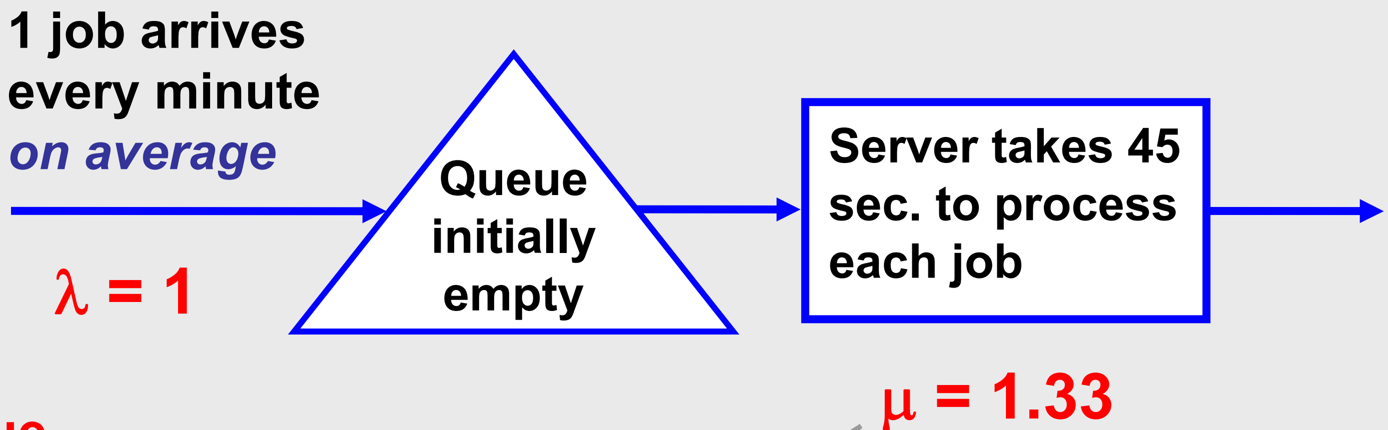
... and Queueing Theory

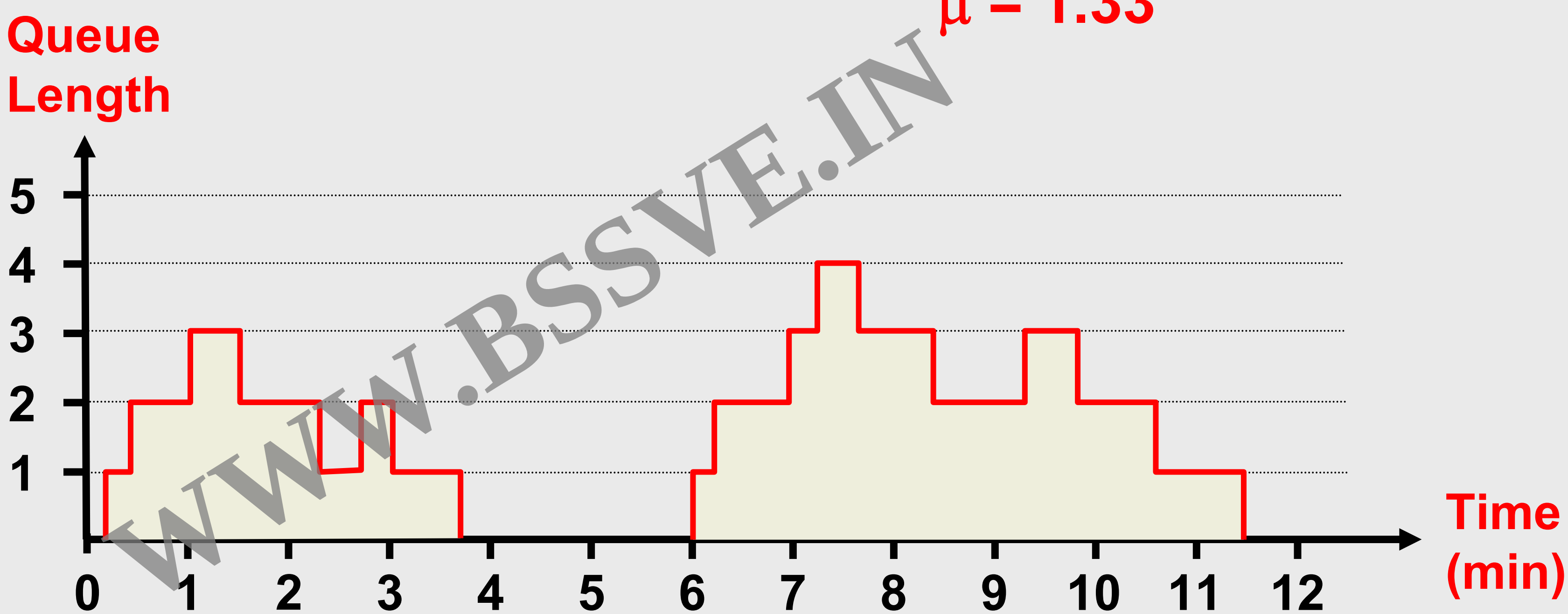


$$W = \frac{1}{\lambda} \frac{\rho^{\sqrt{2(S+1)}}}{1-\rho} \times \frac{C_A^2 + C_S^2}{2}$$

