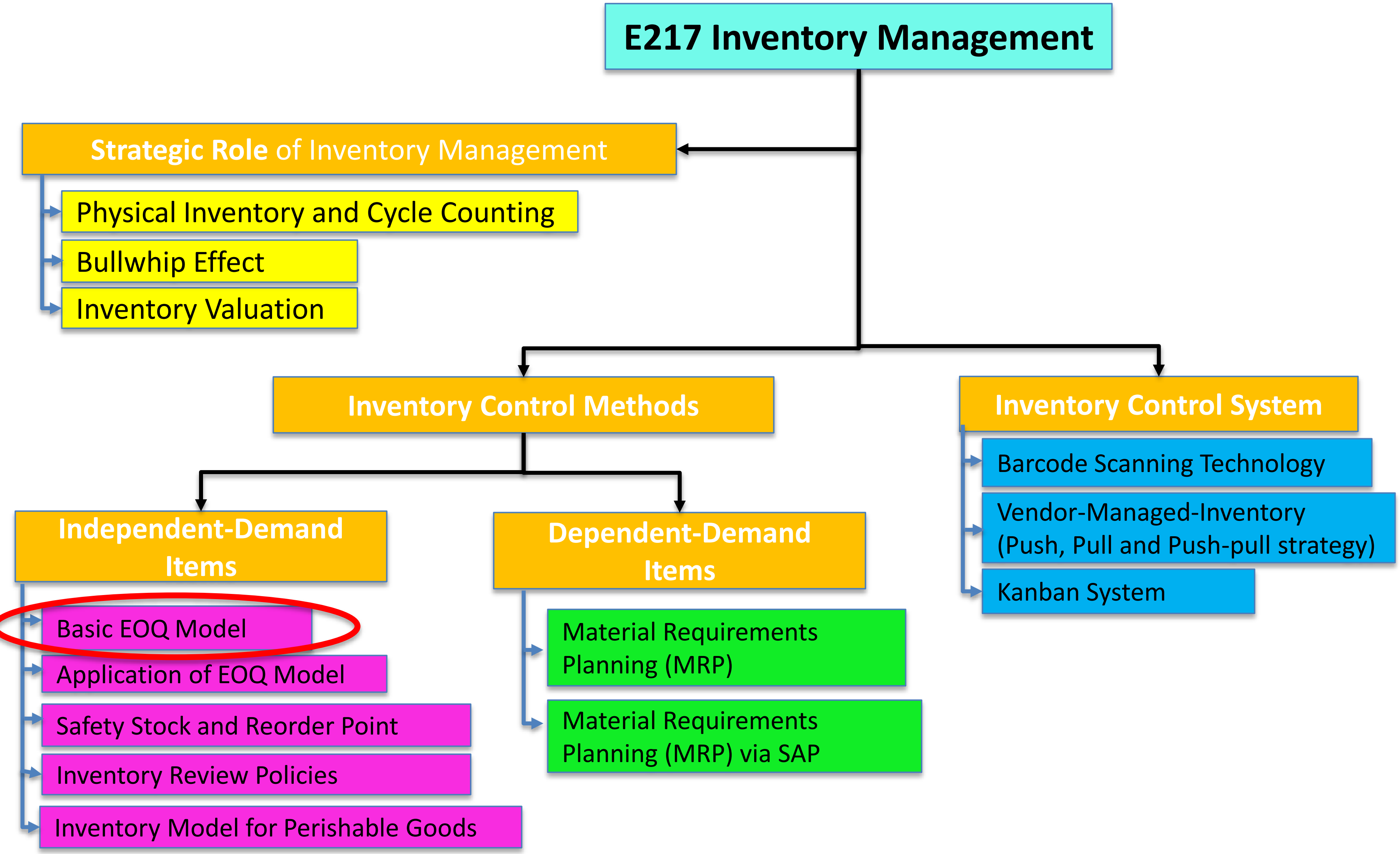
REPUBLIC POLYTECHNIC

Problem 01
Order More or Less

SCHOOL OF ENGINEERING

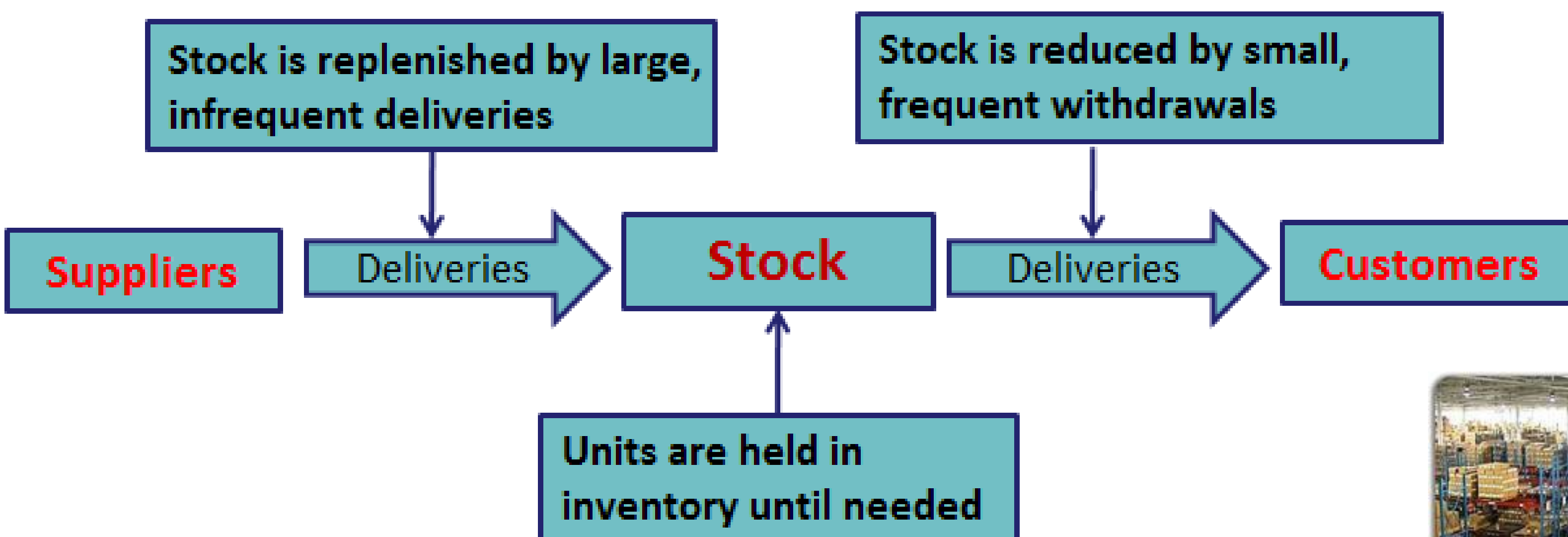
E217 – Inventory Management

E217 Inventory Management Topic Tree

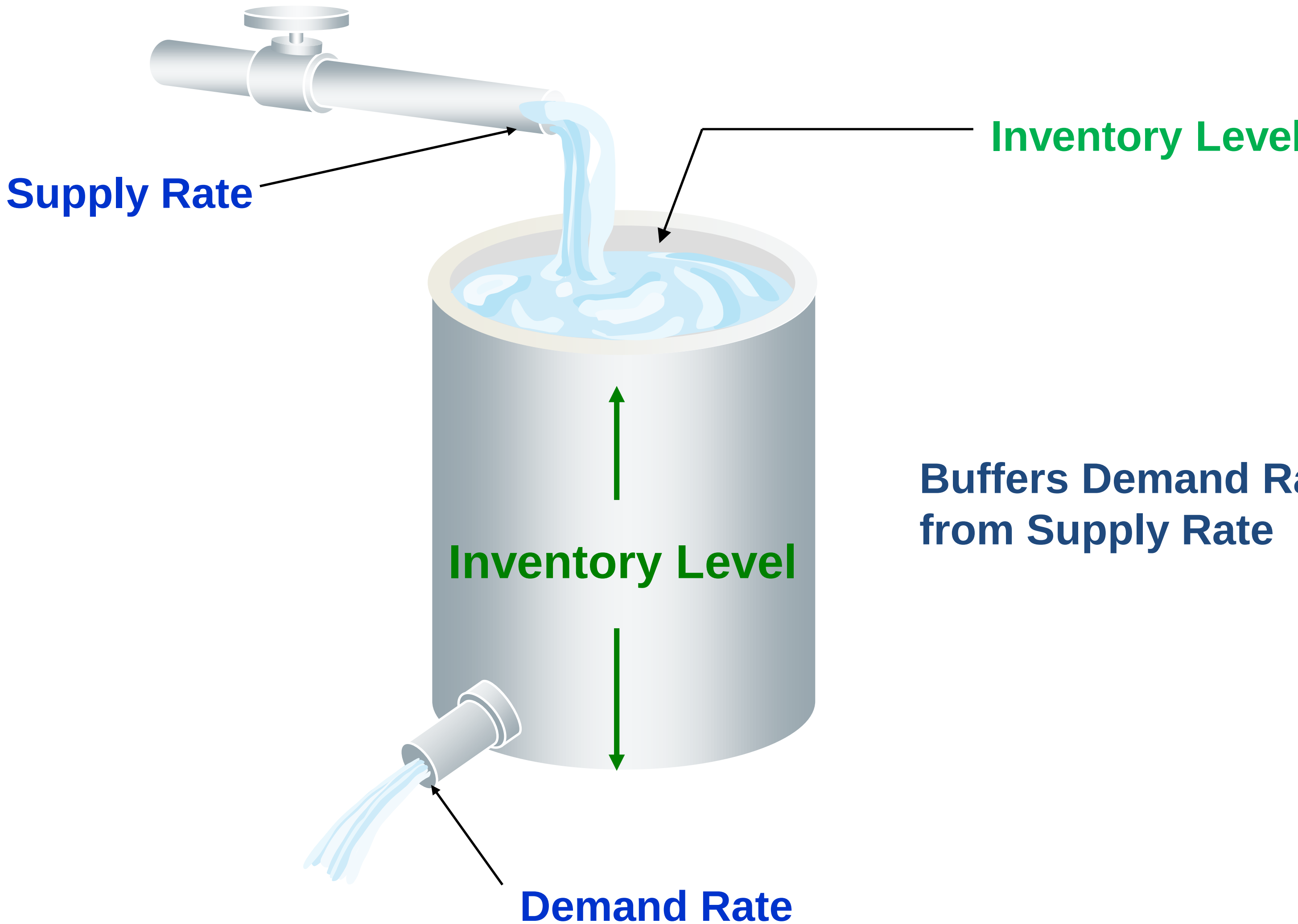


Inventories Everywhere

- One of the most expensive and important assets to many companies
- Stocking of items to meet future demand and provide buffer between supply and demand
- To provide a stock of goods that will provide a “selection” for customers
- To hedge against inflation and upward price changes



Water Tank Analogy for Inventory



Buffers Demand Rate from Supply Rate

Why Manage Inventories and How?

- Inventory is the largest factor in manufacturing costs, and efficient Inventory Management has the greatest potential for increasing profitability
  - *Example: For a typical US manufacturer, 60% of corporate income goes towards the purchase of materials*

- Inputs to be considered
  - Objectives of holding inventory? (service level or cost minimization)
  - What is customer demand pattern?
  - What is the cost of ordering and holding inventory?
  - How long does it take to receive our orders?
    - Lead Time*: the time interval between ordering and receiving an order*

- The need of Inventory Management to determine:
  - **What** inventory need to order?
  - **When** should we replenish our inventory?
  - **How much** should we order?

Major Types of Inventory

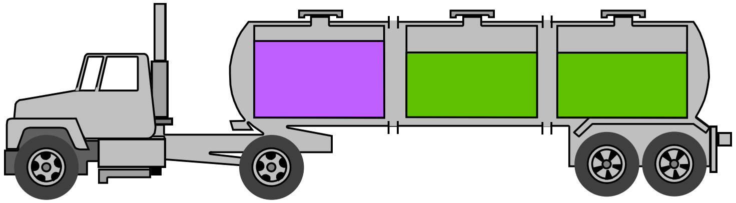
- Raw materials and component parts
- Work-in-process (partially completed) products
- Finished goods

<u>Classification according to the purpose inventory serves:</u>

- Maintenance, Repair and Operating supplies (MRO)

  Examples: repair parts, gloves, tools, screws, office supplies, etc.

- Transit Inventory (pipeline inventory, merchandise shipped by truck or rail or air)
- Buffer inventory (safety stock)
- Cycle inventory (cycle stock), etc.



Major Types of Inventory

Raw materials:

- Inventory items used in the transformation process to produce components, subassemblies or finished products
- They could be purchased from outside the organization
- Considered as a finished product to the supplier, but the purchaser may classify it as a raw material
- For example, grain, minerals, chemicals, paper, steel, etc.

Work-in-Process (WIP):

- WIP is made up of all the materials, parts, assemblies and subassemblies that are being processed or are waiting to be processed
- This generally includes all materials from raw material that has been released for initial processing up to materials that have been completely processed
- Any item that has a parent but is not a raw material is considered to be WIP
- For example, legs, leg assemblies, frames, etc. for a chair

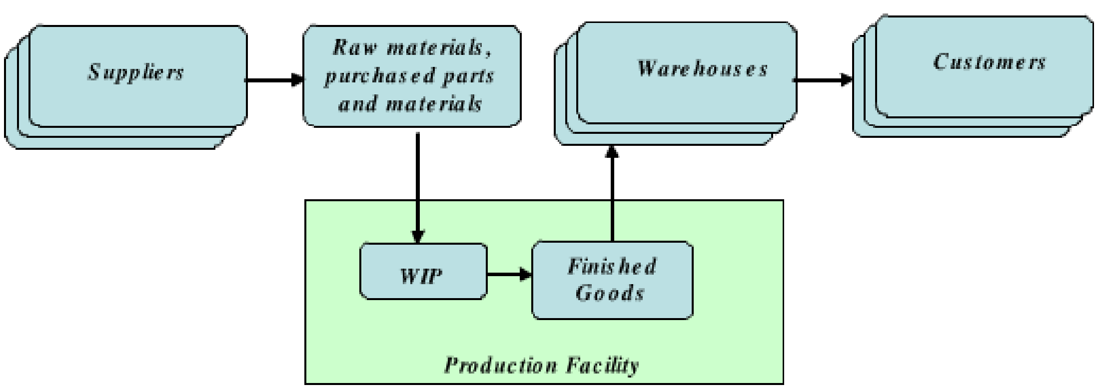
Major Types of Inventory

Finished Goods:

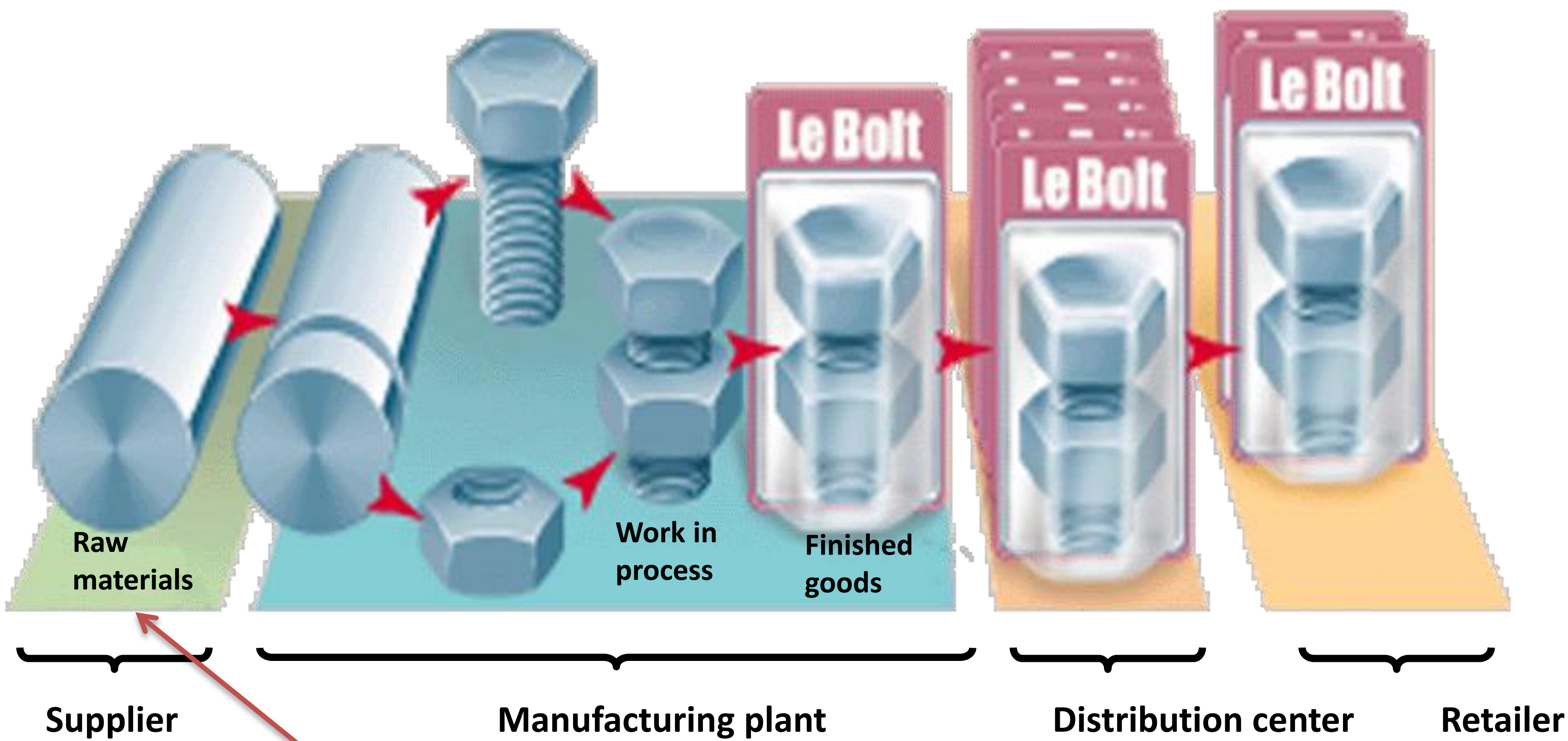
- A completed part that is ready for a customer order
- Finished goods inventory have passed final inspection and can be sold directly or held in anticipation of a customer order
- For example, cookies, drinks, medicines, etc.

Inventories differ depending upon the nature of business:

- A manufacturer will have high level of all 3 kinds of inventories
- A retailer or wholesaler will have finished goods inventory without any inventory of raw materials or WIP
- Inventories may be durable or non-durable
- Inventories may be valuable or inexpensive
- Inventories may be perishable or non-perishable



Inventory at Different Stocking Points



The same item may take on different roles at the upstream of supply chains, e.g. one can be Raw Material to the manufacturer, but Finished Goods to the supplier

Reasons To Hold Inventory

- Act as buffer against uncertain supply or delivery
  - Uncertainty in customer demand
  - Uncertainty in the quantity and quality of the supply, supplier costs and delivery times
- Hedge against demand fluctuation and unforeseen changes
- Keep operations running (running out of only one item can prevent a manufacturer from completing the production of its finished products)
- Even if there is no uncertainty in demand or supply, there is still a need to hold inventory due to delivery lead-times.
- Take advantage of the economy of scale for purchasing, transportation and production
- Improve customer service level

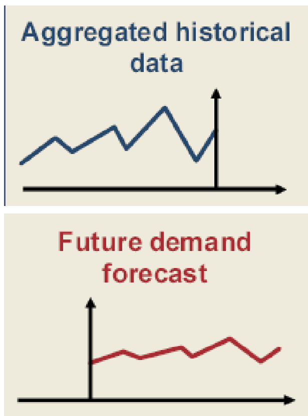
Major Inventory Costs

- Holding/Carrying Costs
  - *Cost of holding items in inventory*
  - *Examples: insurance, damage, warehousing, etc.*
- Ordering Costs
  - *Costs of receiving an order, verifying inventory availability, invoicing and payment, etc.*
  - *Fixed, not dependent on how much you order*
- Setup costs
  - *Cost to prepare a machine or process for manufacturing an order*
  - *Examples: clean-up costs, re-tooling costs and adjustment costs*
- Shortage Costs (Stock-out Costs)
  - *Costs when demand exceeds supply*
  - *The loss due to losing a specific sale, customers' goodwill or future business*

Reasons **Not** To Hold **Too Much** Inventory

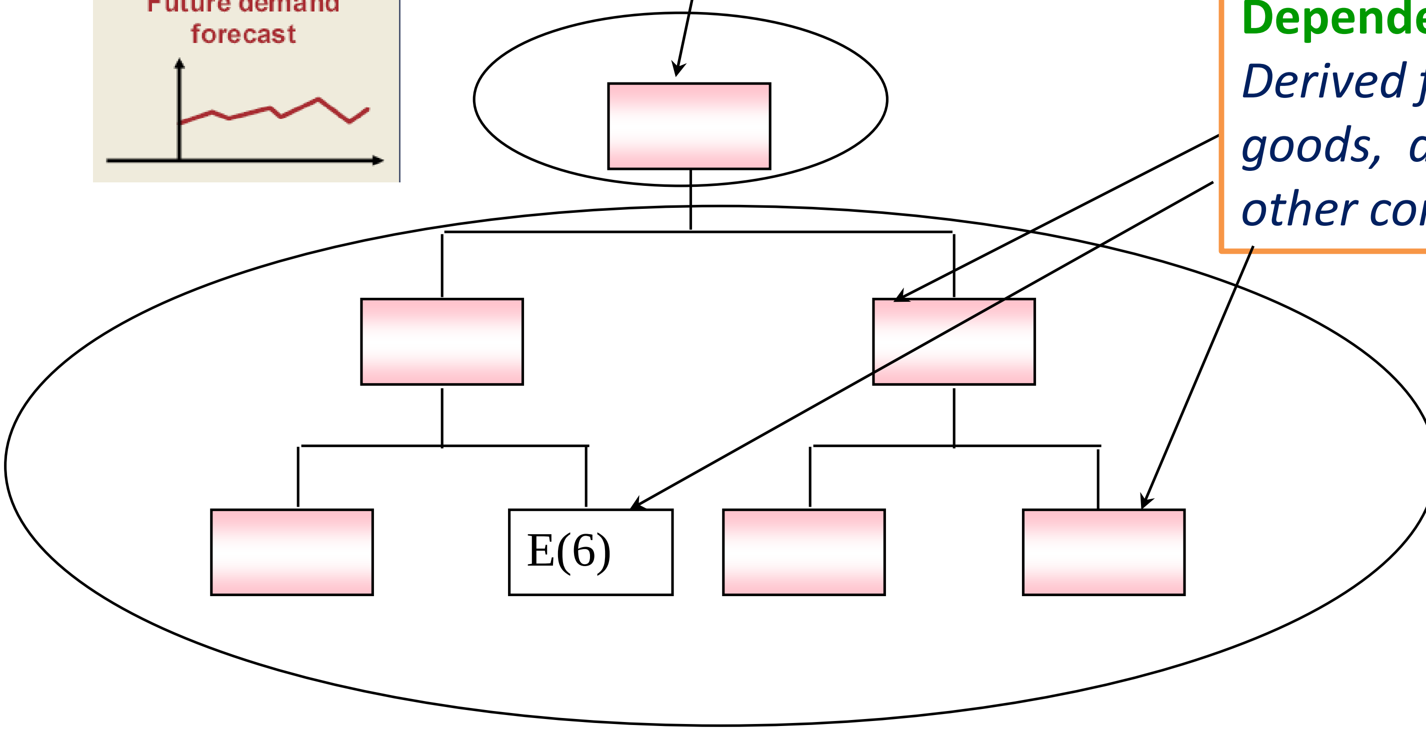
- **Obsolescence costs**
  - *Products lose value over time*
- **Inventory shrinkage**
  - *Generally caused by damage, loss or theft, efforts to reduce shrinkage cost often generate other costs*
- **Storage costs**
  - *Costs associated with occupying space in a plant or warehousing facility*
- **Handling costs**
  - *Costs of employing staff to receive, store, retrieve and move inventory*
- **Insurance costs**
  - *Insure inventory against fire, flood, theft and other perils*
- **Taxes**
  - *Calculated on the basis of the inventory on hand on a particular date*
- **Interest costs**
  - *Money that is required to maintain the investment in inventory*

Independent V.S. Dependent Demand



Independent Demand
Derived from the demand forecast and confirmed orders

Dependent Demand
Derived from finished goods, assemblies and other component parts



Independent V.S. Dependent Demand

For a cookie shop, the daily demand can be:

- Uncertain demand
- Seasonal or Cyclical demand (holiday sales)
- Random and Unpredictable demand
- Finished products that are served to customers

  -- *Such as the cookies (**Finished Goods**) for a cookie shop*
- Forecasting plays a critical role
- Due to uncertainty, extra units must be carried in inventory

Independent demand items

- Raw materials, component parts, or subassemblies that are used to produce a finished product

  -- *Such as the flour, sugar, water, eggs for a cookie shop (**Raw Materials**)*

  -- *Dough or flour that Penny just moved from storage location to cookie making place (**WIP**)*

dependent demand items

Inventory Ordering Decisions

- The inventory ordering decisions are:
  → When to order **(Timing)**
  → How much to order **(Quantity)**
  → What to order **(Variety)**

- The main objective of inventory management is to maintain inventory at an appropriate level so that it is neither excessive nor short of requirement.

- Thus, the management of any business is faced with 2 conflicting objectives:
  → To keep inventory at a sufficiently high level so that production and sales activities are able to proceed smoothly
  → To minimize the investment in inventory so as to maximise business profitability

Inventory Related Costs

- **Inventory ordering cost (denoted by R)** → *Our focus today!*
  - One-time cost charged by suppliers
  - Includes the processing fee, delivery charge, etc. plus internal resource requirements (consist of costs for manpower, equipment, etc needed for order placement, receiving, quality checks, etc)

- **Inventory holding cost (denoted by H)** → *Our focus today!*
  - Cost of holding one unit of the product per year, inclusive of storage costs and interest in paid capital (opportunity cost of borrowed money, that one would have received if the money had been invested in something else, i.e. in the stock market)

Inventory Related Costs

- **Unit cost of the product**

  Purchase price of the product.

- **Stock-out cost**

  Cost due to loss of sales revenue (incurred when the current supply is unable to meet the customer demand).

- **Obsolescence cost**
  - Cost that derives from the risk that the product will lose its value due to changes in the market (i.e. technological developments).
  - For today's case, we assume negligible obsolescence costs.

Economic Order Quantity (EOQ) Model

- Ordering in large quantities helps to reduce the inventory ordering cost, but on the other hand, this increases the inventory holding cost; vice verse if ordering in small amount.

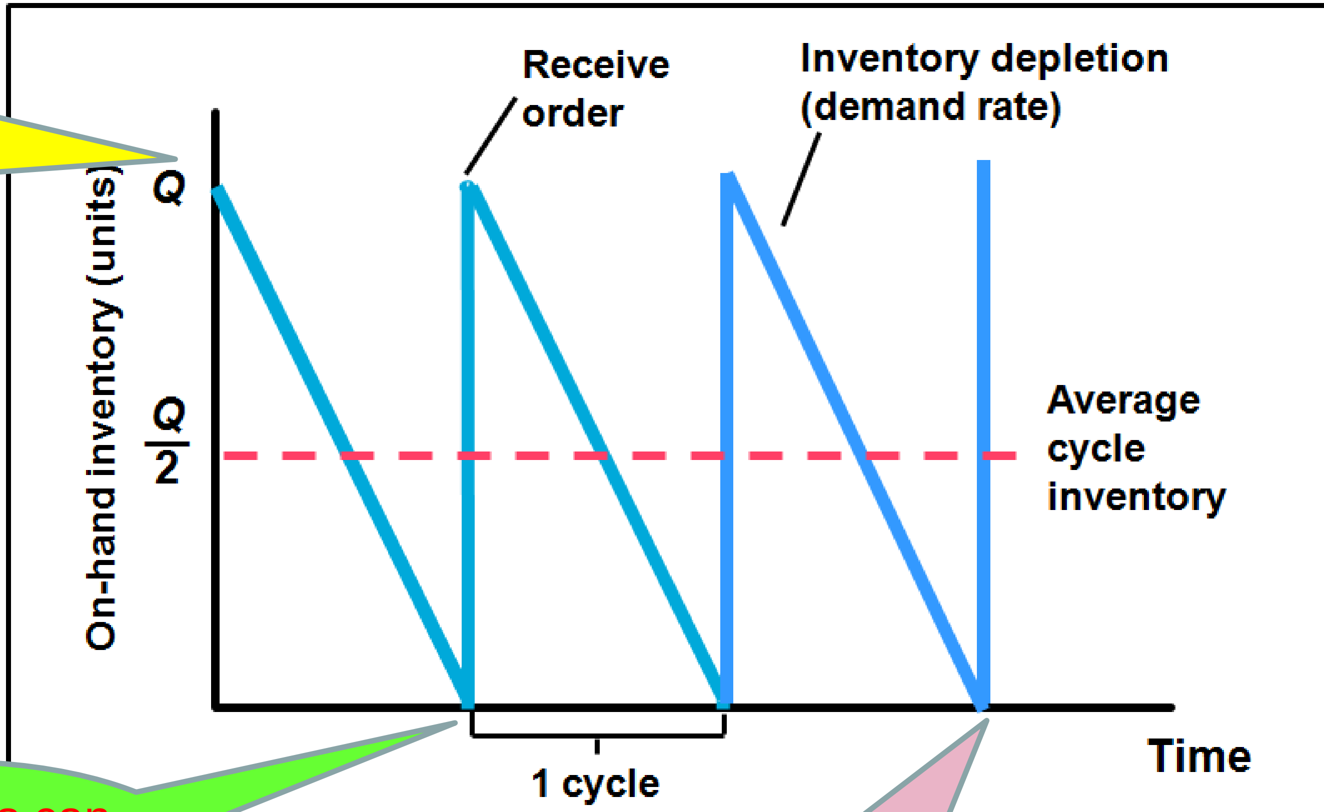
  → We need to strike a balance between these two concerns

- The Economic Order Quantity (EOQ) Model is one of the techniques of inventory control which minimizes total costs required to order and hold inventory.

- Assumptions of the basic EOQ Model:
  - Demand is known, constant and independent
  - Receipt of inventory is instantaneous and complete
  - Only consider 2 relevant cost factors, that is the inventory ordering cost and holding cost
  - Order quantities are fixed per order
  - Products can be analyzed independently. Decisions for items are independent of other items
  - Stock-outs can be completely avoided

Economic Order Quantity (EOQ) Model

Order quantities are fixed per order



Stock-outs can be completely avoided

Receipt of inventory is instantaneous and complete

Economic Order Quantity (EOQ) Model

- Notations for EOQ:

D = Demand rate (units/year)

R = Constant ordering cost ($)

H = Holding cost ($/unit/year)

Q = Order Quantity (units)

Q* = Optimal Order Quantity

Annual Demand

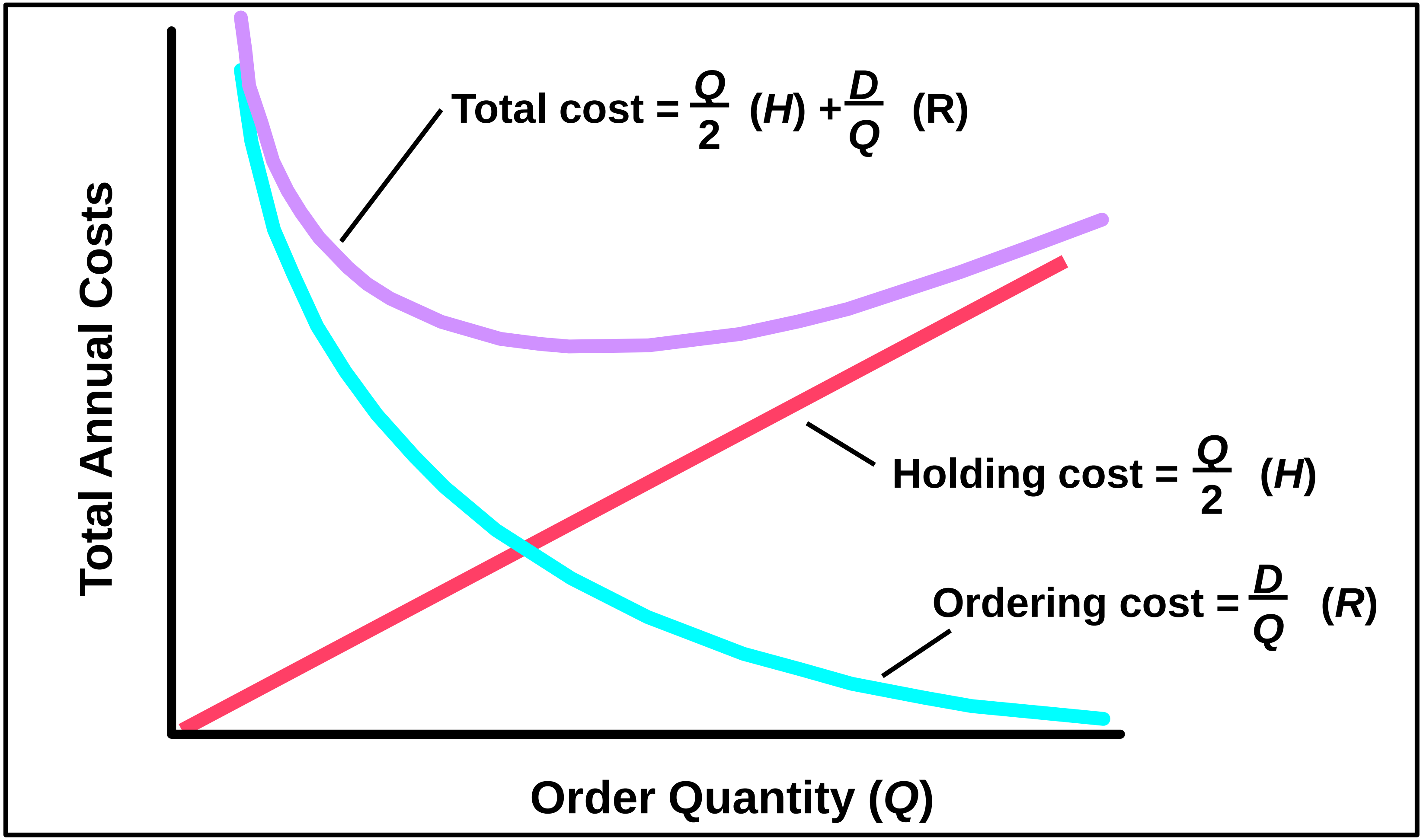
$$Q^* = \sqrt{\frac{2DR}{H}}$$

Ordering Cost per order

Annual Holding Cost Per Unit

Economic Order Quantity (EOQ) Model

- Inventory Costs for EOQ:



Today's Problem

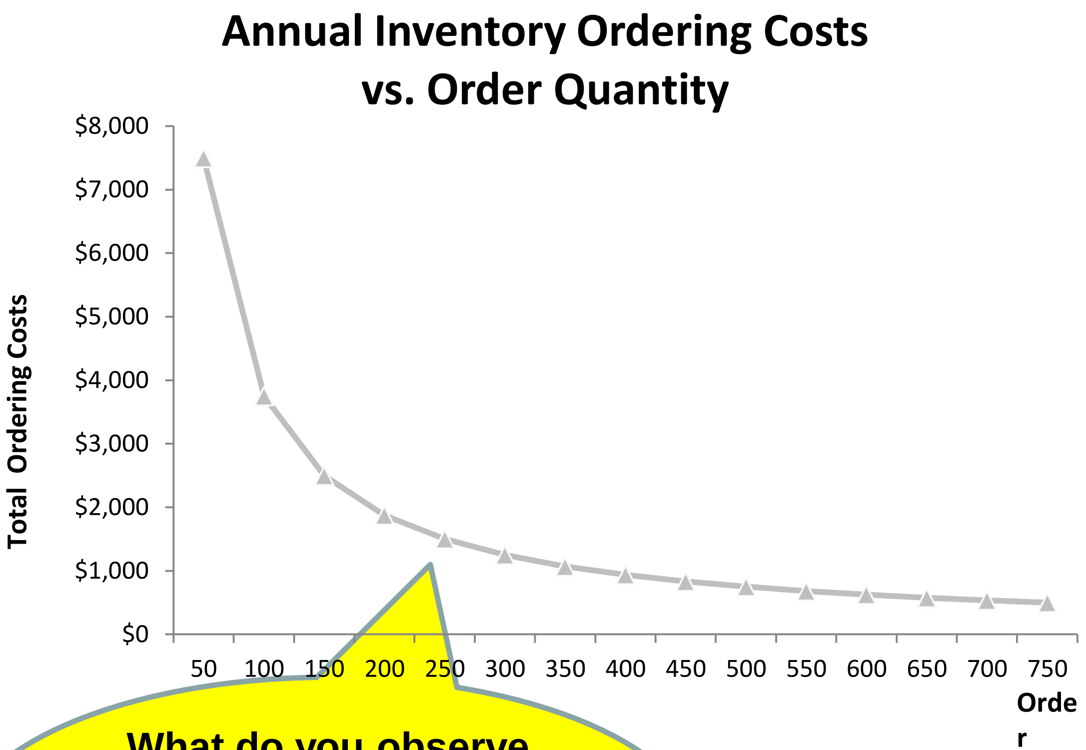
Given Information:

- Annual Demand, D = 3,750 units
- Inventory Ordering Cost, R = $100 per order
- Inventory Holding Cost, H = $15 per unit per year
- Replenishment Lead-time, L = 2 weeks
- No. of operating days in a year = 365 days

Annual Inventory Ordering Costs

- Annual Inventory Ordering Costs
  = (D/Q) * R
  = (3,750/Q) * 100
  = <u>375,000 / Q</u>

Order Quantity, Q	Annual Ordering Costs
50	$7,500
100	$3,750
150	$2,500
200	$1,875
250	$1,500
300	$1,250
350	$1,071
400	$938
450	$833
500	$750
550	$682
600	$625
650	$577
700	$536
750	$500

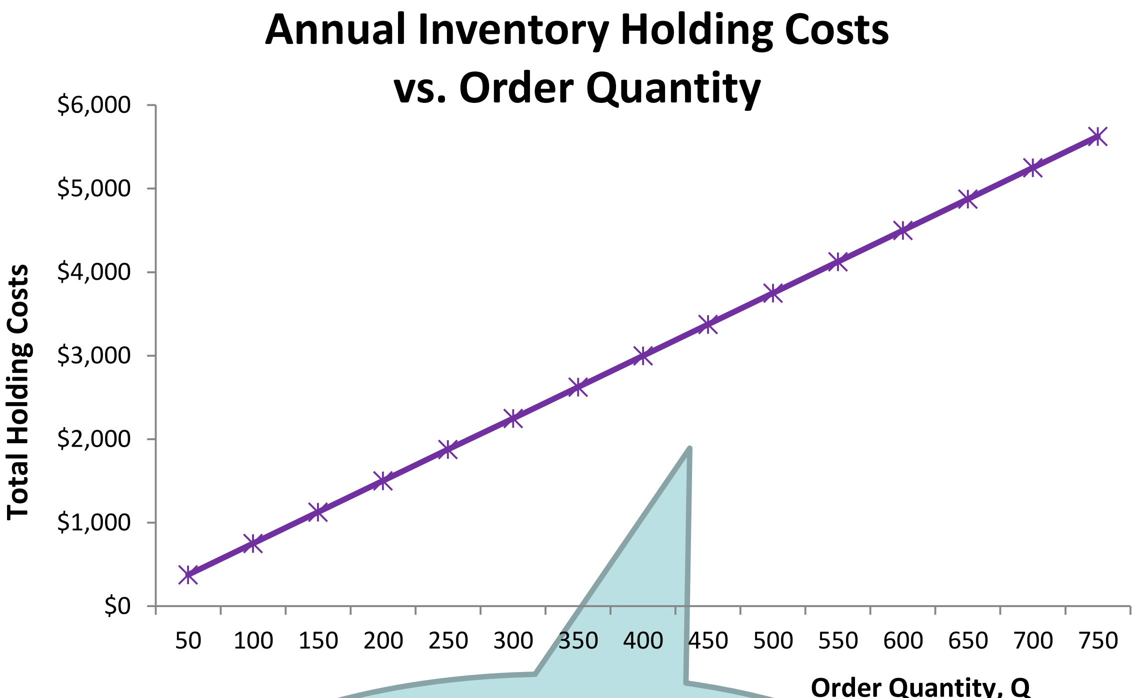


What do you observe about the trend of Annual Inventory Ordering Costs as the Order Quantity increases?

Annual Inventory Holding Costs

- Annual Inventory Holding Costs
  = (Q/2) * H
  = (Q/2) * 15
  = **7.5* Q**

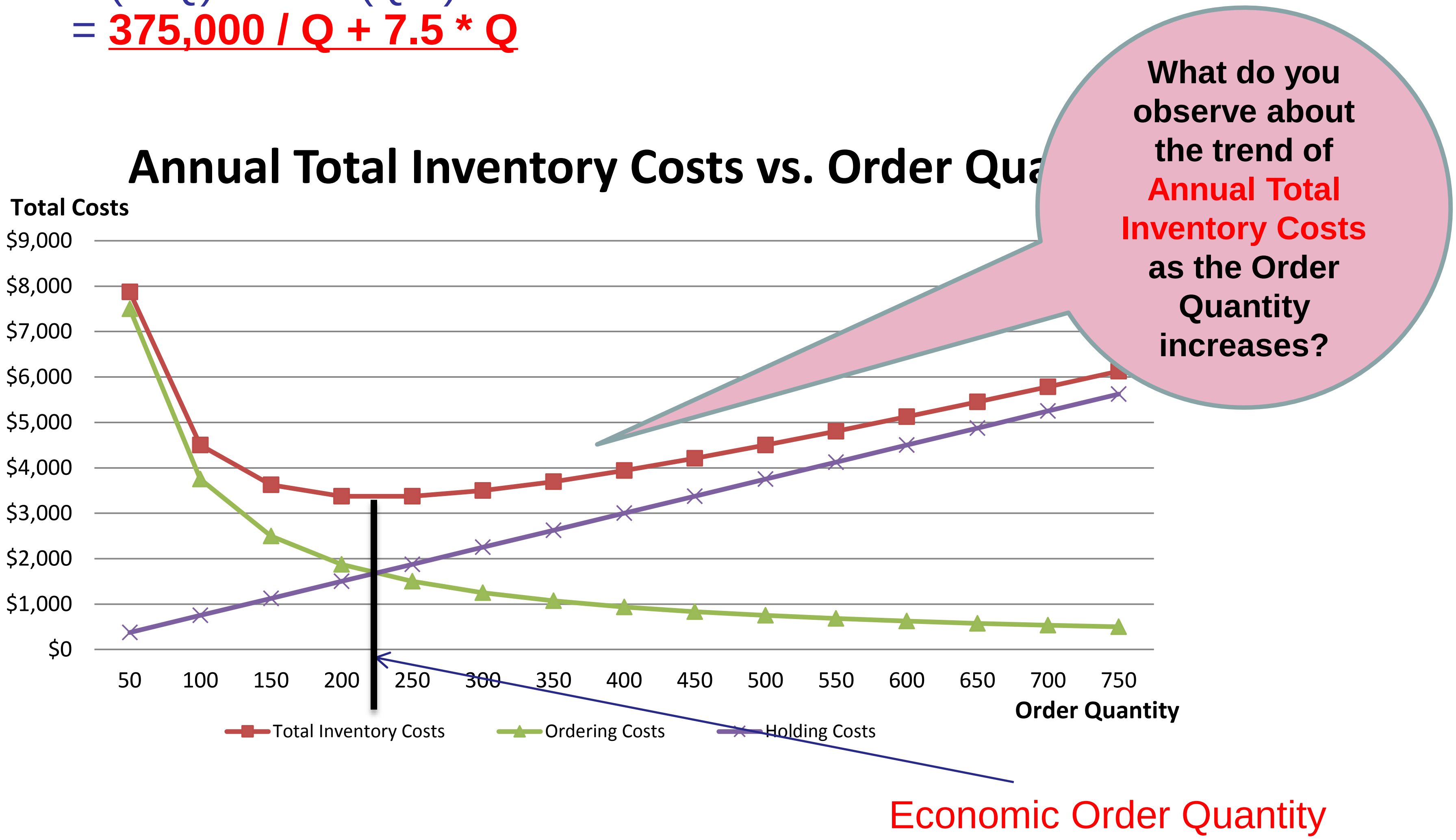
Order Quantity, Q	Annual Holding Costs
50	$375
100	$750
150	$1,125
200	$1,500
250	$1,875
300	$2,250
350	$2,625
400	$3,000
450	$3,375
500	$3,750
550	$4,125
600	$4,500
650	$4,875
700	$5,250
750	$5,625



What do you observe about the trend of Annual Inventory Holding Costs as the Order Quantity increases?

Total Annual Inventory Costs

- Total Annual Inventory Costs
  = Annual Inventory Ordering Costs + Annual Inventory Holding Costs
  = (D/Q)*R + (Q/2)*H
  = **375,000 / Q + 7.5 * Q**



Optimal Order Quantity, Q* and Total Costs

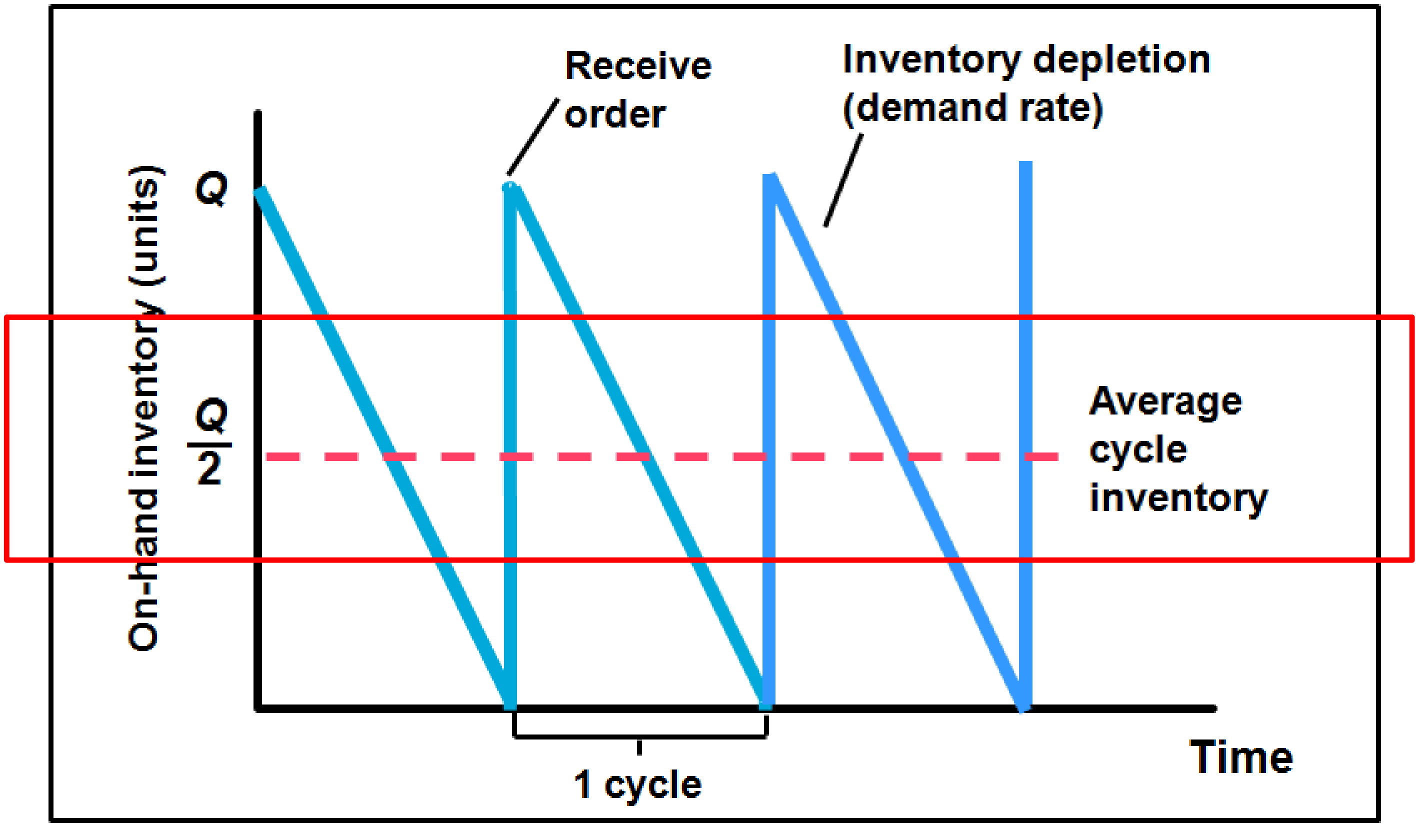
- Optimal order quantity, EOQ (Q*)
  = **<u>224 units</u>** (roundup to nearest integer)

$$Q^* = \sqrt{\frac{2RD}{H}} = \sqrt{\frac{2*100*3750}{10}} = 223.60$$

- Optimal Total Annual Inventory Costs
  = **<u>375,000 / Q + 7.5 * Q</u>**
  = 375,000/224+ 7.5*224
  = **<u>$3,354.11</u>** (roundup to 2 decimal places)

Average Inventory Level

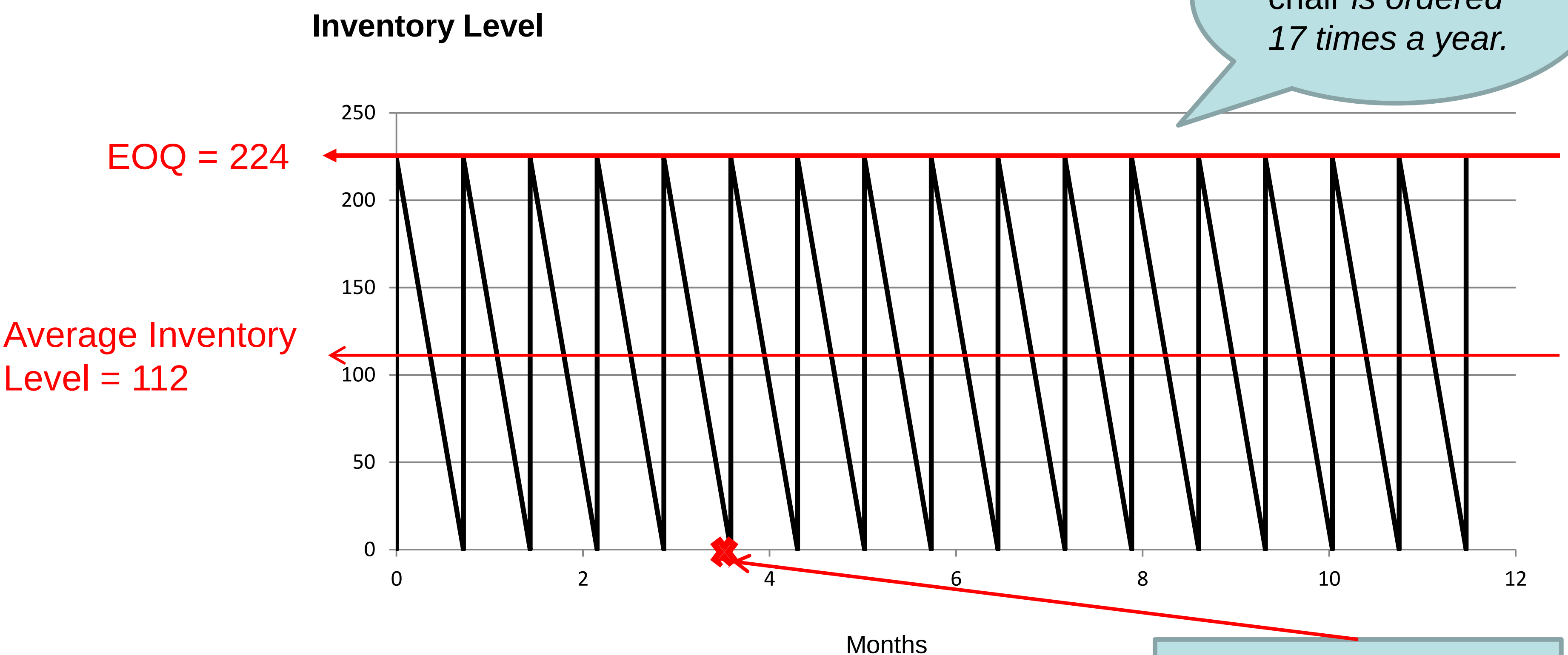
- Average Inventory Level
  = Optimal Order Quantity, Q* / 2
  = 224 / 2
  = **<u>112 units</u>**



Proposal: a Simple EOQ Ordering System

Q: How much shall we order?
A: Q = EOQ

The sleeping chair *is ordered 17 times a year.*



Note that the inventory drops to 0 just before the new stock arrives!