2002 - Jérémie Gallien

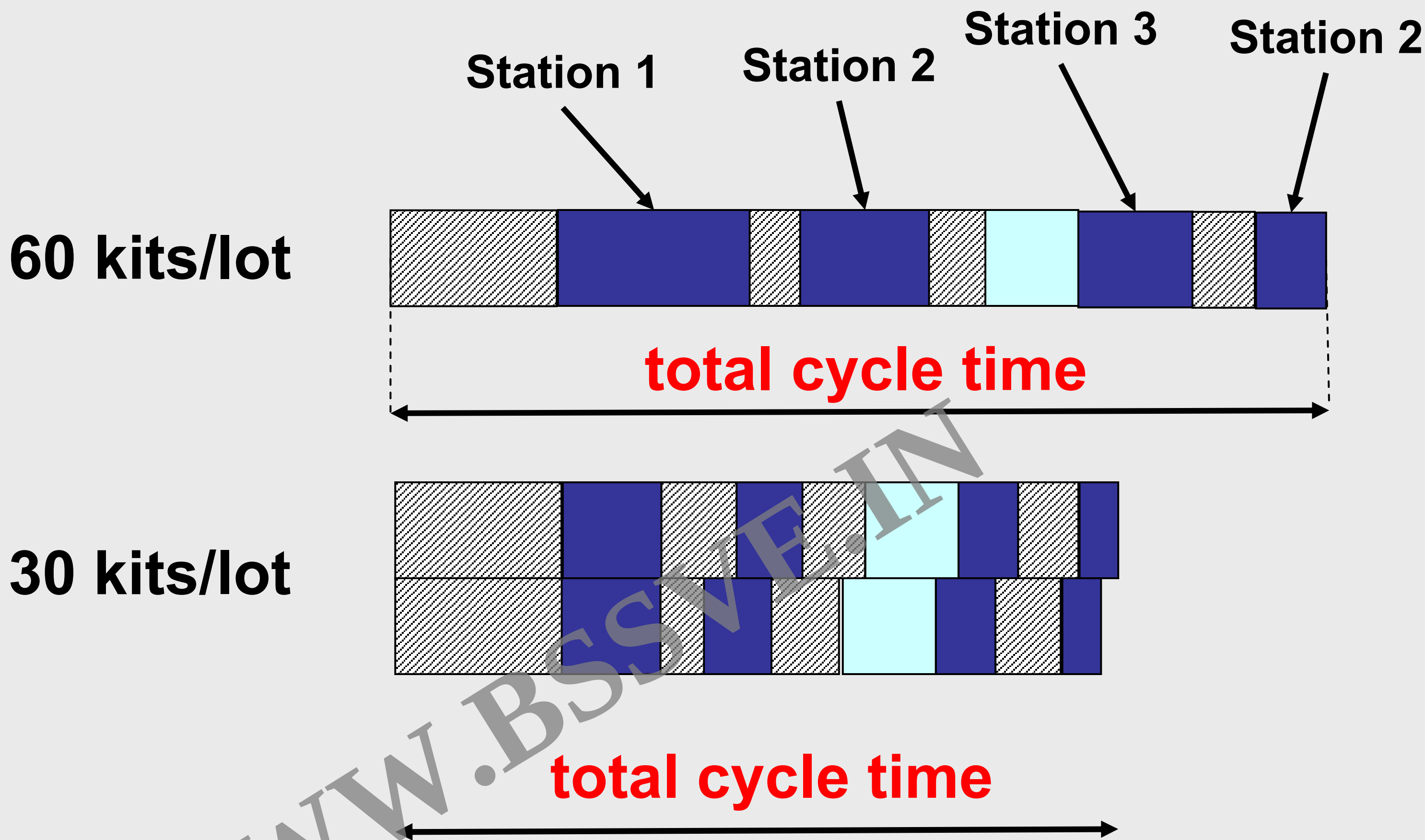
An Example for Insight