Benefits of the Proposed Ordering System

Comparing to the current practices of ordering 600 pcs and re-order at 200 pcs, the new ordering system by using EOQ model could reduce average inventory level and total inventory cost.

- Average inventory level reduction = 300 - 112 = 188 units
- Expected total inventory cost reduction = $1771

	Current practice	**EOQ model**
Order Quantity (Q)	Q= 600 units	Q=EOQ= 224 units
Average Inventory (Q/2)	600/2=300 units	334/2 = 112 units
Total Inventory Cost (Ordering cost+ holding cost)	= (D/Q)*R + (Q/2)*H = 375,000 / Q + 7.5 * Q = 375,000/**600** + 7.5***600** = **$5,125**	= (D/Q)*R + (Q/2)*H = 375,000 / Q + 7.5 * Q = 375,000/**224** + 7.5***224** = **$3,354**

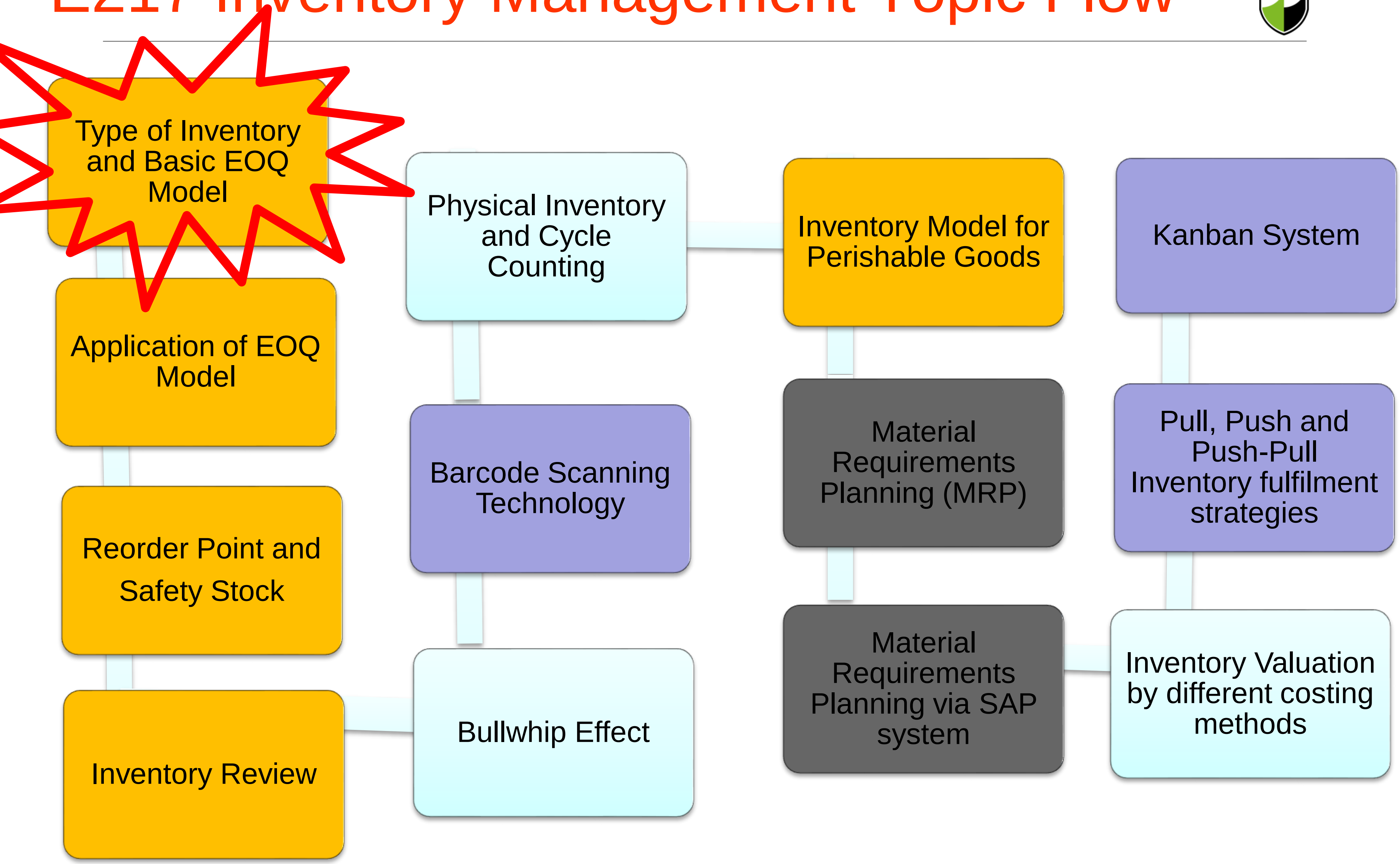
Benefits of the Proposed Ordering System

- Providing systematical way to manage inventory (i.e. determine optimal order quantity and order timing while minimizing the total inventory costs)
- Taking into consideration of the demand, lead time and two important inventory costs (ordering cost and holding costs)
- Easy to understand and implement without additional cost and investment
- Lower the storage space required and total inventory cost by keeping lower inventory of 112 units on average instead of keeping 300 units on average.

Learning Objectives

- Define the various types of stock and the strategic role of inventory in a typical supply chain
- State the major types of inventory-related costs (holding costs, ordering costs, stock-out costs, etc.) and how they affect inventory management decisions
- State the assumptions of the EOQ Model
- Perform EOQ calculations to determine:
  - EOQ, Q*
  - Optimal Total Annual Inventory Costs
  - Optimal Annual Order Frequency
  - Average Inventory Level

E217 Inventory Management Topic Flow



P02

Art of Purchasing

E217 – Inventory Management

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E217 Inventory Management Topic Tree

E217 Inventory Management

Strategic Role of Inventory Management
- Physical Inventory and Cycle Counting
- Bullwhip Effect
- Inventory Valuation

Inventory Control Methods

Independent-Demand Items
- Basic EOQ Model
- Application of EOQ Model
- Safety Stock and Reorder Point
- Inventory Review Policies
- Inventory Model for Perishable Goods

Dependent-Demand Items
- Material Requirements Planning (MRP)
- Material Requirements Planning (MRP) via SAP

Inventory Control System
- Barcode Scanning Technology
- Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
- Kanban System

Relevancy of The Basic EOQ Model

Relating to the assumptions of the EOQ Model that you learnt in Problem 1 and considering today's problem:

- Ordering & holding costs are assumed to be fixed in the basic EOQ model.
  - *But in reality, these costs vary according to the stock and ordering situations*

- Customer demand is assumed to be constant in the basic EOQ model.
  - *But in reality, demand fluctuates and may not be independent over time.*

Relevancy of The Basic EOQ Model

- The basic EOQ model assumes that the unit cost of the item remains unchanged regardless of the ordered quantity.
  - *In reality, quantity discounts may be given for the purchasing price due to bulk purchase or saving in transportation costs.*
  - *Hence, we need to modify the basic EOQ Model to cope with the situations of quantity discounts.*
  - *For today’s problem, Tristan could make a comparison of the Total Cost (TC) curves for the quantity discounts offered.*

Pros and Cons of the Basic EOQ Model

Pros of EOQ

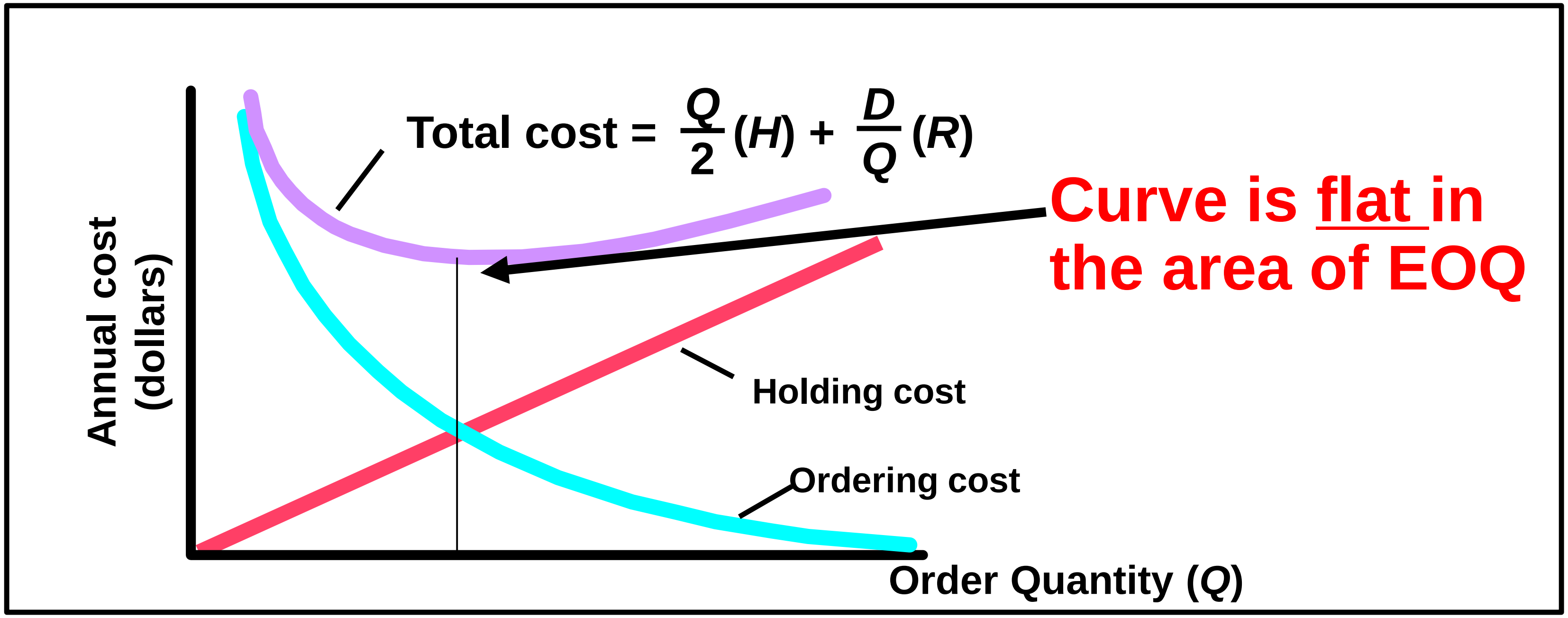
- Suitable for independent demand instead of dependent demand items
- Easy and quick estimate of order size
- Can be modified to take into account things like variable lead time, safety stock, finite replenishment, etc.

Cons of EOQ

- Q* is usually not an integer answer
- Not able to place orders of different items together (to save cost and facilitate procurement)
- Suppliers or manufacturers may supply goods in batches

EOQ Model is Robust!

- The EOQ model is fairly robust.
- It gives satisfactory answers even with substantial variation in its parameters (e.g. order cost – R , demand – D)
- We can observe from the graph that the curve portion for Total Cost around the turning point is **flat** and **not sensitive to changes in order quantity**



EOQ Model with Quantity Discount

- Quantity discount is simply a decreased unit cost for an item when it is purchased in larger quantities. Suppliers often offer discounts for large orders to entice buyers to purchase in bulk.

- Buyers must weigh the potential benefits of <u>reduced unit price and fewer orders from larger order quantities</u> against the <u>increased holding cost</u> caused by higher average inventories.

- Include the purchase cost in the basic EOQ model, minimize the following equation:

  Total cost = Holding Costs + Ordering Costs + <u>Material costs</u>
  Total cost = (Q/2)*H + (D/Q)*R + <u>P*D</u>
  where P = per unit cost price

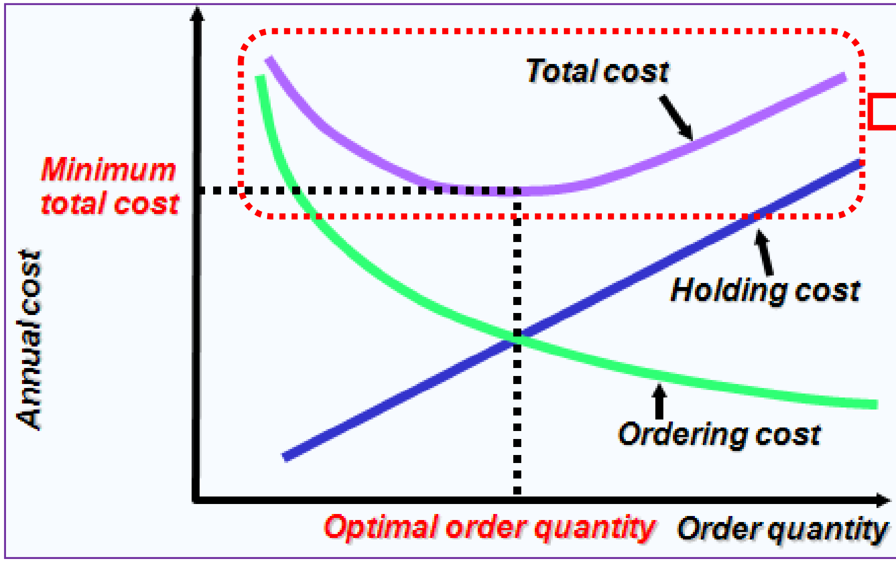
- For the optimal order quantity, the annual holding and ordering costs are <u>not necessarily</u> equal.

EOQ Model with Quantity Discount

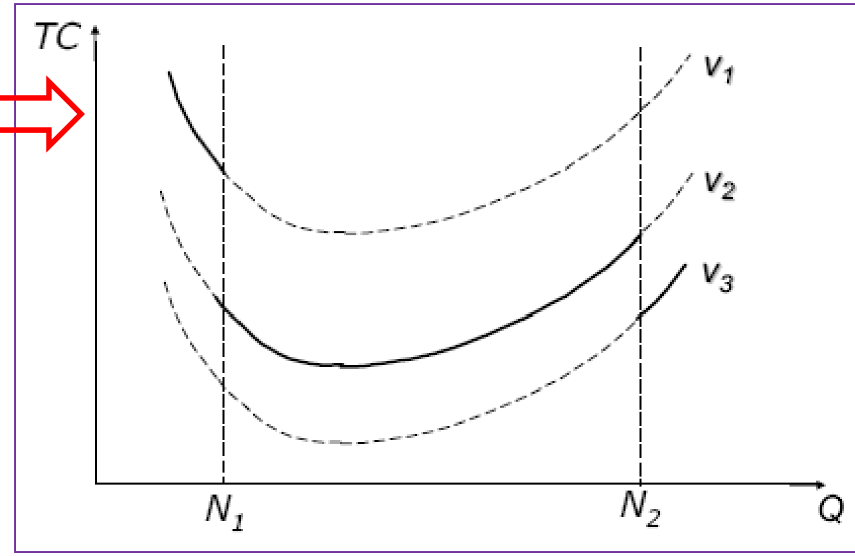
Assumptions:

- Demand occurs at a constant rate per year
- Ordering Cost is constant per order
- Holding Cost is either constant or proportional to unit purchase price
- Purchase Cost varies according to order quantity
- Delivery time (lead time) is constant
- Ordered quantity arrives in full (no shortages).

EOQ Model with Quantity Discount



EOQ curve without Quantity Discount



EOQ curve with Quantity Discount

Suppose the supplier offers price breaks as follows:

- Cost price is V_1 if $Q < N_1$
- Cost price is V_2 if $N_1 \leq Q < N_2$
- Cost price is V_3 if $Q \geq N_2$

where Q is the order quantity

Determining the Q* and Lowest TC*

Step 1.

For each discount offer, calculate Optimal Order Quantity Q* by using

$$Q^{*} = \sqrt{\frac{2RD}{H}}$$

Step 2.

If Q* for a discount doesn't qualify, choose the best possible order size to get the discount

Step 3.

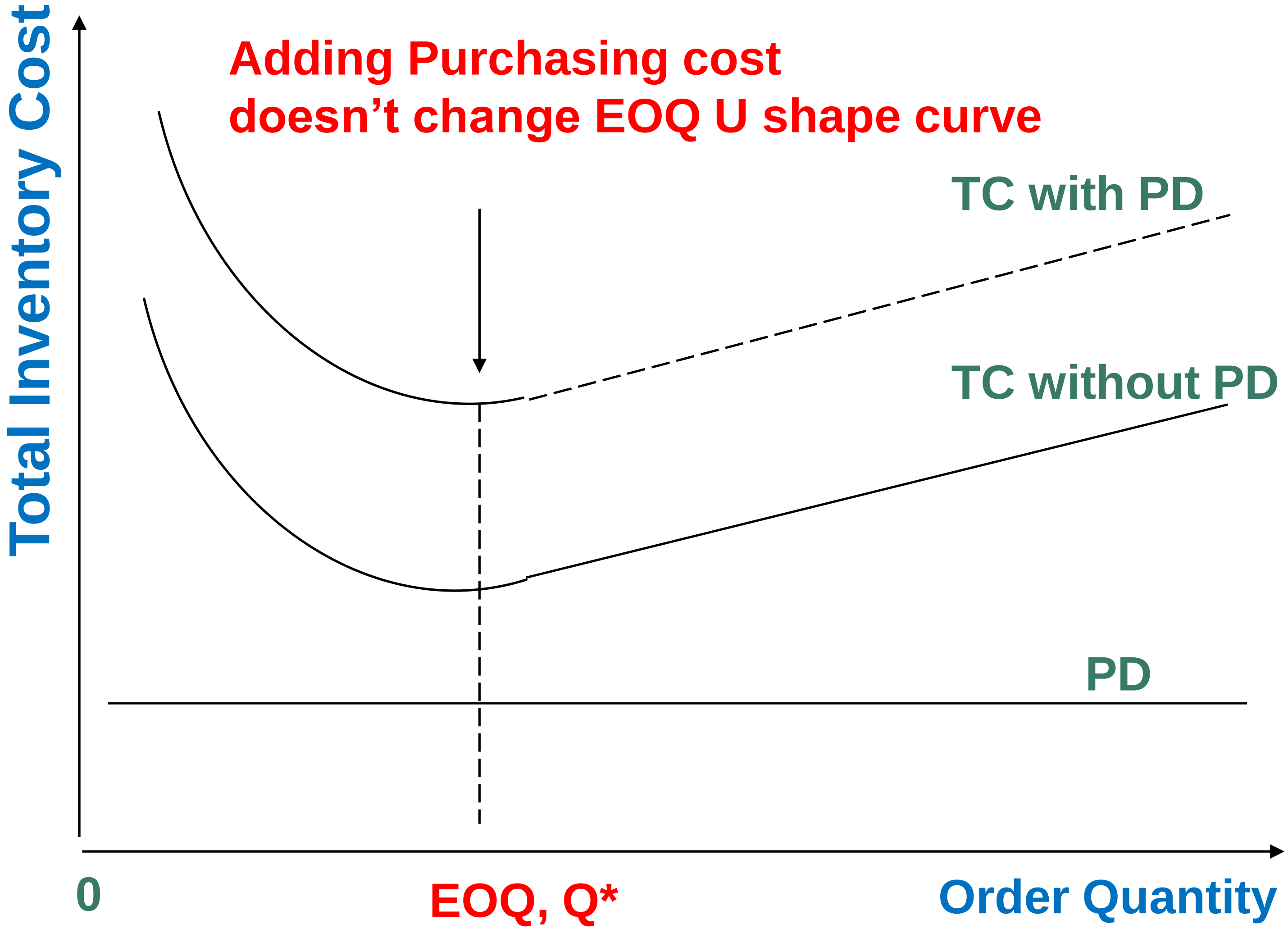
Compute the total cost for each Q* or adjusted order quantity from Step 2 by using

$$TC = \frac{D}{Q}R + \frac{Q}{2}H + PD$$

Step 4.

Select the Q* that gives the lowest total cost

Additional study on effect of P*D on Total Inventory Cost (TC)



Recommendations for Today's Problem

Case 1: V_1 = \$8.00 when Q < 10,000 (≥ 4000 of MOQ)

Optimal Order Quantity,

$$Q_1 = \sqrt{\frac{2RD}{H}} = \sqrt{\frac{2 \times 2000 \times 30000}{25\% \times 8.00}} \approx 7746$$

This optimal order quantity is 7,746 (within the quantity-price range)

The lowest total cost for this case is **\$255,492** at

Q_1* = 7,746

TC_1* = (Q_1*/2)*H + (D/Q_1*)*R + P*D

= (7746/2)*25%*8 + (30000/7746)*2000 + 8*30000

= \$255,492

Recommendations for Today's Problem

Case 2: V_2 = \$7.50 when $10,000 \leq Q < 20,000$

Optimal Order Quantity,

$$Q_2 = \sqrt{\frac{2RD}{H}} = \sqrt{\frac{2*2000*30000}{25\%*7.5}} \approx 8000$$

This optimal order quantity of 8,000 is **NOT feasible** as the price validity applies to quantity range between 10,000 and 20,000.

Adjusted order quantity 10,000 is chosen as it gives the lowest total cost on the curve. Hence, the minimum total cost is **\$240,375** at **$Q_2^* = 10,000$**

$TC_2^* = (Q_2^*/2)*H + (D/Q_2^*)*R + P*D$

$= (10000/2)*25\%*7.5 + (30000/10000)*2000 + 7.5*30000$

$= \$240,375$

Recommendations for Today's Problem

Case 3: V_3 = \$7.00 when Q ≥ 20,000

Optimal Order Quantity,

$$Q_3 = \sqrt{\frac{2RD}{H}} = \sqrt{\frac{2*2000*30000}{25\%*7.0}} \approx 8281$$

This optimal order quantity of 8,281 is **NOT feasible** as the price validity applies to quantity range ≥ 20,000.

Adjusted order quantity 20,000 is chosen as it gives the lowest total cost on the curve. Hence, the minimum total cost is **\$230,500** at **$Q_3^* = 20,000$**

$$\begin{aligned} TC_3^* &= (Q_3^*/2)*H + (D/Q_3^*)*R + P*D \\ &= (20000/2)*25\%*7.0 + (30000/20000)*2000 + 7.0*30000 \\ &= \$230,500 \end{aligned}$$

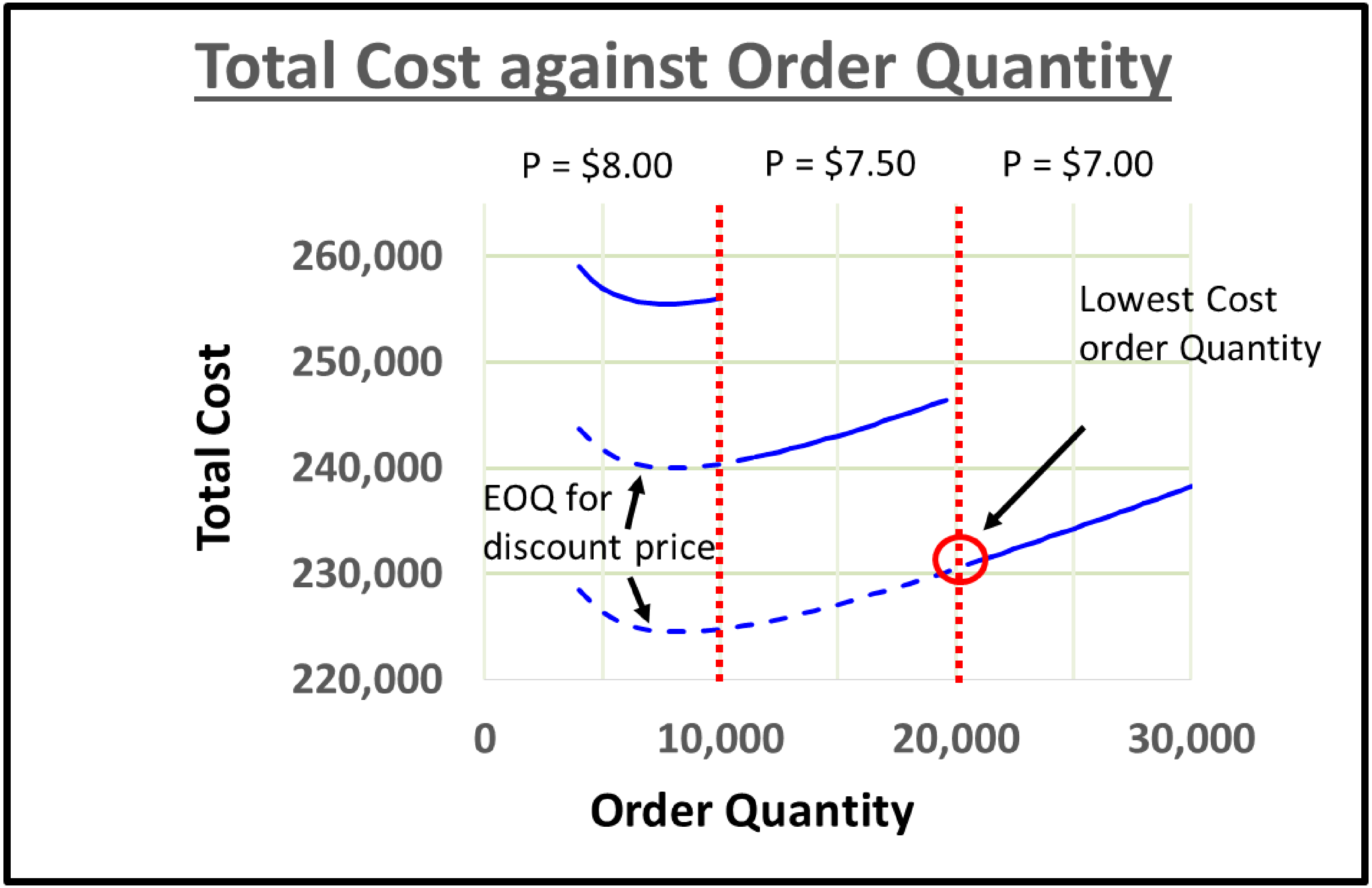
Recommendations for Today's Problem

Case	Unit purchase price	Optimal Order Qty	Ordering Costs	Material Cost	Holding Cost	Total Cost
1	$8.00	7,746	7,746	240,000	7,746	255,492
2	$7.50	10,000	6,000	225,000	9,375	240,375
3	$7.00	20,000	3,000	210,000	17,500	230,500

Tristan could follow the below recommendations on the ordering of Grease:

- Overall Optimal Order Quantity is **20,000**
- Lowest Total Inventory Cost is **$230,500**
- Unit Purchase Price is **$7.00**

Today's Problem: Total Cost Curve



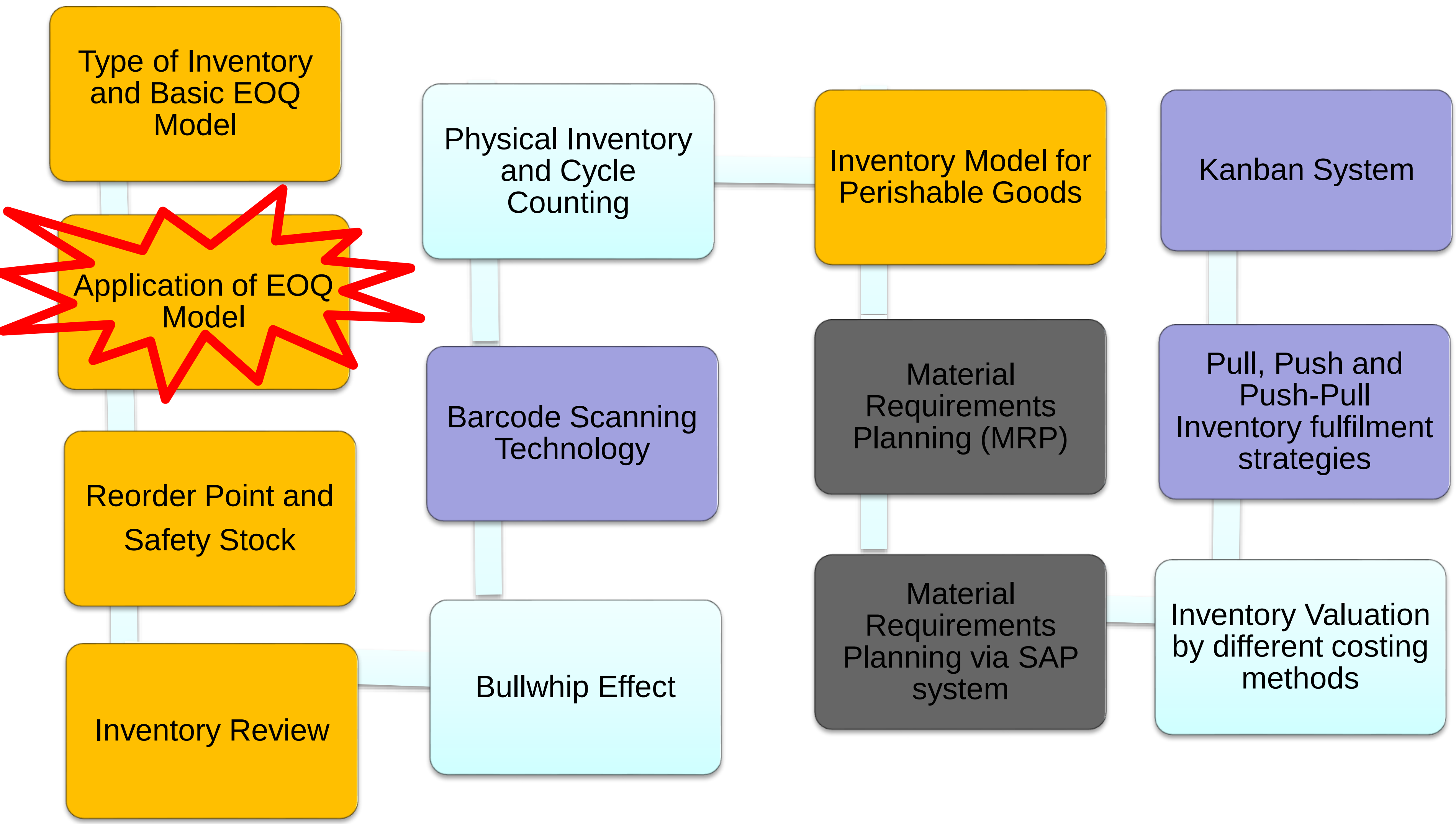
Practical Considerations of the EOQ Model

- EOQ is sufficiently robust for most independent demand items with stable demand (trendless) and lead time.
- EOQ is useful despite its highly restrictive assumptions
- Can be used as a quick estimation of the order size and total cost.
- In many practical situations quantity discounts exist, by taking advantage of it can result in substantial savings

Learning Objectives

- Describe the relevancy of the basic EOQ Model
- Describe the limitations of the basic EOQ Model
- Describe the robustness of the basic EOQ Model
- Apply quantity discount to the basic EOQ Model
- Calculate the optimal order quantity and optimal total costs for a given case-study
- Describe the practical considerations of the EOQ Model

E217 Inventory Management Topic Flow



P03
Prevent Stock-out

E217 – Inventory Management

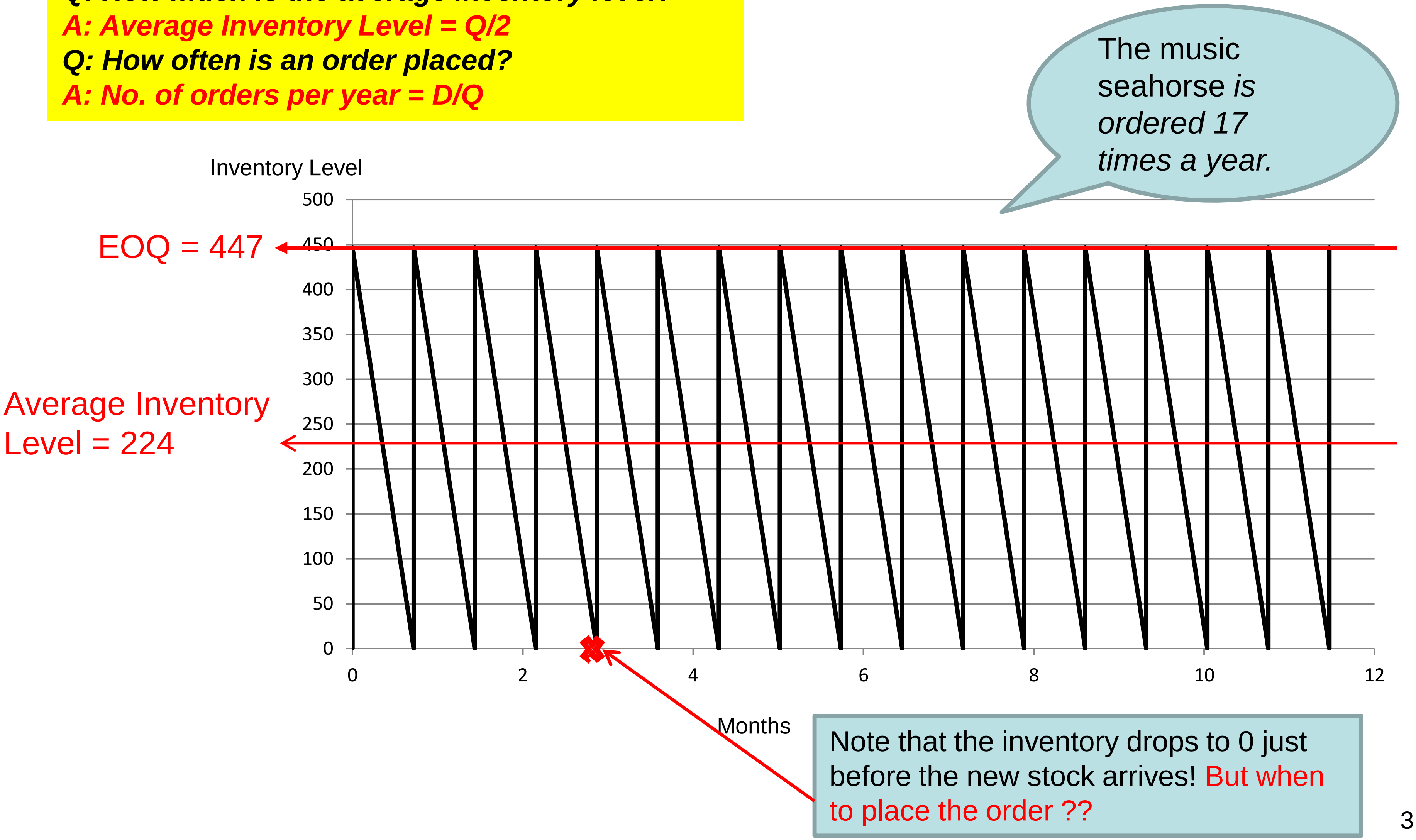
SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

- **E217 Inventory Management**
  - **Strategic Role** of Inventory Management
    - Physical Inventory and Cycle Counting
    - Bullwhip Effect
    - Inventory Valuation
  - **Inventory Control Methods**
    - **Independent-Demand Items**
      - Basic EOQ Model
      - Application of EOQ Model
      - Safety Stock and Reorder Point
      - Inventory Review Policies
      - Inventory Model for Perishable Goods
    - **Dependent-Demand Items**
      - Material Requirements Planning (MRP)
      - Material Requirements Planning (MRP) via SAP
  - **Inventory Control System**
    - Barcode Scanning Technology
    - Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
    - Kanban System

Basic EOQ Model Recap

Q: How much shall we order?
A: Q = EOQ
Q: How much is the average inventory level?
A: Average Inventory Level = Q/2
Q: How often is an order placed?
A: No. of orders per year = D/Q



The Reorder Point (ROP)

WHAT IS IT?

The level of inventory stock that triggers a reorder of the Q*/ EOQ

PURPOSE

Reduces or eliminates the probability of an inventory stock-out during the reorder waiting period (*lead time*)

Note: Check consistency of time unit. In this case, convert all the information to days

DAYS
WEEKS
MONTHS

LEAD TIME

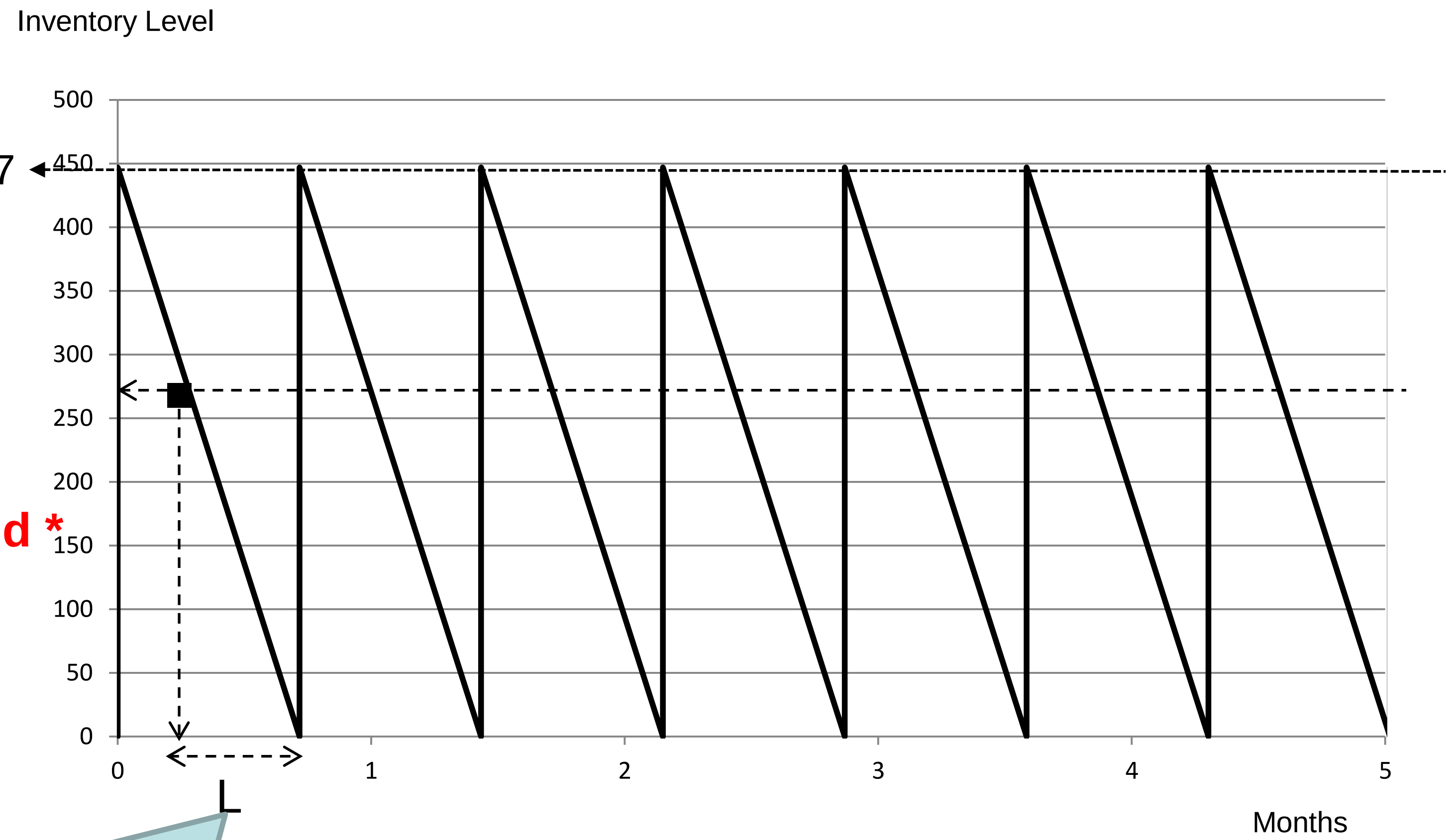
$$ROP = d \times L$$

DAILY
WEEKLY
MONTHLY

DEMAND

Basic EOQ Model Recap

Q: When shall we order?
A: When inventory = ROP



ROP
= weekly demand * Lead Time
= (7470/52) * 2
= 288

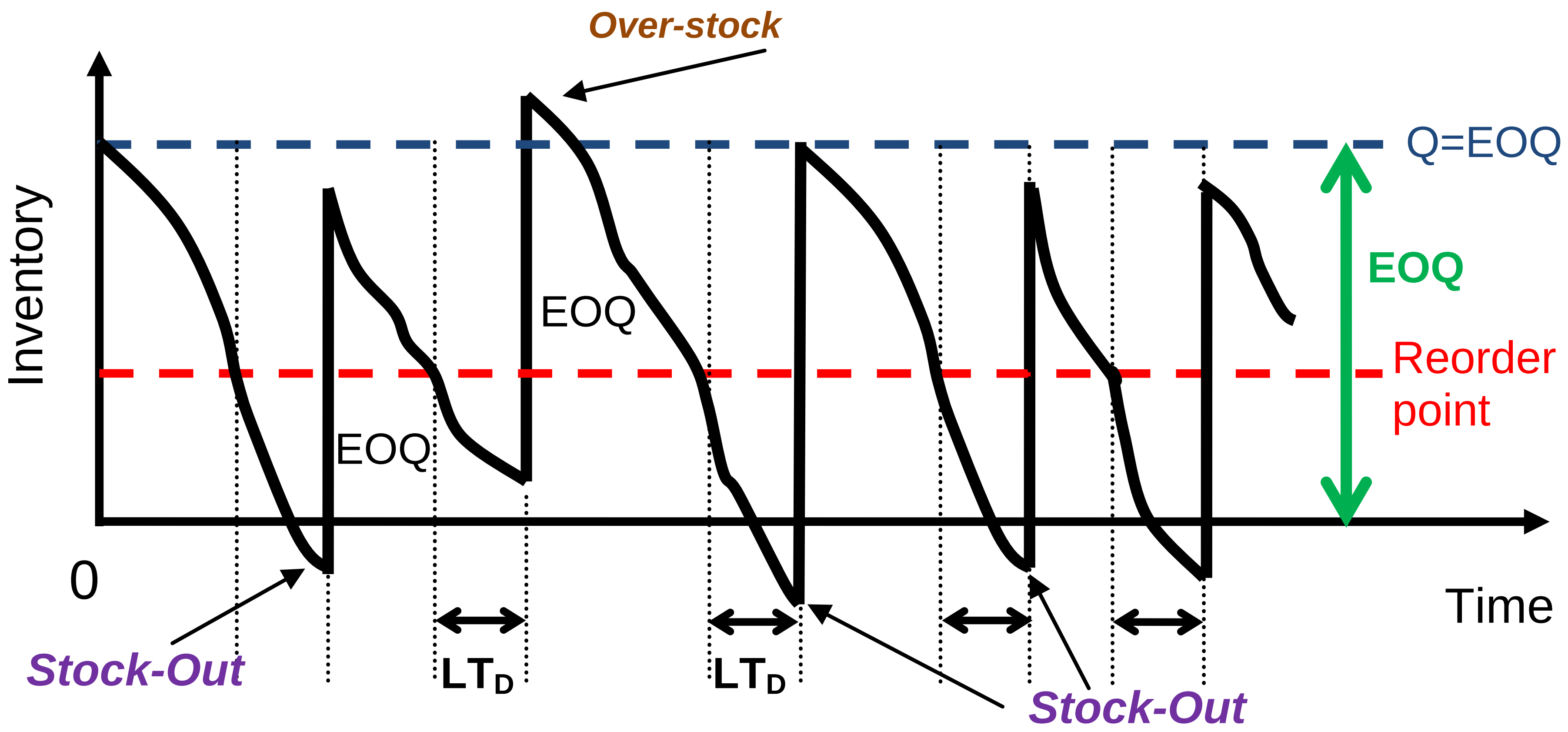
Reorder Point / Daily Demand =288/144 = 2 weeks (this is exactly the replenishment lead-time)

Limitations of EOQ Model

- EOQ assumption: Customer demand is known, constant and independent over time.
  - *In reality: Though customer demand is known, it is observed that there are fluctuations from week to week, month to month, etc.*
  - *Thus it may cause unexpected <u>stock-outs</u> during the period of replenishment lead-time.*

- EOQ assumption: Receipt of inventory is instantaneous and complete.
  - *In reality, it is not instantaneous as assumed in the ideal EOQ model. Usually it takes some amount of time between order placement, and receipt of the goods. Some times, the large orders might be delivered in several parts.*

Real Life – Full of Uncertainty in Demand

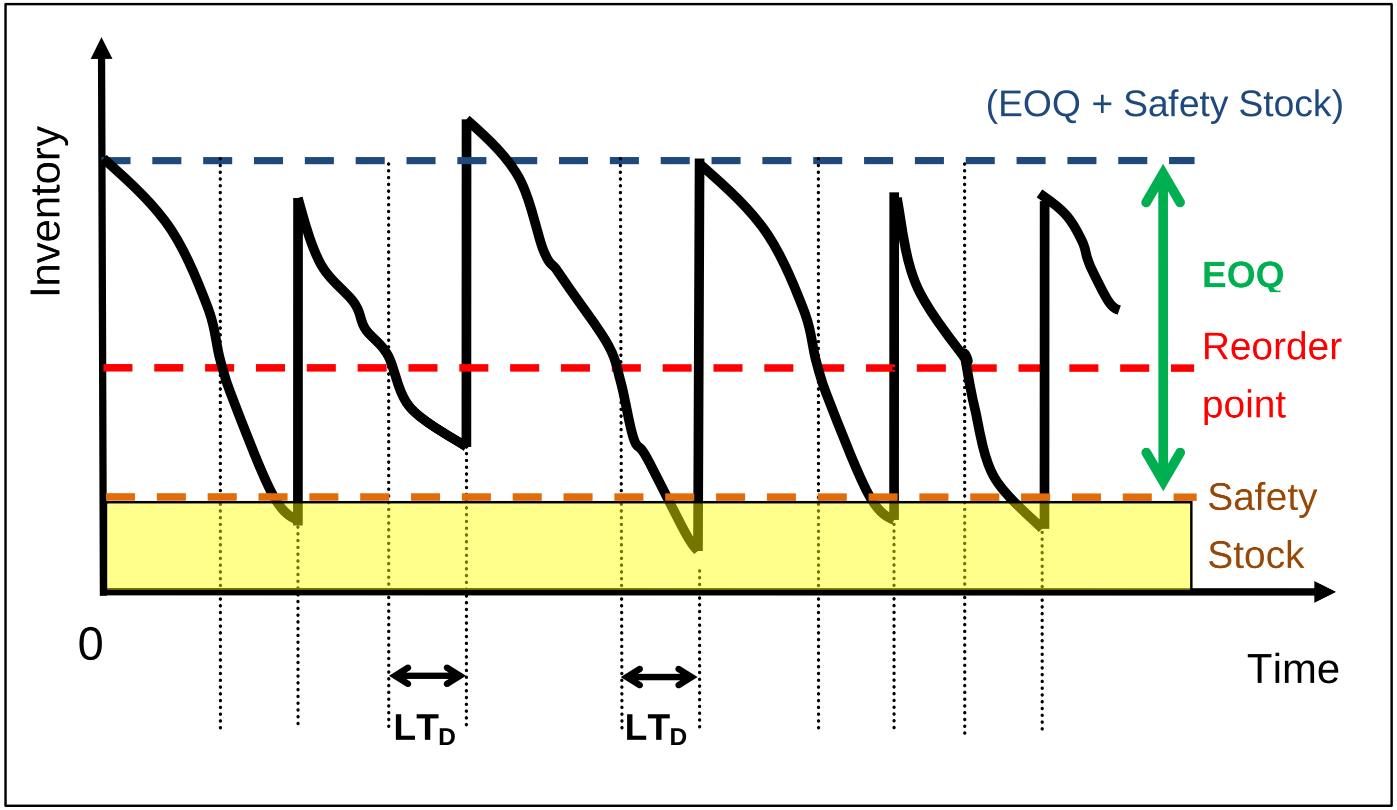


Real Life - Uncertain Customer Demand

- There is always possibility of stock-out or over-stock situations in businesses.
- In today's problem, a certain level of safety stock can be maintained. But over-stocking will result in high inventory holding cost for the product.
- Need to have extra storage space in warehouse.
- Under normal circumstances:
  - *Jon needs not to target to meet the extreme customer demands, e.g. 100% customer service*
  - *Instead, he should aim to meet customers' orders within the desired customer service level, e.g. 98%*

Safety Stock

- Safety stock (a.k.a. buffer stock) is a term used to describe the level of extra stock that is maintained to mitigate the risk of stock outs
- Stock out - shortfall in raw material / packaging / finished products due to the fluctuations in demand.
- The stock-out situation is under control to certain extent when safety stock is being maintained.



Safety Stock

- The level of safety stock an organization chooses to keep on hand can affect their business.
- Too much safety stock can result in high holding costs of inventory.
- In addition, products which are stored for too long a time can spoil, expire, or break during the warehousing process.
- Too little safety stock can result in lost sales and, thus, a higher rate of customer turnover.
- As a result, finding the right balance between too much and too little safety stock is essential.

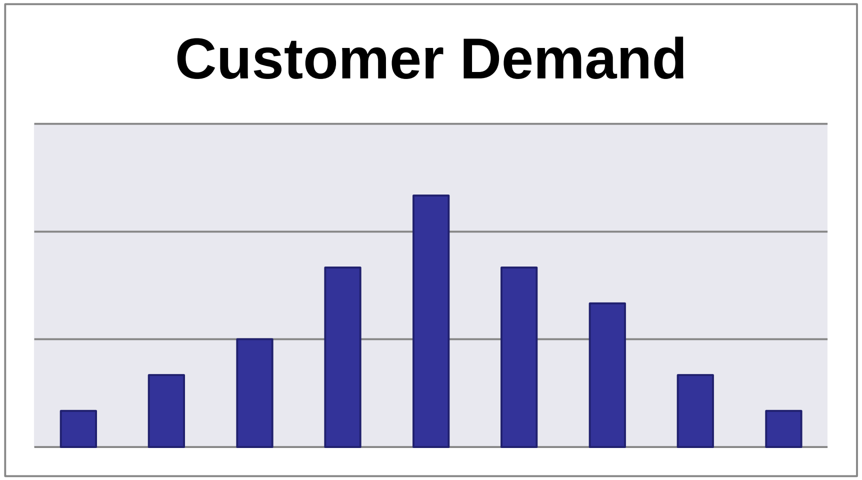
Demand Frequency & Probability

- Frequency - How often a certain demand occurs during a particular period of time.
- Probability- The chance that a certain demand occurs compared to the sum of demand frequency during a particular period of time.

Demand Min	Demand Max	Frequency	Probability	Cumulative Probability
110	115	1	0.0192	0.019
116	120	2	0.0385	0.058
121	125	4	0.0769	0.135
126	130	4	0.0769	0.212
131	135	5	0.0962	0.308
136	140	6	0.1154	0.423
141	145	7	0.1346	0.558
146	150	6	0.1154	0.673
151	155	5	0.0962	0.769
156	160	4	0.0769	0.846
161	165	3	0.0577	0.904
166	170	2	0.0385	0.942
171	175	2	0.0385	0.981
176	180	1	0.0192	1.000
Total		52	1.000	

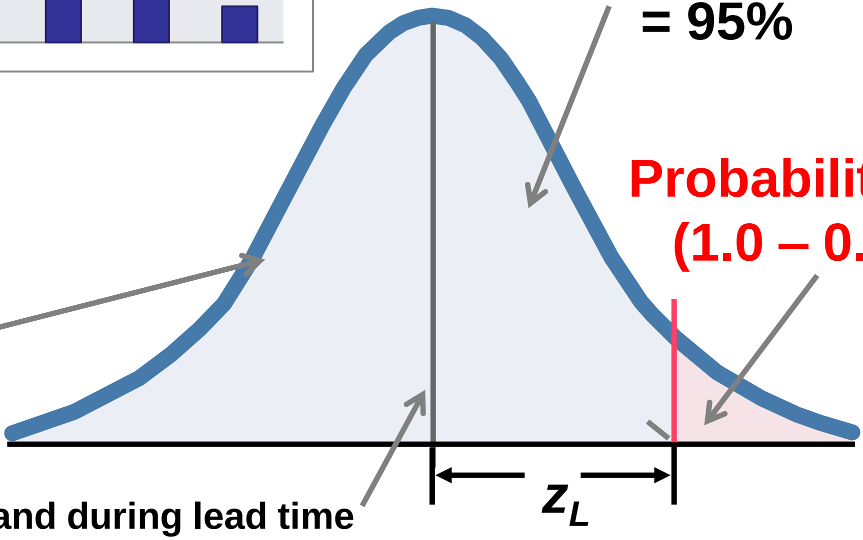
= 6/52
(individual frequency / total frequency)

Customer Service Level (Cycle Service Level)



Plot- relative frequency vs. demand:

Approximates to <u>Normal Distribution</u> (by Central Limit Theorem as sample size is >=30)



Note: 95% of customer service level means 95% of customer fulfill rate OR 5% of stock-out probability

Safety Factor

Relationship of Customer Service Level and the Safety Factor

Customer Service Level	90%	91%	92%	93%	94%	95%	96%	97%	98%	99%	99.9%
Safety Factor, Z	1.28	1.34	1.41	1.48	1.56	1.65	1.75	1.88	2.05	2.33	3.08

For customer service level of 98%

Safety factor, z = NORMSINV(98%) = 2.05

Measuring Demand Variability

Mean:

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n}$$

Standard Deviation:

$$\sigma_d = \sqrt{\frac{\sum_{i=1}^{n} (d_i - \bar{d})^2}{n}}$$

Standard Deviation During Lead Time:

$$\sigma_L = \sigma_d \sqrt{L}$$

σ_d = Standard Deviation of demand during a given period of time

σ_L = Standard Deviation of demand during replenishment lead time

Safety Stock and Reorder Point

Safety Stock = $Z\sigma_L = Z\sigma_d\sqrt{L}$

Reorder Point

= Average demand during lead time + Safety stock

= $\bar{d}L + Z\sigma_d\sqrt{L}$

Where:

$\text{L = lead time periods}$

$\bar{d}$ = forecast average demand per period

z = safety factor (the number of standard deviations for a specified service level)

σ_L = standard deviation of demand during replenishment lead time

σ_d = standard deviation of demand during a given period of time

Backorders

- An order for a good or service that cannot be filled at the current time due to a lack of available supply. Customers are willing to wait for some time. Under these situations, backorders are suitable.
- Costs associated with backorders may include admin cost, loss of goodwill, loss of future orders, emergency orders, etc.
- Usually happens in capital-goods firm (e.g. car distributors, computer manufacturers, furniture makers) when cost of keeping an item in stock becomes higher than the profit in selling.
- Lost sales occur when demands are not fulfilled due to stock-out. i.e. customers switch to other suppliers.

Backorder EOQ

B = Backorder cost

Optimal order size: $$Q_o = \sqrt{\frac{2RD(H+B)}{HB}}$$

Optimal quantity to be backordered:

$$Q_s = \sqrt{\frac{2RHD}{B(H+B)}} = Q_o\left(\frac{H}{H+B}\right)$$

Total cost per unit time: $$TC = \frac{RD}{Q_o} + \frac{H(Q_o - Q_s)^2}{2Q_o} + \frac{BQ_s^2}{2Q_o}$$

Today's Problem

- Fluctuating demand from customers.
- Frequent stock-outs might lead to loss of sales
- How to counter?

Given information

- Ordering Cost, R = $200 per order
- Holding Cost, H = $15 per unit per year
- Replenishment Lead-time, L = 2 weeks
- No. of operating weeks = 52 weeks / year
- Customer Service Level = 98%

Recommendations for Today's Problem

- Weekly Average Demand, d = **144 units/week**
- Weekly Standard Deviation, STDEV = **15.57 units/week**
- Annual Demand, D = **7470 units/year**

- Optimal Order Quantity, Q* ~ **447 units**

$$Q^* = \sqrt{\frac{2RD}{H}} = \sqrt{\frac{2*200*7470}{15}} = 446.32$$

- Reorder Point **without considering the safety stock**
  = Weekly Average Demand * Replenishment Lead-time
  = 144 * 2
  = **288 units**

If using the weekly average demand, the lead time should also be in weeks

Recommendations for Today's Problem

For customer service level at 98%

- Safety Factor = NORMSINV(0.98) = 2.05

- Safety Stock

  = Safety Factor * STDEV * SQRT (L)

  = 2.05 * 15.54 * SQRT(2)

  = 45.14 units

  ~ **46 units**

- Reorder Point **considering the safety stock**

  = Weekly Average Demand * Replenishment Lead time + Safety Stock

  = 288 + 46

  = **334 units**

Recommendations for Today's Problem

For other customer service levels – X%

X %	90%	92%	94%	96%	98%
Safety Factor	**1.28**	**1.41**	**1.55**	**1.75**	**2.05**
Safety Stock	**10**	**11**	**12**	**14**	**16**

Some observations:

1. Higher desired customer service level results in bigger safety factor and hence more safety stock required. This can be explained via formula below:

   Safety Stock $= Z\sigma_d\sqrt{L}$

2. More safety stock results in higher re-order points. This can be derived from the formula below:

   Reorder Point

   = Average demand during lead time + Safety Stock

   $= \bar{d}L + Z\sigma_d\sqrt{L}$

Recommendations - If Backorders are Allowed

- Optimal order quantity, Qo = **547**

$$Q_o = \sqrt{\frac{2RD(H+B)}{HB}} = \sqrt{\frac{2*200*7470*(15+30)}{15*30}} = 546.63$$

- Optimal quantity to be backordered, Qs = **183**

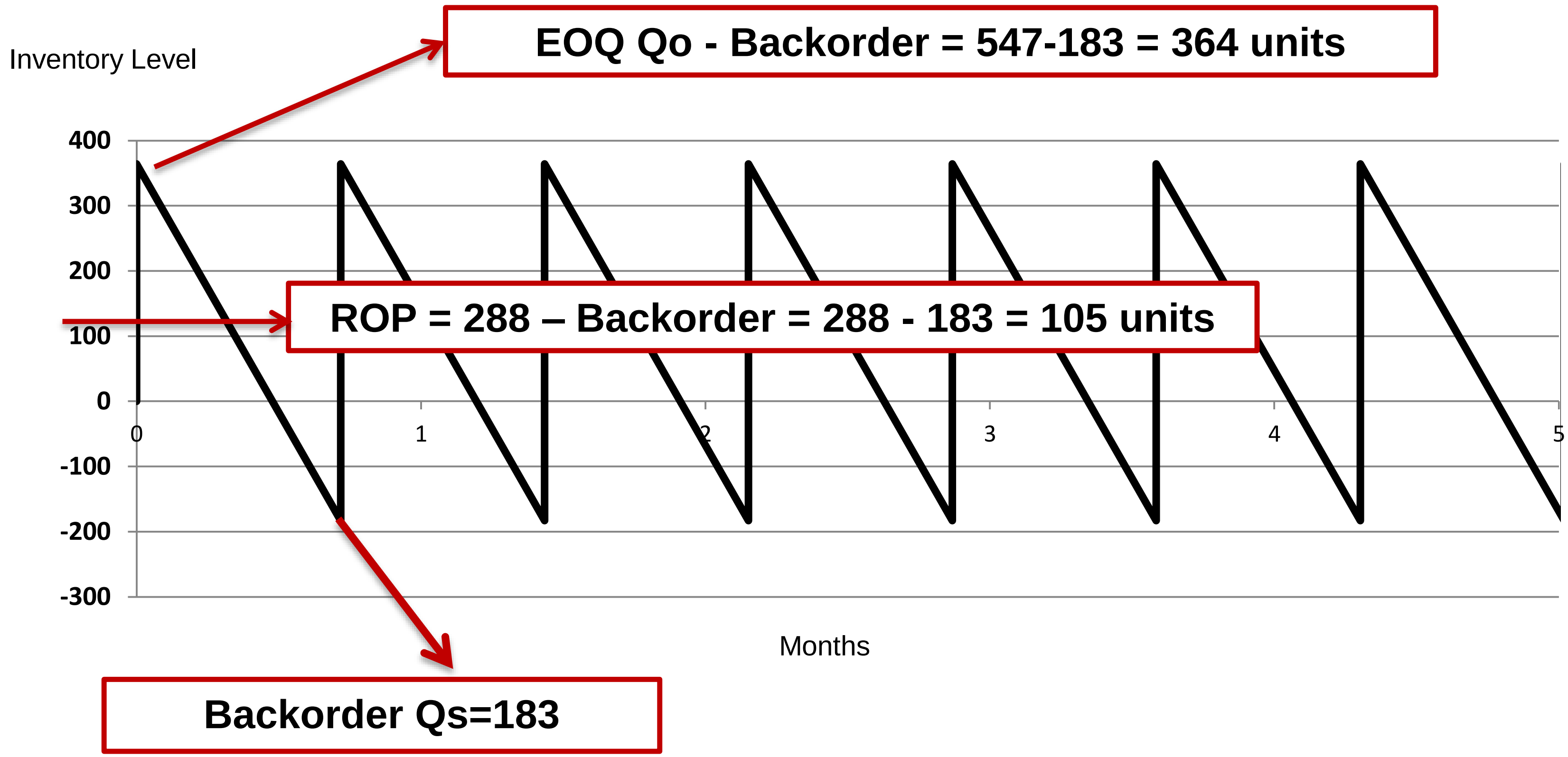
$$Q_s = \sqrt{\frac{2RHD}{B(H+B)}} = Q_o\left(\frac{H}{H+B}\right) = 7 = 547*\left(\frac{15}{15+30}\right) = 183$$

- Total Cost per year, TC = **$5,467 (without Safety Stock)**

$$TC = \frac{RD}{Q_o} + \frac{H(Q_o - Q_s)^2}{2Q_o} + \frac{BQ_s^2}{2Q_o} = \$5,467$$

Understanding the Backorder EOQ Model

At replenishment point, 547 units (Qo) arrive and 183 units(Qs) are immediately allocated to fulfill the backorders, leaving 364 units in stock.



Note: In the backorder EOQ, no safety stock is required, hence the ROP = 288 -backorder

Recommendations – If Backorders are Not Allowed

- Optimal quantity, Q = **447 units**

$$Q = \sqrt{\frac{2RD}{H}} = \sqrt{\frac{2*200*7470}{15}} = 447$$

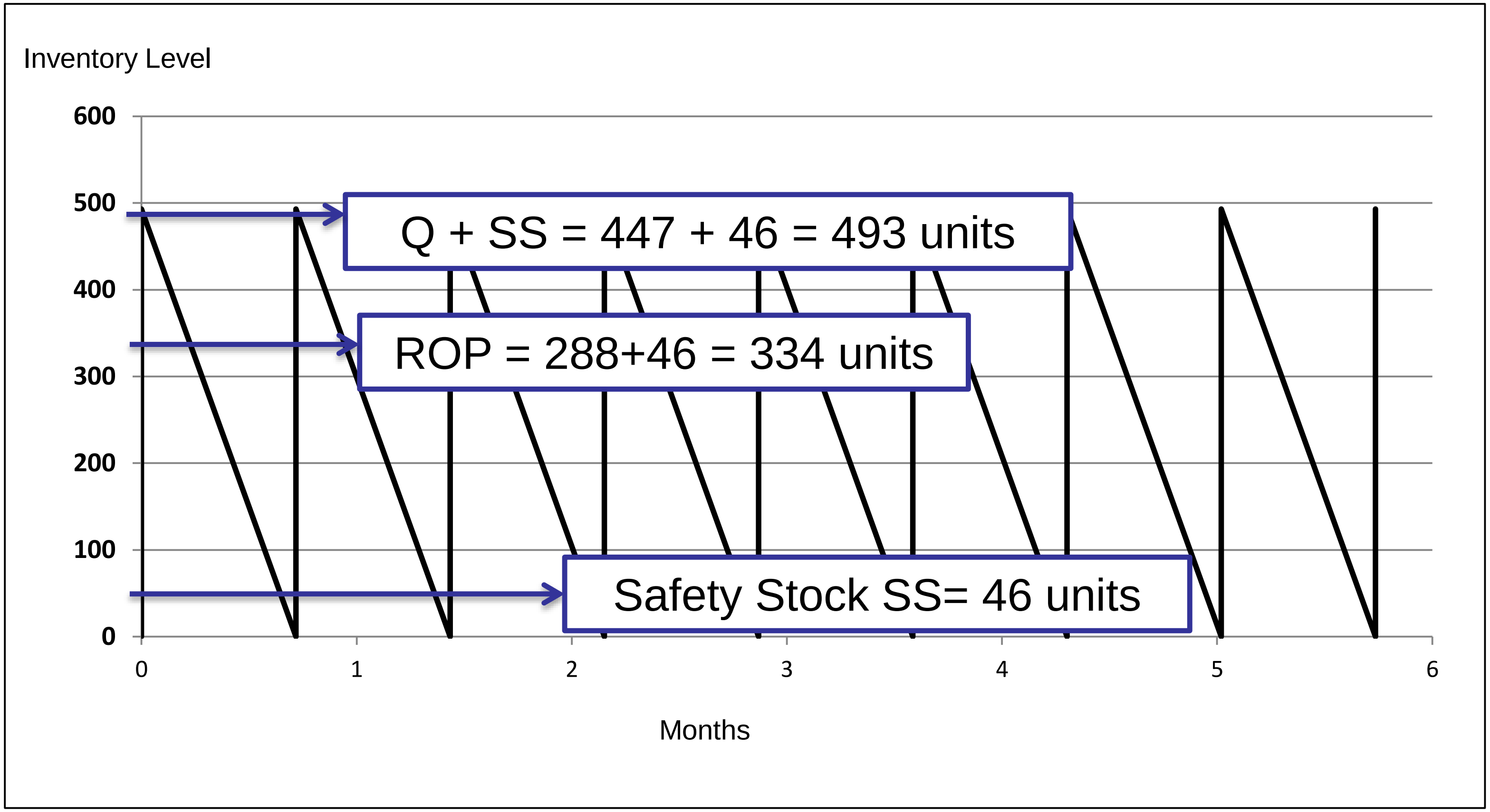
- Total Cost per year= **$7,385 (with Safety Stock)**, this is the optimal total cost for today's problem.

$$TC = \frac{D}{Q}R + \frac{Q}{2}H + SS*H = \frac{7470}{447}(200) + \frac{447}{2}(15) + 46*(15) = \$7385$$

Additional carrying cost incurred due to safety stock!

Recommendations – If Backorders are Not Allowed

Stock level with NO backorders



Note: If backorder is not allowed, safety stock is required, hence the ROP = 288+SS

Recommendations for Today's Problem

- Considering from the viewpoint of inventory costs, it is favourable to have back-orders as total inventory cost is reduced as a result. This can be seen in the total cost changes:

- **Allowing backorders**, total inventory cost, TC = **$5,467**

- **Not allowing backorders**, total inventory cost, TC = **$7,385**

- Cost savings = **$1,918** (savings if backorders are allowed)

E217 Inventory Management Topic Flow

- Type of Inventory and Basic EOQ Model
- Application of EOQ Model
- Reorder Point and Safety Stock
- Inventory Review
- Bullwhip Effect
- Barcode Scanning Technology
- Physical Inventory and Cycle Counting
- Inventory Model for Perishable Goods
- Material Requirements Planning (MRP)
- Material Requirements Planning via SAP system
- Inventory Valuation by different costing methods
- Pull, Push and Push-Pull Inventory fulfilment strategies
- Kanban System

Learning Objectives

- Describe the practical considerations of the EOQ Model
- Describe the objectives of carrying safety stock
- Calculate the safety factor for a specified customer service level
- Calculate the appropriate level of safety stock and reorder point for a specified customer service level
- Describe the situations whereby backorders are allowed
- Calculate the total cost per unit time when backorders are allowed versus backorders are not allowed

P04
How to Review

E217 – Inventory Management

SCHOOL OF ENGINEERING

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    - Kanban System

Inventory Decision Rules

Order Frequency	Order Quantity	
Variable (s)	**s, Q**	**s, S**
Fixed (P)	**R, s, S**	**R, S**

- (s, Q) : Continuous review, reorder point (s)
  Fixed order quantity (Q)
- (s, S): Continuous review, reorder point (s)
  Order-up-to level (S)
- (R, S): Periodic review, review period (R)
  Order-up-to level (S)
- (R, s, S): Combination of (s, S) and (R, S)

- Q = order a fixed quantity, Q can be approximated by an EOQ
- S = order up to a fixed expected opening inventory, S
- s = place an order when the inventory balance drops to s
- R = place an order every R periods

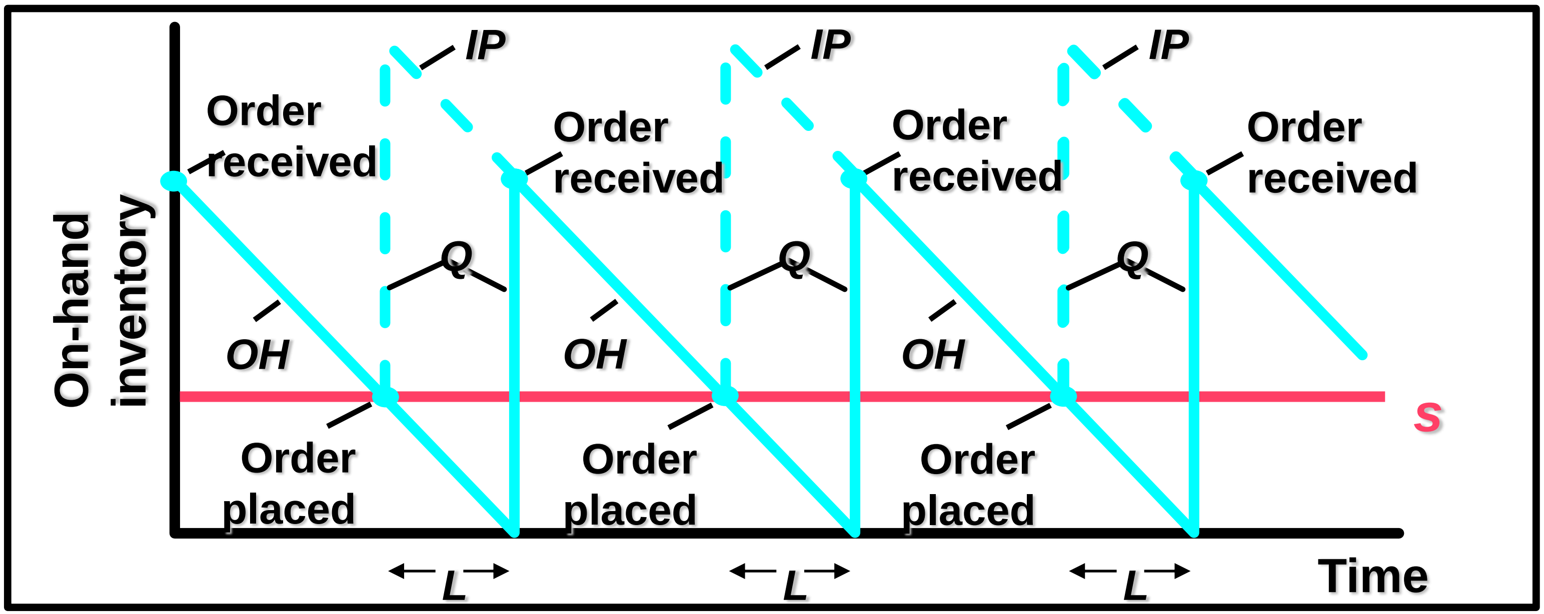
Continuous Review System

- Continuous monitoring of Inventory status
- Either manually or by using computerized systems
- An action on replenishment can be made immediately when the inventory level declines to any preset value
- Costly, may replenish at irregular intervals
- If a firm deals with a large number of items, it may not be feasible to review all items continuously
- Better customer service with lower safety stocks
- Order quantity is fixed
- Time between orders varies

Example: in a wafer fabrication facility, running out of a critical part may lead to hours of costly downtime

Continuous Review System (s, Q)

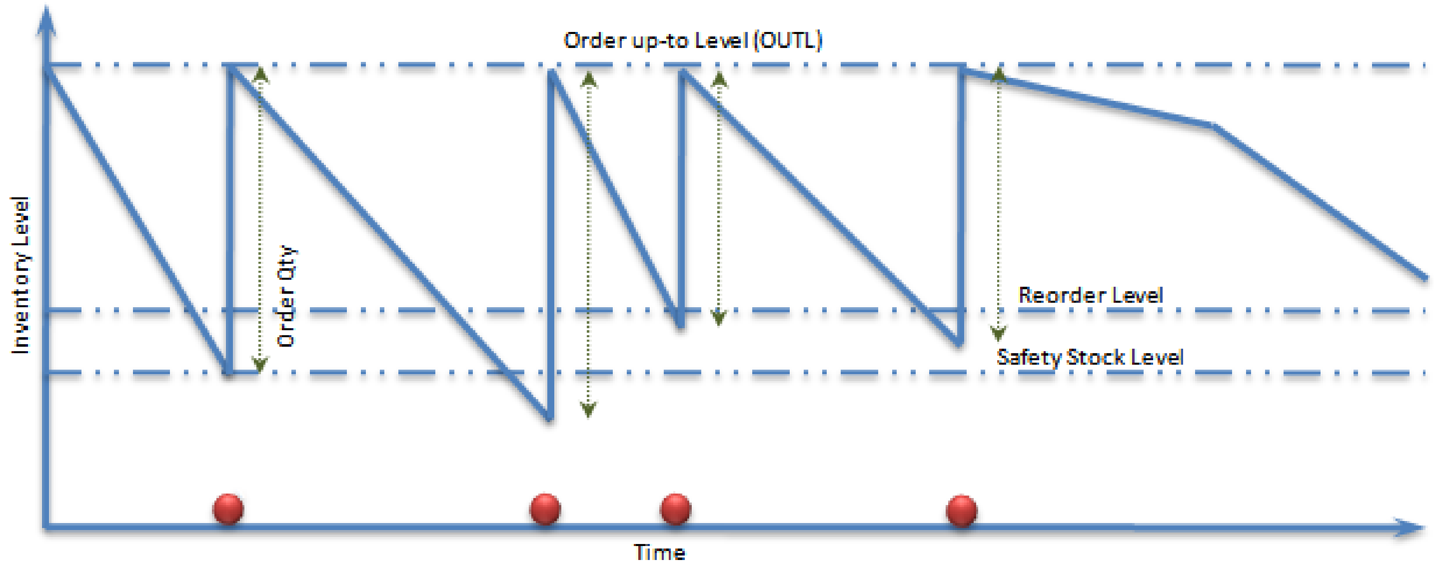
- A fixed quantity Q is ordered every time the inventory position drops to the reorder point ‘s’.
- Simple to understand, errors are less likely.



***OH**: on hand inventory (physically on the shelf, stock to satisfy customer directly)*
***IP**: inventory position = (Net stock) + (On-order stock) – (Committed stock)*
where Net stock = (On-hand stock) – (backorders)

Continuous Review System (s, S)

- Also known as a min-max system
- A variable quantity (S-s) is ordered every time the inventory position drops to the reorder point s.
- Best (s, S) policy is better than best (s, Q) policy in terms of total costs.
- Computational effort to find optimal (s, S) policy is substantial.
- Useful for items with large orders (that may take the stock level well below the reorder level)



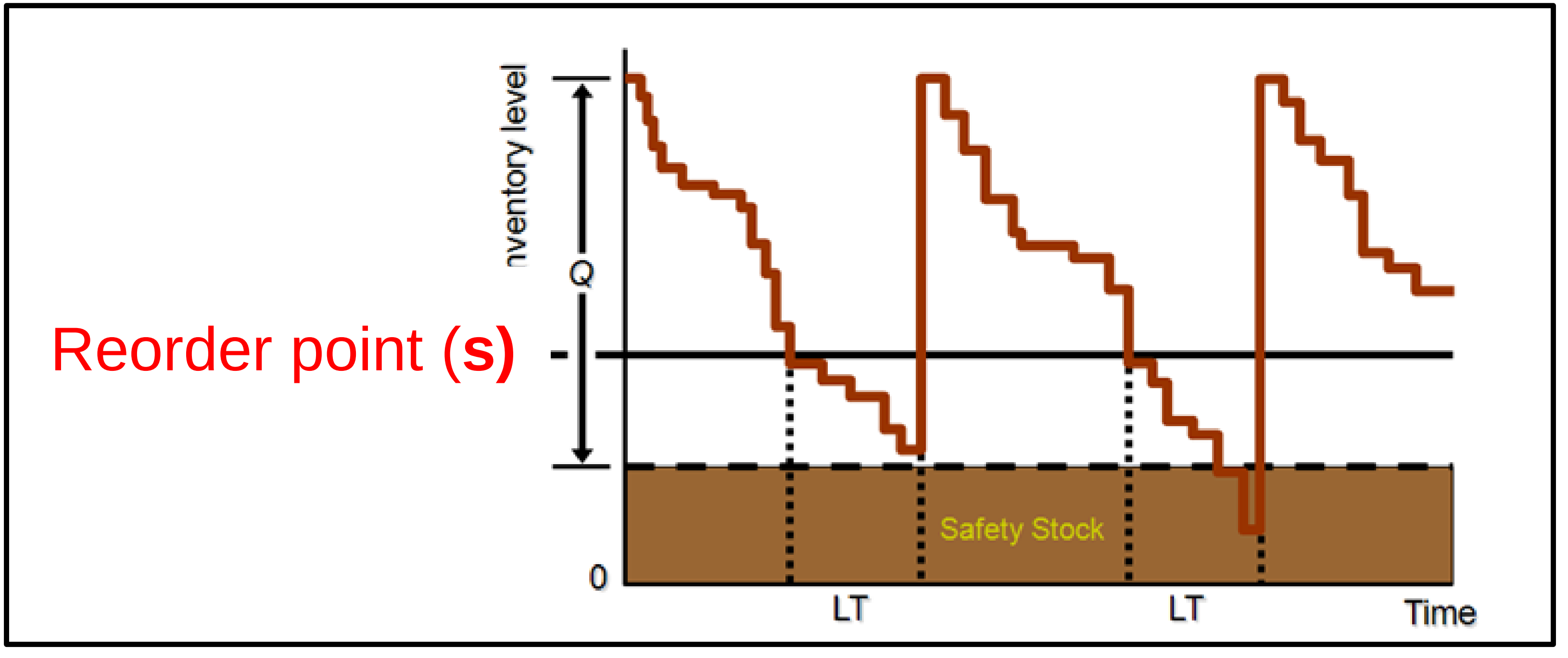
Reorder Point (s) for Continuous Review System

- When demand is certain

  Reorder point (s) = Average demand during lead time

- When demand is uncertain

  Reorder point (s) = Average demand during lead time + Safety stock



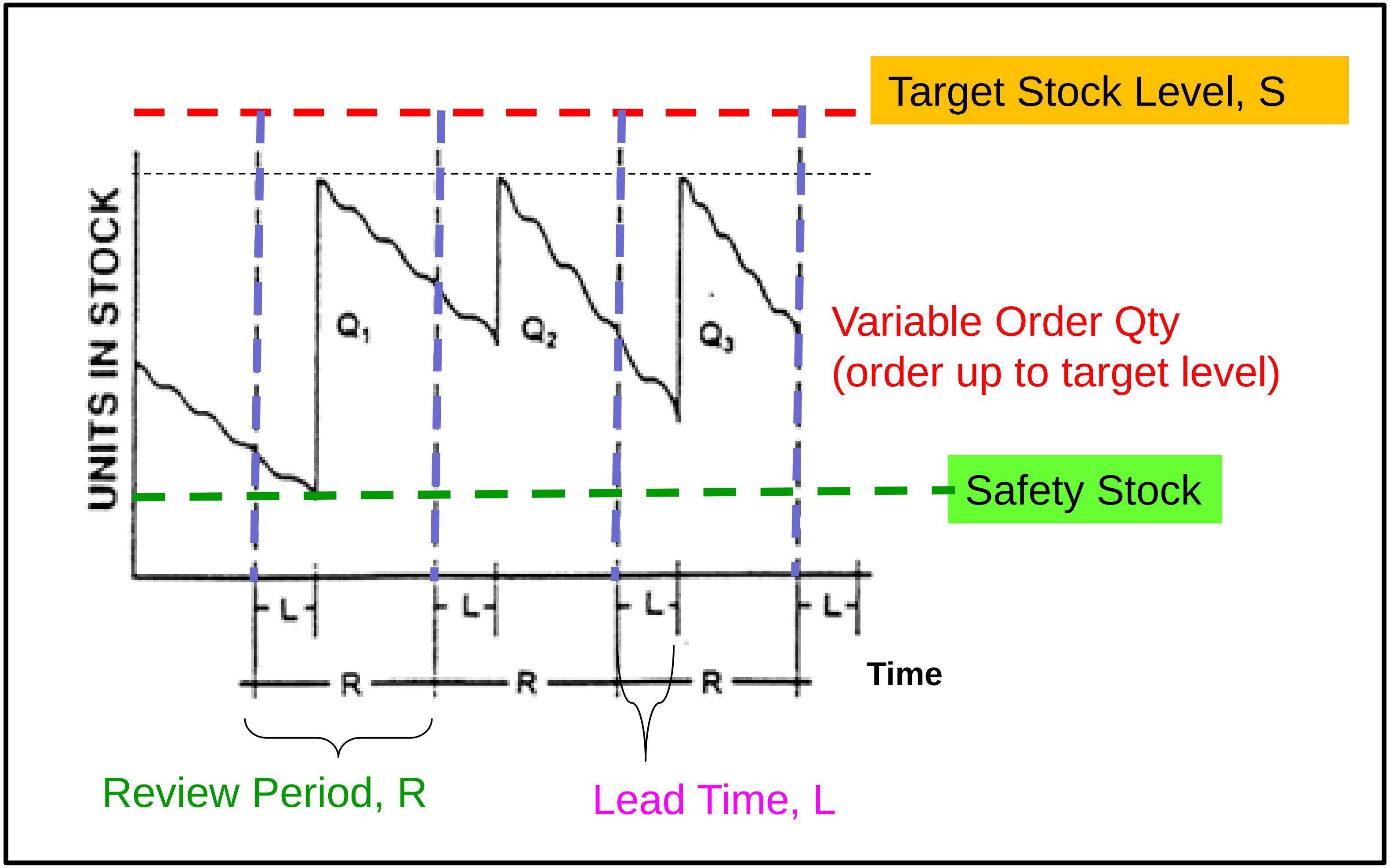
Periodic Review System

- Inventory status is reviewed only every R time units.
- Order quantities vary, but intervals fixed
- Ordering is often on a weekly or monthly basis
- Items may be grouped and ordered on the same day
- Easier multi-unit review and ordering
- Demand variability may cause huge backorders between orders or during review period
- Good for coordination of replenishments of several items

Periodic Review System (R,S)

- Sufficient quantity is ordered in each replenishment cycle (R time units) to raise the inventory to level S.
- Common use, particularly in companies not using computer control.
- Preferred if a joint replenishment policy is used.
- Offers opportunity to adjust S to respond to changing demand pattern.

Periodic Review System (R,S)



Periodic Review System (R,S)

- The quantity on hand must last until the next shipment is received

S =Target level (TL) or Order-Up-To-Level

= Demand during lead time + Demand during review time + Safety Stock

= D (L + R) + SS

Where:

TL = Target Level

D = Demand per unit of time

R = Review Period

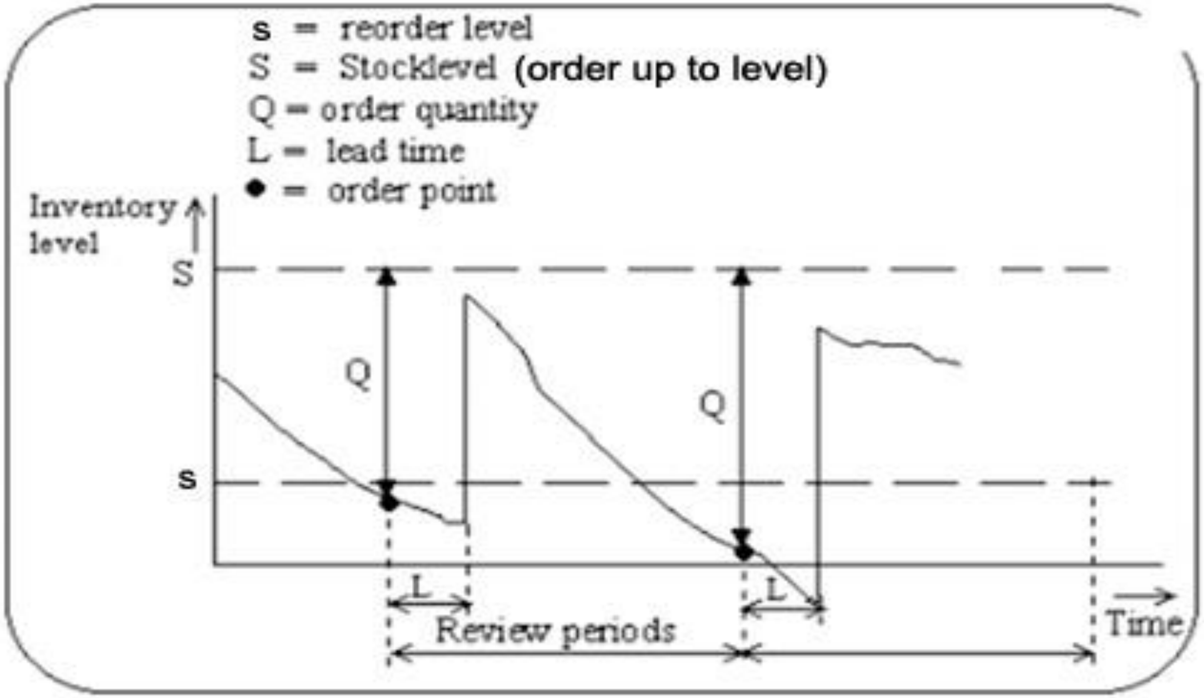
L = Lead Time

- Order Quantity = Target level – Current Inventory Position

(R, s, S) Review System

- A combination of (s, S) and (R, S) systems.
- Every R units of time we check the inventory position.
- If it is at or below reorder point s, we order enough to raise it to S.
- Best overall in terms of total replenishment, carrying and shortage costs.
- Computationally very difficult. Also, difficult to understand.
- Special cases:

R = 0 → (s, S) system
s = S-1 → (R, S) system



Continuous Versus Periodic Review System

Continuous Review System

•Able to provide same level of service with less safety stock (hence, lower carrying cost)

•Fixed lot sizes may make it easier to obtain quantity discounts

•Individual review of items is used and this may be desirable for expensive items

Periodic Review System

•Less time consuming and less expensive to maintain

• Allows combining orders to the same supplier

•Good for coordination of replenishments of several items

•Allows reasonable prediction of workload of staff

Using Continuous Review System (s, Q)

- Safety Factor, z = NORMSINV(0.95) = **1.6449**
- Annual Average Demand
  = Monthly Average Demand X No. of months in a year
  = 30000 x 12 = **360000**
- Optimal Order Quantity, Q
  =SQRT(2*Fixed Ordering Cost* Annual Average Demand
  /Holding Cost per Unit per Year)
  = SQRT(2*500*360000/10) = 6000 = **6000 Units**
- Safety Stock, SS
  = z * Monthly Demand Standard Deviation * SQRT(L)
  = 1.6449* 3000 * SQRT(1/4) = 2467.28 = **2468 units**
- Reorder Point, s
  = Weekly Average Demand*(L) + Safety Stock
  =(30000/4)*1+2468 = **9968 Units**

Note: convert from weeks to months

Using Periodic Review System (R, S)

- Given that John wishes to review the inventory status every 4 weeks and achieve the same customer service level of 99%.

- Weekly Average Demand
  = Monthly Average Demand/ number of weeks per month
  = 30000/4= 7500

Note: convert from weeks to months

- Safety Stock
  = z * **Monthly** demand Standard Deviation * SQRT(**R+L**)
  = 1.6449 * 3000 * SQRT(**(1+4)/4**)= 5517.16 = **5518 units**

  (Note: Safety Stock in (s, Q) system = 2468 units)

More Safety stock required in periodic review system!

- S = Target Level
  = Average Weekly Demand*(R+L) + Safety Stock
  = 7500 * (4+1) + 5518 = **43018 units**

❖ This means that John should place an order every 4 weeks, so as to raise the inventory level to 43018 units

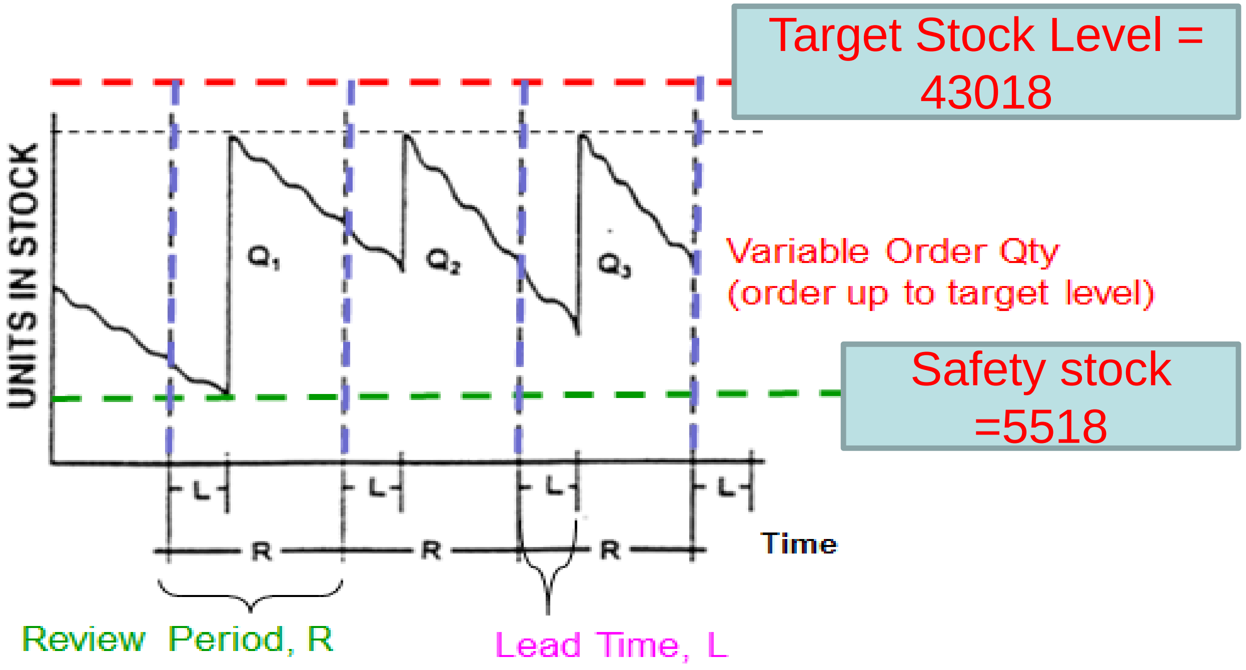
❖ This target level is also known as the Order-Up-To-Level, S

Using Periodic Review System (R, S)

- John reviews the inventory every 4 weeks. The quantity that he should order every time is found by:

  Order Quantity = Target level – <u>Current Inventory Position</u>

- If current inventory is 5000 units, order quantity = 43018 – 5000 = 38018 units
- The "Current Inventory Position" may vary in every review time, hence the order quantity is variable.



Recommendations to John

- Current reorder point (by past experience) was not effective when the demand was not constant. However, the safety stock can provide buffer against stock-out to certain extent.
  - *Reorder point should take into account safety stock and average demand during lead time, when the demand is not constant.*
- If the review period is set to be too long (i.e. monthly in this case), he might run out of stocks even before he does the review.
- A continuous review model is recommended to accurately and closely monitor the inventory level to prevent from stock-out. i.e. When the stock level hits the reorder point, he should place the order for the product.

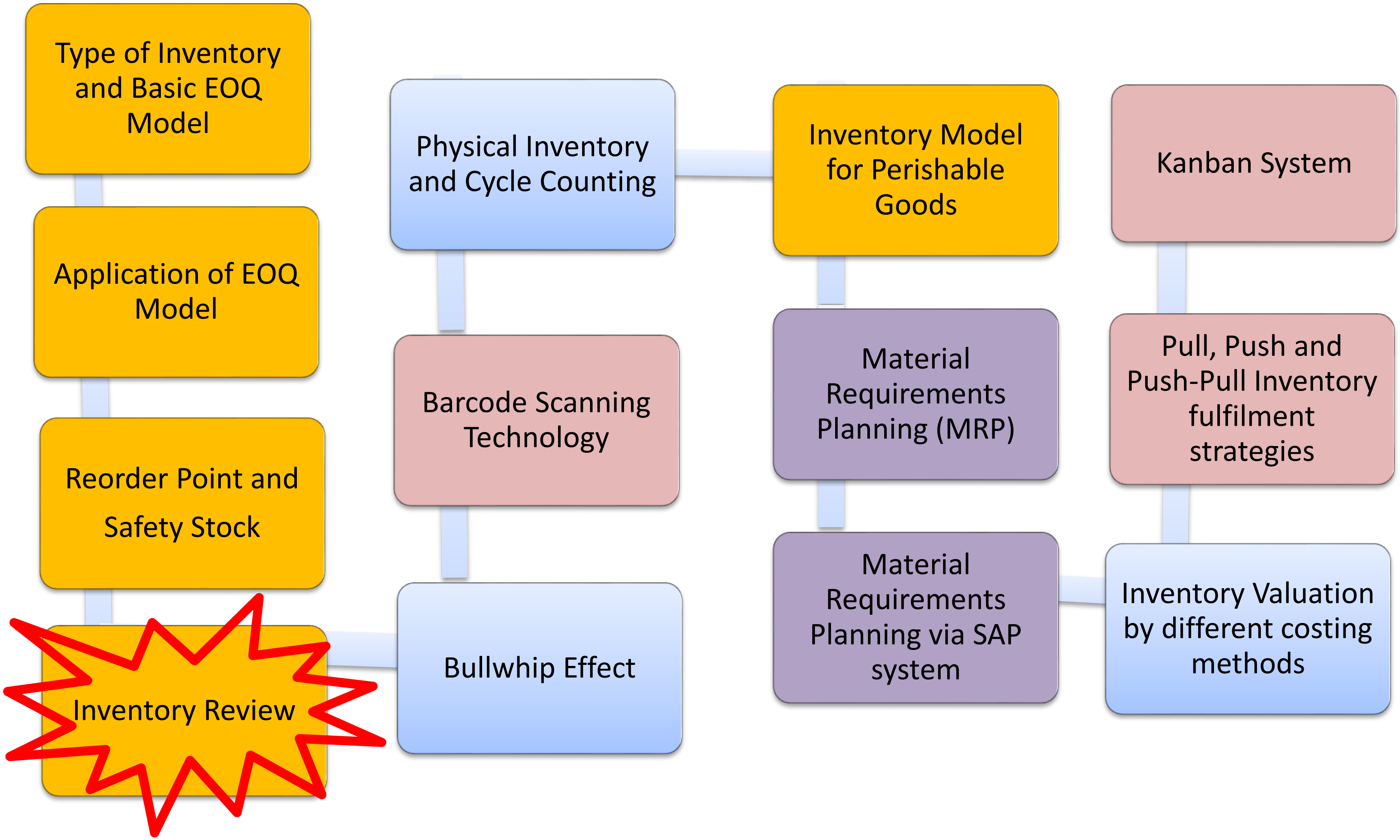
Overall Recommendations

- For *slow moving items*, he can continue to use the periodic review system with an appropriate review period (not too short).
- For *fast moving/ high profit/ high value items*:
  - He may want to invest in technology that enables him to continuously monitor the stock levels, thus enabling him to use the continuous review system (s, S).
  - If using periodic review system, he can implement (R, S) but set a shorter review interval; or even the (R, s, S). The difficulty with (R, s, S) is that it is not easy to obtain the best value for the 3 parameters. It is more complicated than other review systems.
- General rule:
  - If the stockout of an item is especially costly for the firm, or the more critical the item, the more pressing the need to adopt a continuous review system

Learning Objectives

- Describe the characteristics of a Continuous Review System
  - Reorder Point, Order Quantity (s, Q) system
  - Reorder Point, Order-Up-To-Level (s, S) system
- Describe the characteristics of a Periodic Review System
  - Periodic-Review, Order-Up-To-Level (R,S) system
  - (R, s, S) system
- Perform calculations for a Continuous Review System (s, Q)
- Perform calculations for a Periodic Review System (R, S)
- Identify the appropriate inventory review system to be used for today's problem

E217 Inventory Management Topic Flow



REPUBLIC POLYTECHNIC

P05
Small Ripples, Huge Waves!