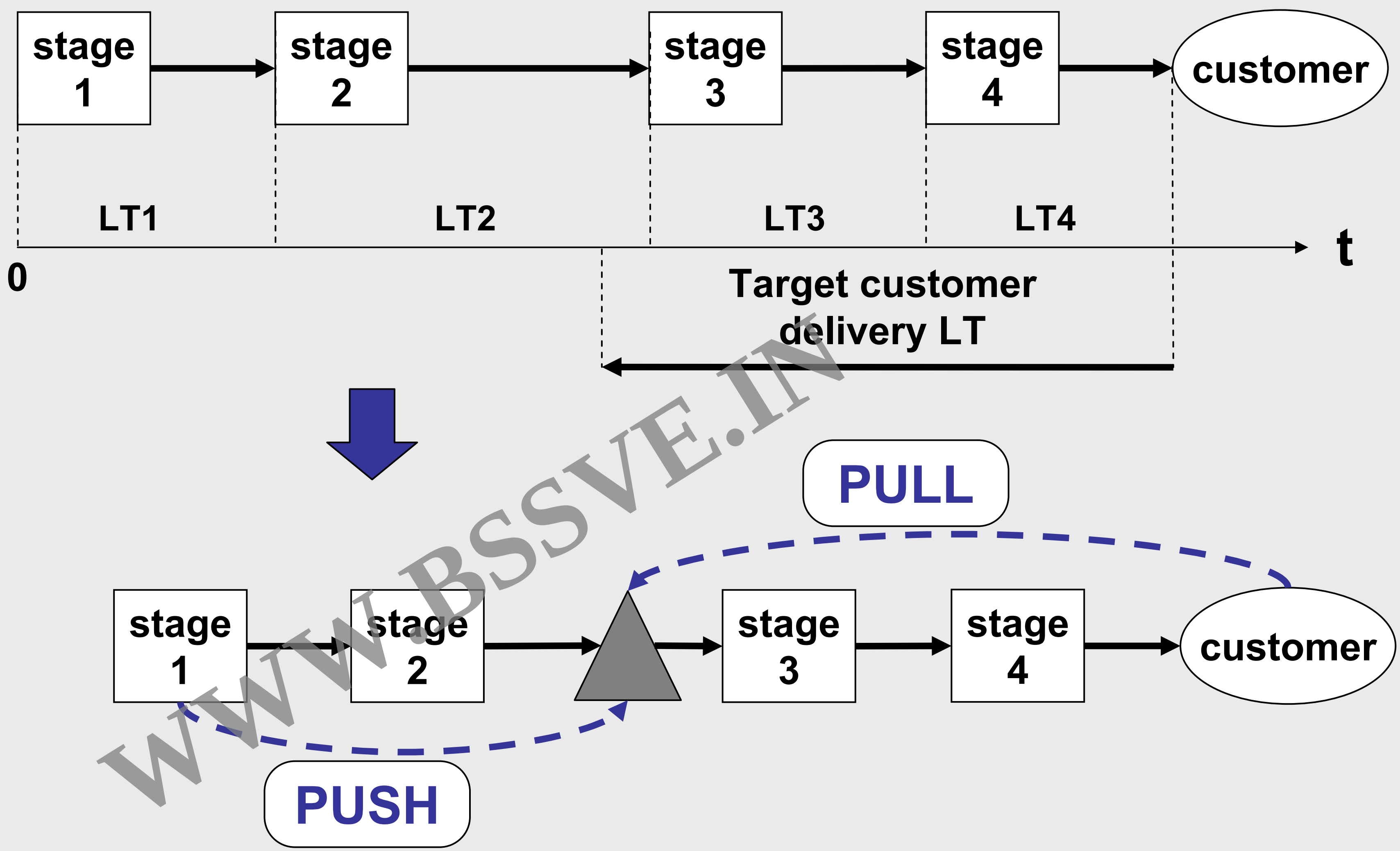
2002 - Jérémie Gallien

Cycle Time Analysis



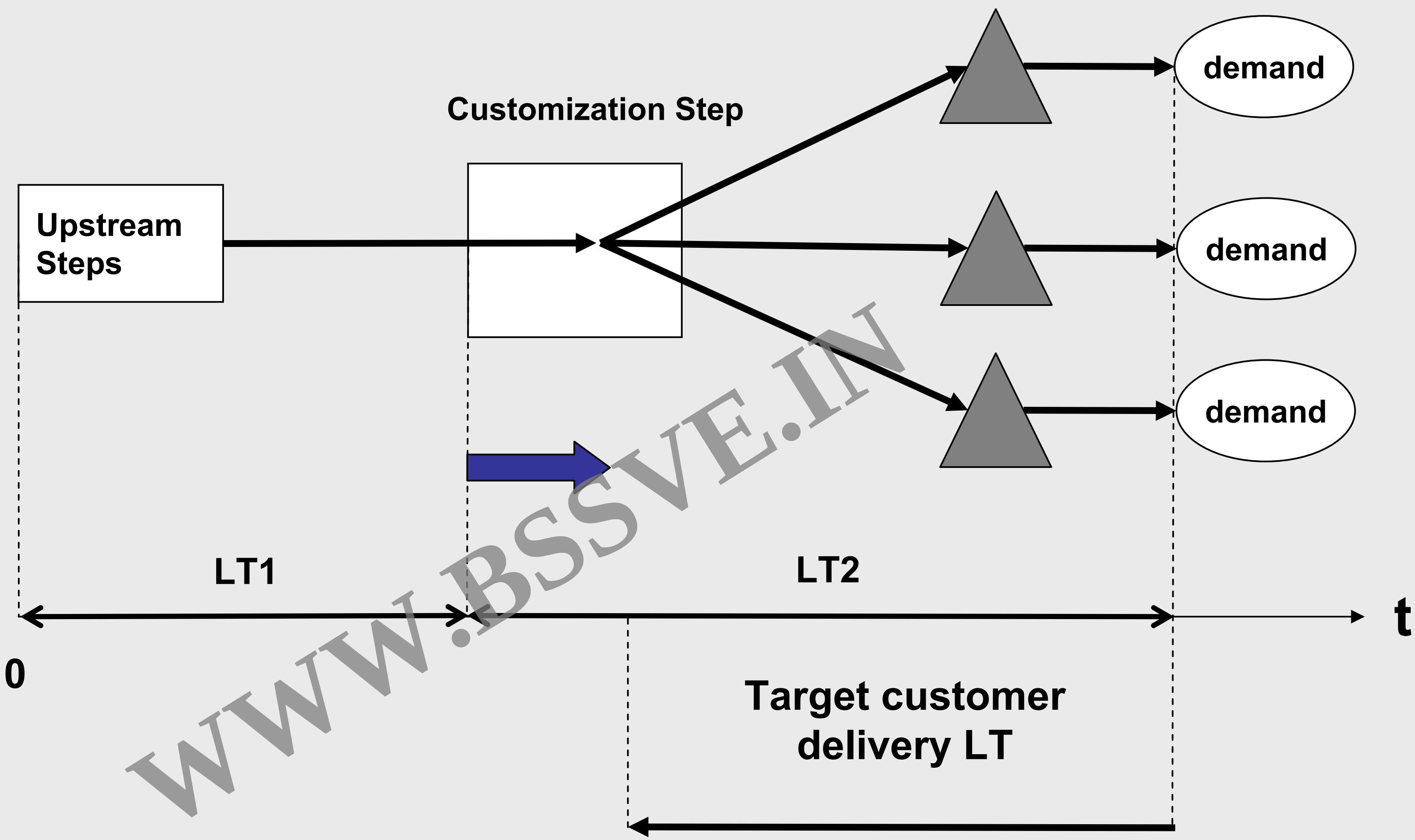