E217 – Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

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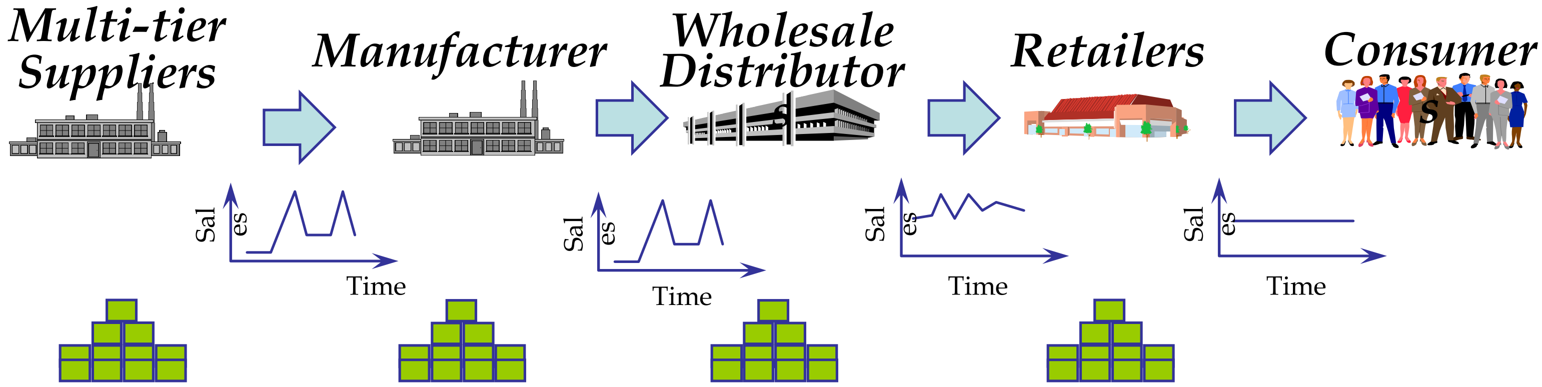
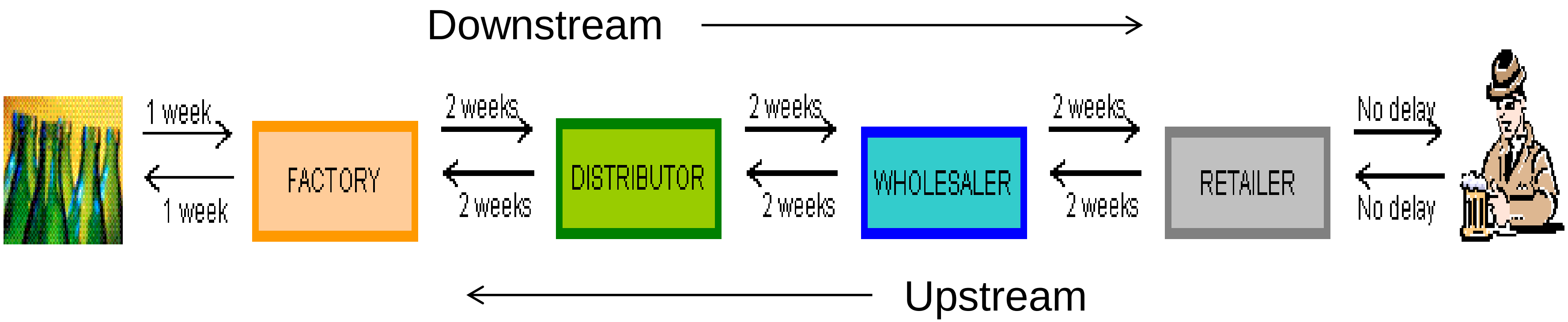
System Dynamics

- The Beer Game was developed to introduce the concept of system dynamics.
- The results of the beer game simulation teach a lot about how to coordinate the actions of different companies in a supply chain.
- Each player experienced the pressures of playing a role in a complex system and can see long range effects during the course of the game.
- Bullwhip Effect is one of the most common dynamics in supply chains



Bullwhip Effect

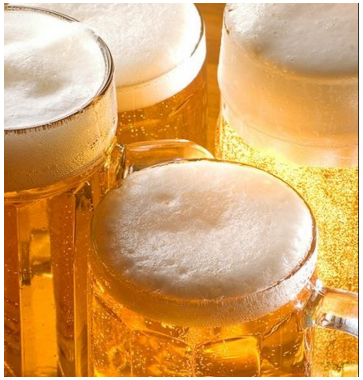
The Online Beer Game



① Beer Game shows the typical coordination problems of traditional supply chains without information sharing and collaboration

② Companies at different stages in the supply chain behave in ways that at first create product shortages and then lead to an excess supply of products

- Single product (beer)
- Fulfil demand from inventory
- 2-week lead time (order /delivery)
- One decision: how much to order?



The Online Beer Game (1)

Input Screen for Retailer of Game 2

For Week **5**

Incoming order

On-hand Inventory+ incoming delivery

Demand from Customer : **8**	Beginning Inventory : **12**
On Backorder : **0**	Incoming Shipment : **12**
------	------
Total requirements : **8**	Total available : **24**

Incoming order + Backorder if any

Units Shipped to Customer this week: **8**

Ending inventory **16**

Enter the number of units to be purchased from Wholesaler :

submit

Retailer INFORMATION FOR THE LAST TEN WEEKS

NOTE : The two orders placed to Wholesaler before week 1 are 4 and 4 units

Week	Inv/Bk	Demand	Incom. ship	Outg. ship	Order placed	Current cost
1	12	4	4	4	12	6
2	12	4	4	4	12	12
3	12	4	4	4	8	18
4	12	4	4	4	8	24

Cumulative inventory cost, e.g. 12*0.5 = $6 per week

The Online Beer Game (2)

Status of other Supply Chain Channel Members of Game 2
This page will be refreshed every 15 seconds

When all the players have completed the order for the current week, the player will automatically receive a link to proceed to next week

The status will be updated in 6 seconds.

Week 5

Factory : **Has not ordered**

Distributor : **Has not ordered**

Wholesaler : **Has not ordered**

Retailer : **Has not ordered**

Inventory and Order Status plots For Retailer

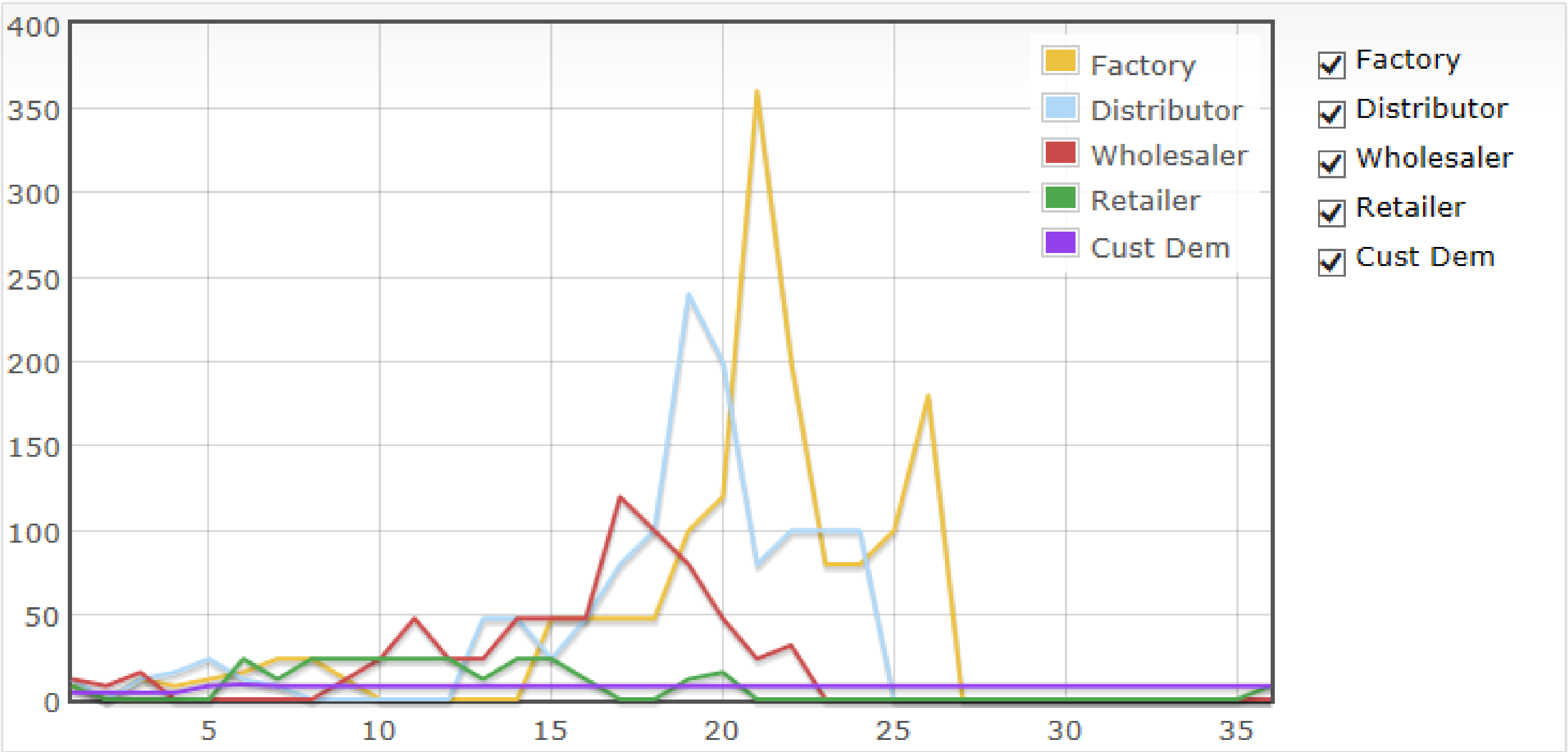
Customer Demand Plot | Inv/Backorder Plot

Order Plot | Plot all

Supply Chain Settings for Retailer:
Holding cost : **0.5**
Backorder cost : **1**
Downstream Player : Customer
Upstream Player: Wholesaler
Shipping Delay : **2 weeks** (Wholesaler -> Retailer)
Information Delay : **2 weeks** (Retailer -> Wholesaler)

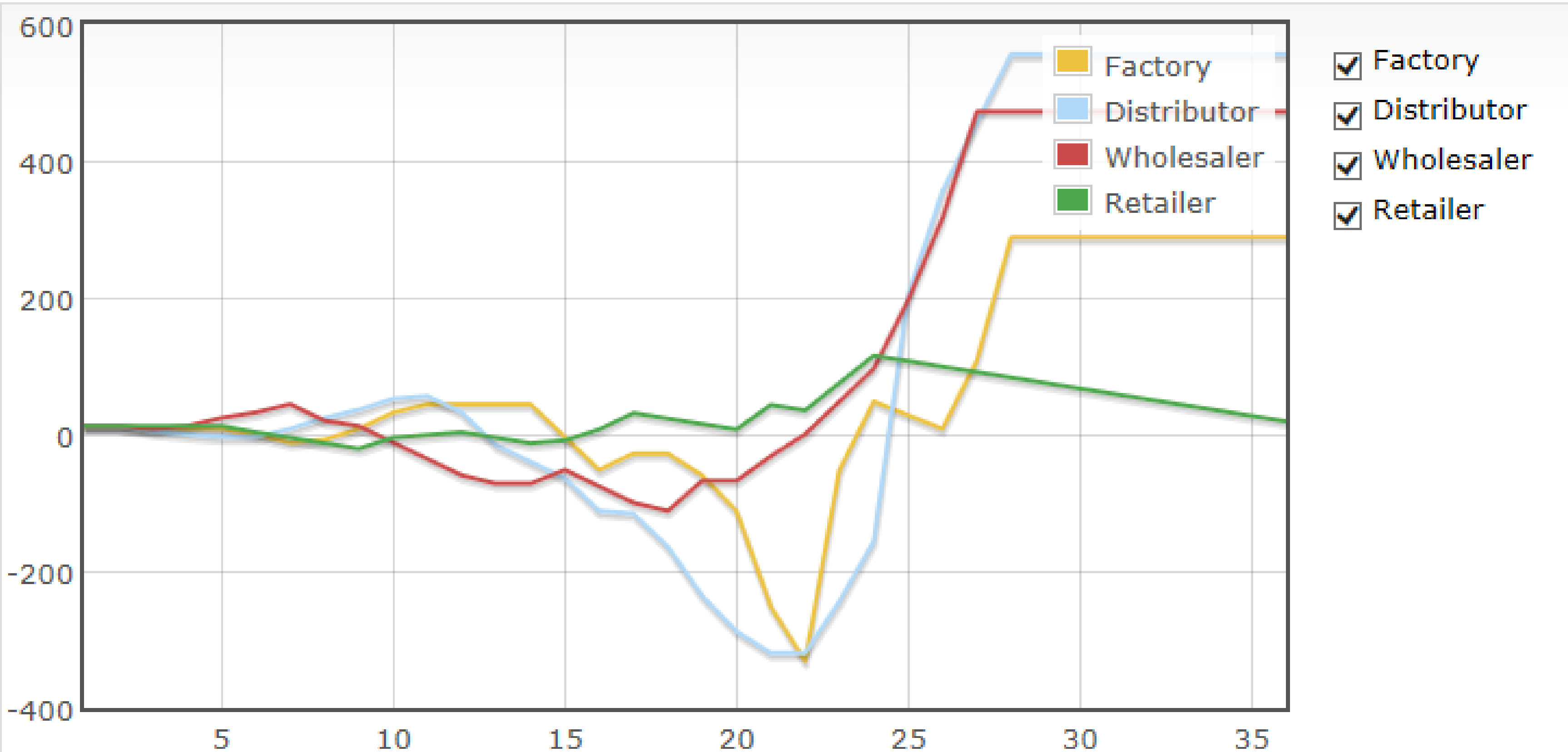
Game settings

Order Pattern Observed in Beer Game



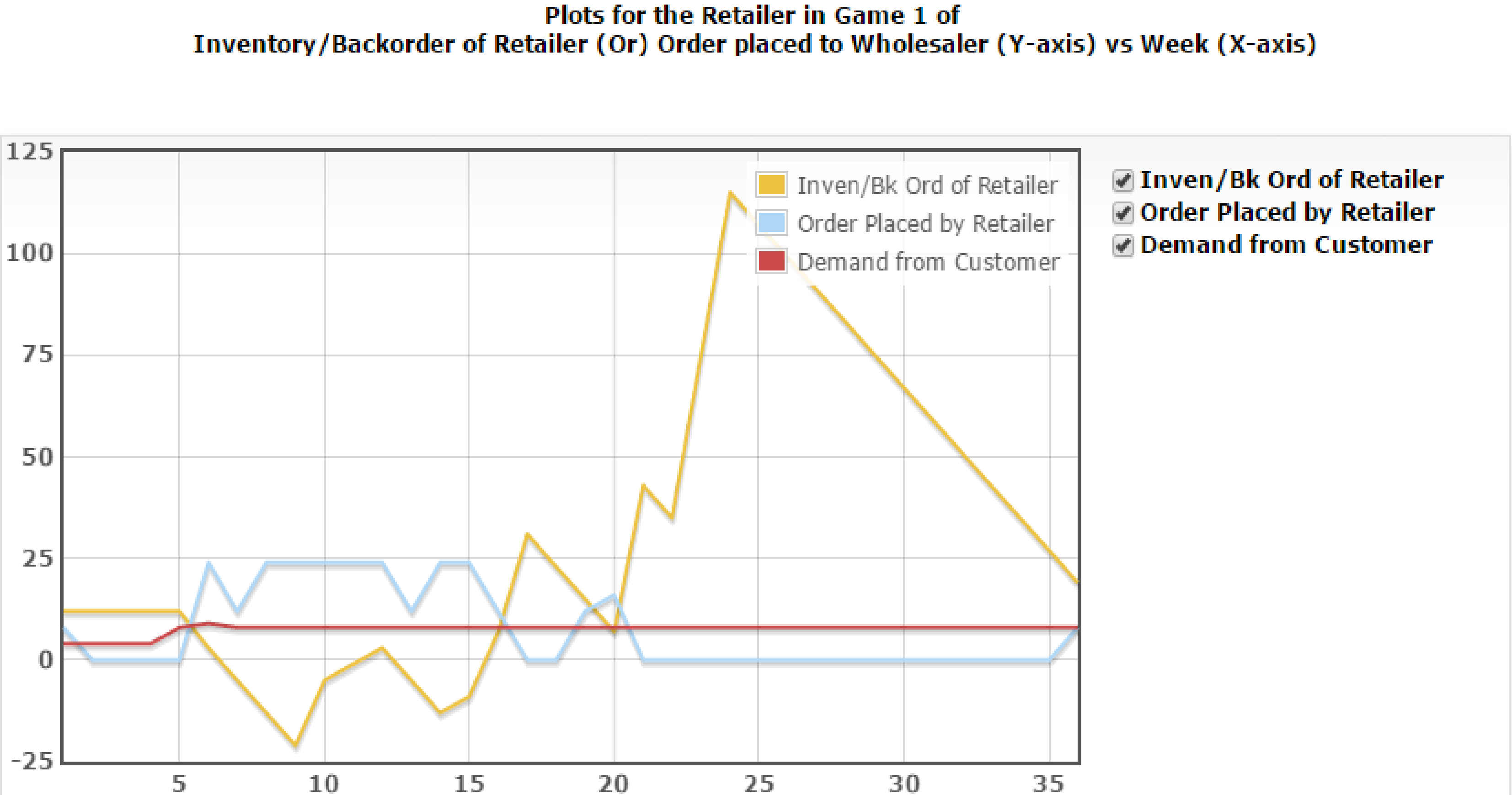
- Companies at different stages in the supply chain come to have very different pictures of market demand
- Factory performed the worst with the biggest demand variability
- Demand variability increases as one moves upstream from the retailers to the manufacturers (factory).

Inventory/Backorder Observed in Beer Game



Note: **X -axis** represents Number of weeks and **Y-axis** represents Number of Beer cases (in units).

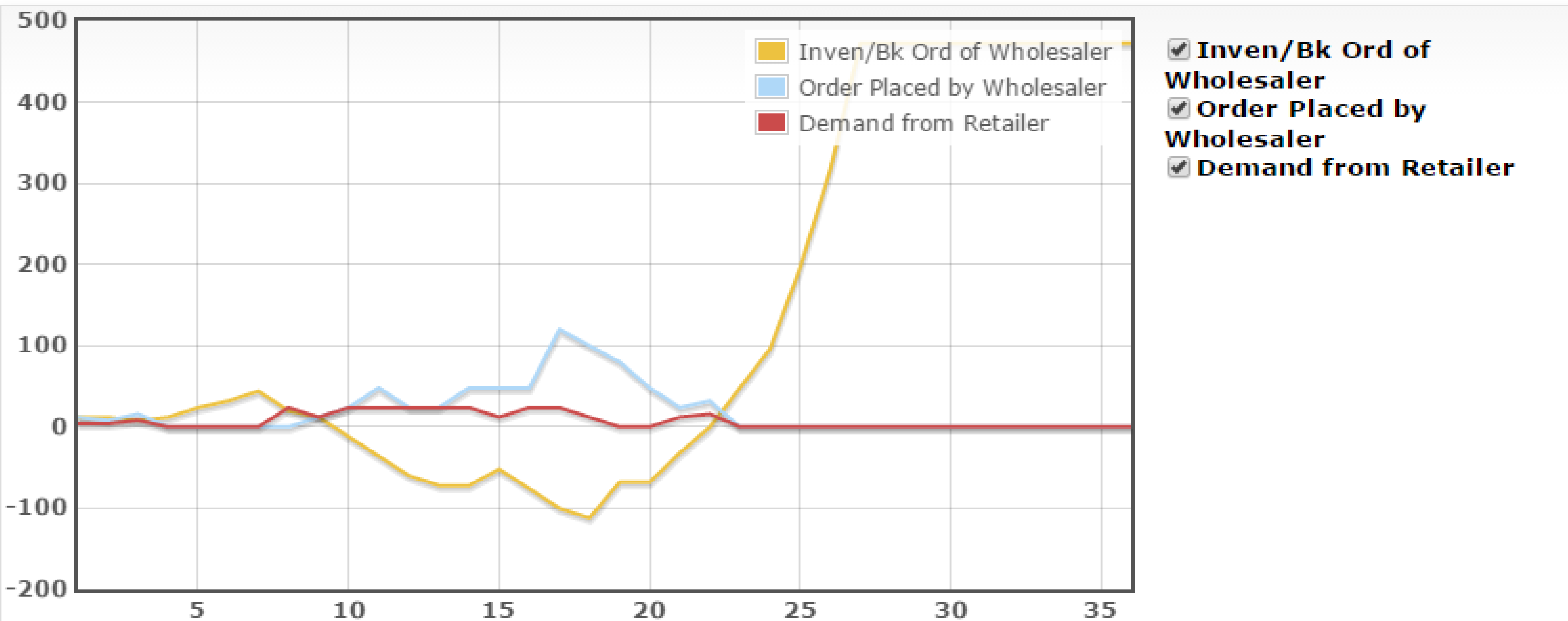
Fluctuations Along the Supply Chain (Retailer)



Note: X -axis represents Number of weeks and Y-axis represents Number of Beer cases (in units).

Fluctuations Along the Supply Chain (Wholesaler)

Status of Wholesaler in Game 1 of RP2016S1
Wholesaler's Inventory/Backorder/Demand/Order (Y-axis) vs Week (X-axis)

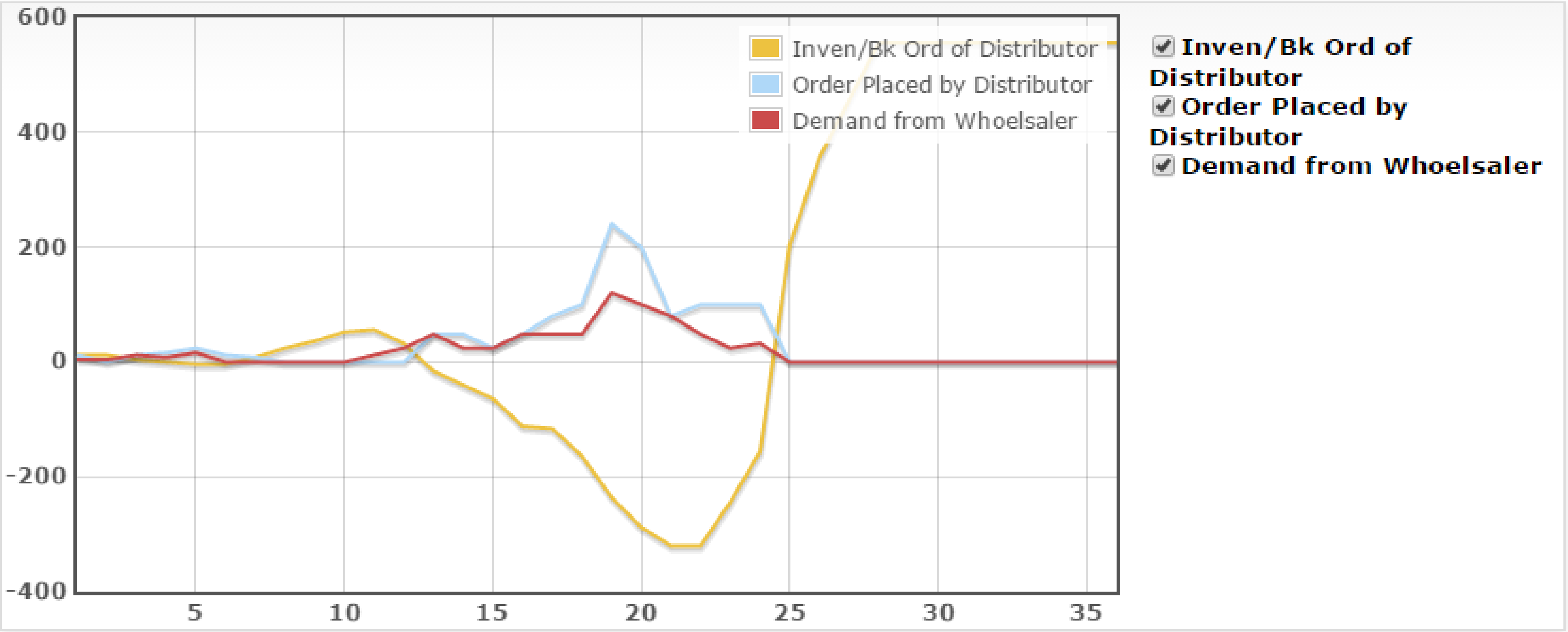


Note: X -axis represents Number of weeks and Y-axis represents Number of Beer cases (in units).

Total Current Cost : $ 3536
Average cost per week : $ 98.2222222222222
See values in table format

Fluctuations Along the Supply Chain (Distributor)

Status of Distributor in Game 1 of RP2016S1
Distributor's Inventory/Backorder/Demand/Order (Y-axis) vs Week (X-axis)

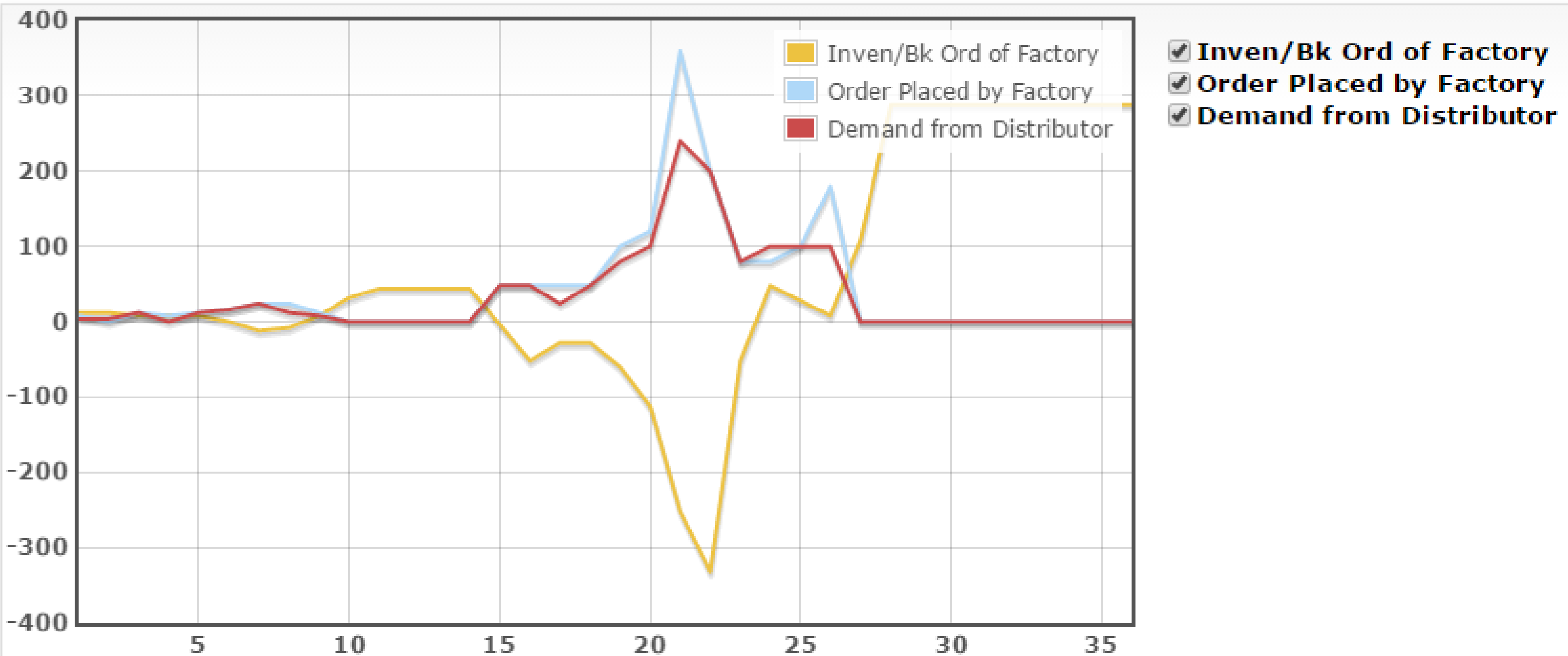


Note: X -axis represents Number of weeks and Y-axis represents Number of Beer cases (in units).

Total Current Cost : $ 5212
Average cost per week : $ 144.777777777778
See values in table format

Fluctuations Along the Supply Chain (Factory)

Status of Factory in Game 1 of RP2016S1
Factory's Inventory/Backorder/Demand/Order (Y-axis) vs Week (X-axis)



Note: X -axis represents Number of weeks and Y-axis represents Number of Beer cases (in units).

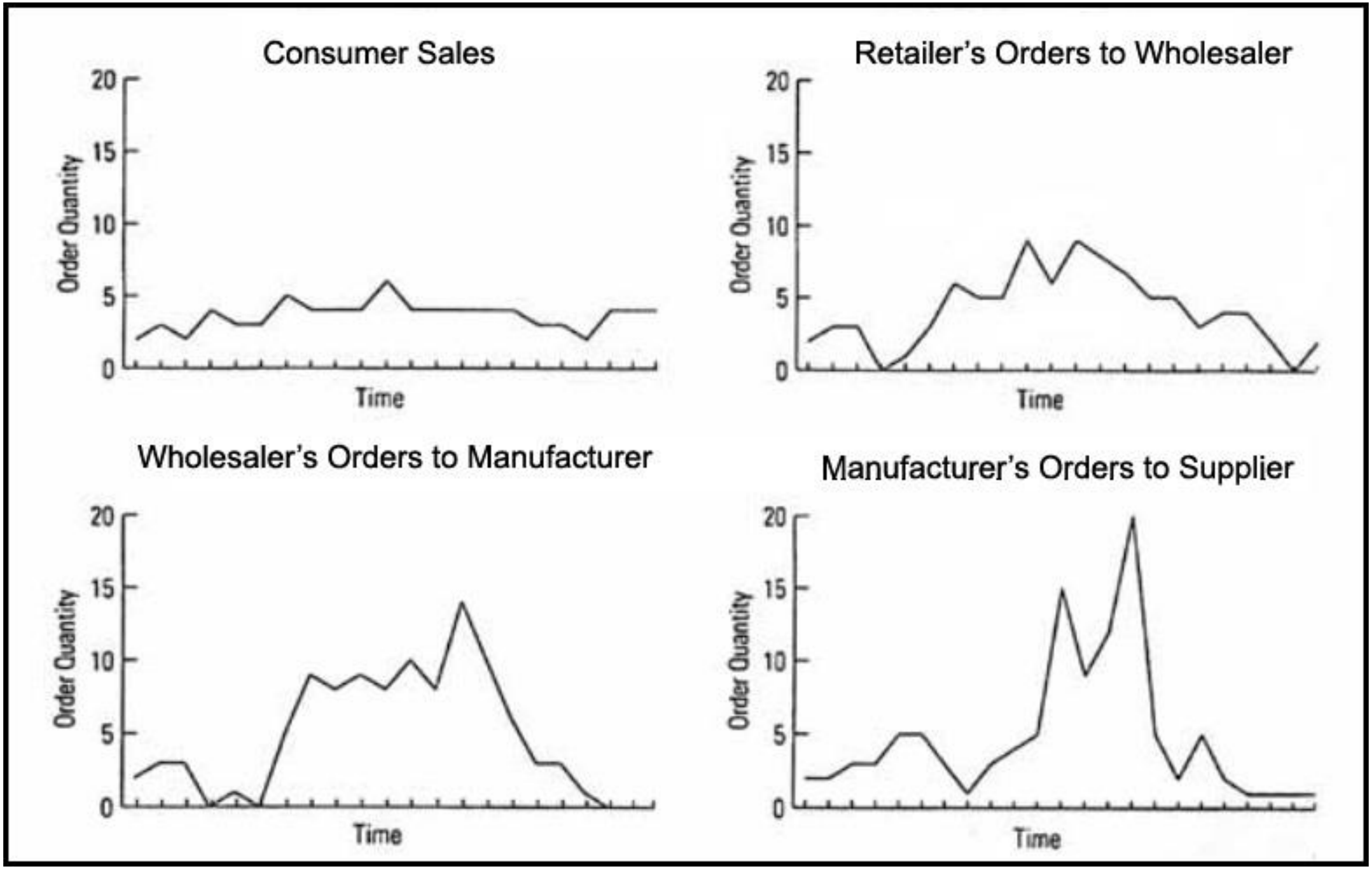
Total Current Cost : $ 2464
Average cost per week : $ 68.4444444444444

See values in table format

Origins of Bullwhip Effect

- Proctor & Gamble (P&G) coined the term "Bullwhip Effect" by studying the demand fluctuations for disposable diaper, "Pampers".
- Retail sales of "Pampers" were fairly uniform, there is no particular day or month whereby demand is significantly higher or lower than the other
- However, the distributor's orders placed to the factory fluctuated more than the retail sales
- In addition, P&G's orders to its suppliers fluctuated even more
- This increase in demand variability as we travel up the supply chain is known as the Bullwhip Effect

Bullwhip Effect in the Real World (P&G Diapers)

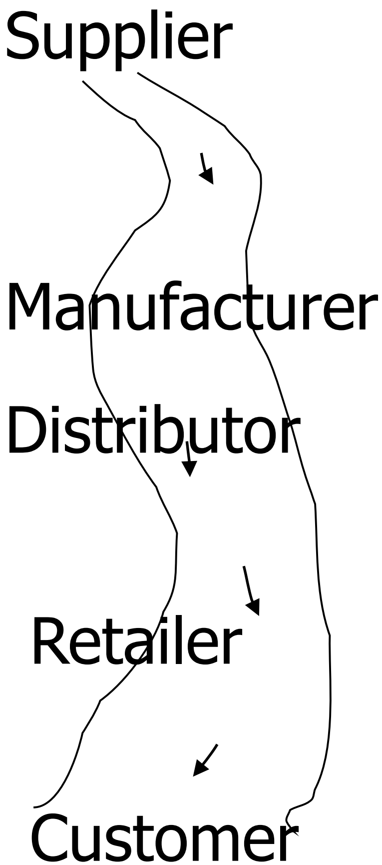


Bullwhip Effect

- ✓ Distortion in demand information, what you see is not what they face
- ✓ A small change in customer demand can result in large variations in order placed upstream because of the distortion in information that occurs with each step in the supply chain, from consumer, to retailer, to wholesaler, to manufacturer.
- ✓ Through the Beer Game, we experience typical coordination problems of traditional supply chains without information sharing and collaboration.

- *Note that the Beer Game only simulates a simplified 4-stage beer supply chain; you can imagine how complex the real-life supply chains are!*

Causes of Bullwhip Effect in Beer Game



- No communications with other players when you make order decisions, based solely on orders from the next downstream player which become available only after the delivery delay (lead time).
- The ordering patterns share a common, recurring theme: the variability of an upstream site is always greater than those of the downstream site. This is a simple and yet powerful illustration of the bullwhip effect.
- The bullwhip effect is a consequence of the **players' rational behavior** within the supply chains infrastructure.

Operational Causes of Bullwhip Effect (I)

- Demand Forecast Updating
  - Forecasting is often based on the order history from immediate customers.
  - Demand forecasting based on orders received instead of end user demand data will inherently become more and more inaccurate as it moves up the supply chain.
  - Lead times cause companies to hold safety stock, which in turn worsens the fluctuation in orders placed.
  - Retailers often order more when they notice a slight increase in demand

- Price Fluctuations
  - Promotions, discounts and rebates may cause customers to buy in bulk and stock up.
  - When price returns to normal, customer demand often drops
- Overreactions to backlogs
- No communication and coordination

Operational Causes of Bullwhip Effect (II)

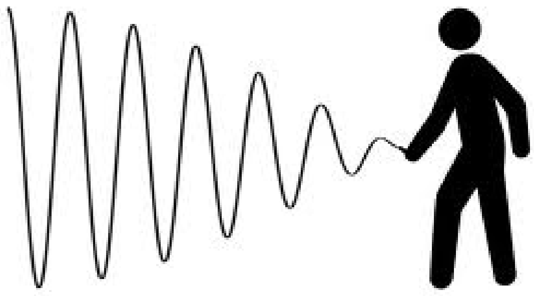
- Order Batching (MOQ)
  - Companies often place orders in batches to reduce order processing costs, save transportation cost or in anticipation of seasonal demands
  - Because of order batching, these orders vary from the actual demand and this variance is magnified as it moves up the supply chain.

- Rationing and Shortage Gaming
  - In times of anticipated shortage of products (such as the introduction of popular hand-phones or computers during the holidays), manufacturers will impose limits on customer orders, for example shipping each customer only 40% of an actual order.
  - Customers therefore try to “game” and “beat” the rationing system, by ordering extra quantities in advance.
  - In the end, manufactures do not get a realistic sense of the size of actual demand, and after the rationing is over, many customers cancel duplicate orders that they had placed to several manufacturers, causing excess inventory costs in the supply system.

Consequences of Having the Bullwhip Effect

When a supply chain is plagued with the Bullwhip Effect and demand information is distorted, it results in:

- Excessive inventory
- Insufficient or excessive capacity (transportation, production, etc)
- Longer cycle times
- Poor customer service due to unavailable products or long backlogs
- Poor forecast accuracy
- Lost sales and profit
- Overall costs increase



Strategies to Manage the Bullwhip Effect

Reducing uncertainty

- Centralize actual customer demand information and each partner in the supply chain can still use different forecasting techniques and buying practices
- All companies in a supply chain to share a common set of demand data from which to do their forecasting
- Information sharing along the supply chain
- Sharing of Point-of-sale (POS) data captured by bar-coding system

Reducing variability

- Reduce factors that increase variability in customer demand (e.g. Promotions and discounts)
- Year round or everyday low price strategy, etc.
- If the end customers for a product believe that they will get a good price whenever they purchase the product, they will make purchases based on real need and not other considerations. This in-turn makes demand easier to forecast and companies in the supply chain can respond more efficiently.

Strategies to Manage the Bullwhip Effect

Reducing Lead Time

- Supply chain redesign, networks, processes, tasks and roles
- Information lead time: accurate information passed on electronically, such as the Internet, Electronic Data Interchange (EDI), etc.
- Order lead time: Cross-docking, etc.

Alliances: Collaboration in the supply chain

- Build strategic partnerships among the supply chain partners
- Develop effective collaborative demand forecasting methods
- Vendor-Managed Inventory (VMI)
- Coordinated planning
- Integrated distribution strategy, etc.

We can only reduce, but can never eliminate the Bullwhip Effect !

Case-study of Wal-Mart

- Theoretically the Bullwhip Effect does not occur if all orders exactly meet the demand of each period. This is consistent with findings of supply chain experts who have recognized that the Bullwhip Effect is a problem in forecast-driven supply chains, and careful management of the effect is an important goal for Supply Chain Managers

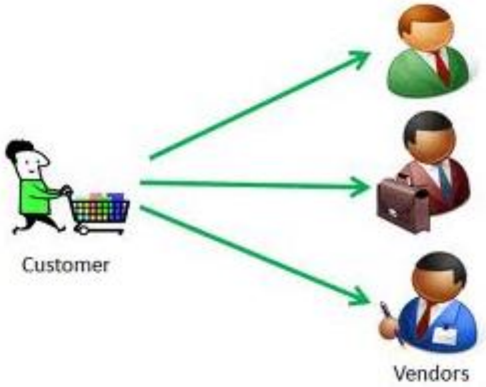
- Therefore it is necessary to extend the visibility of customer demand as far as possible. One way to achieve this is to establish a demand-driven supply chain which reacts to actual customer orders. In manufacturing, this concept is called Kanban. This model has been most successfully implemented in Wal-Mart's distribution system.

- Individual Wal-Mart stores transmit point-of-sale (POS) data from the cash register back to corporate headquarters several times a day.

Case-study of Wal-Mart

- This demand information is used to queue shipments from the Wal-Mart distribution center to the store and from the supplier to the Wal-Mart distribution center.

- The result is near-perfect visibility of customer demand and inventory movement throughout the supply chain. Better information leads to better inventory positioning and lower costs throughout the supply chain. Barriers to the implementation of a demand-driven supply chain include the necessary investment in information technology and the creation of a corporate culture of flexibility and focus on customer demand.



Today’s Problem Statement

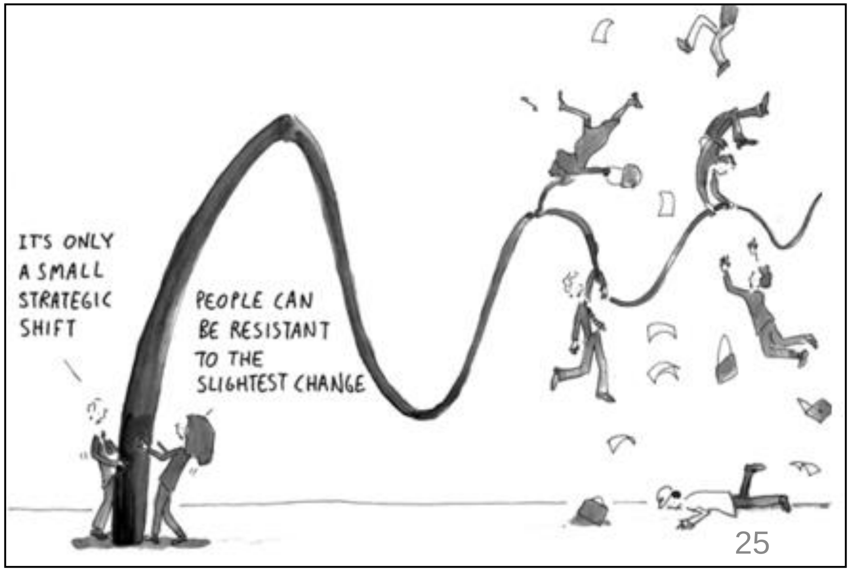
- The phenomenon that the manufacturer Florrick Brewery is experiencing is called the Bullwhip Effect.
- The simulation study using Beer Game suggested that Bullwhip Effect is caused by lack of communications between each partner in the supply chain. While the game is being played, each supply chain partner has no information about the upstream or downstream inventory cost or order quantity.
- Operational cause of Bullwhip Effect can be a result of demand forecasting based on historical demand rather than real time data. It can also be caused by price fluctuations, large orders with quantity discount, ration and shortage gaming, etc. Hence, demand variability increases as one moves upstream from the retailers to the manufacturers (factory or brewery) and the overall inventory cost increases also.
- Hence, some suggested strategies:
  - ❑ centralized inventory information
  - ❑ reduce lead time in information passing
  - ❑ supply chain partnership

Learning Objectives

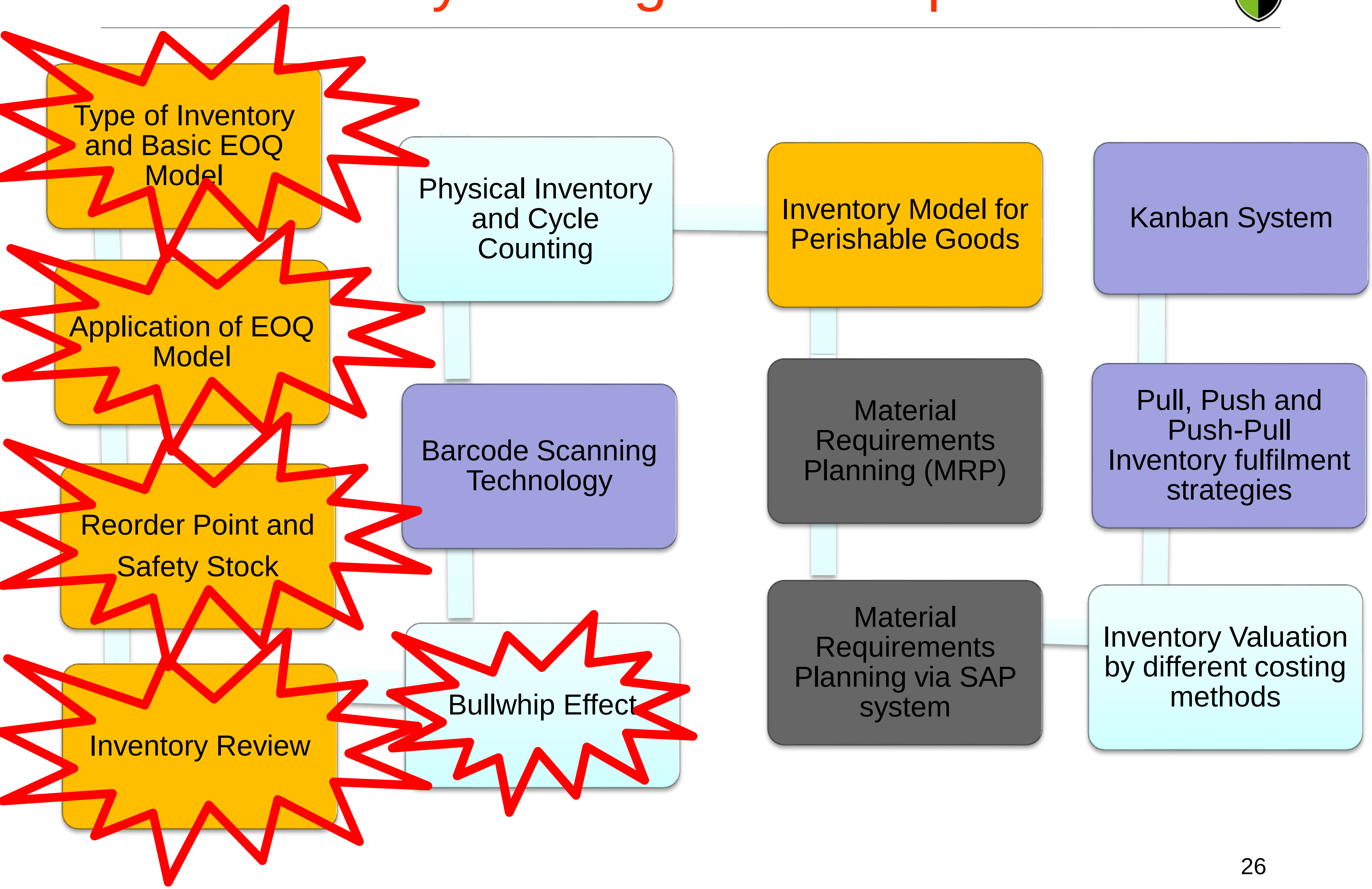
- Analysis via the Beer Simulation Game

- Describe the roles of the 4 supply chain partners in the Beer Game
  - Retailer, Wholesaler, Distributor and Factory
  - Concept of downstream and upstream stage
  - Incoming orders and deliveries
  - Outgoing orders and deliveries
  - Backorders
  - Total inventory cost

- Describe the Bullwhip Effect
  - Background
  - Major Causes
  - Consequences
  - Strategies to cope with



E217 Inventory Management Topic Flow



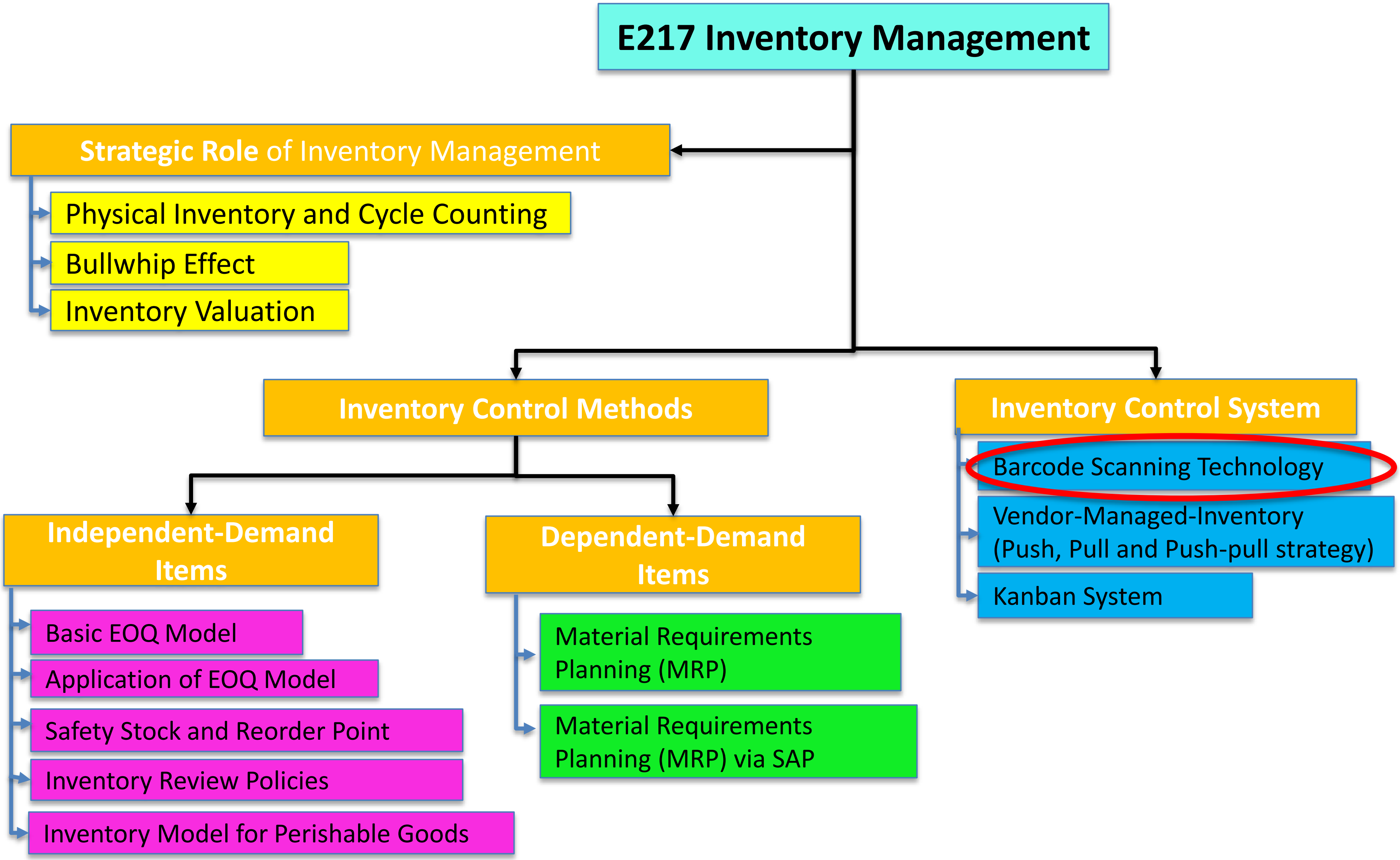
Problem 06

Read the Codes

E217 – Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree



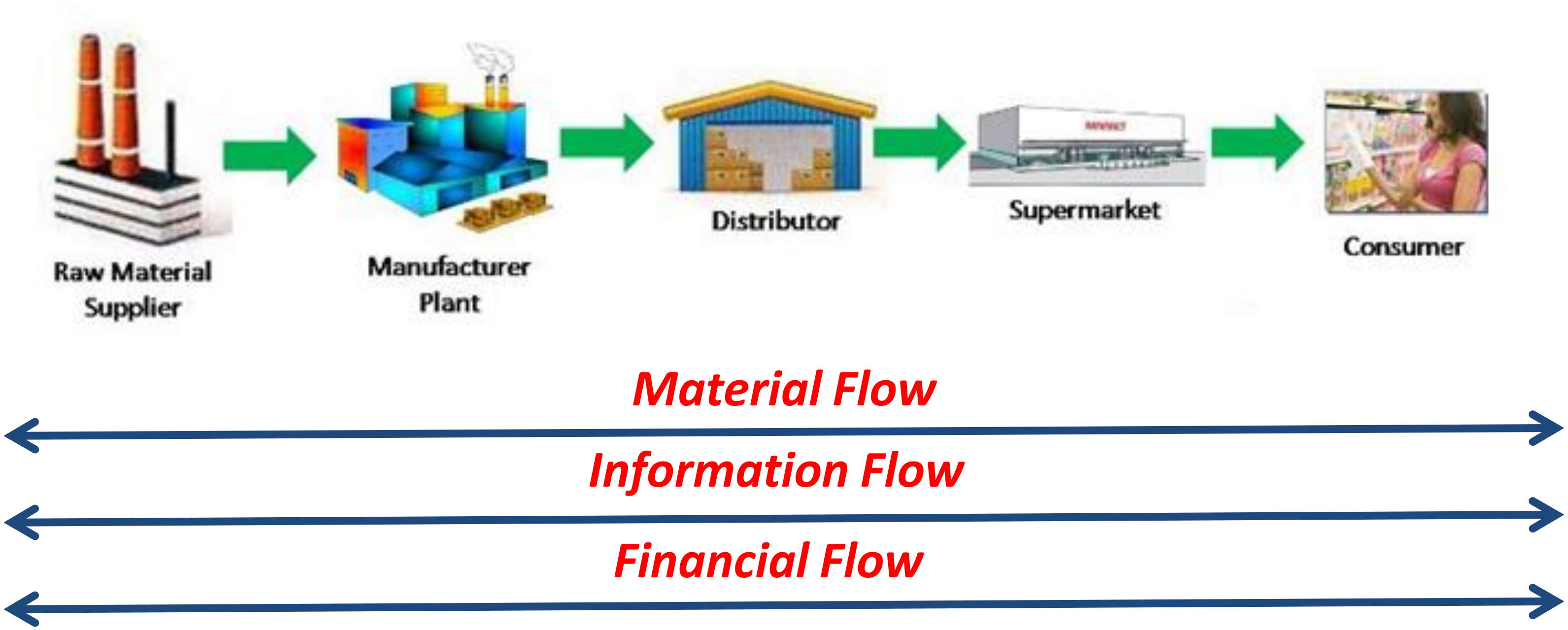
What is Supply Chain ?

- A supply chain is the network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers.

- It spans all movements and storage of raw materials, work-in-process inventory and finished goods from point-of-origin to point-of-consumption.

- For example, a detergent supply chain starts from the raw materials all the way to the consumer.

3 Flows in a Supply Chain



- In a typical supply chain, **material** (products / services) usually flows from left to right.
- Due to the growing importance of reverse logistics (product recall, customers returning products that are unacceptable, damaged, obsolete, etc.), we are seeing a growing trend of material flows from right to left.

3 Flows in a Supply Chain

- Traditionally we view **information** flowing in the opposite direction of material flow, i.e. right to left (from the customer back to the wholesalers and manufacturers). Examples: customer demand or sales data

- **Information** that flows from left to the right include many forms such as Advance Shipment Notices (ASNs), order status information, inventory availability information, the sharing of sales information on a more real-time basis via Point-of-Sales (POS) system

- **Financial flow** – This refers specifically to cash. Traditionally, financial flow has been viewed as one-directional, from right to left for the payment of goods, services and orders received.

Various Barcodes

- Everyday you see barcodes – on *canned drinks, greeting cards, pens, air tickets, etc.*
- Used in almost every business.

Barcoding Technology

- Barcoding is one of the AIDC (Automatic Identification and Data Collection) technologies
- Reduces human involvement in data entry.
- Thereby reduces error and time.
- Type of barcode to use depends on the industry.
- Consumer products scanned at POS follow UPC/EAN standards, administered by GS1 organization.
- Barcodes can be read by optical scanners called barcode readers *or* as a scanned image by software.
- Series of black bars and white spaces of varying widths are printed on labels to unique identification.
- It measures reflected light and interprets the code into numbers and letters, passed on to a computer.

Barcodes - Common Areas

- Retailing:
  - Point-of-Sale (POS)
  - Sales management
  - Replenishment management
- Production control and management
- Logistics management
- Inventory management
- Hospitals, etc.

Barcodes – Industry Uses

- Uses:

✓ to track assets in an office - *every desk, computer, telephone, copier and desk accessory.*

✓ to track mail - *from the time it arrives in the mail room to the time it is delivered.*

✓ to help security guards - *identify every employee, every door they enter and every room they work in.*

✓ to manage the inventory/products *in a shop.*

✓ to manage and track - *your vehicle fleet and each driver*

Linear (1D) Barcode Symbologies

- The Universal Product Code (UPC) is a barcode symbology that is widely used in North America, and in countries including the UK, Australia, and New Zealand for tracking trade items in stores.

- Widely used UPC has **2** parts:

✓ The **machine-readable** bar code: the vertical lines and space.

✓ The **human-readable** 12-digit UPC number:

- The *first six (6)* digits identify the manufacturer. Within them, the first two or three digits represent the country of origin.
- The *next five (5)* digits are the item identification given to that product by the manufacturer. This allows a maximum of 99,999 products that they can make.
- The *12th* digit is a check digit

0 12345 67890 5

Manufacturer #
UCC Company Prefix

Product #

Check Digit

Linear (1D) Barcode Symbologies

- An EAN-13 barcode (originally European Article Number, but now renamed International Article Number even though the abbreviation EAN has been retained) is a 13 digit (12 + check digit) barcoding standard

EAN-13

- The less commonly used EAN-8 barcodes are used also for marking retail goods; however, they are usually reserved for smaller items, for example confectionery.

EAN-8

- Are UPC-A and EAN-13 the same? NO
- EAN = 0012345678905
  UPC = (0)012345678905

EAN

UPC

Linear (1D) Barcode Symbologies

- ITF-14 is the GS1 implementation of an Interleaved 2 of 5 bar code to encode a Global Trade Item Number. ITF-14 symbols are generally used on packaging levels of a product, such as a case box of 24 cans of soup. The ITF-14 will always encode 14 digits.

- Code 128 is a very high-density barcode symbology. The symbology includes a checksum digit for verification. (A special version of it called GS1-128 is used extensively world wide in shipping and packaging industries.) It is used for alphanumeric or numeric-only barcodes.

Linear (1D) Barcode Symbologies

- Code 39 is the first alpha-numeric symbology to be developed. The Code 39 barcode symbology supports 43 characters plus an additional character used as a delimiter or start/stop character.
- A check digit is not often used with Code 39 but a few critical applications may require one. The check digit is the modulus 43 sum of all the character values in the message. It is printed as the last data character.

Identification of Trade Items

- A trade item is any item (product or service) upon which there is a need to retrieve predefined information and that may be priced, ordered or invoiced at any point in any supply chain. This definition covers raw materials through to end-user products and also includes services, all of which have pre-defined characteristics.

- The trade items are numbered by a **Global Trade Item Number** (GTIN) using four data structures: GTIN-8, GTIN-12, GTIN-13 and GTIN-14. The choice of data structure depends on the nature of the item and on the scope of the user's applications.

- Since January 2005, North American users accept GTIN-13 Identification Numbers and EAN-13 Bar Codes. Prior to this time, companies selling goods in the American and Canadian markets were required to use a GTIN-12 data structure represented in a UPC-A or UPC-E Symbol.

GTIN Numbering Structures

GTIN-13 Data Structure

GS1 Company Prefix →	← Item Reference	Check Digit
N_1 N_2 N_3 N_4 N_5 N_6 N_7 N_8 N_9 N_{10} N_{11} N_{12}		N_{13}

GTIN-13: 5412345000259

GTIN-12 Data Structure

U.P.C. Company Prefix →	← Item Reference	Check Digit
N_1 N_2 N_3 N_4 N_5 N_6 N_7 N_8 N_9 N_{10} N_{11}		N_{12}

GTIN-8 Data Structure

GTIN-8 Prefix →	← Item Reference	Check Digit
N_1 N_2 N_3 N_4 N_5 N_6 N_7		N_8

GTIN-14 Data Structure

Indicator	GTIN of the items contained (without Check Digit)	Check Digit
N_1	N_2 N_3 N_4 N_5 N_6 N_7 N_8 N_9 N_{10} N_{11} N_{12} N_{13}	N_{14}

About GS1

Gepir Search

GEPIR (Global Electronic Party Information Registry) is a unique, internet-based service that gives access to basic contact information for companies that are registered users of GS1.

Available on the App Store

GET IT ON Google play

- GS1 Singapore is a not-for-profit organisation established in 1987 to implement and administer the global multi-industry GS1 standards-based system of automatic identification (using barcodes, 2D-codes and RFID - radio frequency identification) and communication for products, services, assets and locations.
- In Singapore, GS1 barcodes are used to capture over $5 billion worth of sales at retail point-of-sales (POS) terminals.
- GS1 identification numbers and barcodes permit organisations of any size to order, track, trace, deliver and pay for goods across the supply chain, anywhere in the world.
- GS1 Singapore is here to help Singapore companies become more efficient; our fundamental role apart from allocating GS1 company prefix numbers and Global Location Number, is also to help companies adopt world's best practices in supply chain management.

GS1 Singapore

Inside GTIN

✓ **GS1 Company Prefix**

- The first two or three digits N1, N2, N3 constitute the GS1 Prefix allocated by GS1 Global Office to each GS1 Member Organisation.
- It does not mean that the item is produced or distributed in the country to which the prefix has been allocated. The GS1 Prefix only denotes the Member Organisation that allocated the Company Number.

✓ **Item Reference**

- The Item Reference is composed typically of one to six digits.
- It is a non-significant number, which means that the individual digits in the number do not relate to any classification or convey any specific information. The simplest way to allocate Item References is sequentially, that is 000, 001, 002, 003, etc.

Inside GTIN

✓ Check Digit

The Check Digit is the last digit (rightmost) of the GTIN. It is calculated from all other digits in the number, in order to ensure that the bar code has been correctly scanned or that the number is correctly composed

✓ Indicator

This is only used in the GTIN-14 Data Structure. It takes the value 1 to 8 for fixed quantity trade items. The value 9 has a special usage for variable quantity trade items and the value 0 is considered a filler digit that does not change the number itself.

Check Digit Calculation

ID Key Format	Digit positions																	
GTIN-8											N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8
GTIN-12							N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}
GTIN-13						N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}
GTIN-14					N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}	N_{14}
GSIN		N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}	N_{14}	N_{15}	N_{16}	N_{17}
SSCC	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}	N_{14}	N_{15}	N_{16}	N_{17}	N_{18}
Step 1: Multiply value of each position by																		
	x3	x1	x3	x1	x3	x1	x3	x1	x3	x1	x3	x1	x3	x1	x3	x1	x3	
Step 2: Add results together to create **sum**																		
Step 3: Subtract the sum from nearest equal or higher multiple of ten = ***Check Digit***																		

Check Digit: GTIN-12 Example

- GTIN-12 id format:

0 84501 24031 8

UPC Barcode

- Step 1:

GTIN-12	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}
Multiply value of each position by	x3	x1	x3	x1	x3	x1	x3	x1	x3	x1	x3	

= 0*3+8*1+4*3+5*1+0*3+1*1+2*3+4*1+0*3+3*1+1*3

- Step 2: Accumulated result =42
- Step 3: Nearest Equal or Higher Multiple of 10 = 50
  Subtract from nearest multiple of 10 = 50-42 = 8
  Check digit = 8

Check Digit: GTIN-13 Example

- GTIN-13 id format:

8 716200 498678

EAN Barcode

- Step 1:

	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}
GTIN-13													
Multiply value of each position by	x1	x3	x1	x3	x1	x3	x1	x3	x1	x3	x1	x3	

8*1+7*3+1*1+6*3+2*1+0*3+0*1+4*3+9*1+8*3+6*1+7*3

- Step 2: Accumulated result = Sum =122
- Step 3: Nearest Equal or Higher Multiple of 10 = 130
  Subtract from nearest multiple of 10
  = 130-122 = 8
  Check digit = 8

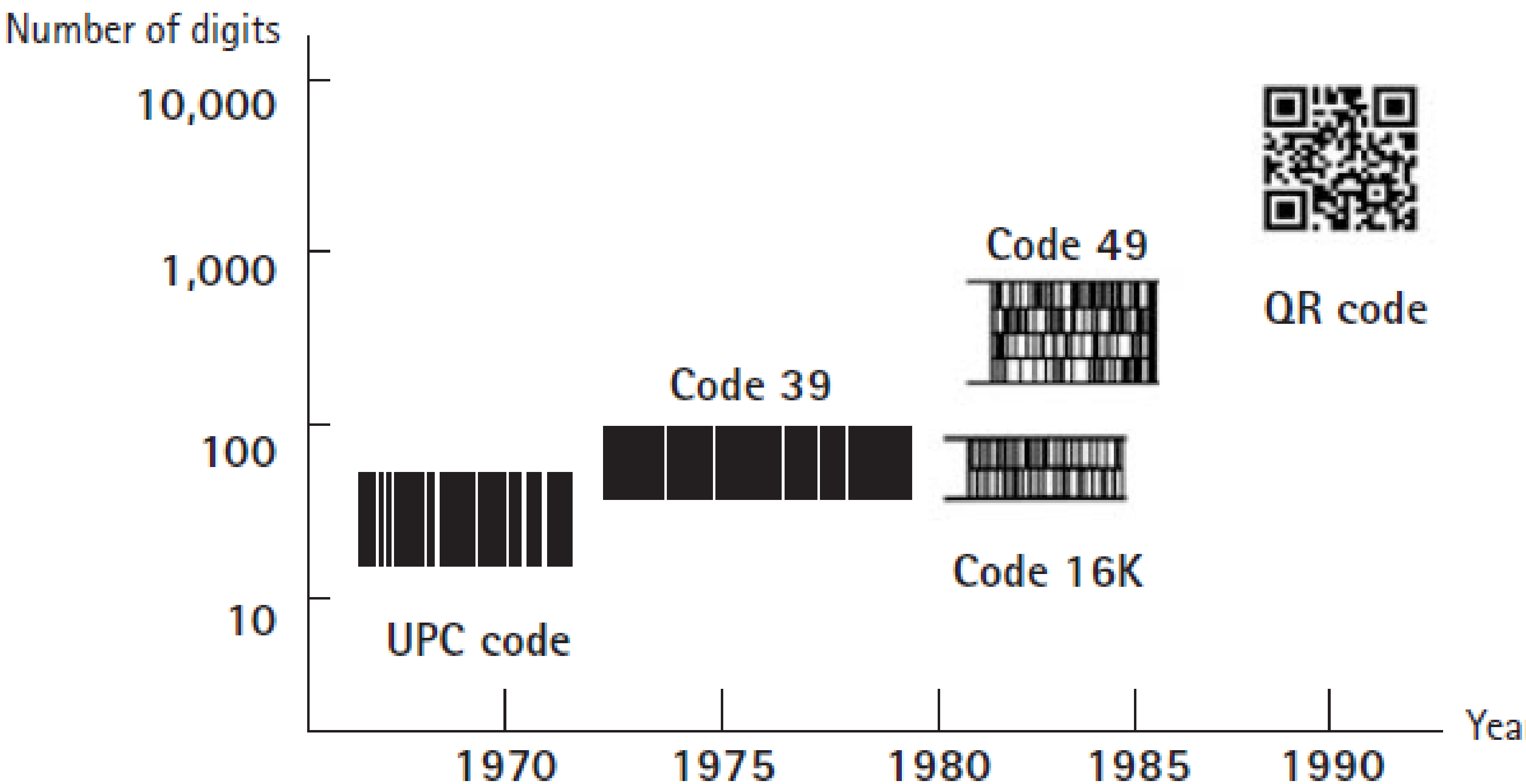
Check Digit: Other Examples

- **Other examples from worksheet:**

✓ **456104220021234556X**	**1**	**SSCC Barcode**
✓ **01010101010X**	**5**	**GTIN12**
✓ **120212020202X**	**2**	**GTIN13**
✓ **5212125X**	**8**	**GTIN8**

History of Barcode Symbology

- Two-dimensional symbols generally contain much more data amount when compared with linear symbols (approx.100 times more), and therefore require much longer data processing time and more complex process.



Types of 2D Barcodes

		QR Code	PDF417	DataMatrix	Maxi Code
Developer(country)		DENSO(Japan)	Symbol Technologies (USA)	RVSI Acuity CiMatrix (USA)	UPS (USA)
Type		Matrix	Stacked Bar Code	Matrix	Matrix
Data capacity	Numeric	7,089	2,710	3,116	138
	Alphanumeric	4,296	1,850	2,355	93
	Binary	2,953	1,018	1,556	
	Kanji	1,817	554	778	
Main features		Large capacity, small printout size High speed scan	Large capacity	Small printout size	High speed scan
Main usages		All categories	OA	FA	Logistics
Standardization		AIM International JIS ISO	AIM International ISO	AIM International ISO	AIM International ISO

2D Barcode Applications

How a mobile ticketing system works

1 Discover: *A movie-goer logs into the mobile phone version of a cinema's ticketing website (right), where he can check movie screening times, buy tickets and choose seats.*

2 Transact: *After choosing a seat, a movie-goer can proceed to pay with a credit card. After payment, a 2-D code ticket is sent via SMS (right) to his phone.*

3 Fulfil: *A movie-goer can either obtain the paper movie ticket by scanning a 2-D code at a kiosk or gain access by presenting the 2-D code ticket at the gantry (below).*

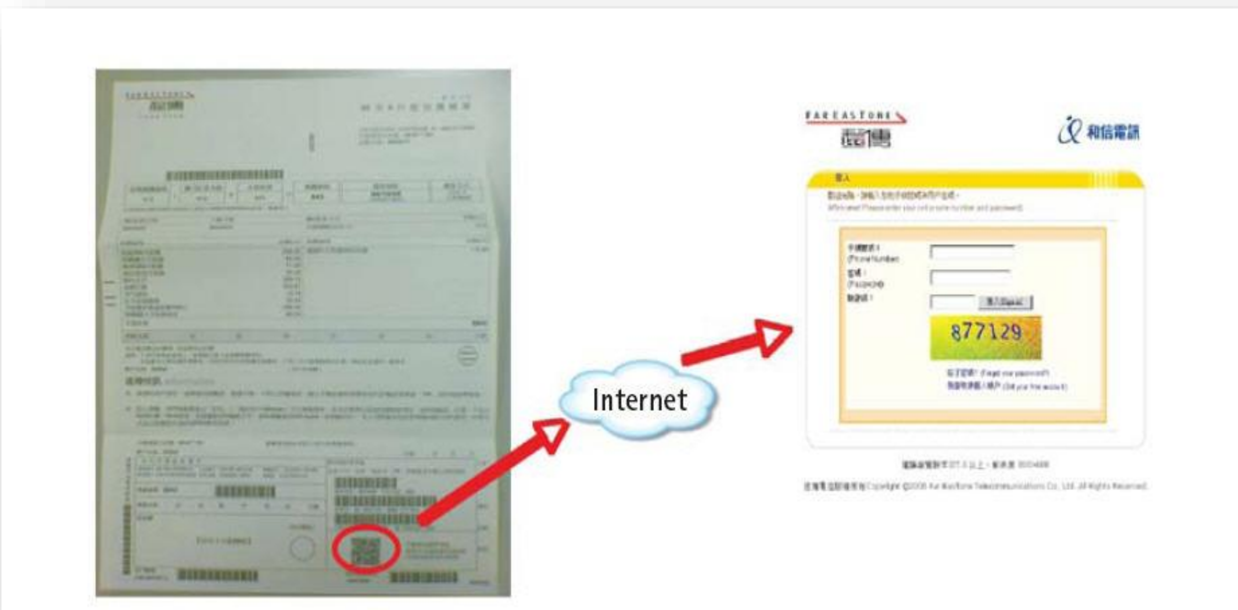
Shipping Control System for Garment Products

Mobile Ticketing

2D Barcode Applications

Jewelry Shop (France)

Bank process management (Thailand)



Payment Slips (Taiwan)

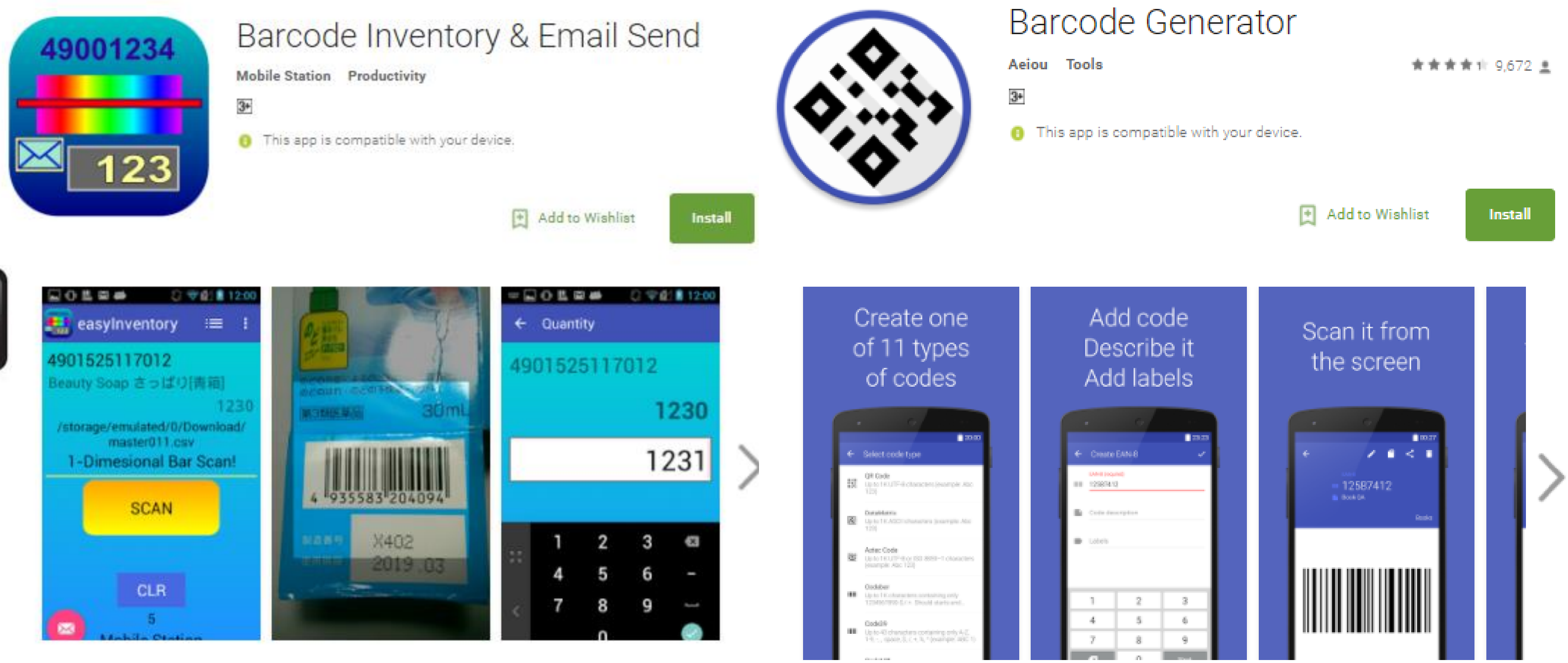
Advertisement (Japan)

Comparison 1D v.s. 2D barcodes

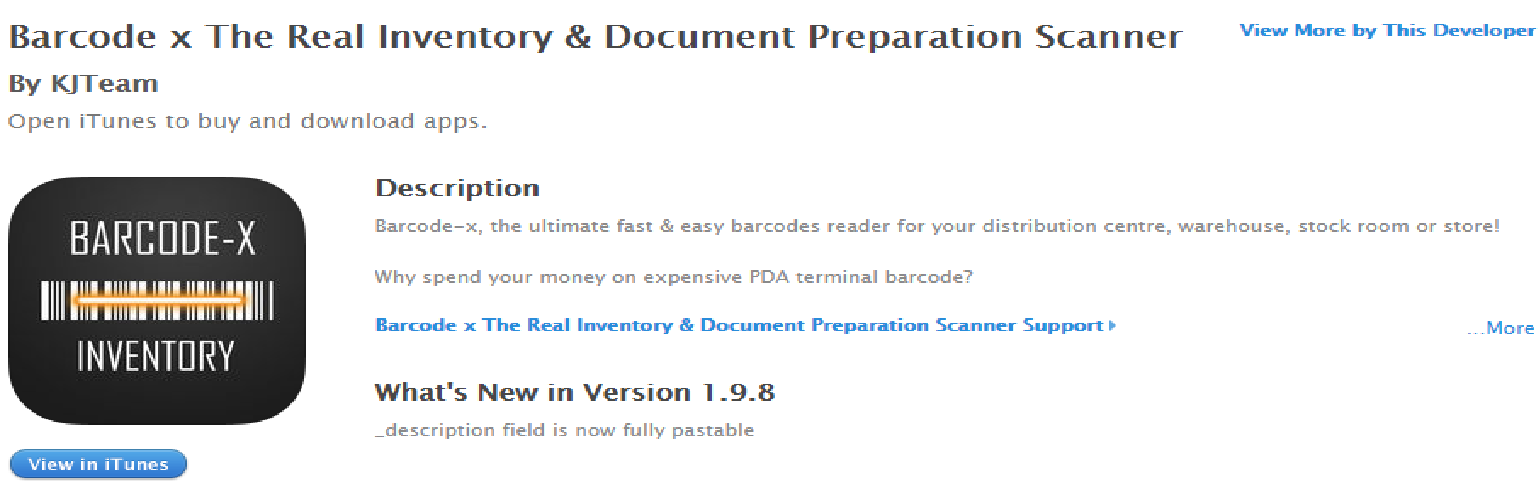
Code type	2D barcode	1D barcode
Data format	Alphabet, numeric, symbols, photo, voice, finger print, electronic signature	Alphabet, numeric, and symbols (Korean language is not allowed for coding)
Data storage capacity	About 2,000 bytes	About 20 bytes
Data density	High density	Low density
Symbol size	Square (minimization possible)	Symbol length increases as data amount is large (misreading is possible)
Reading out speed	Influenced by data amount	Fast
Reading direction	360 degree (independent of direction)	Only in one direction
Bridging to DB	Not necessary (code itself serves as a data)	Necessary (code serves as a data key)
Error detection and fault correction function	With error finding and restoration function	Error detection is possible (restoration not possible)
Certification of electronic digital signature	Available	Not available
Encryption	Required	Not required

Examples of mobile apps for barcoding

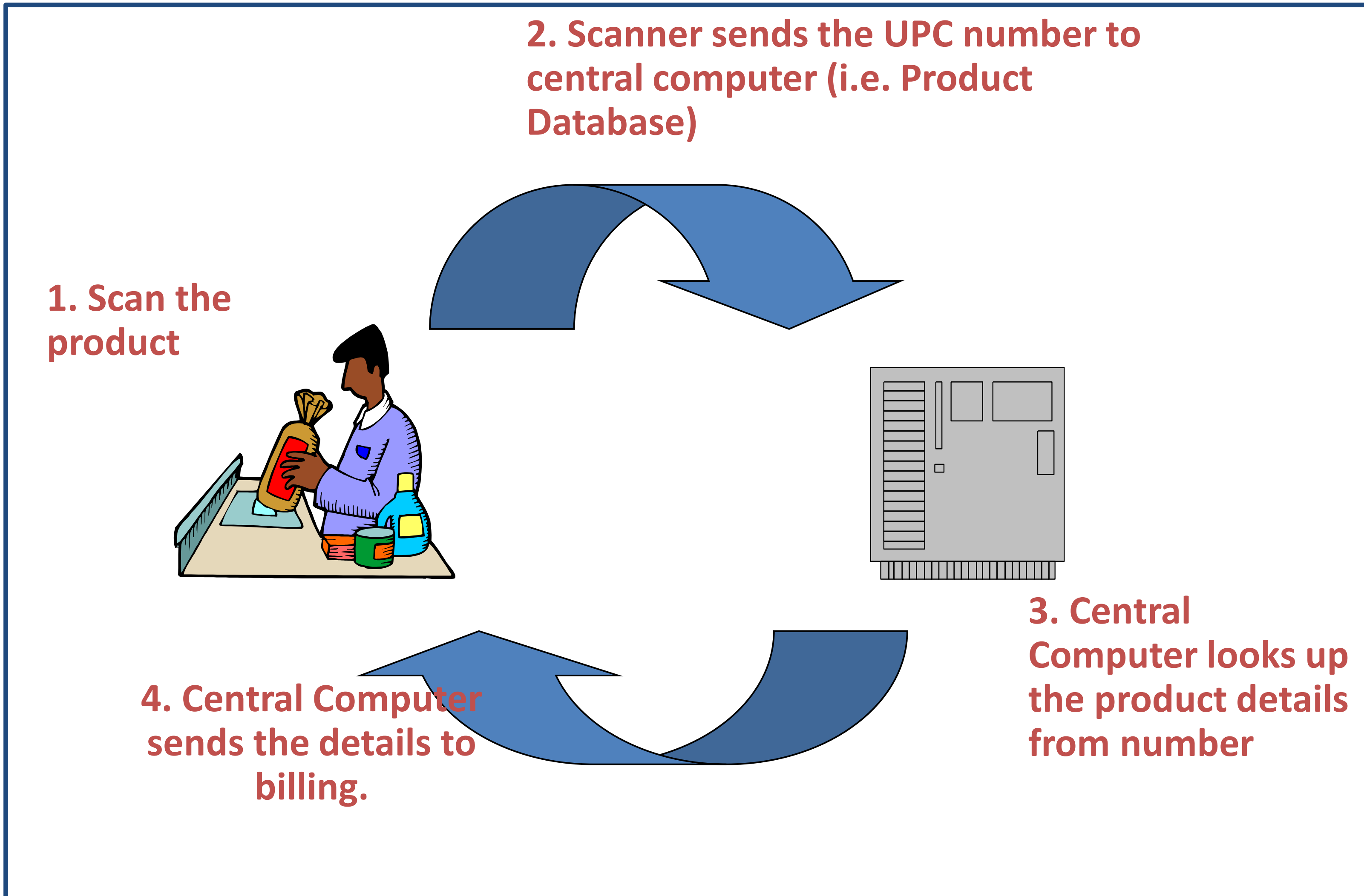
GET IT ON Google play



Available on the App Store



Information Flows in a Barcoding System



Problem Statement

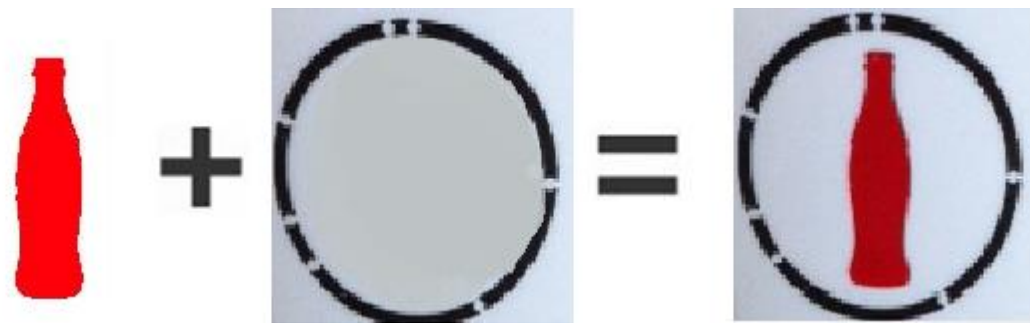
- To improve throughput and traceability through the use of barcodes, he can consider adopting GS1 Barcode system such as the following linear barcodes: UPC-12, EAN-13 or ITF-14
- 2D barcodes might not be really required:
- 1D barcodes might be able to solve the issues. Suppliers barcodes can be used without replacing, by maintaining the related data in his Database.
- If the goods do not come with any barcodes, he can consider pre-generating barcodes that he can scan when these goods arrive, to speed up the accounting process
- He can choose to use the conventional barcode scanner, or use some of the mobile applications that have the capability to scan and save/ email the information

Going Further - SnapTag

- A picture with a circle around it is a SnapTag. A SnapTag is your logo but interactive, are customized QR codes for business.

Brand Logo + Code Ring™ = Branded SnapTag

Your SnapTag with marketing campaign



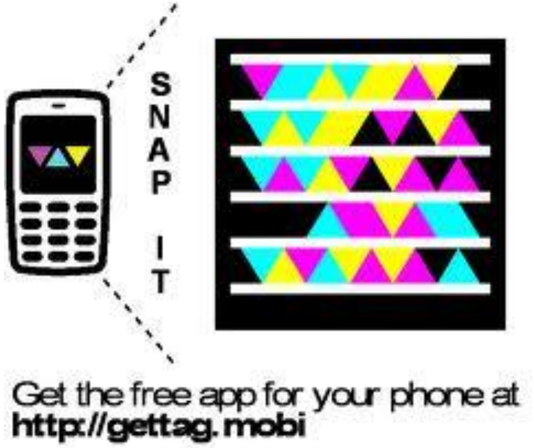
- Instead of just taking people to a link, these designer QR codes opened up whole new lines of interactive communication.
- SnapTags provide marketers an opportunity to engage consumers and activate a sustainable mobile relationship with them.

Going Further - SnapTag

- One logo. One thousand different ways to interact with your customer.
- Unique Code Ring Technology.
- The breaks in the Code Ring can be moved to thousands of different positions creating a new code with each position. Each code can be assigned a unique response.

High Capacity Color Barcode (HCCB)

- HCCB is the name coined by Microsoft for its technology of encoding data in a 2D “barcode”.
- Clusters of colored triangles instead of the square pixels traditionally associated with 2D barcodes.
- Data density is increased by using a palette of 4 or 8 colors for the triangles, although HCCB also permits the use of black and white when necessary.
- The technology was created by Gavin Jancke, an engineering director at Microsoft Research.



WIMO Markers

- Mobile app with 3 different modes of content trigger (UPC/Barcodes, WiMO Markers and WiMO enabled images)
- Example: Sony Pictures launched a campaign enabling moviegoers to interact with 3D content and games via their mobile devices. Moviegoers can use their smartphones to scan the logo and be directed to a mobile site created exclusively for the program.

Facial Codes

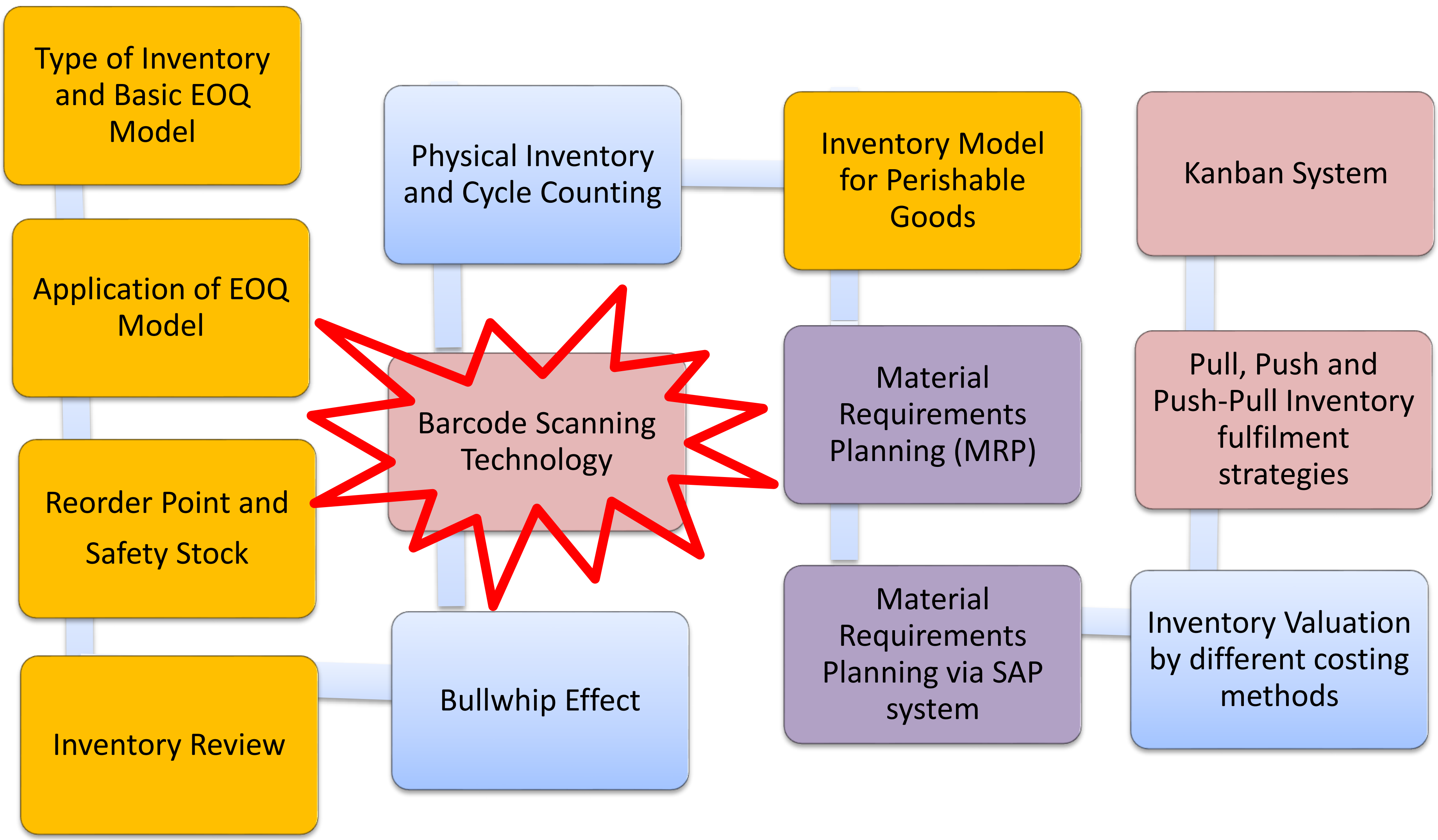
- Facial Codes’ is a series that explores the idea of interactivity in art.
- Easily decoded at high speed with a scanner in mobile phones.
- Each code is uniquely different and contains different messages.
- Just Scan them!

Learning Objectives

- Describe the purposes and applications of barcodes
- Identify the standards used for barcoding
  - GS1 Barcoding Symbologies and format

    - EAN, UPC, ITF-14, Code-128, Code-39
  - Barcode verification: Check Digit calculation
  - Linear (1D) Barcodes versus 2D Barcodes
- Describe the activities of a supply chain and the 3 flows in a supply chain
  - Information, Material, Financial
- Describe the flows in a barcoding system

E217 Inventory Management Topic Flow



Problem 07

Performance

SCHOOL OF ENGINEERING

E217 – Inventory Management

E217 Inventory Management Topic Tree

- **E217 Inventory Management**
  - **Strategic Role** of Inventory Management
    - Physical Inventory and Cycle Counting
    - Bullwhip Effect
    - Inventory Valuation
  - **Inventory Control Methods**
    - **Independent-Demand Items**
      - Basic EOQ Model
      - Application of EOQ Model
      - Safety Stock and Reorder Point
      - Inventory Review Policies
      - Inventory Model for Perishable Goods
    - **Dependent-Demand Items**
      - Material Requirements Planning (MRP)
      - Material Requirements Planning (MRP) via SAP
  - **Inventory Control System**
    - Barcode Scanning Technology
    - Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
    - Kanban System

Why Use Key Performance Indicators?

- It shows where improvements need to be made and if improvements actually happened.
- A set of quantifiable measures that a company or industry uses to gauge or compare performance in terms of meeting their strategic and operational goals.
- KPIs combine real, live data with your business objectives and strategies to provide insight into your performance.
- A comparison of actual results against a pre-specified benchmark.
- KPIs vary between companies and industries, depending on their priorities or performance criteria.

What is a Good KPI ?

- Measured frequently (for example, weekly, monthly, yearly)
- Must be linked to the strategic objectives (things that matter the most)
- All staff understand the measure and what corrective action is required
- Responsibility can be tied down to the individual or team
- Has a positive impact – it affects all other performance measures in a positive way
- A KPI has to be suitable for the specific business, industry and organization and related to the targets on the long run
- Easy to quantify
- Comparable over time
- Based on valid data

KPI Categories

- Direct: the raw facts and actual raw data value as measured (e.g. sales volume, stockouts, etc.)
- Percent/ratio: the comparison of the changes in performance of one value relative to the same value at a different time, geography, etc. (i.e. percentage change in sales vs. last year
- Index: a combination of several separate measures added together that result in an overall indicator of performance (i.e. sales growth)
- Composite average: the addition of the weighted averages of several similar measures that result in an overall composite indicator of performance (i.e. customer satisfaction composite is a mixture of results from surveys, focus groups and product returns)
- Statistics: multiple measures such as mean, variance, standard deviation that capture the spread and distribution of the performance measures (e.g. sales distribution by demographics, geography, channel)

KPI Examples

- SBS Buses:
  On-time bus arrival, Occupancy ratio, Mileage, etc.

- Quality control department of a manufacturing plant:
  no. of units rejected at Final Testing stage, no. of incidences of product mix at Packaging stage, etc.

- RP – IT services
  system availability/downtime, network speed, accessibility during peak hours, no. of data/network breaches, etc.

- Call Center/ Customer service department of a bank:
  % of calls answered in the first minute of a customer's call, duration of waiting time for each customer call, Average handle time, number of callers that hang up before they are served, etc.

KPI differs by industry:

- Inventory Turns is a very important KPI for Manufacturing and Distribution Companies.
- Inventory Accuracy is an important KPI for companies that carry inventory.
- For Retail, the average dollars per sale is a good KPI.
- For Accounts Receivable departments, the number of AR Days outstanding is important.
- For Managers, employee turnover is an important KPI. Etc.

Inventory Turnover

- Inventory Turnover (also known as Inventory Turns) is how fast or slow at which inventory flows through the supply chain.

$$\text{Inventory turns} = \frac{\text{Cost of goods sold}}{\text{Average aggregate value of inventory}}$$

- It shows how many times in one accounting period the company turns over (sells) its inventory.
- The higher the inventory turns, the faster the inventory is being moved out and the company gets the cash back faster
- On the other hand, an extremely high inventory turnover ratio, which indicates that the firm is keeping very little stock.
- It can also mean that the firm is unable to fulfil large and sudden orders, and is missing sales in some instances.

Inventory Turnover – Today's Case

- Inventory Turns = \$100 million / \$10 million = 10
- The company sold and replaced its inventory 10 times in the 12 month period.

- Instead of 10 inventory turns, if the company increases to 12 inventory turns per year
  - Inventory Turns = COGS / Average Inventory
  - Average Inventory = \$100 million / 12 = \$8.333 million
- Reduction in Inventory = \$10 million - \$8.333 million
- By increasing to 12 inventory turns, inventory reduction or savings would be \$1.667 million.

- The appropriate Inventory Turnover that a company should have depends on the specific industry
- We should compare the Inventory Turnover against competitors and the average industry benchmark

Inventory Days of Supply

- A measure of the equivalent number of days of inventory on hand, based on usage.

  Days of Supply = No. of Operating days in year / Inventory Turns

  = 365 / 10 = 36.5 days

$$\text{Days of supply} = \frac{\text{Average aggregate value of inventory}}{(\text{Costs of goods sold})/(365\text{ days})}$$

- The company has 36.5 days worth of inventory on hand.
- Inventory turnover VS days/weeks of supply: They both measure the same thing.

- Days of Supply just gives you another way to think of it.

✓ *Instead of saying, "I turn my inventory over 10 times a year", you would say "I've got 36.5 days' worth of inventory on hand."*

✓ *Instead of saying, "I turn my inventory over 12 times a year", you would say "I've got 30.42 days' worth of inventory on hand."*

- It tells you how soon you will run out, if you don't re-order.

Other KPIs

Net-Sales-to-Inventory Ratio

- Net Sales to Inventory ratio = Net Sales / Average Inventory
- By comparing inventory to sales, this ratio indicates whether there is too little or too much inventory to support the given level of sales.

Total Asset Turnover

- This ratio compares the total assets to revenue (where revenue is the income from sales of products and services)
- This is a gauge of the company's efficiency is using all its assets.

Current Ratio

- Current Ratio = Current Assets/Current Liabilities
- This ratio tells us whether a business is able to settle its current liabilities from its current assets at the balance sheet date.

Need for Accurate Inventory Records

- Inventory = CA$H
- Control Over Inventory = Control Over Costs
- Inventory Record Accuracy (IRA) is a measure of how closely official inventory records match the physical inventory.
- Incoming and outgoing record keeping must be accurate.
- Accurate record is a critical ingredient in production and inventory systems.
- Necessary to make precise decisions about ordering, scheduling, and shipping.
- A measure of how closely official inventory records match the physical inventory.
- Errors lead to wrong planning and delays.

WHY DOES STOCK CONTROL WORK IN SOME SITUATIONS BUT NOT IN OTHERS?

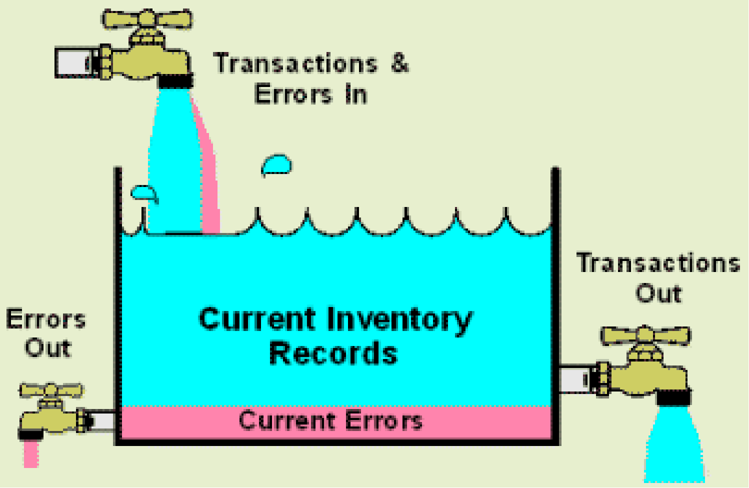
Causes to Errors in Inventory Records

Inbound transactions

- *Receiving*
- *Items misplaced on arrival*
- *Put away*
- *Scan errors (Barcoding, RFID, etc.)*

Outbound transactions

- *Products picked from wrong locations*
- *Shipments*
- *Scan errors, etc.*

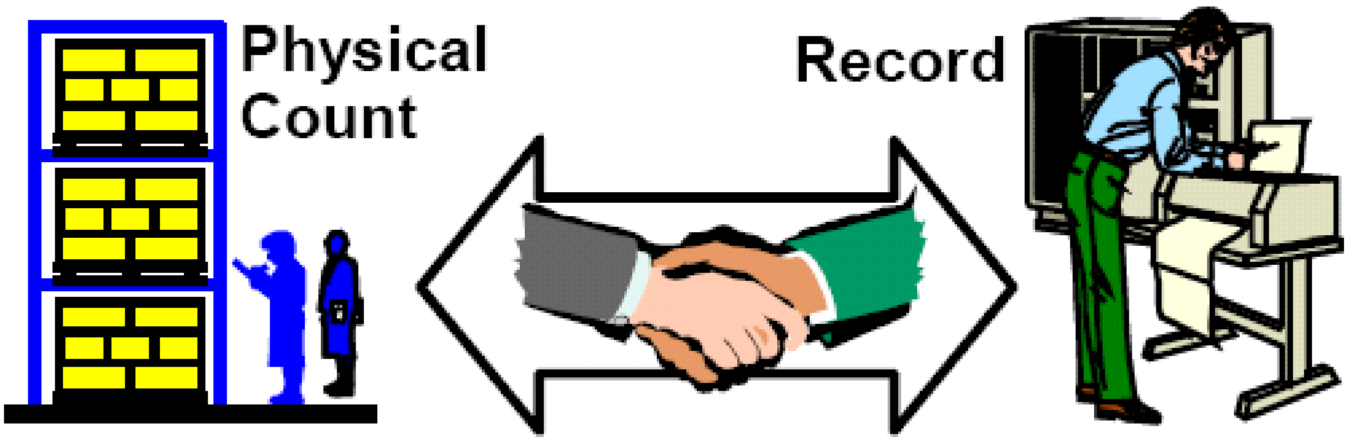


Others

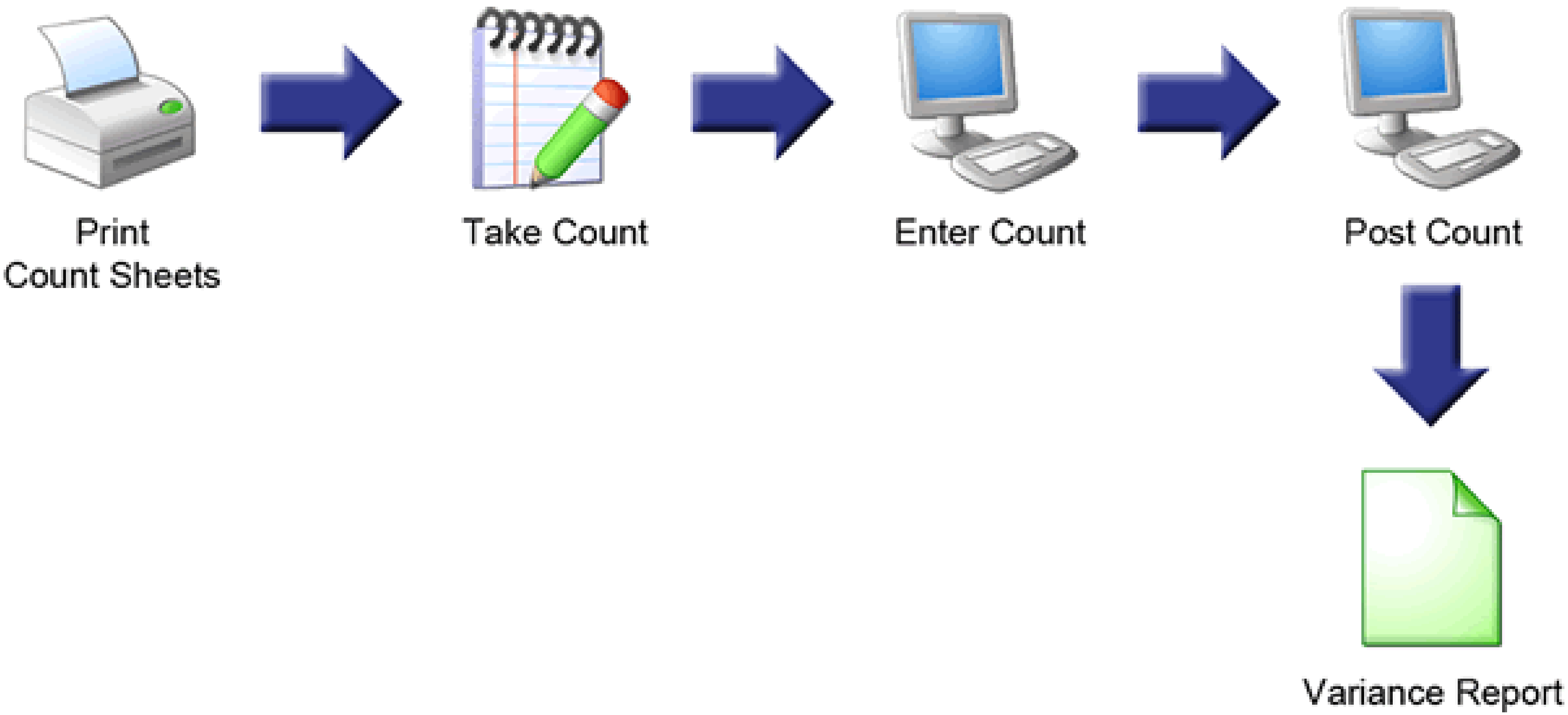
- *Bad units of measure*
- *Conversion errors*
- *Internal goods transfer*
- *Theft*
- *Extra material issue*
- *"Loans" to Sales, Engineering, R&D etc.*

Why Physical Inventory Counting?