2002 - Jérémie Gallien

Customer and Process Timeline



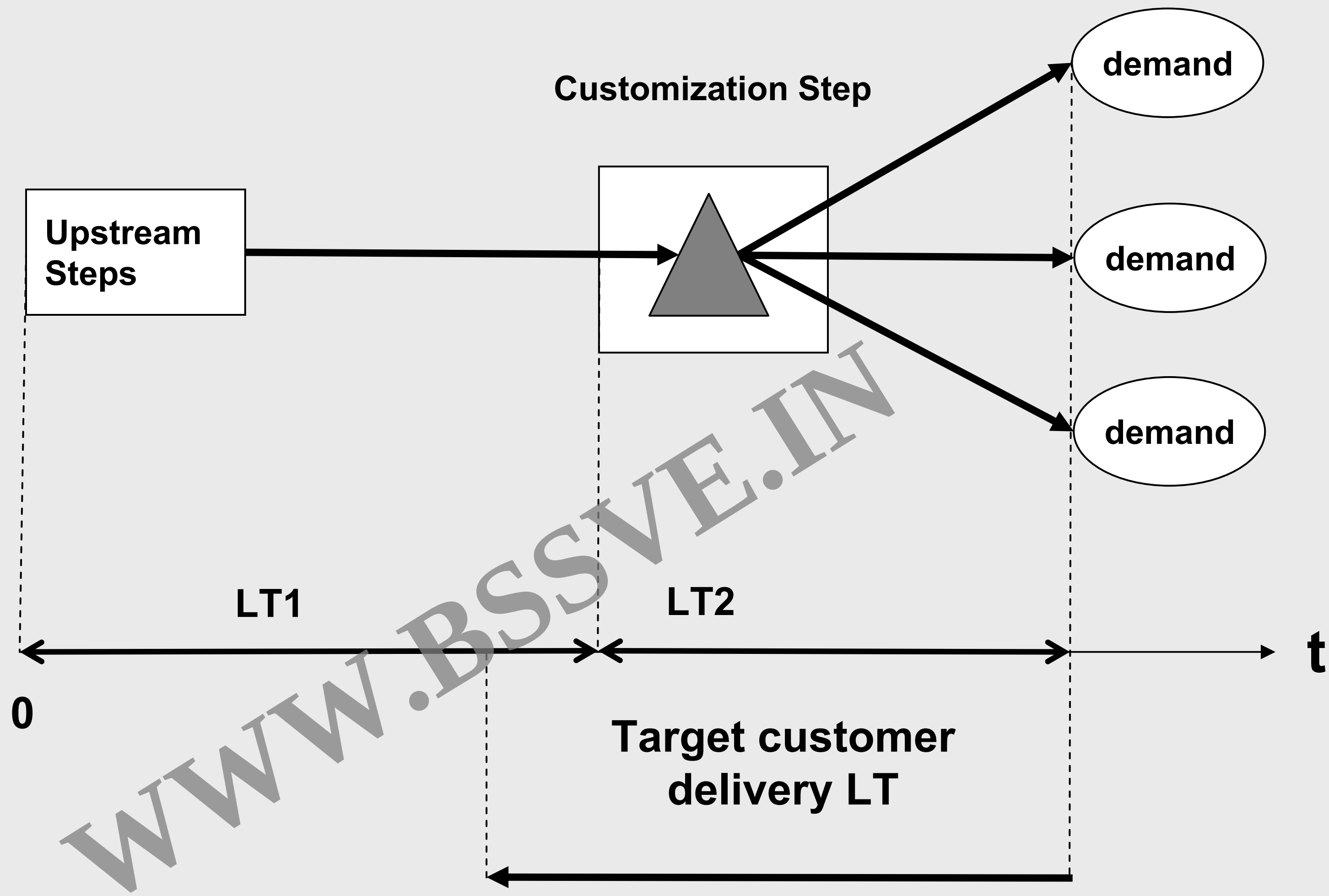