- To identify and correct inventory record errors
- Periodic Physical Counting and Cycle Counting, both are manual processes
- Accurate on-hand quantities are essential for effective planning and minimizing inventory investment



Typical Inventory Counting Process



Periodic Physical Inventory Counting

- Periodic physical counting of inventory:
  - ✓ Annually
  - ✓ Semi-annually
  - ✓ Quarterly

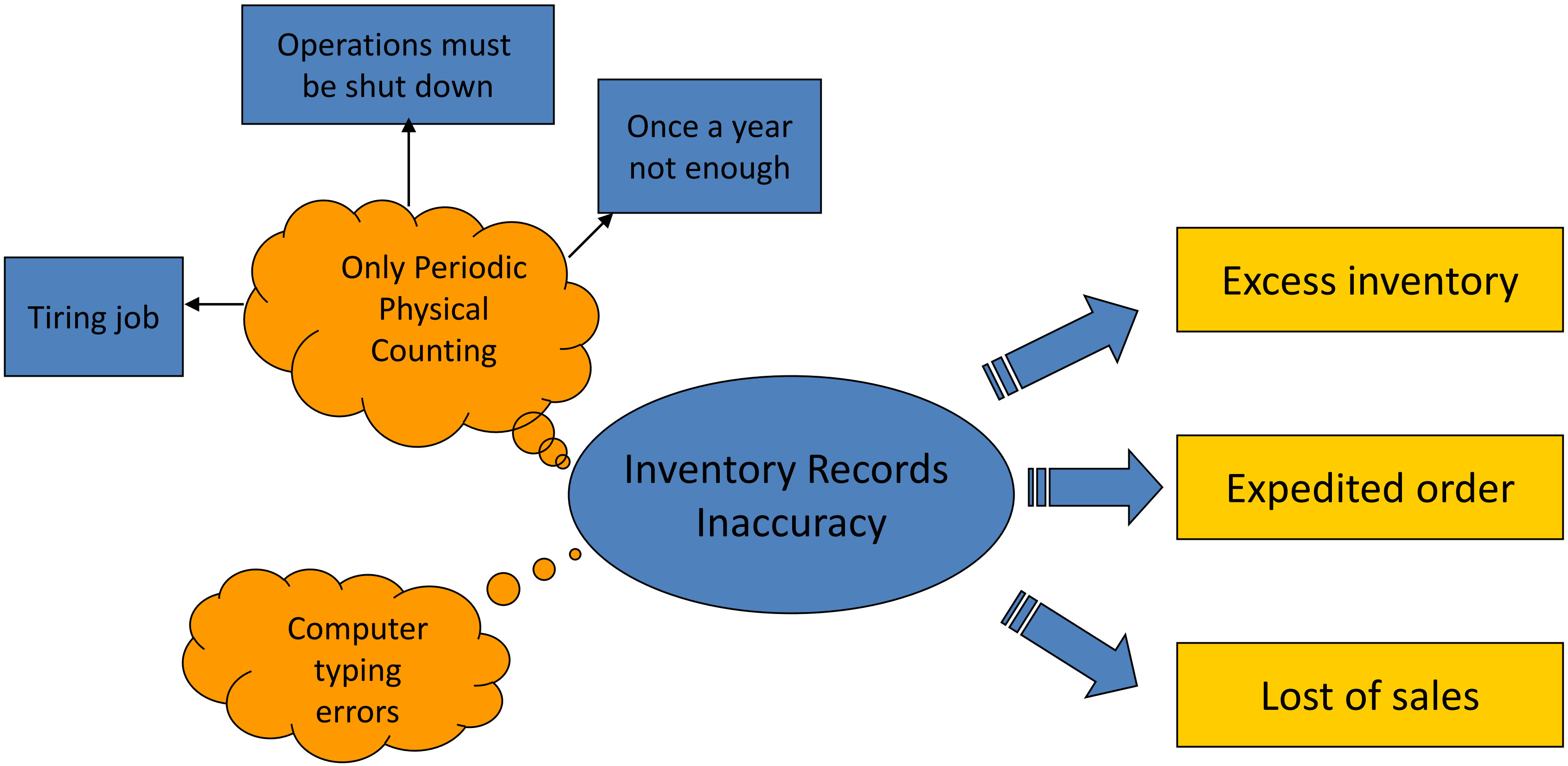
"How can the whole *Internet* be closed for inventory?"

- Expensive process

- Shut down production / shipping – few days to even a week.

- Material/goods remained unidentified or misidentified for long time

Periodic Physical Inventory Counting



Alternative Approach: Cycle Counting

- “*A method for auditing inventory accuracy and reconciles errors on a cyclical schedule rather than fixed once a year counting*.”
  Operations Management; by Roberta S. Russell and Bernard W. Taylor III

- A dynamic inventory audit that allows for real time accuracy of inventory items.
- Can be tailored to focus on items with higher value or higher movement.

- Major Benefits:
  - ✓ *Eliminates shutdowns and interruptions*
  - ✓ *Eliminates annual inventory adjustment*
  - ✓ *Trained personnel audit inventory accuracy*
  - ✓ *Allows causes of errors to be identified and corrected*
  - ✓ *Maintains accurate inventory records*

Two Main Types of Cycle Counting

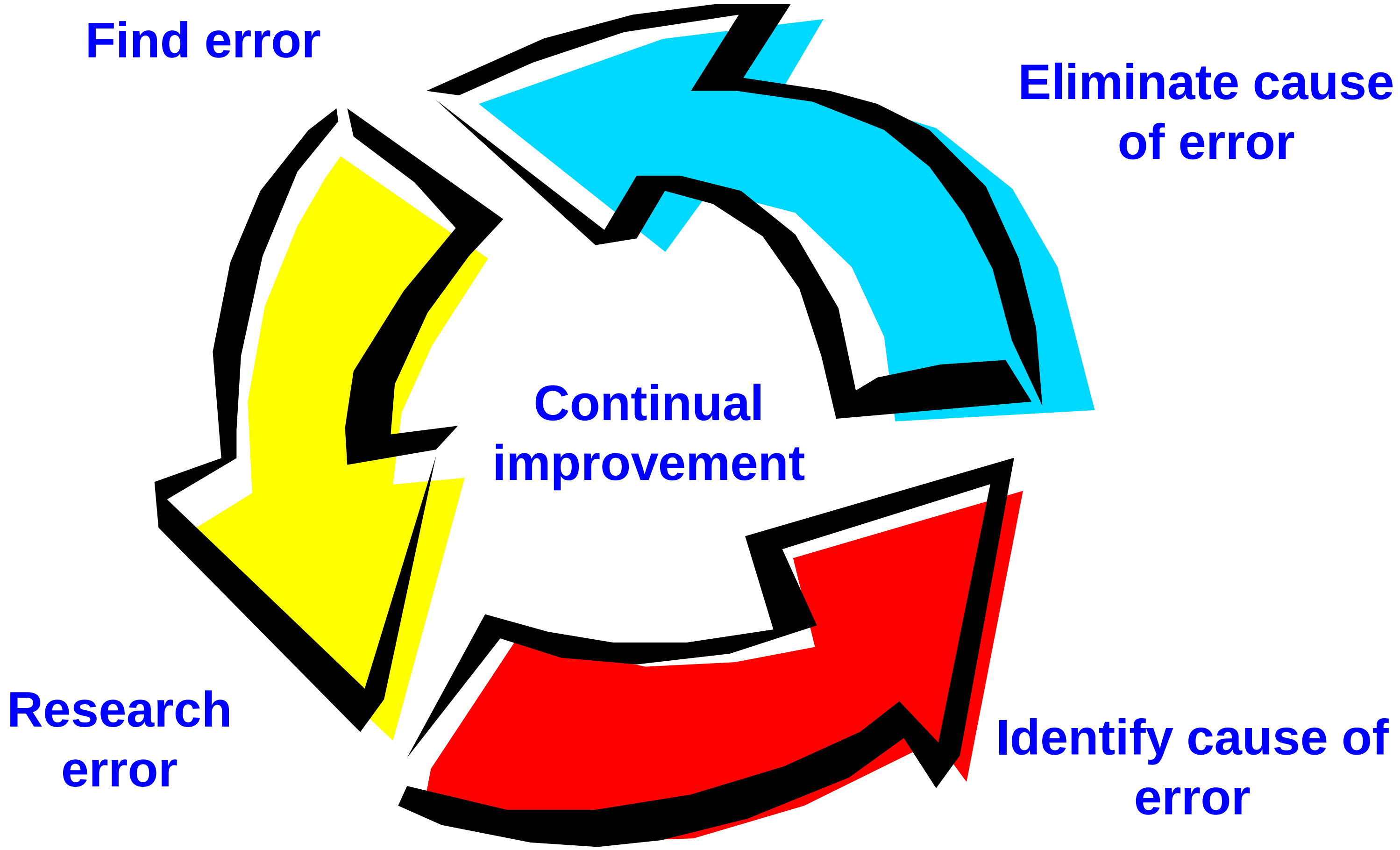
Random Sample Cycle Counting

- When a number of items to be counted are chosen at random, this process is known as random sample cycle counting.
- When a company's warehouse has a large quantity of similar items, they can randomly select a certain number of items to be counted. The count can be performed each day or workday so that a large percentage of the items in the warehouse are counted in a reasonable period.

ABC Cycle Counting (The Ranking Method)

- This method uses the Pareto principle as the basis for this technique.
- Before a cycle count can be performed, the items in the warehouse have to be identified as A, B or C items. Once each of the items in the warehouse has been assigned a category, the number of times each category should be counted needs to be determined.
- The items with the highest sales value should be counted more frequently than items that have low sales. Therefore, an item that has been assigned as an "A" item will be counted more frequently than items that are designated as "C" items

Cycle Counting Process



Cycle Counting - ABC Analysis

- ABC analysis is based on Pareto Principle.
- Pareto Principles is also known as “80/20 Rule”
- Cycle count inventory by percentage of inventory value
- ABC analysis classifies inventory into three classifications on the basis of dollar volume / value.
- The idea is to focus resources on the critical few and not on the trivial many.
- Counting frequency can be determined by ABC Analysis

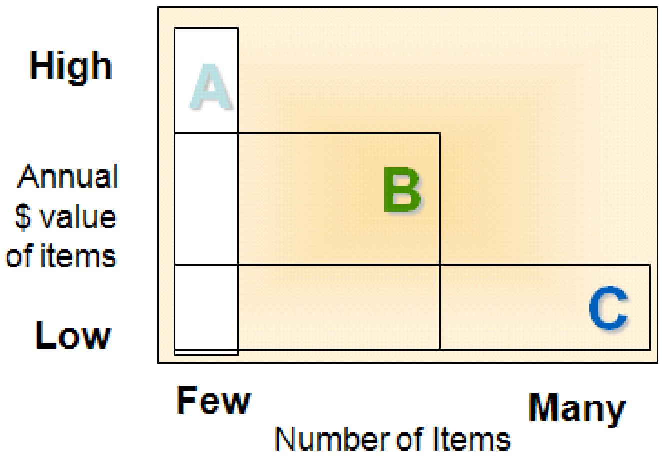
Cycle counting - ABC Analysis

- Divide on-hand inventory into three (3) classes based on annual $ volume (annual sales value).
- Annual $ Volume = [Annual Demand x Unit Cost (*alternately Moving Average Price*)]

- "A" class - Most important.
  Highest value / highest movement.

- "B" class - Less important.
  Less value / less movement.

- "C" class - Least important.
  Least value / least movement.



- Distribution may vary, from organization to organization.

- Counting the faster-moving / high $ items more frequently than the slower-moving/low $ items.

How Does ABC Analysis Work?

1. Determine the dollar volume (sales value)
2. Rank items.
3. Calculate the percentage dollar volume for each item.
4. Determine the cumulative percentages for number of items and dollar volume
5. Classify items as A, B, C, etc.

- ✓ Focus on “A” items.
- ✓ Give tighter physical control of “A” items.
- ✓ Forecast “A” items more carefully.
- ✓ Consider “B” items only after “A” items.
- ✓ Consider “C” items only after “B” items.

ABC Analysis

- Benefits:
  - ✓ Strict control of high dollar volume items
  - ✓ Higher inventory control level at minimum cost
  - ✓ Leads to inventory turnover and service level increases
  - ✓ Resources are better allocated to control efforts.

- Drawbacks:
  - ℘ Less control over B, C, (and remaining) items
  - ℘ Not an “all-purpose” inventory control method
  - ℘ Profit not necessarily maximized

Today's Problem - Determining ABC Items

Item Number	Inventory	Annual Demand	Unit Price S$	Value	% Value Usage	Cumulative	Class
CA885	300	2500	$2,750.00	$6,875,000	52.88%	52.88%	A
CA894	130	700	$2,500.00	$1,750,000	13.46%	66.35%	A
CA886	50	500	$1,200.00	$600,000	4.62%	70.96%	B
CA889	3000	20000	$25.00	$500,000	3.85%	74.81%	B
CA882	600	6000	$80.00	$480,000	3.69%	78.50%	B
CA884	1000	10000	$40.00	$400,000	3.08%	81.58%	B
CA891	1000	8900	$44.00	$391,600	3.01%	84.59%	B
CA883	1000	7000	$52.00	$364,000	2.80%	87.39%	B
CA892	980	9800	$35.00	$343,000	2.64%	90.03%	C
CA887	70	7000	$48.00	$336,000	2.58%	92.61%	C
CA881	1800	18000	$18.00	$324,000	2.49%	95.10%	C
CA888	150	9000	$30.00	$270,000	2.08%	97.18%	C
CA893	250	8000	$20.00	$160,000	1.23%	98.41%	C
CA880	1000	12000	$12.00	$144,000	1.11%	99.52%	C
CA890	1500	12500	$5.00	$62,500	0.48%	100.00%	C
			Total Annual Usage	**$13,000,100**			

Determining Counting Frequency

By usage

- Items more frequently accessed should be counted more often, irrespective of value
- Logical inventory zones can be set up to distinguish items depending on how frequently they are touched
- Volume consumed, volume transacted or volume moved are all ways of determining

Hybrid

- Most cycle counting frequencies are determined first by a computer running Pareto-like or frequency analysis, and then changing the count frequency as needed per item.

Counting Schedule

- Count physical products to verify inventory records:

  ✓ Count “A” items - most frequently
  (for example, once every month).

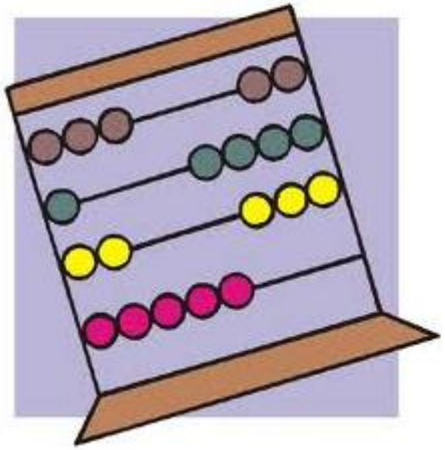
  ✓ Count “B” items - less frequently (every three months).

  ✓ Count “C” items - least frequently (once a year).

- Varies from company to company.

When to Cycle Count ?

- When an order is placed
- When an order is received
- When the inventory record reaches zero
- When a specified number of transactions have occurred
- When an error occurs
- By and large, postpone all counts to the last possible moment when there is no movement of records or items:
  - ✓ *At end of business day*
  - ✓ *Prior to start of day*
  - ✓ *Over the weekend*
  - ✓ *During the slowest shift*
  - ✓ *You would rather count the left or right?*



Today's Problem – Number of Counts

- Based on current company policy:
  - "A" Rank Items 12x per year
  - "B" Rank Items 4x per year
  - "C" Rank Items 1x per year

Item Classification	No. of Items	Counts per year	No. of Counts
A	2	12	24
B	6	4	24
C	7	1	7

- It allows the company to work out the desired number of counts for each product.

Tolerance Level

- An inventory record should be considered accurate if it matches the physical count within a reasonable tolerance.
- A tolerance level for each ABC classification should be defined. These tolerances should be based on the expected inventory accuracy levels.
- The larger the tolerance level allowed, the lower the overall inventory accuracy achieved.
- The calculation of inventory record inaccuracy:

  Inventory Record Inaccuracy(%) = [(Physical Count – Inventory Record) / Inventory Record] X 100%

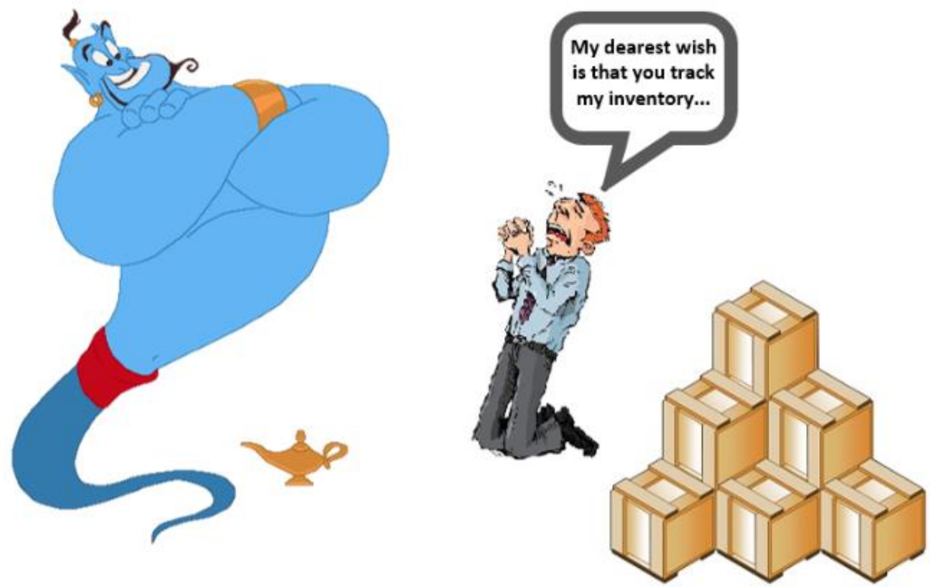
Tolerance Level

- The inventory inaccuracy for CA885, which is a Class A item, is (280-300)/300 = -6.67%.
- This is not acceptable for a Class A item (tolerance level should be ±1.0%.

- The causes of the inaccurate records, then take actions to eliminate these causes:
  - ✓ Poor training of people in materials movement
  - ✓ Bad units of measurements
  - ✓ Theft
  - ✓ Obsolescence
  - ✓ Poor security
  - ✓ Inadequate storage space
  - ✓ Untimely reporting of transactions

Going Further – Success Factors

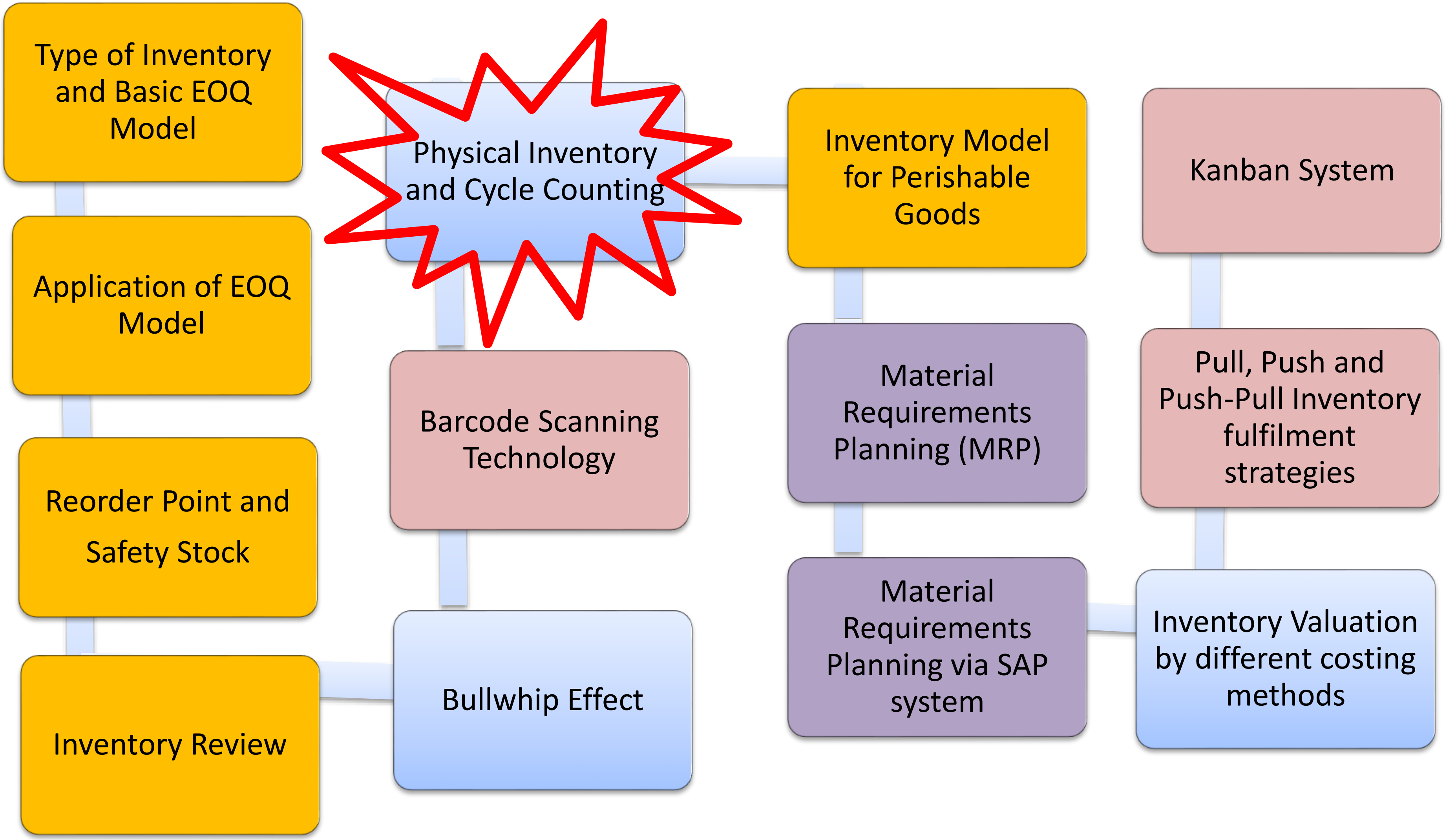
- ✓ Set the count date/schedules
- ✓ Bar code readers to speed up the counting process
- ✓ Count cards / Count sheets for information recording
- ✓ Determine who will count
- ✓ Order the necessary supplies
- ✓ “Clean up” your warehouse or freeze transactions



Learning Objectives

- Describe the purpose of using the Key Performance Indicator (KPI)
- Calculate and analyse the impact of KPIs (Inventory Turnover, Days of Supply) for a given business case-study
- Recommend effective inventory reduction strategies for a given business case-study
- Understand the inventory record accuracy
- Understand the importance of physical inventory checks, and the difference between physical counting & cycle counting
- Understand ABC Cycle Counting
- Perform ABC classification and determine the counting schedule

E217 Inventory Management Topic Flow



Problem 08

Crunch Muffins

E217-Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

- **E217 Inventory Management**
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    - Physical Inventory and Cycle Counting
    - Bullwhip Effect
    - Inventory Valuation
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      - Inventory Model for Perishable Goods
    - **Dependent-Demand Items**
      - Material Requirements Planning (MRP)
      - Material Requirements Planning (MRP) via SAP
  - **Inventory Control System**
    - Barcode Scanning Technology
    - Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
    - Kanban System

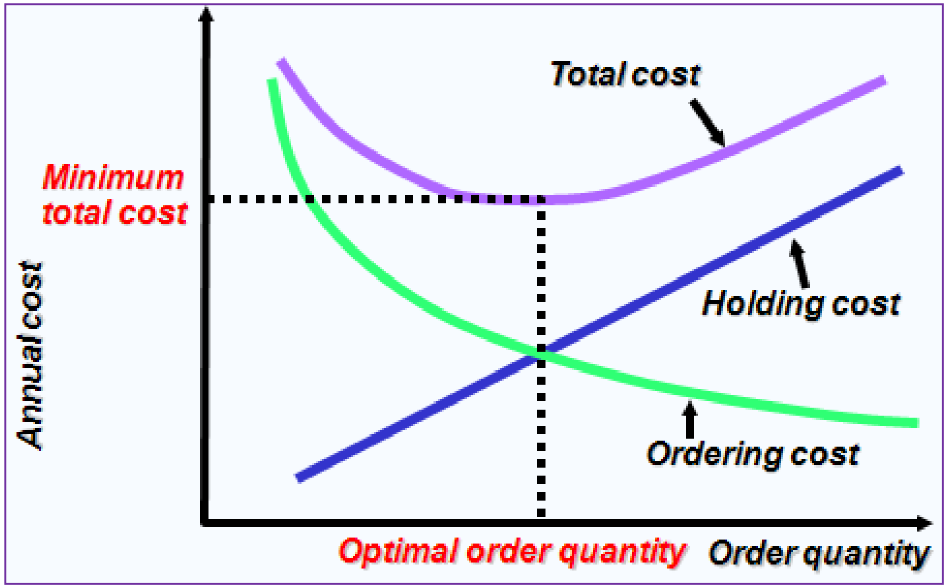
Perishable Goods

- Perishability ≠ Obsolescence
- Perishability refers to physical deterioration or expiry of the product but demand continues.
- Obsolescence implies there is negligible further demand for the SKU. These products are either sold or scraped.
- When demand is uncertain:
  Order less: cannot satisfy the customer demand
  Order more: over-stock means not just inventory holding cost but the total loss of the products
- Examples of Perishable Commodities
  - Bread, vegetables, fresh meat, flowers, Mini Sushi Bento, magazines, etc

EOQ?

No!

- EOQ is to balance ordering cost and holding cost
- For perishable commodities, inventory holding cost is not a major concern and reorder point is determined by when the perishable 'expires'



Safety Stock?

- Safety stock means that certain amounts of **same** products are always stored for unpredicted demand.
- Perishable commodities cannot have safety stock

No!

Demand Frequency and Probability

- Perishables can have very uncertain demands
- Use historical data to estimate the range of demands and their distribution.

Demand	Demand Freq	Demand Probability
90	2	0.02
91	3	0.03
92	6	0.07
93	7	0.08
94	8	0.09
95	10	0.11
96	11	0.12
97	9	0.10
98	9	0.10
99	8	0.09
100	6	0.07
101	5	0.06
102	4	0.04
103	2	0.02
	90	1.00

Frequency

- How often a certain demand occurs during a particular period of time.

Demand Probability

- The **chance** of a certain demand occurs during a particular period of time.

Cab Fare Question

- In a week (5 days), you take a cab to school every day.
- You pay S$20 on Monday and Thursday, S$22 on Tuesday and Wednesday and S$15 on Friday. What is the frequency of paying the different cab fares?
- What is the probability of you paying each specify amount of the cab fare?

Cab Fare (S$)	Frequency	Probability
20	2	0.4
22	2	0.4
15	1	0.2

Expected cab fare:

E(cab fare) = 0.4x20 + 0.4x22 + 0.2x15 = S$19.8

Decision Table Analysis

If selling price is $2.50 and cost price is $1, order quantity and demand vary:

If order quantity > demand

- Profit = demand x $2.50 – order quantity x $1

If order quantity ≤ demand

- Profit = order quantity x ($2.50 - $1)

Payoff Table (Example)

	Demand		
Order Quantity	164	165	166
164	164x1.5	164x1.5	164x1.5
165	164x2.50 -165x1	165x1.5	165x1.5
166	164x2.50 -166x1	165x2.50-166x1	166x1.5

Decision Table Analysis

	Demand	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Frequency	2	3	6	7	8	10	11	9	9	8	6	5	4	2
	Demand Prob	0.02	0.03	0.07	0.08	0.09	0.11	0.12	0.10	0.10	0.09	0.07	0.06	0.04	0.02
Order Quantity	90	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0
	91	134.0	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5
	92	133.0	135.5	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0
	93	132.0	134.5	137.0	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5
	94	131.0	133.5	136.0	138.5	141.0	141.0	141.0	141.0	141.0	141.0	141.0	141.0	141.0	141.0
	95	130.0	132.5	135.0	137.5	140.0	142.5	142.5	142.5	142.5	142.5	142.5	142.5	142.5	142.5
	96	129.0	131.5	134.0	136.5	139.0	141.5	144.0	144.0	144.0	144.0	144.0	144.0	144.0	144.0
	97	128.0	130.5	133.0	135.5	138.0	140.5	143.0	145.5	145.5	145.5	145.5	145.5	145.5	145.5
	98	127.0	129.5	132.0	134.5	137.0	139.5	142.0	144.5	147.0	147.0	147.0	147.0	147.0	147.0
	99	126.0	128.5	131.0	133.5	136.0	138.5	141.0	143.5	146.0	148.5	148.5	148.5	148.5	148.5
	100	125.0	127.5	130.0	132.5	135.0	137.5	140.0	142.5	145.0	147.5	150.0	150.0	150.0	150.0
	101	124.0	126.5	129.0	131.5	134.0	136.5	139.0	141.5	144.0	146.5	149.0	151.5	151.5	151.5
	102	123.0	125.5	128.0	130.5	133.0	135.5	138.0	140.5	143.0	145.5	148.0	150.5	153.0	153.0
	103	122.0	124.5	127.0	129.5	132.0	134.5	137.0	139.5	142.0	144.5	147.0	149.5	152.0	154.5

Expected Profit

Based on the relative frequency of each demand, David can work out the expected daily profit for each order quantity.

E.g. if order quantity = 90,

E(Order qty = 90)

$$= \sum_{d} f_d P_d$$

= 0.02*135+0.03*135+0.07*135+………………+0.06*135+0.04*135+0.02*135

= $135

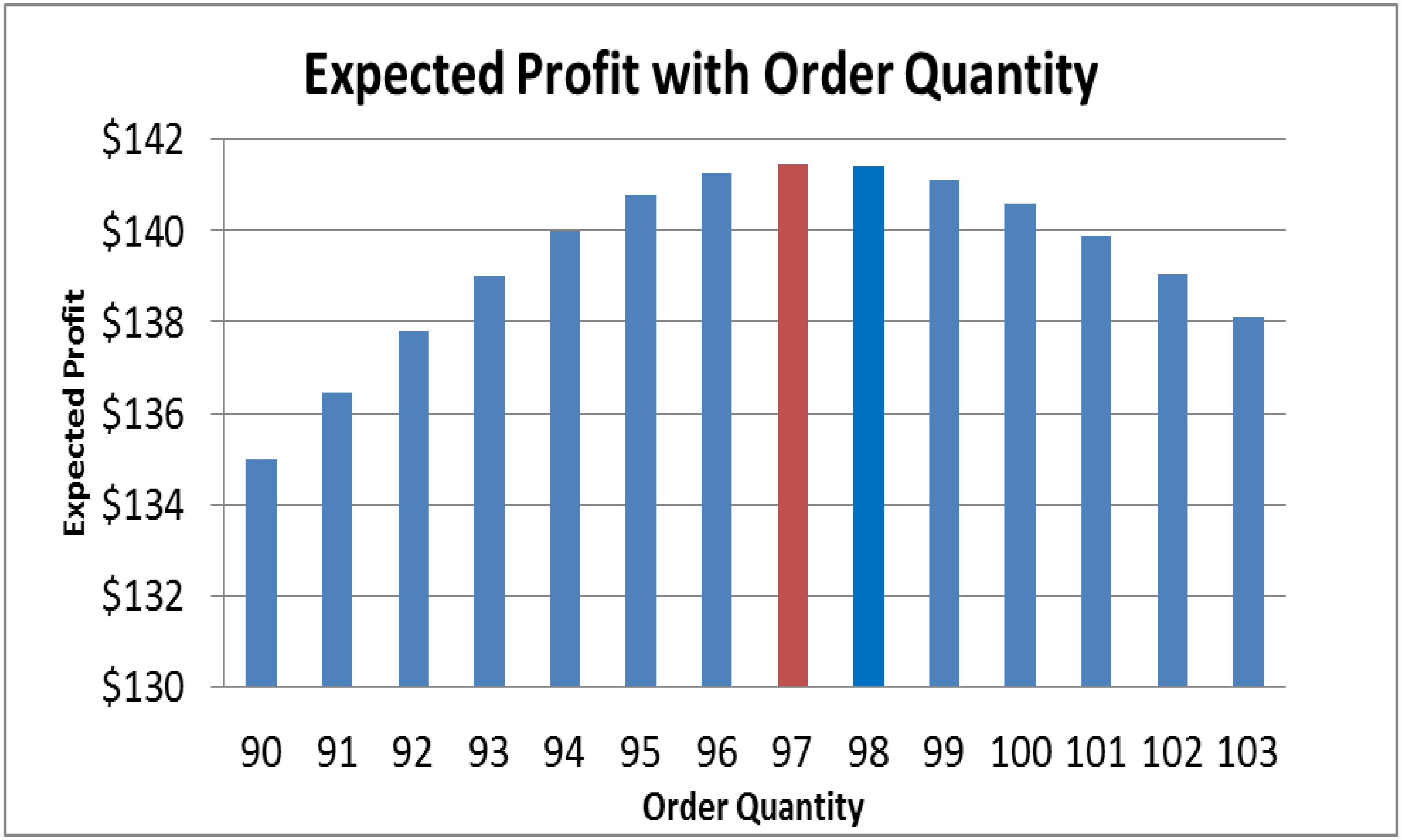
Where f_d = Probability of demand d happening,

P_d = Profit if demand is d

Expected Profit

	Demand	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**	**103**	**Expected Profit**
	Frequency	**2**	**3**	**6**	**7**	**8**	**10**	**11**	**9**	**9**	**8**	**6**	**5**	**4**	**2**	
	Demand Prob	**0.02**	**0.03**	**0.07**	**0.08**	**0.09**	**0.11**	**0.12**	**0.10**	**0.10**	**0.09**	**0.07**	**0.06**	**0.04**	**0.02**	
Order Quantity	**90**	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	135.0	$135.00
	91	134.0	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	136.5	$136.44
	92	133.0	135.5	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	138.0	$137.81
	93	132.0	134.5	137.0	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5	139.5	$139.00
	94	131.0	133.5	136.0	138.5	141.0	141.0	141.0	141.0	141.0	141.0	141.0	141.0	141.0	141.0	$140.00
	95	130.0	132.5	135.0	137.5	140.0	142.5	142.5	142.5	142.5	142.5	142.5	142.5	142.5	142.5	$140.78
	96	129.0	131.5	134.0	136.5	139.0	141.5	144.0	144.0	144.0	144.0	144.0	144.0	144.0	144.0	$141.28
	97	128.0	130.5	133.0	135.5	138.0	140.5	143.0	145.5	145.5	145.5	145.5	145.5	145.5	145.5	$141.47
	98	127.0	129.5	132.0	134.5	137.0	139.5	142.0	144.5	147.0	147.0	147.0	147.0	147.0	147.0	$141.42
	99	126.0	128.5	131.0	133.5	136.0	138.5	141.0	143.5	146.0	148.5	148.5	148.5	148.5	148.5	$141.11
	100	125.0	127.5	130.0	132.5	135.0	137.5	140.0	142.5	145.0	147.5	150.0	150.0	150.0	150.0	$140.58
	101	124.0	126.5	129.0	131.5	134.0	136.5	139.0	141.5	144.0	146.5	149.0	151.5	151.5	151.5	$139.89
	102	123.0	125.5	128.0	130.5	133.0	135.5	138.0	140.5	143.0	145.5	148.0	150.5	153.0	153.0	$139.06
	103	122.0	124.5	127.0	129.5	132.0	134.5	137.0	139.5	142.0	144.5	147.0	149.5	152.0	154.5	$138.11

Expected Profit



Maximum profit of <u>$141.47</u> can be achieved with an order quantity of <u>97 pieces</u>

Marginal Analysis

- Useful for discrete demand distribution, continuous demand distribution, seasonal or perishable goods

- Let :

p = probability of selling at least one more (the marginal) unit

(1-p) = probability of not selling one more unit

MP = profit realized from selling that additional unit (marginal profit)

ML = loss realized if the additional unit is not sold (marginal loss)

Marginal Analysis

- Compare the gain/loss for ordering one more item:
- Expected Profit = Expected Loss

p x MP = (1-p) x ML

p= ML/(MP+ML)

p = margin loss / (marginal loss + marginal profit)

Hence,

Critical Ratio = ML / (MP + ML)

Today's Problem (Q10)

- ML = purchase price = 1
- MP = selling price – purchase price = 2.50 – 1 = 1.5
- **Critical Ratio = ML/ (MP+ML) = 1 / (1.5+1) = 0.4**

The probability of selling 97 or more is 0.48 (this is **more than** 0.4 !!)

The probability of selling 98 or more is 0.38 (this is **less than** 0.4 !!)

Demand (D)	Demand Prob	Prob. Of selling D or MORE
90	0.02	1.00
91	0.03	0.98
92	0.07	0.94
93	0.08	0.88
94	0.09	0.80
95	0.11	0.71
96	0.12	0.60
97	0.10	0.48
98	0.10	0.38
99	0.09	0.28
100	0.07	0.19
101	0.06	0.12
102	0.04	0.07
103	0.02	0.02

- Recommendations: order **97** pieces of the Cinnamon Crunch Muffins.

Today's Problem (Q11)

If Salvage value is $0.80

- ML = purchase price – salvage value = 1.0 – 0.8= 0.2
- MP = selling price – purchase price = 2.5 – 1.0 = 1.5

- **Critical Ratio = ML/ (MP+ML) =0.2/(1.5+0.2) = 0.118**

The probability of selling 101 or more is 0.12 (this is **more than** 0.118 !!)

The probability of selling 102 or more is 0.07 (this is **less than** 0.118 !!)

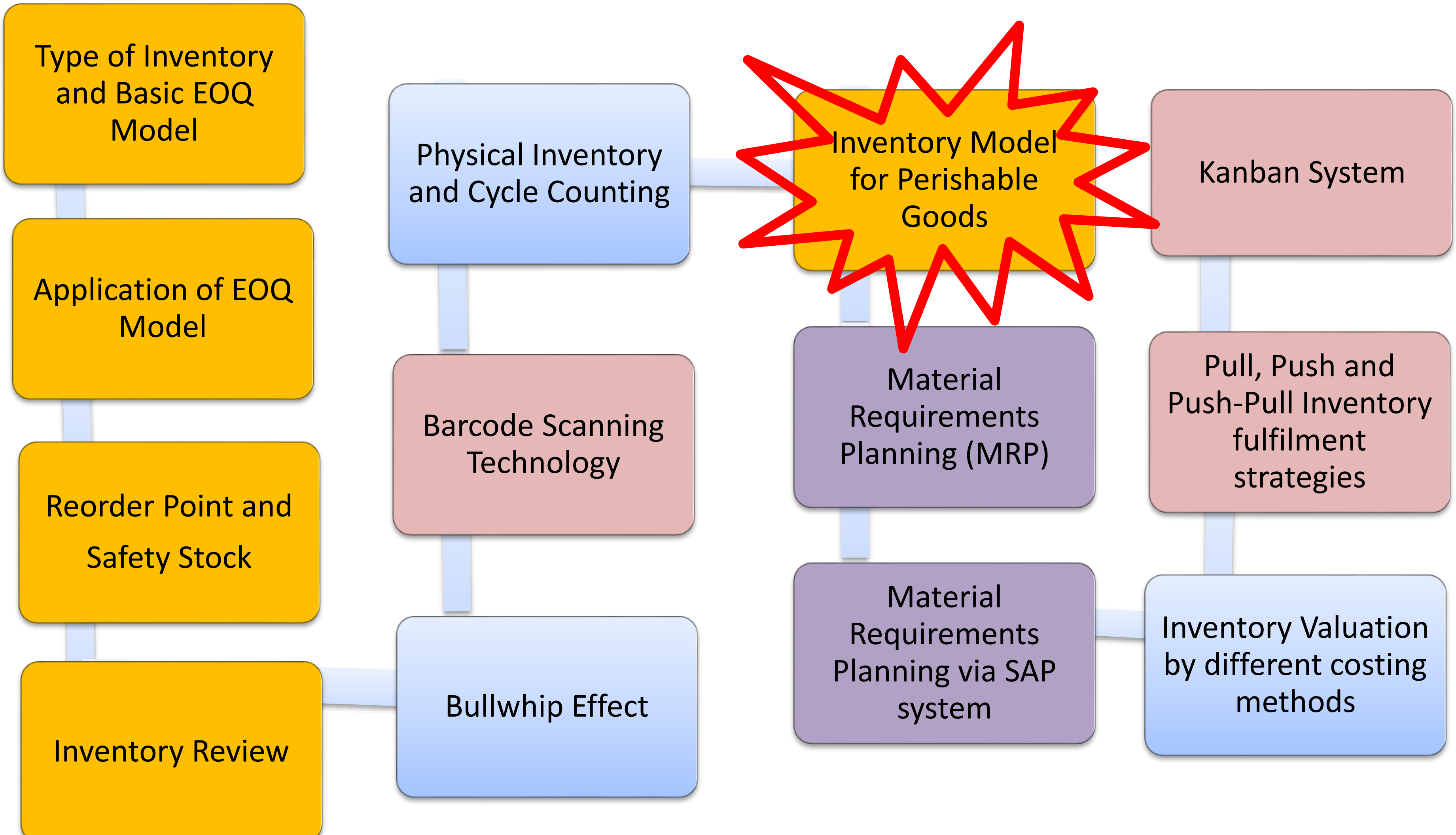
Demand (D)	Demand Prob	Prob. Of selling D or MORE
90	0.02	1.00
91	0.03	0.98
92	0.07	0.94
93	0.08	0.88
94	0.09	0.80
95	0.11	0.71
96	0.12	0.60
97	0.10	0.48
98	0.10	0.38
99	0.09	0.28
100	0.07	0.19
101	0.06	0.12
102	0.04	0.07
103	0.02	0.02

With salvage value for the Cinnamon Crunch Muffins, the recommended order quantity will be **101 pieces**.

Learning Objectives

- Describe the characteristics of perishables
- Describe why the EOQ model is not an appropriate inventory management model for perishables
- Describe why carrying safety stock is not appropriate for perishables
- Apply the Payoff Table Analysis to a given business case-study
- Apply the Marginal Analysis to a given business case-study
- Calculate the optimal order quantity and profits for a given business case-study

E217 Inventory Management Topic Flow



Problem 09

Plan to Buy

E217 – Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

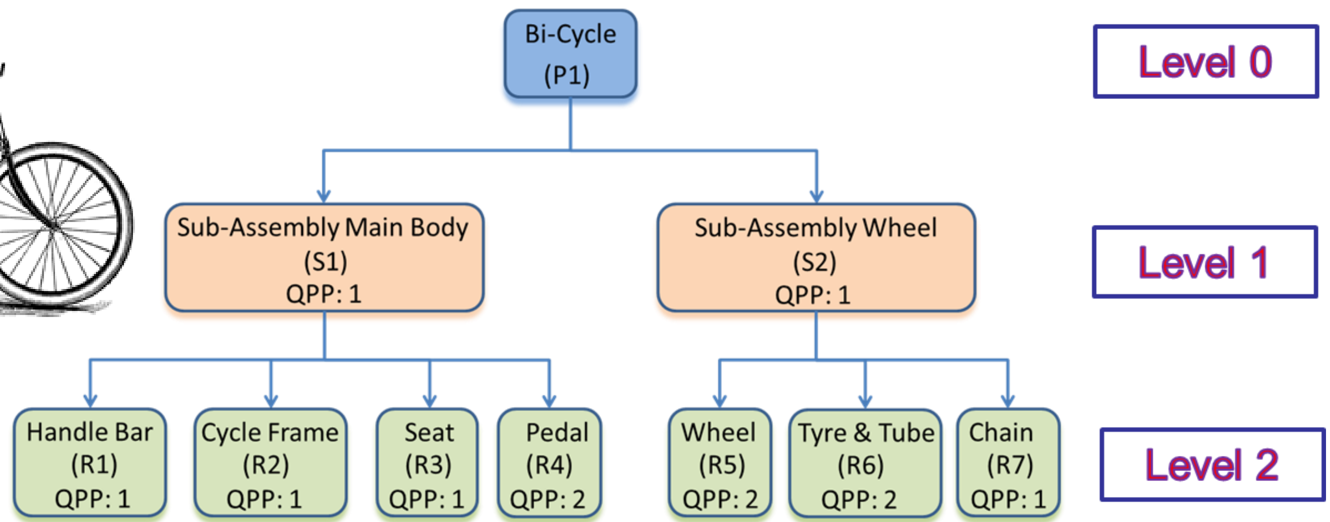
- **E217 Inventory Management**
  - **Strategic Role** of Inventory Management
    - Physical Inventory and Cycle Counting
    - Bullwhip Effect
    - Inventory Valuation
  - **Inventory Control Methods**
    - **Independent-Demand Items**
      - Basic EOQ Model
      - Application of EOQ Model
      - Safety Stock and Reorder Point
      - Inventory Review Policies
      - Inventory Model for Perishable Goods
    - **Dependent-Demand Items**
      - Material Requirements Planning (MRP)
      - Material Requirements Planning (MRP) via SAP
  - **Inventory Control System**
    - Barcode Scanning Technology
    - Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
    - Kanban System

Need of Planning

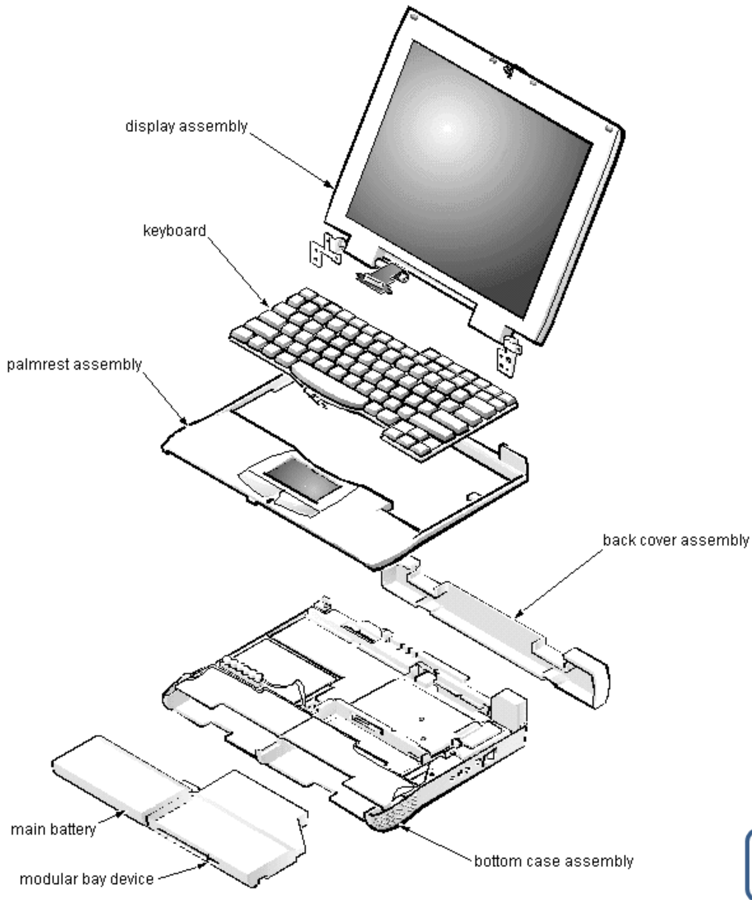
- Making business operations as efficient as possible is the key to economic advantage.
- To make operations as effective as possible, one area to focus on is the cost reduction and operations optimization.
- A big part of optimization processes depends on how manufacturing companies plan their operations, control inventory and organize logistics.
- To help companies make better decisions in these areas, material requirements planning (MRP) has been introduced in the 1960's.
- It helps manufacturers to plan and schedule their production operations in such a way that it will not require any excessive inventory.