2002 - Jérémie Gallien

Delayed Differentiation



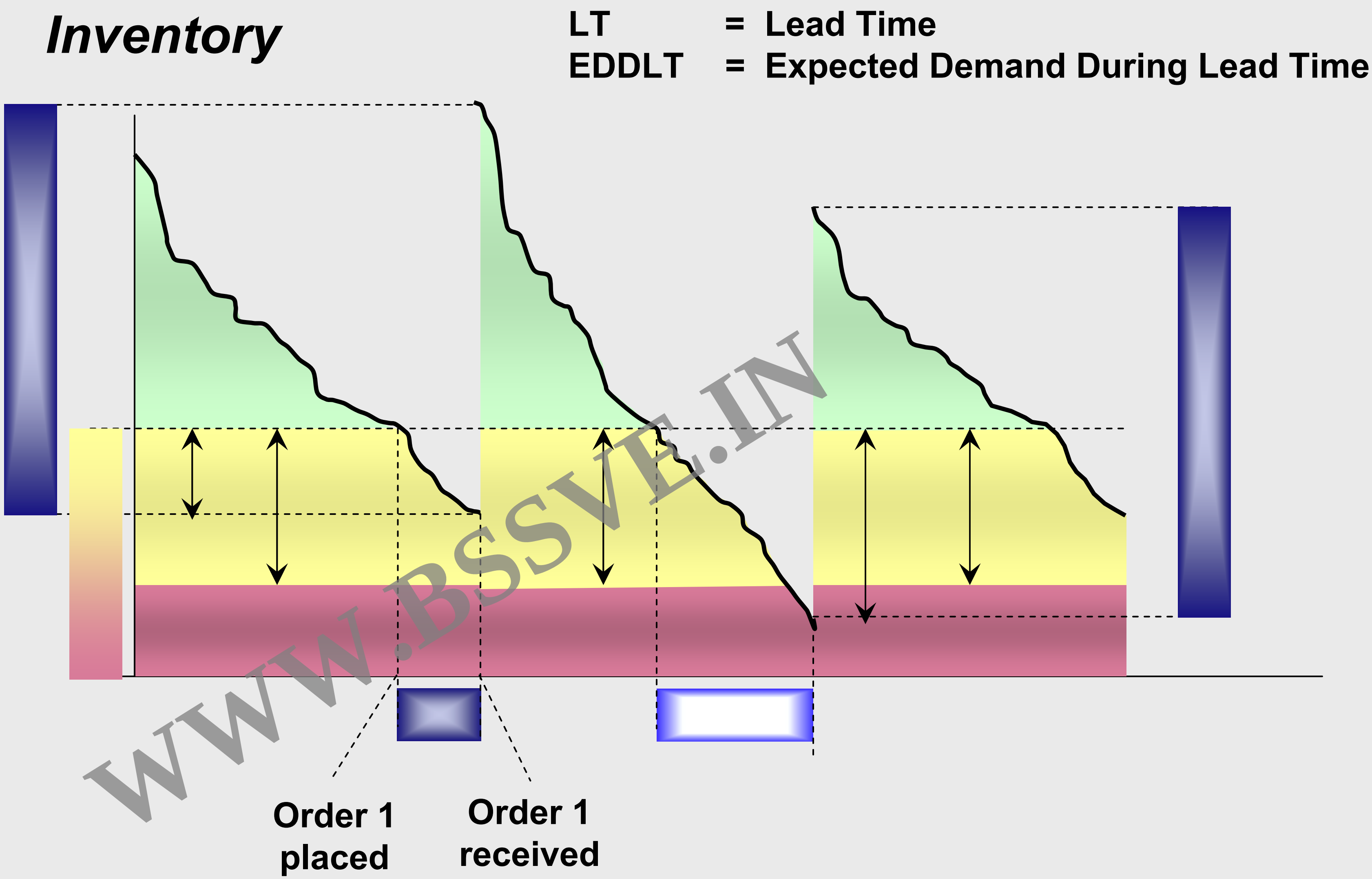
2002 - Jérémie Gallien

Delayed Differentiation



2002 - Jérémie Gallien

Inventory Theory...