Bill of Materials (BOM)

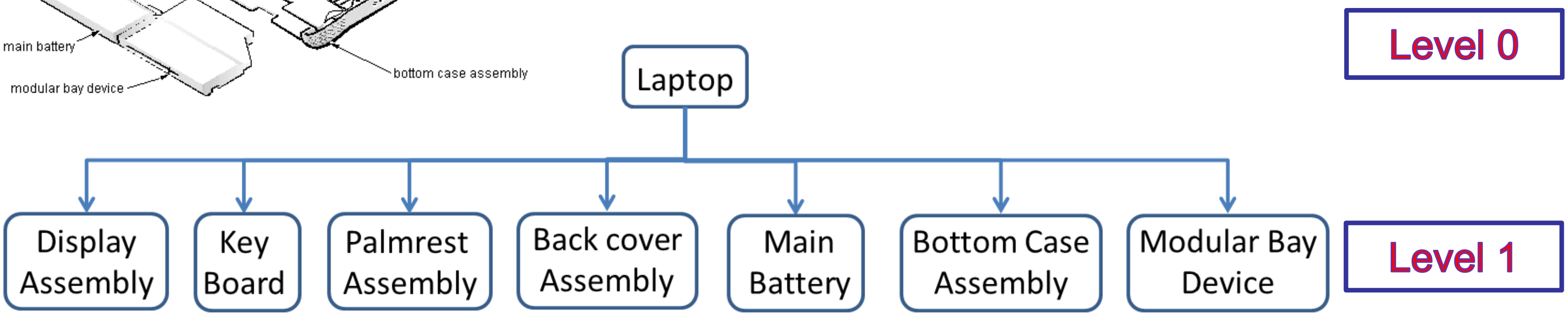
- A structured list of the components which make up a product (finished product) or assembly (sub assembly).
- The list contains each component as well as the quantity.
- Parent item (finished product) shown at highest level or level zero, parts that go into parent item are called level 1 components and so on
- Example:



BOM for Laptop

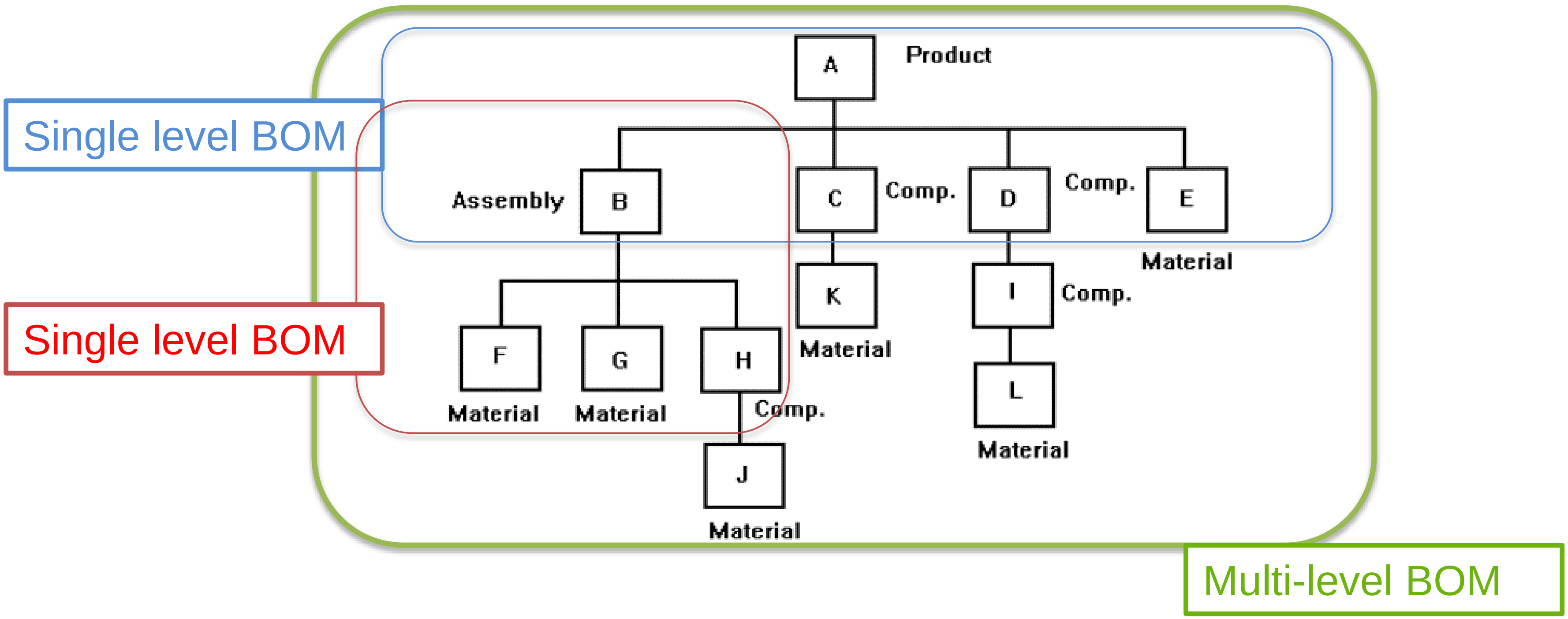


Components	Quantity
Display Assembly	1
Key board	1
Palmrest Assembly	1
Back cover Assembly	1
Main battery	1
Bottom case Assembly	1
Modular Bay device	1

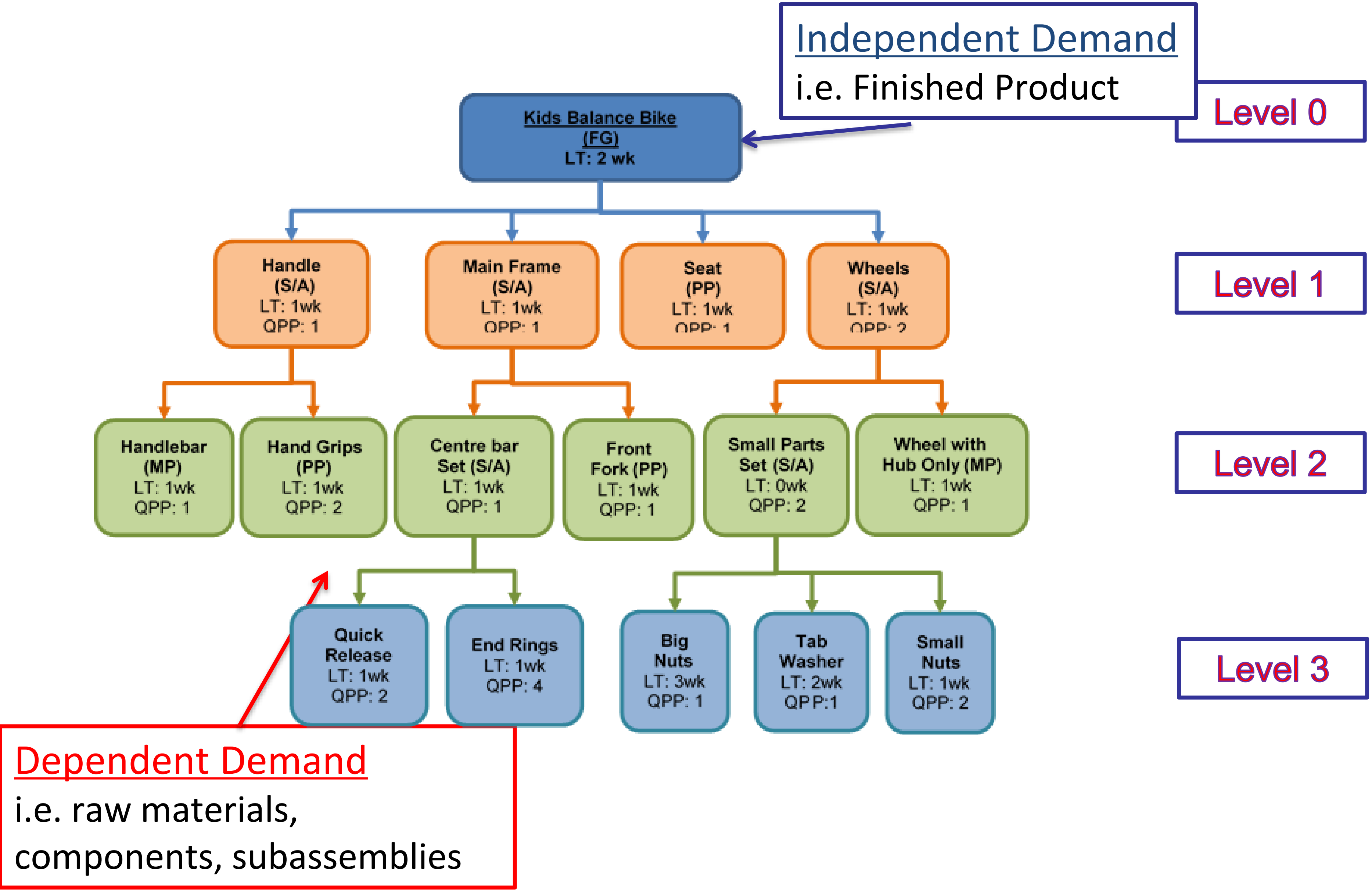


Bill of Materials (BOM)

- Single level bill of material: A bill of material that lists the materials, parts and labor required to make another part.
- Multi-level bill of material: A bill of material that lists the components, assemblies, and materials required to make a part, the components, assemblies, and materials required to make each component and assembly of the part, and so forth.



BOM for Kids Balance Bike



MPS & MRP

Master Production Scheduling (MPS)

- A statement of how many finished items are to be produced and when they are to be produced
- What, when and how many
- MPS outputs are the gross requirements for components’ MRP calculations

Material Requirements Planning (MRP)

- Translates end-product requirements from MPS into individual component requirements.
- It calculates the exact quantity, need date & planned order release date for each subassemblies, components & raw materials required to manufacture the end product.
- MRP output is a schedule for obtaining raw materials, detailed manufacturing schedule, and financial information.

The main theme of MRP is “getting the right materials to the right place at the right time”.

MRP Assumptions

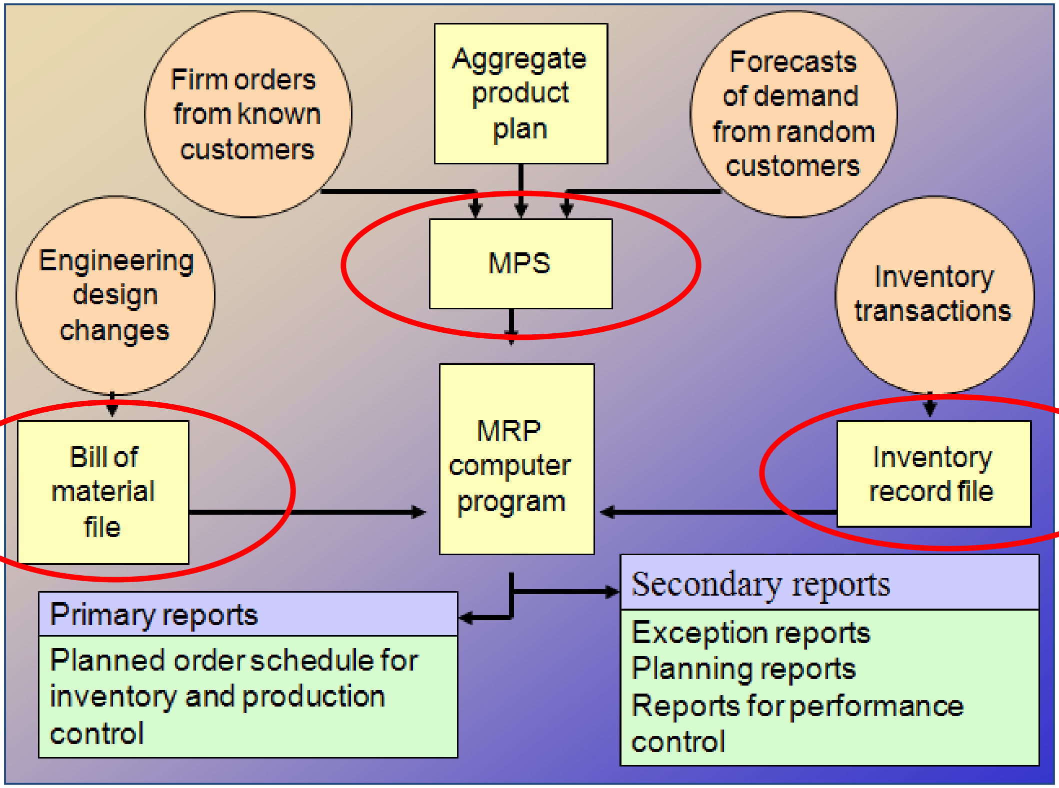
- Production of all the products finish at the **end** of each period (week, month, etc.)
- All the components/raw materials are used at the **beginning** of each period.
- No inventory cost for the products at the period that they are produced.
- No inventory carrying cost occurs when an item comes to stock and gets consumed in the same period.

MRP Terminology

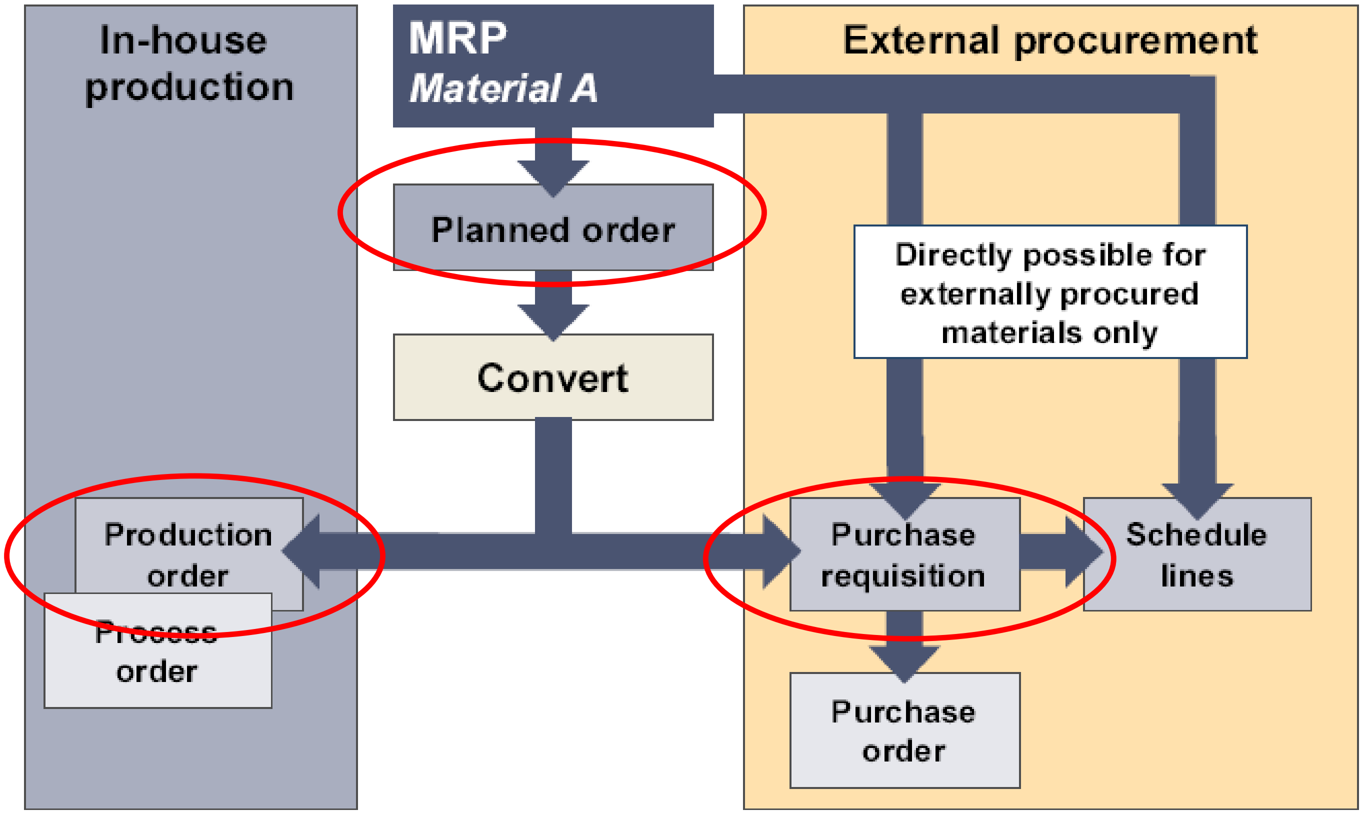
- Gross requirement is based on MPS and exploded BOM
- Scheduled Receipts: open orders scheduled to arrive
- On hand inventory is the stock available at the end of the period
- Net requirements = gross requirements – on hand inventory – scheduled receipts
- Planned receipts: quantity expected to received at the beginning of the period offset by lead time to meet net requirement
- Planned order releases - Authorization for the execution of planned orders
- Lot sizing: determine the batch size to be purchased or produced

Inputs to MRP

- MRP takes the end product requirements from the MPS and breaks them down into their component parts and subassemblies to create materials plan.
- This plan specifies when production and purchase orders must be placed for each part and subassembly so as to complete the products on schedule.



MRP Outputs



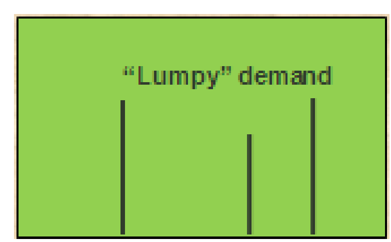
- The output of MRP is either a planned order or a purchase requisition.
  - *Planned order can be converted into either a Production Order or a Purchase Requisition.*
  - *Purchase Requisition can also be converted into a Purchase Order.*

Lot-Sizing

- **Lot Size:** The amount of a particular item that is ordered from the plant or a vendor.
- Determine the batch size to be purchased or produced.
- Lot size decision affects inventory levels, setup & ordering costs, capacity requirement & availability.
- The benefits of using lot-sizing techniques properly:
  - *Reduced expenditures associated with ordering or setting up*
  - *Lower charges for carrying the resulting inventory*

Lot for Lot (LFL)

- The most straightforward and simple application of discrete lot sizing. The lot size is equal to the requirement in each period.
- No extra on-hand inventory
- It results in variable order quantities and a new setup is required for each run
- Use when setup costs are low and inventory carrying costs are high.
- Very effective for lumpy demands and when the goal is to minimize inventory investment.
- Very effective when demand patterns have periods of no requirements and the item is very expensive.
- Ideally, there is no inventory carrying cost with this approach since the quantity receipt and consumption of the items occurs in the same period.



Fixed Order Quantity (FOQ)

- FOQ uses a fixed order size for every order or production run

$$q_t = Q$$

q = Order quantity in number of units
Q = Fixed/Constant quantity
t = Period index

- The order quantity of FOQ can be determined by:
  - EOQ
    - A type of Fixed Order Quantity (FOQ) that determines the amount of an item to be purchased or produced at one time.
    - Wish to minimize the combined cost of ordering and carrying inventory
  - Quantity Discount
  - Truckload Capacity
  - Minimum Purchase Quantity
  - For manufacturing, the batch size for certain machines

Using EOQ to Determine the Lot Size

- 8 weeks' demand = 175 units
- Weekly Average Demand = 1480/8 = 185 units/week
- Ordering cost is $90/order
- Holding cost is $0.3 per unit per week
- EOQ = SQRT (2*90*185/0.3) = 334 units
- Note: order a multiple of EOQ if net requirement exceeds 334

Small Nuts	Lead time 1				Lot size	**FOQ** *Determined by using EOQ*			
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	80	320	400	360	320	0	0	0
Scheduled Receipt		300	0	0	0	0	0	0	0
On Hand Inventory	150	370	50	0	0	0	0	0	0
Projected On Hand Inventroy		370	50	318	292	306	306	306	306
Net Requirements		0	0	350	42	28	0	0	0
Planned receipts		0	0	668	334	334	0	0	0
Planned orders		0	668	334	334	0	0	0	0

Examples of MRP Calculation

On-hand inventory is the stock available at the **end** of the week

Kids Balance Bike	Lead time	2	Qty Per Product	1	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements			60	45	55	40	50	45	40
Scheduled Receipt			80						
On Hand Inventory at the end of the week	40	40	60	15	0	0	0	0	0
Net Requirements			0	0	40	40	50	45	40
Planned receipts			0	0	40	40	50	45	40
Planned orders		0	40	40	50	45	40	0	0

Gross requirements for Seat is 1 times of the planned orders for the Bike, QPP = 1

Seat	Lead time	1	Qty Per Product	1	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	0	40	40	50	45	40	0	0
Scheduled Receipt									
On Hand Inventory	20	20	0	0	0	0	0	0	0
Net Requirements			20	40	50	45	40	0	0
Planned receipts			20	40	50	45	40	0	0
Planned orders		20	40	50	45	40	0	0	0

Planned orders will be released by a period of lead time (1 weeks ahead of planned receipt)

Examples of MRP Calculation

Handle	Lead time	1	Qty Per Product	1	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	0	40	40	50	45	40	0	0
Scheduled Receipt									
On Hand Inventory	30	30	0	0	0	0	0	0	0
Net Requirements			10	40	50	45	40	0	0
Planned receipts			10	40	50	45	40	0	0
Planned orders		10	40	50	45	40	0	0	0

Gross requirements for Hand Grips is **2** times of the planned orders for Handle, QPP = 2

Hand Grips	Lead time	1	Qty Per Product	2	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	20	80	100	90	80	0	0	0
Scheduled Receipt		0	0	0	0	0	0	0	0
On Hand Inventory	40	20	0	0	0	0	0	0	0
Net Requirements			60	100	90	80	0	0	0
Planned receipts			60	100	90	80	0	0	0
Planned orders		60	100	90	80	0	0	0	0

MRP Calculations – Other Level-1 items

Main Frame	Lead time	1	Qty Per Product	1	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	0	40	40	50	45	40	0	0
Scheduled Receipt									
On Hand Inventory	40	40	0	0	0	0	0	0	0
Net Requirements			0	40	50	45	40	0	0
Planned receipts			0	40	50	45	40	0	0
Planned orders		0	40	50	45	40	0	0	0

Wheels	Lead time	1	Qty Per Product	2	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	0	80	80	100	90	80	0	0
Scheduled Receipt									
On Hand Inventory	40	40	0	0	0	0	0	0	0
Net Requirements			40	80	100	90	80	0	0
Planned receipts			40	80	100	90	80	0	0
Planned orders		40	80	100	90	80	0	0	0

MRP Calculations – Other Level-2 items

Centre Bar Set	Lead time	1	Qty Per Product	1	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	0	40	50	45	40	0	0	0
Scheduled Receipt		0	0	0	0	0	0	0	0
On Hand Inventory	40	40	0	0	0	0	0	0	0
Net Requirements			0	50	45	40	0	0	0
Planned receipts			0	50	45	40	0	0	0
Planned orders		0	50	45	40	0	0	0	0

Small Parts Set	Lead time	0	Qty Per Product	2	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	80	160	200	180	160	0	0	0
Scheduled Receipt		0	0	0	0	0	0	0	0
On Hand Inventory	40	0	0	0	0	0	0	0	0
Net Requirements		40	160	200	180	160	0	0	0
Planned receipts		40	160	200	180	160	0	0	0
Planned orders		40	160	200	180	160	0	0	0

MRP Calculations – Level-3 items

Quick Release	Lead time	1	Qty Per Product	2	Lot size	**LFL**	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	0	100	90	80	0	0	0	0
Scheduled Receipt		50	0	0	0	0	0	0	0
On Hand Inventory	80	130	30	0	0	0	0	0	0
Net Requirements			0	60	80	0	0	0	0
Planned receipts			0	60	80	0	0	0	0
Planned orders		0	60	80	0	0	0	0	0

End Rings	Lead time	1	Qty Per Product	4	Lot size	**LFL**	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	0	200	180	160	0	0	0	0
Scheduled Receipt		0	0	0	0	0	0	0	0
On Hand Inventory	90	90	0	0	0	0	0	0	0
Net Requirements			110	180	160	0	0	0	0
Planned receipts			110	180	160	0	0	0	0
Planned orders		110	180	160	0	0	0	0	0

MRP Calculations – Level-3 items

Big Nuts	Lead time	3	Qty Per Product	1	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	40	160	200	180	160	0	0	0
Scheduled Receipt		150	100	170	0	0	0	0	0
On Hand Inventory	150	260	200	170	0	0	0	0	0
Net Requirements			0	0	10	160	0	0	0
Planned receipts			0	0	10	160	0	0	0
Planned orders		10	160	0	0	0	0	0	0

Tab Washer	Lead time	2	Qty Per Product	1	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	40	160	200	180	160	0	0	0
Scheduled Receipt		90	100	0	0	0	0	0	0
On Hand Inventory	300	350	290	90	0	0	0	0	0
Net Requirements			0	0	90	160	0	0	0
Planned receipts			0	0	90	160	0	0	0
Planned orders		0	90	160	0	0	0	0	0

Small Nuts	Lead time	1	Qty Per Product	2	Lot size	LFL	LFL: Lot for Lot		
	Week 0	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	80	320	400	360	320	0	0	0
Scheduled Receipt		300	0	0	0	0	0	0	0
On Hand Inventory	150	370	50	0	0	0	0	0	0
Net Requirements			0	350	360	320	0	0	0
Planned receipts			0	350	360	320	0	0	0
Planned orders		0	350	360	320	0	0	0	0

MRP and Lot Sizing

- Based on a master production schedule, a MRP system:
    - Creates schedules identifying the specific parts and materials required to produce end items
    - Determines exact numbers needed
    - Determines the dates when orders for those materials should be released, based on lead times
- MRP is not a demand planning tool, input quantities are production quantities, not demand
- MRP is deterministic, all input numbers are known
- Lot Sizing needs to be done on all components of the finished product

Learning Objectives

- Describe where and when MRP is used
- Describe the inputs to MRP
  - Master Production Schedule, Bill of Materials, Inventory Master File
- Calculate the outputs from MRP
  - Planned order release in terms of order quantity and schedule
- Describe the importance of Lot Sizing decisions
- Know the various MRP Lot Sizing techniques and perform calculations for a given case-study:
  - LFL
  - FOQ (EOQ)

E217 Inventory Management Topic Flow

Problem 10

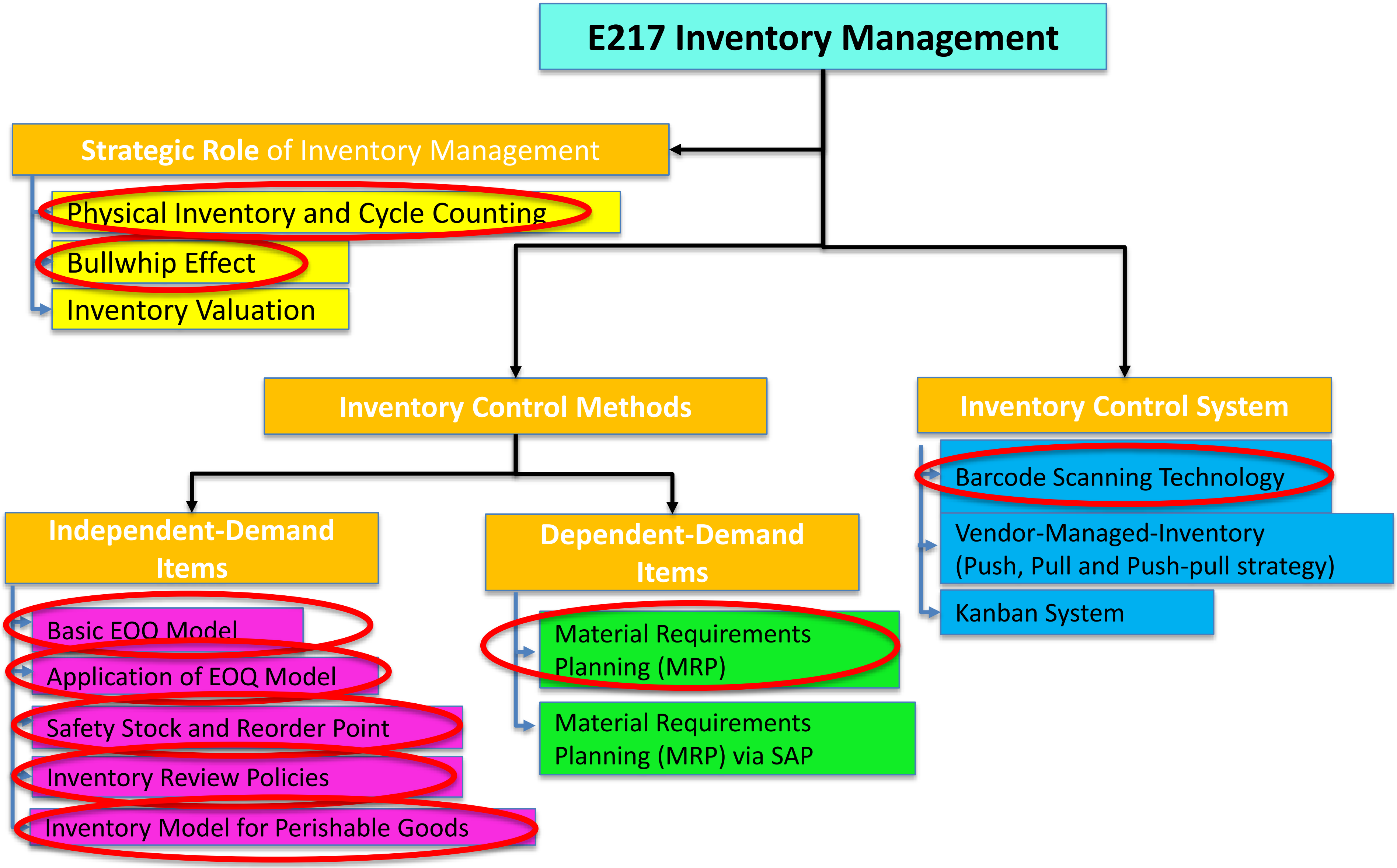
Simple Numbers to Detailed Plan

(1st Half)

E217 – Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree



Why ERP (Enterprise Resource Planning)?

Key Functional Areas	Business Process
Sales & Distribution	• Liaise with customers on sales orders • Manage sales orders and distribute goods out
Purchasing & Inventory Management	• Purchase required materials • Manage inventory internal transfer and customer deliveries
Production	• Plan for production • Manufacture the required goods
Finance	• Pay the suppliers • Receive payment from customers

- Complexity of business planning leads to the necessity of IT systems
- Sharing data effectively among functional areas leads to more efficient business processes

ERP is an integrated information system that:

- Manages company-wide business processes
- Coordinates information in different business areas of an organisation by using a common database

SAP Enterprise Resource Planning (SAP ERP)

Who is SAP?

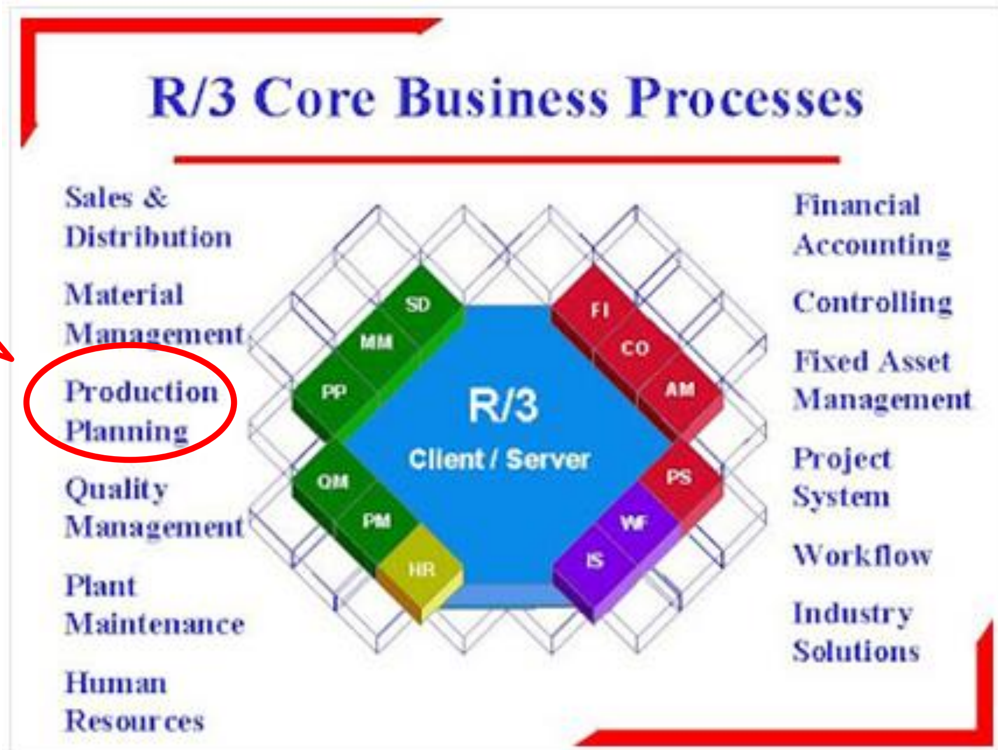
- Systems, Applications, and Products in Data Processing (SAP)
- Founded in Walldorf, Germany in 1972
- World's Largest Business Software Company
- World's Third-largest Independent Software Provider

How SAP helps?

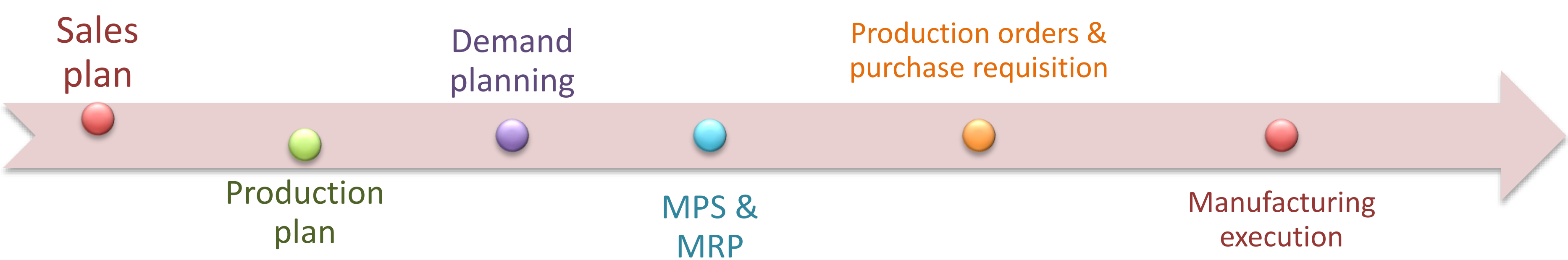
- Enables a company to optimize its business processes
- Ties together disparate business functions (integrated business solution) such as
  - Finance (Financial Accounting, Managerial Accounting, etc.)
  - Logistics (Sales, Procurement, Production, Quality, etc.)
  - Human Resources etc.
- Helps the organization run smoothly
- Real-time environment

SAP Production Planning (PP)

You are here today!



PP module supports the planning and control of the manufacturing activities.



SAP Production Planning (Make)

- The PP application module is integrated with:
  - Materials Management (MM)
  - Financial Accounting (FI)
  - Managerial Accounting and Controlling (CO)
  - Sales and Distribution (SD)
- Organizational Levels:
  - Client
  - Company Code
  - Plant
  - Storage Location
- Master Data in Production Planning:
  - Material Master
  - Bill of Materials (BOM)
  - Work Center
  - Product Routing

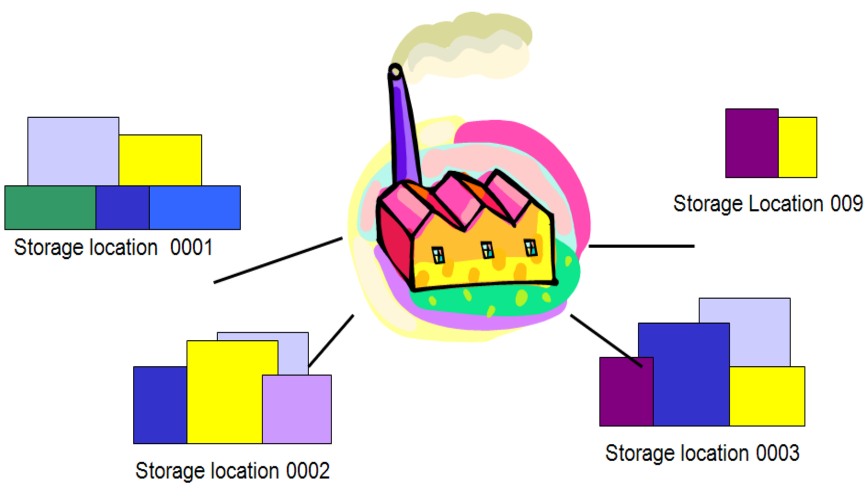
PP Organizational Levels

Client :

It represents a single company or a group of companies. The highest level in SAP.

Company Code:

Independent accounting unit; Balance sheet and Income statement are created at the company code level.



Plant :

A manufacturing facility or a warehouse /distribution center

Storage Location :

Further differentiation of material stocks within a plant (raw materials, WIP or Finished Goods, Spare parts, etc.)

Data Stored in SAP

Master Data

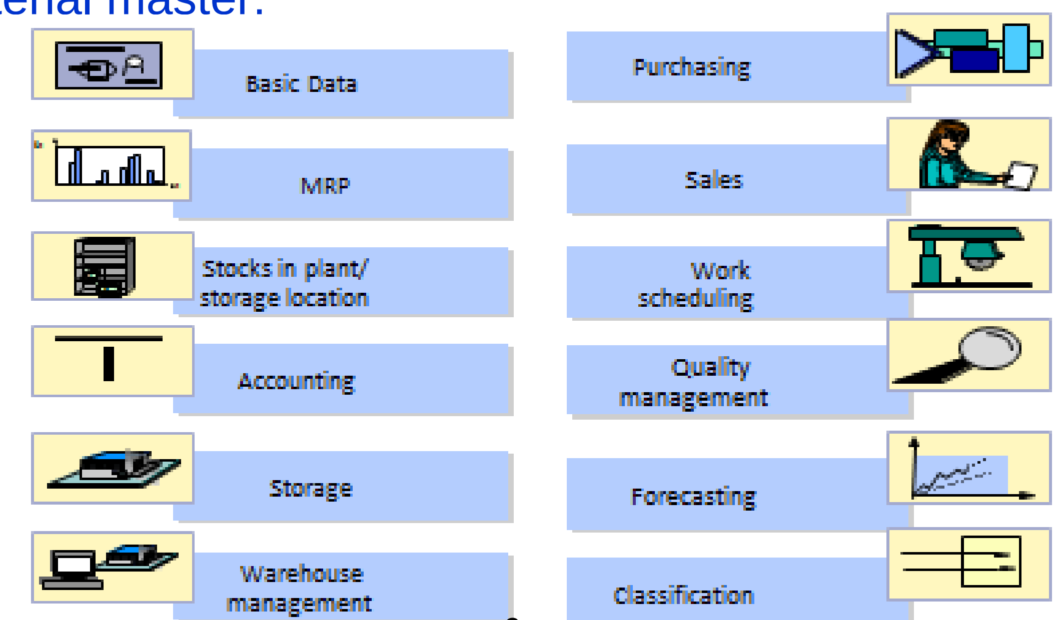
- Data that is relatively stable and not changing frequently
- Examples: Materials Master, Customer Master, Vendor Master

Transaction Data

- Data that is relatively temporary and unique to a particular transaction
- Stored at various stages of a business process
- Examples:
  - Customer orders, purchase orders, production orders, etc.
  - Quantity being ordered, manufactured, or sold
  - Dates – order date, delivery date, billing date, etc.
  - Amounts – total dollar amount for the transaction

Material Master: Views

- SAP maintains and displays material master using views
- Each user department has its own unique view of a Material Master
- Basic data is applicable to the entire company, while other views such as MRP and Accounting are specific to each plant
- For example:
  - Data that relates to the accounting department is stored in the accounting views
  - Data that relates to material planning is stored in the MRP views
- Material Master contains all data required to define and manage all types of materials, data held in the material master:
  - Material number
  - Descriptions
  - Units of measure
  - Material type
  - Weight etc.
  - Standard price
  - Lot size rule
  - Safety stock
  - Etc.

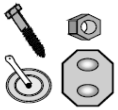


Material Master: Material Types

The material type is the most important value assigned to a material. It identifies the business processes and functions allowed for a product.

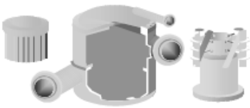
Raw materials:

Materials purchased from external suppliers



Semi-finished goods (Sub-assemblies):

Components that have been assembled from raw materials

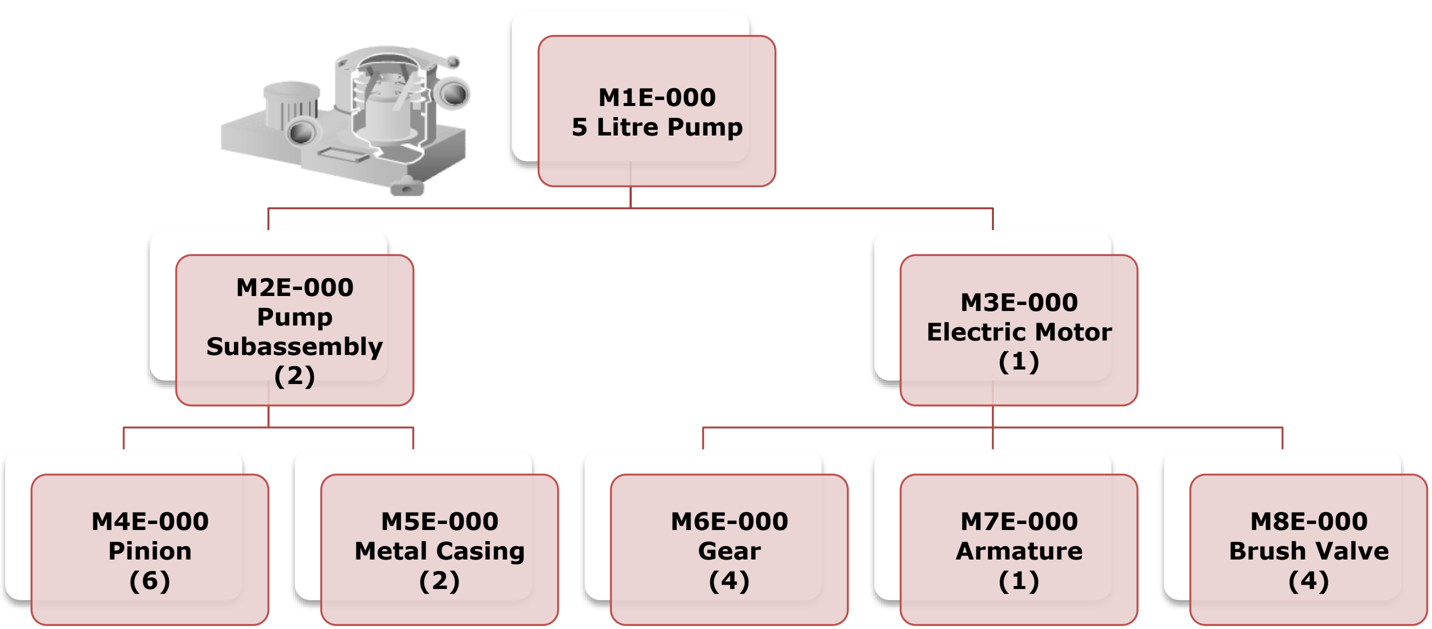


Finished goods:

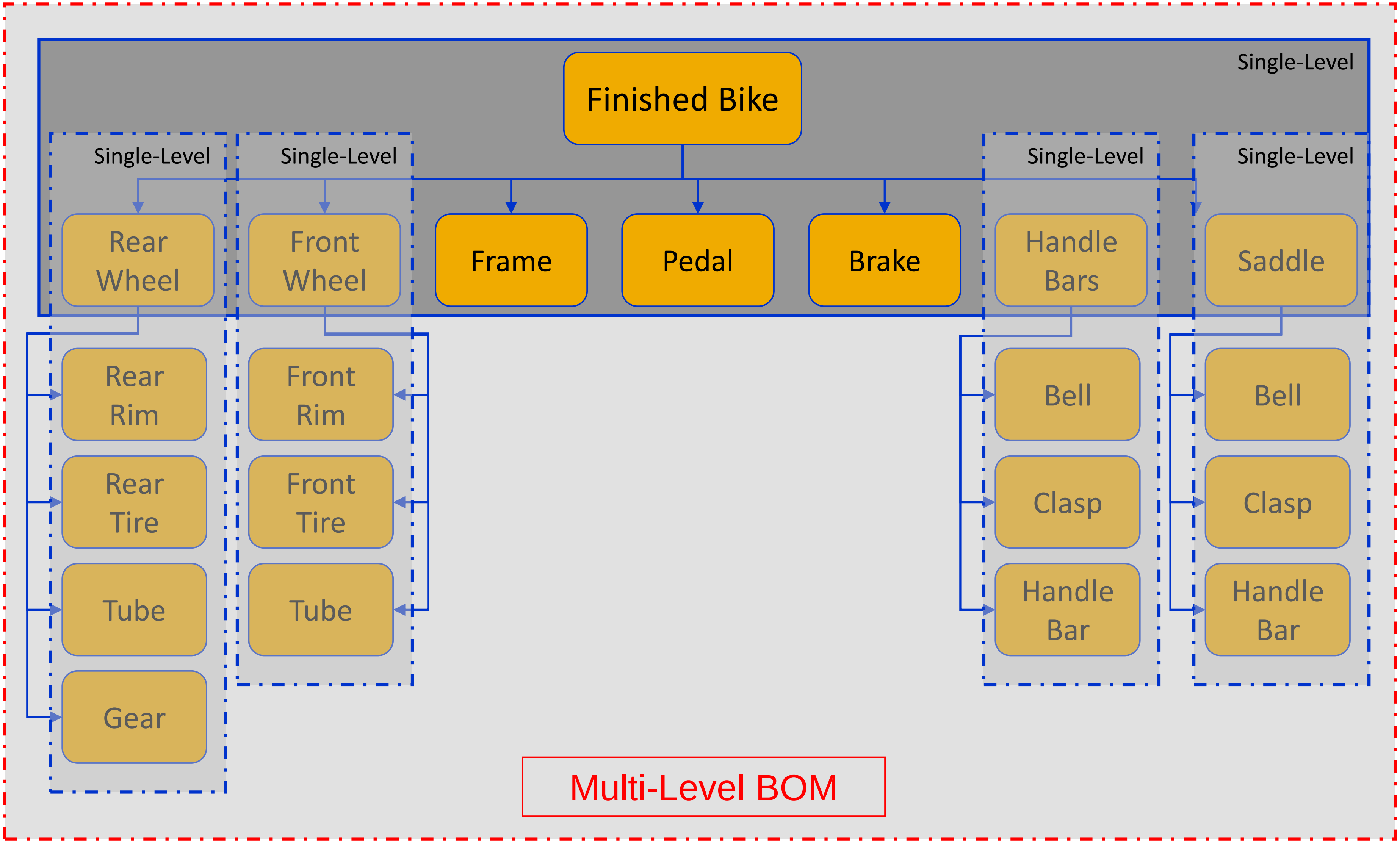
The final product that is sold to the customer

Bill of Materials (BOM)

- The Bill of Material is a structured list of the components which make up a product or assembly.
- The list contains the material code of each component as well as the quantity per and unit of measure.
- The Bill Of Material (BOM) plays an important function in many departments within a company: production, engineering, plant maintenance, costing, sales and distribution, etc.