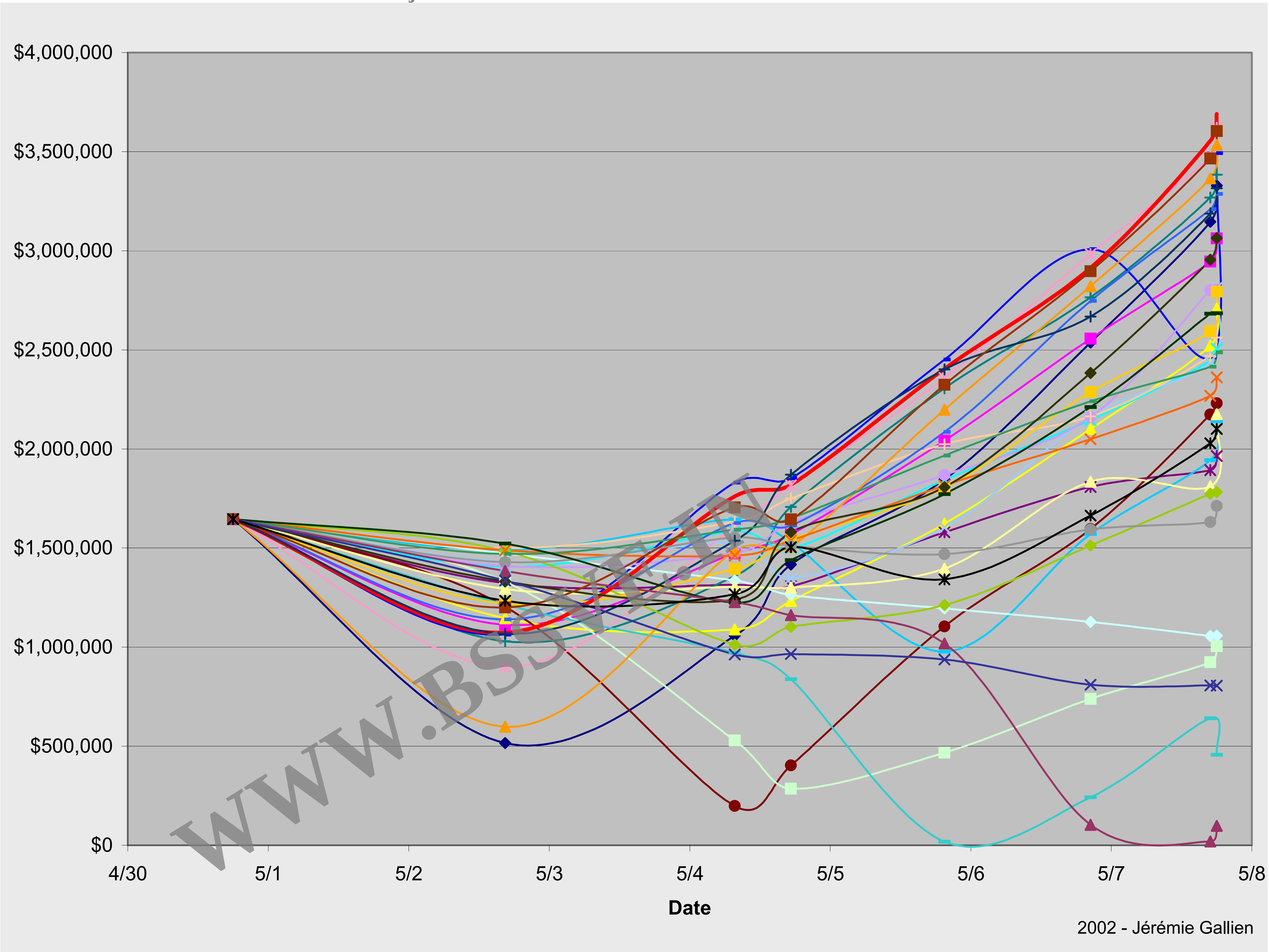


2002 - Jérémie Gallien

Slide courtesy of Prof. Thomas Roemer, MIT

… and Inventory Practice

- EOQ Model
- ROP/ROQ
- Newsboy Model
- Continuous Review/Periodic Review


$4,000,000
$3,500,000
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
4/30
5/1
5/2
5/3
5/4
5/5
5/6
5/7
5/8
Date
2002 - Jérémie Gallien
WWW.BSSVE.IN

Simulation Performance Drivers

- Proactive Vs. Reactive Strategy: this is what models allow!!!
- Extent of quantitative analysis does have an impact BUT describing qualitatively the correct trade-offs brings you a long way…
- Understanding financial impact of operational data (lead time, utilization, queues, etc…) had a huge impact!

Final Words

Do Keep in Touch and…
GOOD LUCK!!!

2002 - Jérémie Gallien

15.760B, Spring 2004 – Prof. Jérémie Gallien

Case Write-Up

This paper should be written in the form of a memo for a manager to whom you report. In preparing this assignment, please adhere to the following guidelines:

1. Work in groups of three students. Any exception must be cleared by the professor.
2. Hand in one paper copy of the case write-up for each group (email attachments will *not* be accepted).
3. Written assignments are to be turned in at the beginning of class for your section, in the classroom, on the day they are due.
4. Each student should have a personal copy of his/her team write-up for the corresponding class discussion.
5. Written assignments must be less than **1500** words in length, accompanied by up to **6** supporting exhibits. This is a firm constraint.
6. Exhibits should contain specific types of analysis, such as financial analysis, break-even charts, cost analysis, process-flow analysis, etc. Exhibits should contain any relevant supporting information that is too detailed for the body of the paper. Exhibits must not be simply an extension of the text.

The case write-ups will be graded using the following criteria:

Analysis

1. Does the paper contain analysis of the major issues?
2. Does the analysis incorporate properly the relevant tools?
3. Are assumptions made in the analysis stated explicitly?
4. Does the analysis isolate the fundamental causes of problems in the case?

Recommended Actions

1. Are the criteria for choosing among alternative recommendations stated?
2. Are the criteria appropriate?
3. Is the plan of action integrated in a logical way and linked to the analysis?
4. Is the action plan specific, complete, and practical?
5. Is it likely that the recommendations will achieve their intended results?

Exhibits

1. Are the analyses in the exhibits done correctly?
2. Do the exhibits support and add to the text on key points?

Presentation

1. Is the paper too long?
2. Is the presentation of professional quality?
3. Is the paper logically consistent and effectively structured to sell its recommendations?