Single-Level & Multi-Level BOM



Master Production Scheduling (MPS) in SAP

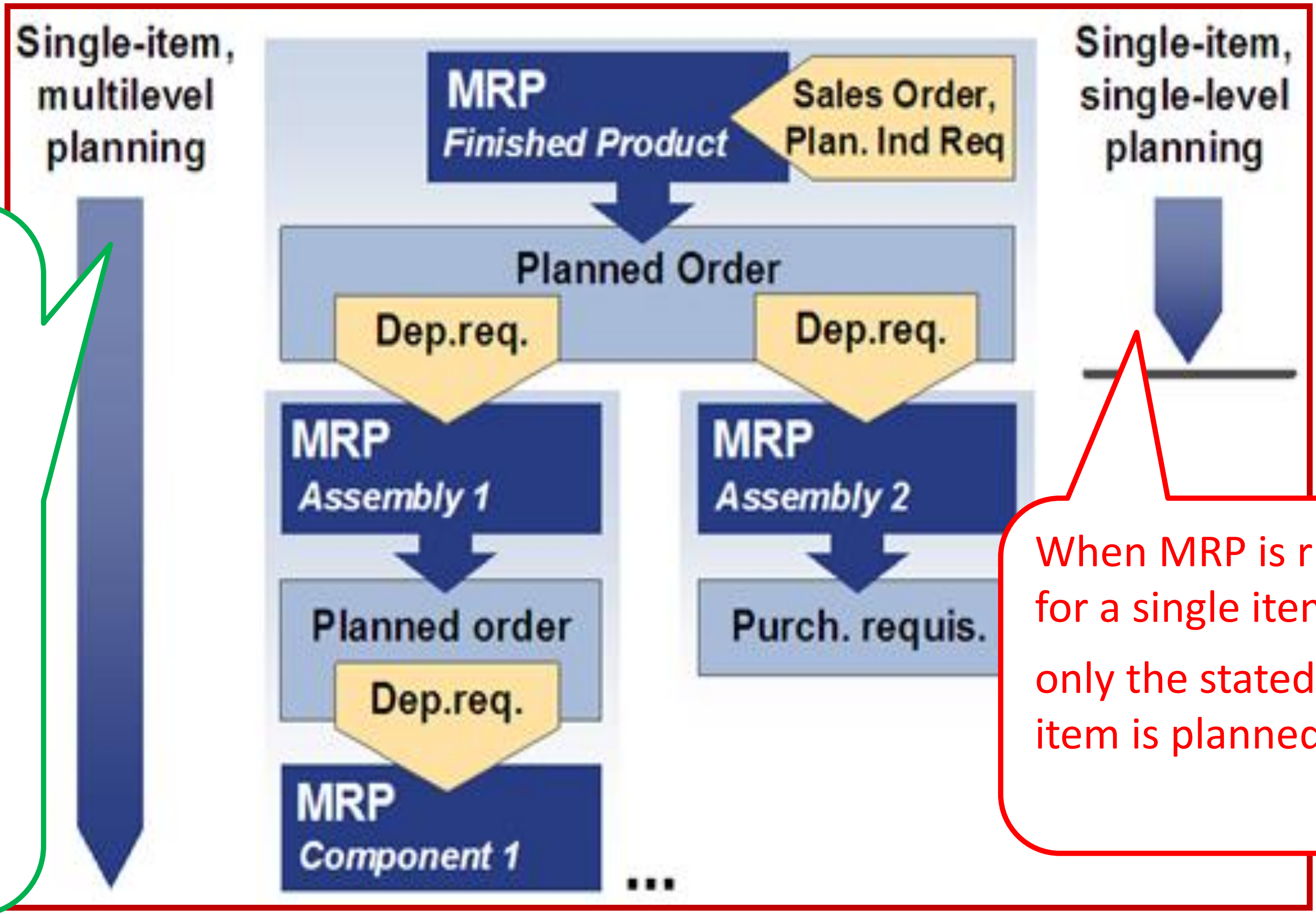
For materials, which greatly influence company profits or which take up critical resources:

- Schedule the production by using the independent requirements → *you enter the independent requirements into SAP manually today*
- In manufacturing, MPS contains the volume and timing of end items or critical products to be made
- It forms the inputs to Materials Requirements Planning (MRP)
- In SAP, MPS is executed using the same principles as MRP

Material Requirements Planning (MRP) in SAP

- Main function is to guarantee material availability
- To procure or produce the requirement quantities on time both for internal purposes and for sales and distribution.
- MRP involves:
  - Monitoring of stocks
  - Explosion using the BOM for the material and planning takes place right down to component level
  - Automatic creation of Planned Orders which could be converted into: (MRP initially “proposes” but human must “convert” proposal to concrete action!)
    - Production proposals
    - Procurement proposals

Multi-level Materials Requirements Planning



When MRP is run for the finished product,

based on the finished product's BOM,

the dependent requirements of components are also created

When MRP is run for a single item

only the stated item is planned

Source: help.sap.com

View MRP Outputs using Stock/Requirement List

- Stock/requirements list is a dynamic report giving up-to-date information about new requirements of a material
- Whenever there is a receipt or issue of the material, the same is updated in stock/requirements list on a real-time basis
- Key terms in the Stock/requirements list:

MRP Element	Description	Where does this come from?
PlOrd	Planned Order	Created during MRP run
IndReq	Planned Independent Requirements	Directly entered via MD62 today
PrdOrd	Production Order	Converted from planned order or created manually
PchOrd	Purchase Order	When PR is converted to PO Or when a PO is created manually for this item
PurRqs	Purchase Requisition	When planned order is converted to PR Or when a PR is created manually or via MRP for this item
Stock	Stock	Current available stock quantity
DepReq	Dependent requirements	For lower level items in BOM, could be either produced in house or procured externally, the dependent requirements of the components are determined during MPS/MRP run based on QPP

Problem 10

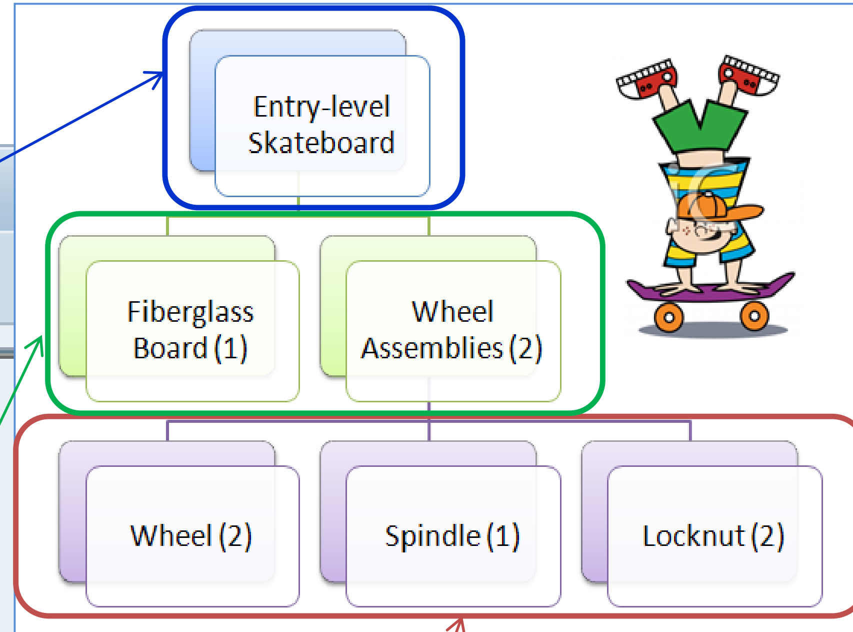
Simple Numbers to Detailed Plan

(2nd Half)

E217 – Inventory Management

SCHOOL OF ENGINEERING

BOM Created in SAP



Display Multilevel BOM

Material FG-888
Plant/Usage/Alt. 3000 / 1 / 01
Description Entry-level skateboard
Base Qty (PC) 1.000
Reqd Qty (PC) 1

Explosion lev...	Item	O...	Component number	Object description	O...	Comp. Qty (CUn)	Un	Ict
.1	0010		SF1-888	Fiberglass Board		1	PC	L
.1	0020		SF2-888	Wheel Assemblies		2	PC	L
..2	0010		RM1-888	Wheel		4	PC	L
..2	0020		RM2-888	Spindle		2	PC	L
..2	0030		RM3-888	Locknut		4	PC	L

MPS Results of FG-XXX

Stock/Requirements List as of 08:16 hrs

Show Overview Tree

Finished Goods

Planned production order quantity is determined by **Lot-for-lot** and **independent requirement** that you entered

Material FG-199 Entry-level skateboard

MRP area 3000 New York

type M1 Material Type FERT Unit PC

Order is planned for SS at the beginning of next planning

A..	Date	MRP ...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Available Qty
	15.06.2017	Stock			96		0
	15.06.2017	SafeSt	Safety Stock			50-	50-
	29.06.2017	---->	End of Planning Tim...				
	29.06.2017	PlOrd.	0000037519/Stck	15.06.2017	30	50	0
	14.09.2017	PlOrd.	0000037520/Stck			250	250
	14.09.2017	IndReq	LSF			250-	0
	21.09.2017	PlOrd.	0000037521/Stck			200	200
	21.09.2017	IndReq	LSF			200-	0
	28.09.2017	PlOrd.	0000037522/Stck			150	150
	28.09.2017	IndReq	LSF			150-	0
	05.10.2017	PlOrd.	0000037523/Stck			150	150
	05.10.2017	IndReq	LSF			150-	0

Stock/Requirement List of SF1-XXX after MPS & before MRP

Stock/Requirements List as of 08:22 hrs

Show Overview Tree

Material: SF1-199 — Fiberglass board

MRP area: 3000 — New York

Plant: 3000 — MRP type: PD — Material Type: HALB — Unit: PC

WIP

Dependent requirement from safety stock (50) of FG-xxx, QPP = 1

A..	Date	MRP ...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Available Qty
	15.06.2017	Stock			96		0
	15.06.2017	SafeSt	Safety Stock			30-	30-
	27.06.2017	DepReq	FG-199			50-	80-
	12.09.2017	DepReq	FG-199			250-	330-
	19.09.2017	DepReq	FG-199			200-	530-
	26.09.2017	DepReq	FG-199			150-	680-
	03.10.2017	DepReq	FG-199			150-	830-

Its own SS = 30

Dependent requirement which depends on the end product or parent item based on the BOM

Stock/Requirement List of SF1-XXX after MRP run

Stock/Requirements List as of 08:42 hrs

Show Overview Tree

Material SF1-199 Fiberglass board

MRP area 3000 New York

Plant 3000 MRP type PD Material Type HALB Unit PC

In-house production lead time for FG-XXX is 2 working days; This is to meet the demand on 14 Sep for FG-XXX

Lot-for-Lot, so order quantity = requirement

			scheduli...	E..	Receipt/Reqmt	Available Qty
15.06.2017	Stock			96		0
15.06.2017	SafeSt	Safety Stock			30-	30-
21.06.2017	PlOrd.	0000037530/Stck	15.06.2017	30	30	0
27.06.2017	PlOrd.	0000037531/Stck		05	50	50
27.06.2017	DepReq	FG-199			50-	0
12.09.2017	PlOrd.	0000037532/Stck		52	250	250
12.09.2017	DepReq	FG-199			250-	0
19.09.2017	PlOrd.	0000037533/Stck		52	200	200
19.09.2017	DepReq	FG-199			200-	0
26.09.2017	PlOrd.	0000037534/Stck			150	150
26.09.2017	DepReq	FG-199			150-	0
03.10.2017	PlOrd.	0000037535/Stck			150	150
03.10.2017	DepReq	FG-199			150-	0

1*independent requirement of FG-XXX, QPP = 1

Stock/Requirement List of SF2-XXX after MPS & before MRP

Stock/Requirements List as of 09:12 hrs

Show Overview Tree

Material SF2-199 Wheel Assemblies

MRP area 3000 New York

Plant 3000 MRP type PD Material Type HALB Unit PC

WIP

Dependent requirement from safety stock (50) of FG-xxx, QPP = 2

A..	Date	MRP ...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Available Qty
	15.06.2017	Stock			96		0
	15.06.2017	SafeSt	Safety Stock			40-	40-
	27.06.2017	DepReq	FG-199			100-	140-
	12.09.2017	DepReq	FG-199			500-	640-
	19.09.2017	DepReq	FG-199			400-	1.040-
	26.09.2017	DepReq	FG-199			300-	1.340-
	03.10.2017	DepReq	FG-199			300-	1.640-

Its own SS = 40

Dependent requirement on the end product FG-XXX

Stock/Requirement List of SF2-XXX after MRP run

Stock/Requirements List as of 08:48 hrs

Show Overview Tree

Material SF2-199 Wheel Assemblies

MRP area 3000 New York

Material Type HALB Unit PC

In-house production lead time for FG-XXX is 2 working days, semi-finished items should be ready 2 days before the requirement date which is 12 Sep.

			...	E..	Receipt/Reqmt	Available Qty
15.06.2017	Stock			96		0
15.06.2017	SafeSt	Safety Stock			40-	40-
22.06.2017	PlOrd.	0000037524/Stck	15.06.2017	30	40	0
27.06.2017	PlOrd.	0000037525/Stck		05	100	100
27.06.2017	DepReq	FG-199			100-	0
12.09.2017	PlOrd.	0000037526/Stck			500	500
12.09.2017	DepReq	FG-199			500-	0
19.09.2017	PlOrd.	0000037527/Stck			400	400
19.09.2017	DepReq	FG-199			400-	0
26.09.2017	PlOrd.	0000037528/Stck			300	300
26.09.2017	DepReq	FG-199			300-	0
03.10.2017	PlOrd.	0000037529/Stck			300	300
03.10.2017	DepReq	FG-199			300-	0

2*independent requirement of FG-XXX, QPP = 2

Stock/Requirement List of RM1-XXX after MRP run

Stock/Requirements List as of 08:46 hrs

Show Overview Tree

Material: RM1-199 Wheel

MRP area: 3000 New York

Plant: 3000 MRP type: PD Material Type: ROH Unit: PC

Raw Materials

Dependent requirement: 4*safety stock (50) of FG-xxx

A..	Date	MRP ...	MRP element data			Receipt/Reqmt	Available Qty
	15.06.2017	Stock					0
	15.06.2017	DepReq	SF2-199			80-	80-
	20.06.2017	DepReq	SF2-199			200-	
	23.06.2017	PurRqs	0010016013/00010	15.06.2017	30	500	
	05.09.2017	PlOrd.	0000037536/ExtP			500	
	05.09.2017	PlOrd.	0000037537/ExtP			500	1.220
	05.09.2017	DepReq	SF2-199			1.000-	220
	12.09.2017	PlOrd.	0000037538/ExtP			500	720
	12.09.2017	PlOrd.	0000037539/ExtP			500	1.220
	12.09.2017	DepReq	SF2-199			800-	420
	19.09.2017	PlOrd.	0000037540/ExtP			500	920
	19.09.2017	DepReq	SF2-199			600-	320
	26.09.2017	PlOrd.	0000037541/ExtP			500	820
	26.09.2017	DepReq	SF2-199			600-	220

Dependent requirement: 2*safety stock (40) of SF2-xxx

2*dependent requirement of SF2-XXX

FOQ = 500
Set in Material Master, MRP1 view

2 FOQ are planned

Stock/Requirement List of RM2-XXX after MRP run

Stock/Requirements List as of 09:15 hrs

Show Overview Tree

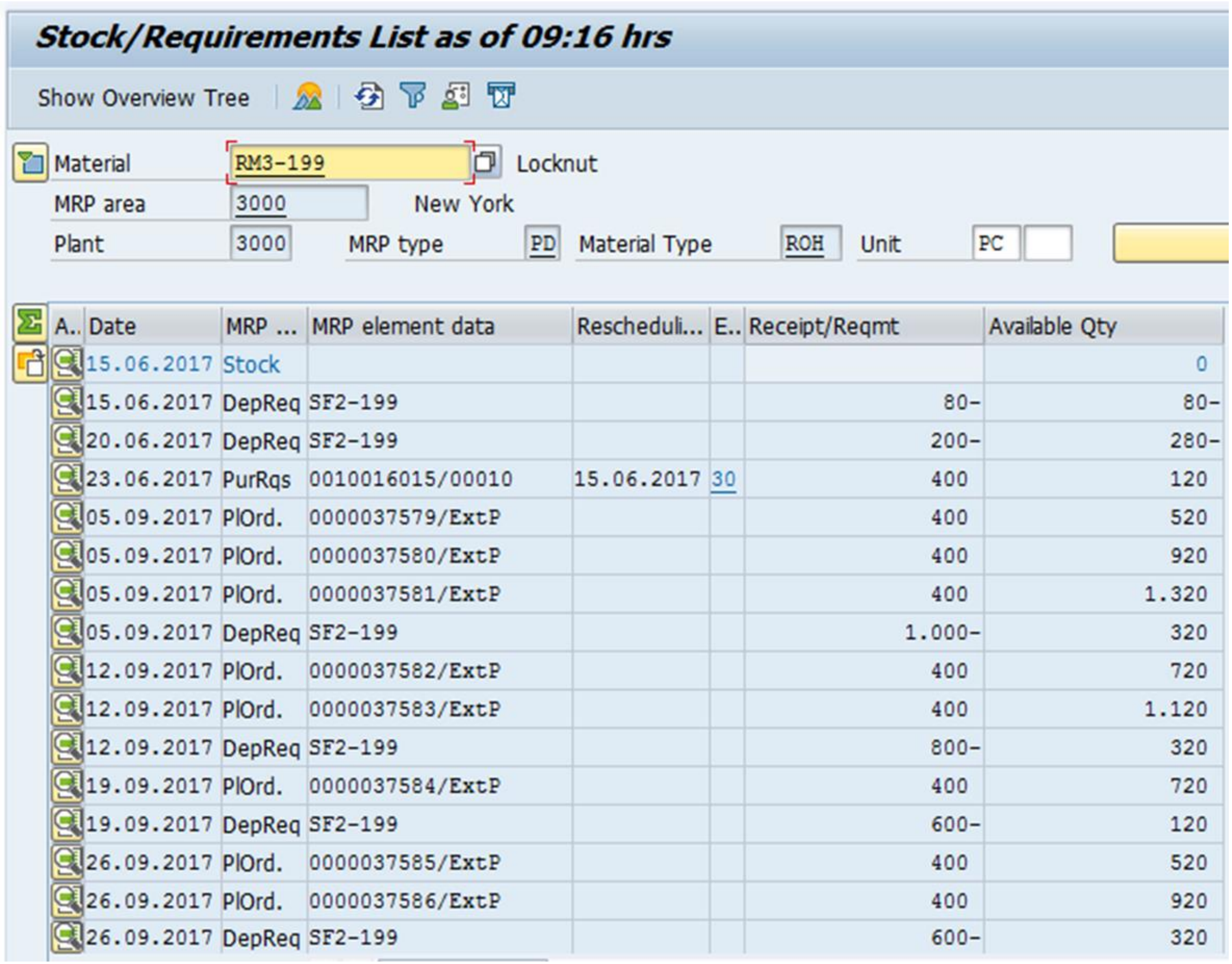
Material RM2-199 Spindle

MRP area 3000 New York

Plant 3000 MRP type PD Material Type ROH Unit PC

A..	Date	MRP ...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Available Qty
	15.06.2017	Stock					0
	15.06.2017	DepReq	SF2-199			40-	40-
	20.06.2017	DepReq	SF2-199			100-	140-
	23.06.2017	PurRqs	0010016014/00010	15.06.2017	30	300	160
	05.09.2017	PlOrd.	0000037574/ExtP			300	460
	05.09.2017	PlOrd.	0000037575/ExtP			300	760
	05.09.2017	DepReq	SF2-199			500-	260
	12.09.2017	PlOrd.	0000037576/ExtP			300	560
	12.09.2017	DepReq	SF2-199			400-	160
	19.09.2017	PlOrd.	0000037577/ExtP			300	460
	19.09.2017	DepReq	SF2-199			300-	160
	26.09.2017	PlOrd.	0000037578/ExtP			300	460
	26.09.2017	DepReq	SF2-199			300-	160

Stock/Requirement List of RM3-XXX after MRP run



Stock/Requirements List as of 09:16 hrs

Show Overview Tree

Material RM3-199 Locknut

MRP area 3000 New York

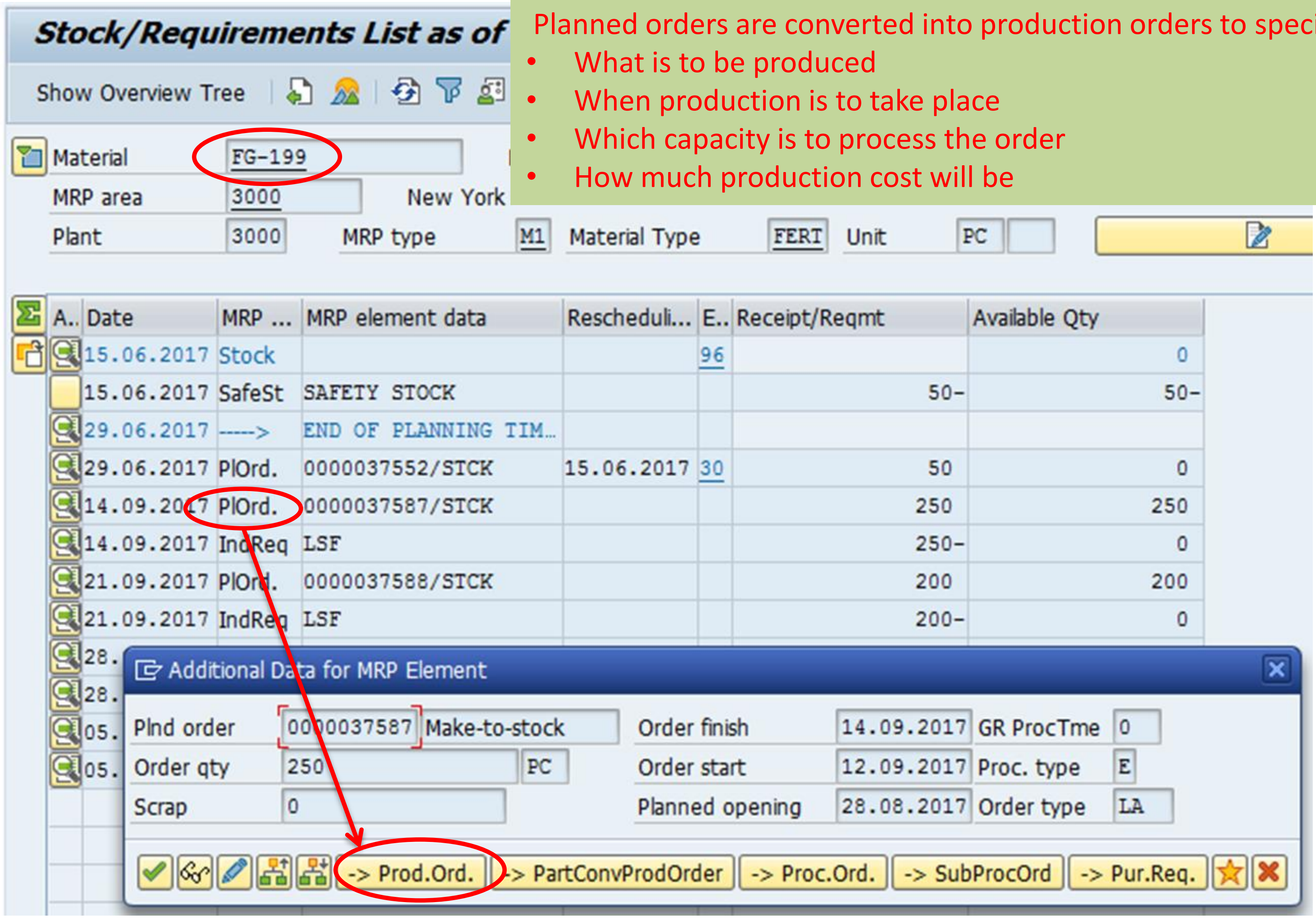
Plant 3000 MRP type PD Material Type ROH Unit PC

A..	Date	MRP ...	MRP element data	Rescheduli...	E..	Receipt/Reqmt	Available Qty
	15.06.2017	Stock					0
	15.06.2017	DepReq	SF2-199			80-	80-
	20.06.2017	DepReq	SF2-199			200-	280-
	23.06.2017	PurRqs	0010016015/00010	15.06.2017	30	400	120
	05.09.2017	PlOrd.	0000037579/ExtP			400	520
	05.09.2017	PlOrd.	0000037580/ExtP			400	920
	05.09.2017	PlOrd.	0000037581/ExtP			400	1.320
	05.09.2017	DepReq	SF2-199			1.000-	320
	12.09.2017	PlOrd.	0000037582/ExtP			400	720
	12.09.2017	PlOrd.	0000037583/ExtP			400	1.120
	12.09.2017	DepReq	SF2-199			800-	320
	19.09.2017	PlOrd.	0000037584/ExtP			400	720
	19.09.2017	DepReq	SF2-199			600-	120
	26.09.2017	PlOrd.	0000037585/ExtP			400	520
	26.09.2017	PlOrd.	0000037586/ExtP			400	920
	26.09.2017	DepReq	SF2-199			600-	320

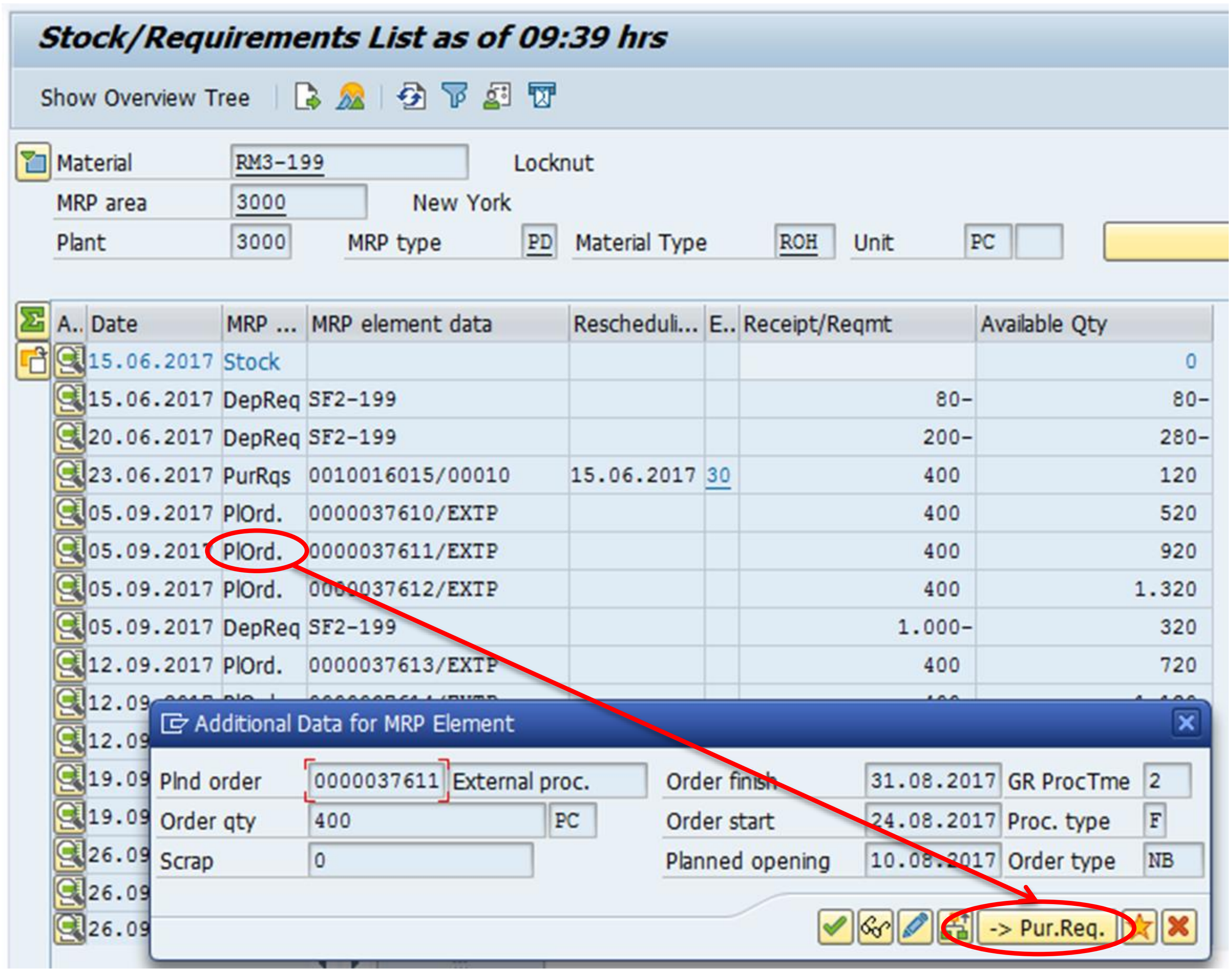
Converting Planned Order into Production Order

Planned orders are converted into production orders to specify:

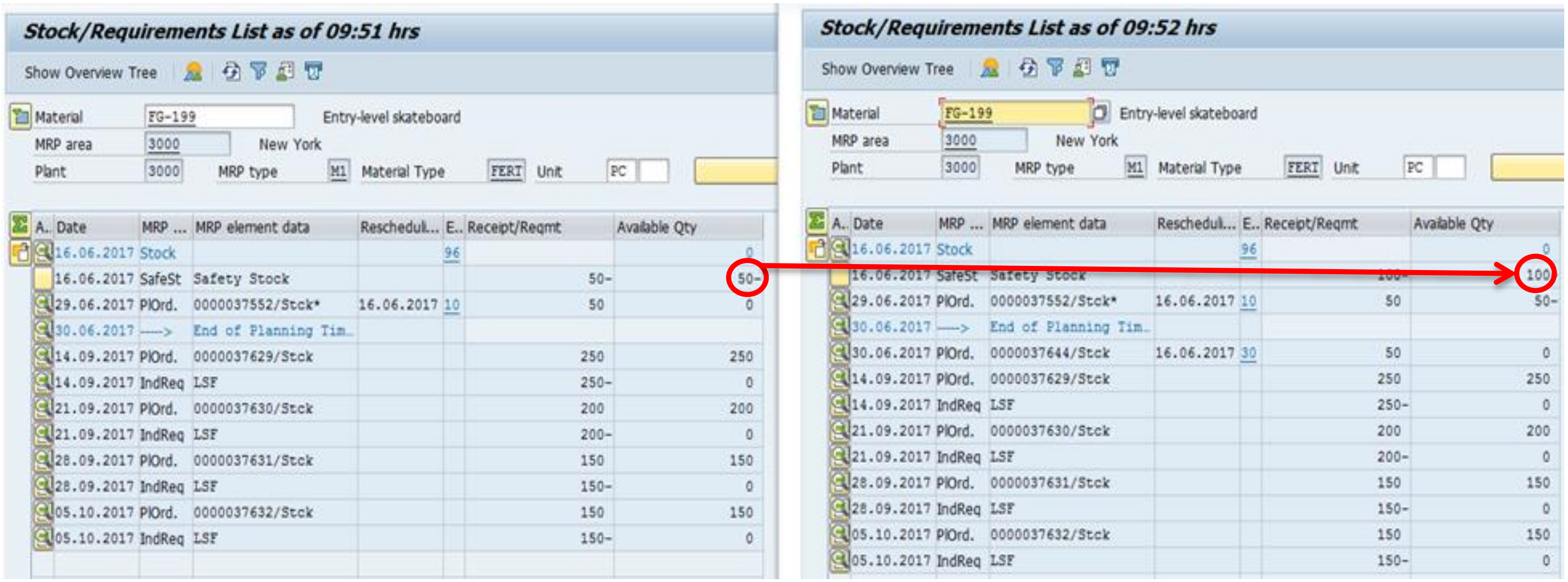
- What is to be produced
- When production is to take place
- Which capacity is to process the order
- How much production cost will be



Converting Planned Order into Purchase Requisition



Scenario 1 : Safety stock of Entry-level Skateboard increased to 100



Stock/Requirements List as of 09:51 hrs

Show Overview Tree

Material FG-199 Entry-level skateboard
MRP area 3000 New York
Plant 3000 MRP type M1 Material Type FERT Unit PC

A..	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock			96		0
	16.06.2017	SafeSt	Safety Stock			50-	50-
	29.06.2017	PlOrd.	0000037552/Stck*	16.06.2017	10	50	0
	30.06.2017	--->	End of Planning Tim...				
	14.09.2017	PlOrd.	0000037629/Stck			250	250
	14.09.2017	IndReq	LSF			250-	0
	21.09.2017	PlOrd.	0000037630/Stck			200	200
	21.09.2017	IndReq	LSF			200-	0
	28.09.2017	PlOrd.	0000037631/Stck			150	150
	28.09.2017	IndReq	LSF			150-	0
	05.10.2017	PlOrd.	0000037632/Stck			150	150
	05.10.2017	IndReq	LSF			150-	0

Stock/Requirements List as of 09:52 hrs

Show Overview Tree

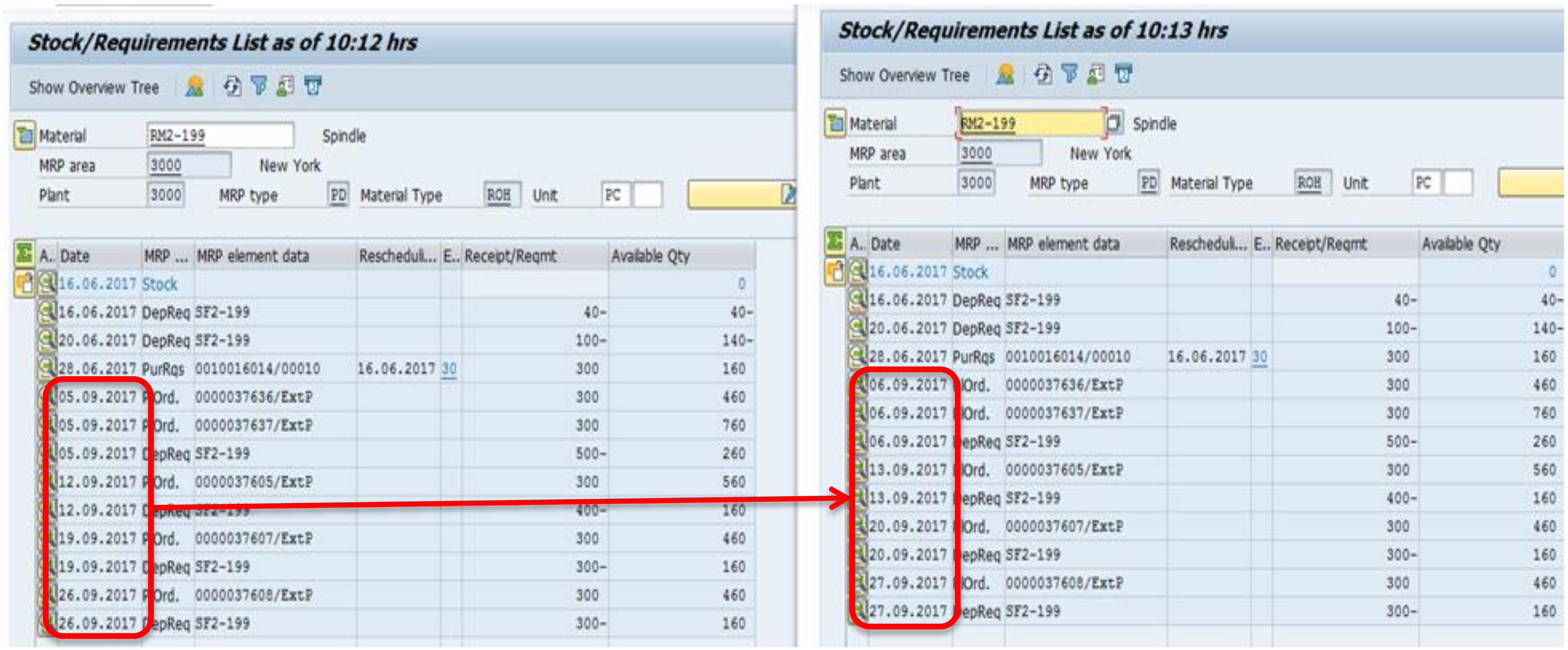
Material FG-199 Entry-level skateboard
MRP area 3000 New York
Plant 3000 MRP type M1 Material Type FERT Unit PC

A..	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock			96		0
	16.06.2017	SafeSt	Safety Stock			100-	100
	29.06.2017	PlOrd.	0000037552/Stck*	16.06.2017	10	50	50-
	30.06.2017	--->	End of Planning Tim...				
	30.06.2017	PlOrd.	0000037644/Stck	16.06.2017	30	50	0
	14.09.2017	PlOrd.	0000037629/Stck			250	250
	14.09.2017	IndReq	LSF			250-	0
	21.09.2017	PlOrd.	0000037630/Stck			200	200
	21.09.2017	IndReq	LSF			200-	0
	28.09.2017	PlOrd.	0000037631/Stck			150	150
	28.09.2017	IndReq	LSF			150-	0
	05.10.2017	PlOrd.	0000037632/Stck			150	150
	05.10.2017	IndReq	LSF			150-	0

Use MM02 to change from 50→100, and run MRP

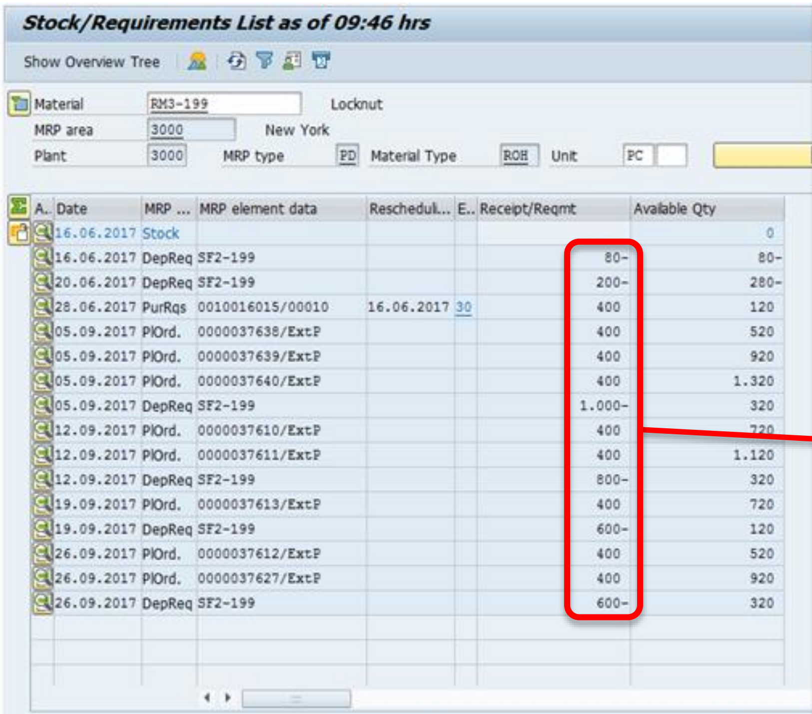
SS increased from 50→100. All other components also increased accordingly.

Scenario 2 : In-house production lead time is reduced to 1 days due to automation.



Use MM02 to change from 2→1, and run MRP
Requirement date is 1 day later.

Scenario 3 : Engineering design change, 3 locknuts are now needed for safety reasons.

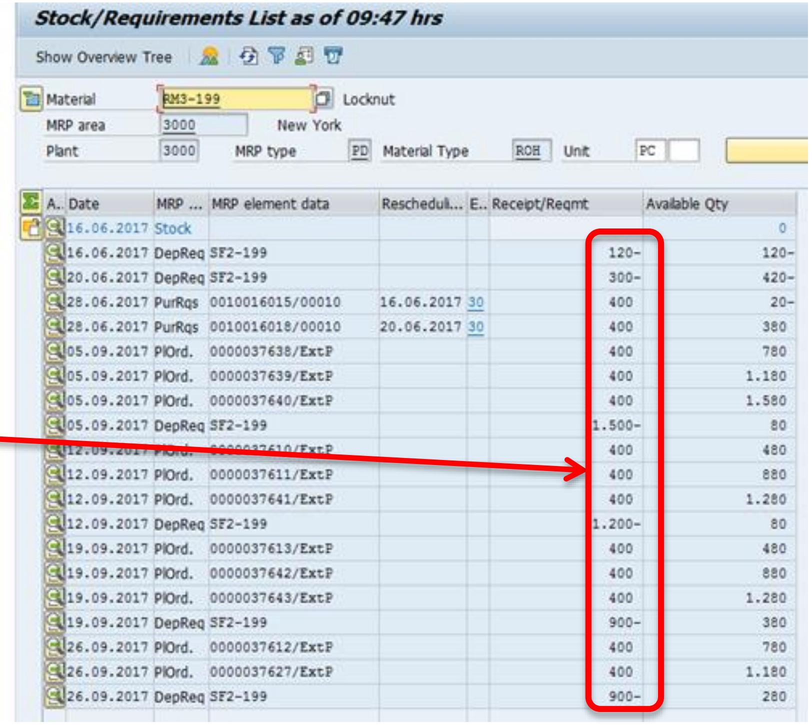


Stock/Requirements List as of 09:46 hrs

Show Overview Tree

Material RM3-199 Locknut
MRP area 3000 New York
Plant 3000 MRP type PD Material Type ROH Unit PC

A..	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock					0
	16.06.2017	DepReq	SF2-199			80-	80-
	20.06.2017	DepReq	SF2-199			200-	280-
	28.06.2017	PurRqs	0010016015/00010	16.06.2017	30	400	120
	05.09.2017	PlOrd.	0000037638/ExtP			400	520
	05.09.2017	PlOrd.	0000037639/ExtP			400	920
	05.09.2017	PlOrd.	0000037640/ExtP			400	1.320
	05.09.2017	DepReq	SF2-199			1.000-	320
	12.09.2017	PlOrd.	0000037610/ExtP			400	720
	12.09.2017	PlOrd.	0000037611/ExtP			400	1.120
	12.09.2017	DepReq	SF2-199			800-	320
	19.09.2017	PlOrd.	0000037613/ExtP			400	720
	19.09.2017	DepReq	SF2-199			600-	120
	26.09.2017	PlOrd.	0000037612/ExtP			400	520
	26.09.2017	PlOrd.	0000037627/ExtP			400	920
	26.09.2017	DepReq	SF2-199			600-	320



Stock/Requirements List as of 09:47 hrs

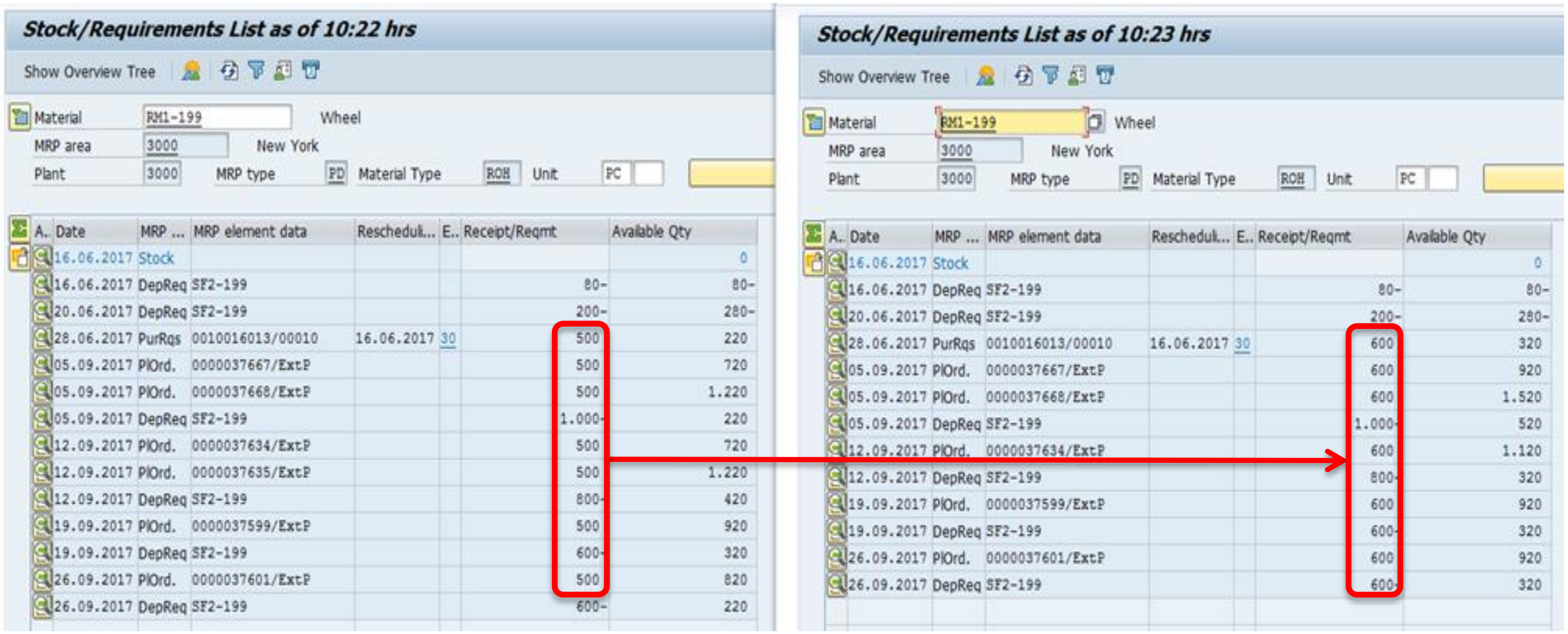
Show Overview Tree

Material RM3-199 Locknut
MRP area 3000 New York
Plant 3000 MRP type PD Material Type ROH Unit PC

A..	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock					0
	16.06.2017	DepReq	SF2-199			120-	120-
	20.06.2017	DepReq	SF2-199			300-	420-
	28.06.2017	PurRqs	0010016015/00010	16.06.2017	30	400	20-
	28.06.2017	PurRqs	0010016018/00010	20.06.2017	30	400	380
	05.09.2017	PlOrd.	0000037638/ExtP			400	780
	05.09.2017	PlOrd.	0000037639/ExtP			400	1.180
	05.09.2017	PlOrd.	0000037640/ExtP			400	1.580
	05.09.2017	DepReq	SF2-199			1.500-	80
	12.09.2017	PlOrd.	0000037610/ExtP			400	480
	12.09.2017	PlOrd.	0000037611/ExtP			400	880
	12.09.2017	PlOrd.	0000037641/ExtP			400	1.280
	12.09.2017	DepReq	SF2-199			1.200-	80
	19.09.2017	PlOrd.	0000037613/ExtP			400	480
	19.09.2017	PlOrd.	0000037642/ExtP			400	880
	19.09.2017	PlOrd.	0000037643/ExtP			400	1.280
	19.09.2017	DepReq	SF2-199			900-	380
	26.09.2017	PlOrd.	0000037612/ExtP			400	780
	26.09.2017	PlOrd.	0000037627/ExtP			400	1.180
	26.09.2017	DepReq	SF2-199			900-	280

Use CS02 to change from 2→3
DepReq is 50% increased, results in more PlOrd also.

Scenario 4 : Purchasing has negotiated a new deal with Wheel supplier. Lot size is now 600.



Stock/Requirements List as of 10:22 hrs

Show Overview Tree

Material RM1-199 Wheel
MRP area 3000 New York
Plant 3000 MRP type PD Material Type ROH Unit PC

A.	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock					0
	16.06.2017	DepReq	SF2-199			80-	80-
	20.06.2017	DepReq	SF2-199			200-	280-
	28.06.2017	PurRqs	0010016013/00010	16.06.2017	30	500	220
	05.09.2017	PlOrd.	0000037667/ExtP			500	720
	05.09.2017	PlOrd.	0000037668/ExtP			500	1.220
	05.09.2017	DepReq	SF2-199			1.000-	220
	12.09.2017	PlOrd.	0000037634/ExtP			500	720
	12.09.2017	PlOrd.	0000037635/ExtP			500	1.220
	12.09.2017	DepReq	SF2-199			800-	420
	19.09.2017	PlOrd.	0000037599/ExtP			500	920
	19.09.2017	DepReq	SF2-199			600-	320
	26.09.2017	PlOrd.	0000037601/ExtP			500	820
	26.09.2017	DepReq	SF2-199			600-	220

Stock/Requirements List as of 10:23 hrs

Show Overview Tree

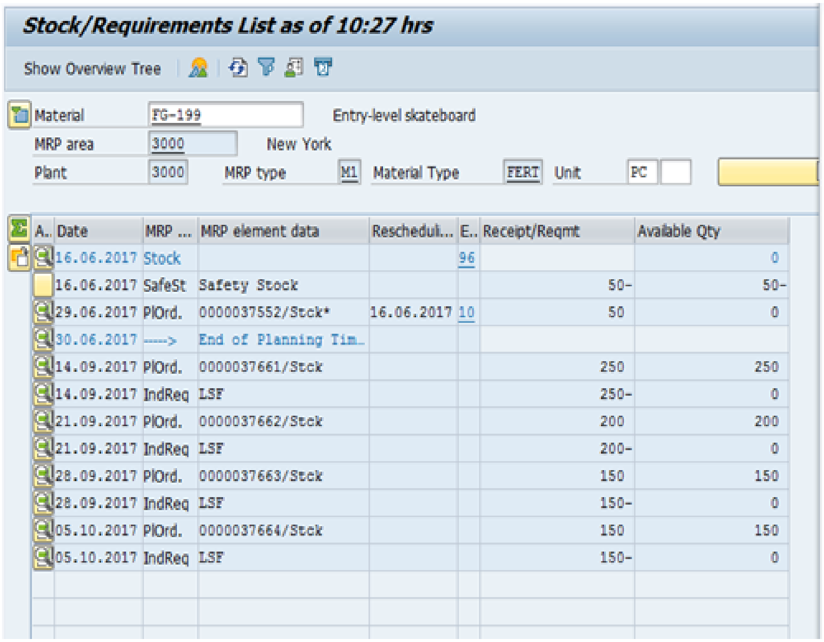
Material RM1-199 Wheel
MRP area 3000 New York
Plant 3000 MRP type PD Material Type ROH Unit PC

A.	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock					0
	16.06.2017	DepReq	SF2-199			80-	80-
	20.06.2017	DepReq	SF2-199			200-	280-
	28.06.2017	PurRqs	0010016013/00010	16.06.2017	30	600	320
	05.09.2017	PlOrd.	0000037667/ExtP			600	920
	05.09.2017	PlOrd.	0000037668/ExtP			600	1.520
	05.09.2017	DepReq	SF2-199			1.000-	520
	12.09.2017	PlOrd.	0000037634/ExtP			600	1.120
	12.09.2017	DepReq	SF2-199			800-	320
	19.09.2017	PlOrd.	0000037599/ExtP			600	920
	19.09.2017	DepReq	SF2-199			600-	320
	26.09.2017	PlOrd.	0000037601/ExtP			600	920
	26.09.2017	DepReq	SF2-199			600-	320

Use MM02 to change from 500→600

PlOrd are changed from 500→600. Number of Orders are also reduced.

There is an additional order of 300 pcs from customers on 21st August.

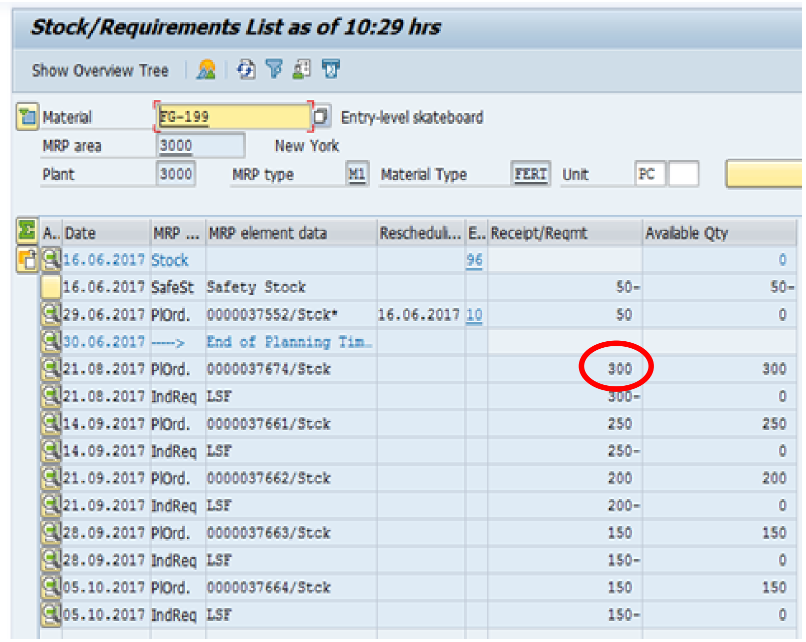


Stock/Requirements List as of 10:27 hrs

Show Overview Tree

Material FG-199 Entry-level skateboard
MRP area 3000 New York
Plant 3000 MRP type M1 Material Type FERT Unit PC

A..	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock			96		0
	16.06.2017	SafeSt	Safety Stock			50-	50-
	29.06.2017	PlOrd.	0000037552/Stck*	16.06.2017	10	50	0
	30.06.2017	--->	End of Planning Tim...				
	14.09.2017	PlOrd.	0000037661/Stck			250	250
	14.09.2017	IndReq	LSF			250-	0
	21.09.2017	PlOrd.	0000037662/Stck			200	200
	21.09.2017	IndReq	LSF			200-	0
	28.09.2017	PlOrd.	0000037663/Stck			150	150
	28.09.2017	IndReq	LSF			150-	0
	05.10.2017	PlOrd.	0000037664/Stck			150	150
	05.10.2017	IndReq	LSF			150-	0



Stock/Requirements List as of 10:29 hrs

Show Overview Tree

Material FG-199 Entry-level skateboard
MRP area 3000 New York
Plant 3000 MRP type M1 Material Type FERT Unit PC

A..	Date	MRP ...	MRP element data	Reschedul...	E..	Receipt/Reqmt	Available Qty
	16.06.2017	Stock			96		0
	16.06.2017	SafeSt	Safety Stock			50-	50-
	29.06.2017	PlOrd.	0000037552/Stck*	16.06.2017	10	50	0
	30.06.2017	--->	End of Planning Tim...				
	21.08.2017	PlOrd.	0000037674/Stck			300	300
	21.08.2017	IndReq	LSF			300-	0
	14.09.2017	PlOrd.	0000037661/Stck			250	250
	14.09.2017	IndReq	LSF			250-	0
	21.09.2017	PlOrd.	0000037662/Stck			200	200
	21.09.2017	IndReq	LSF			200-	0
	28.09.2017	PlOrd.	0000037663/Stck			150	150
	28.09.2017	IndReq	LSF			150-	0
	05.10.2017	PlOrd.	0000037664/Stck			150	150
	05.10.2017	IndReq	LSF			150-	0

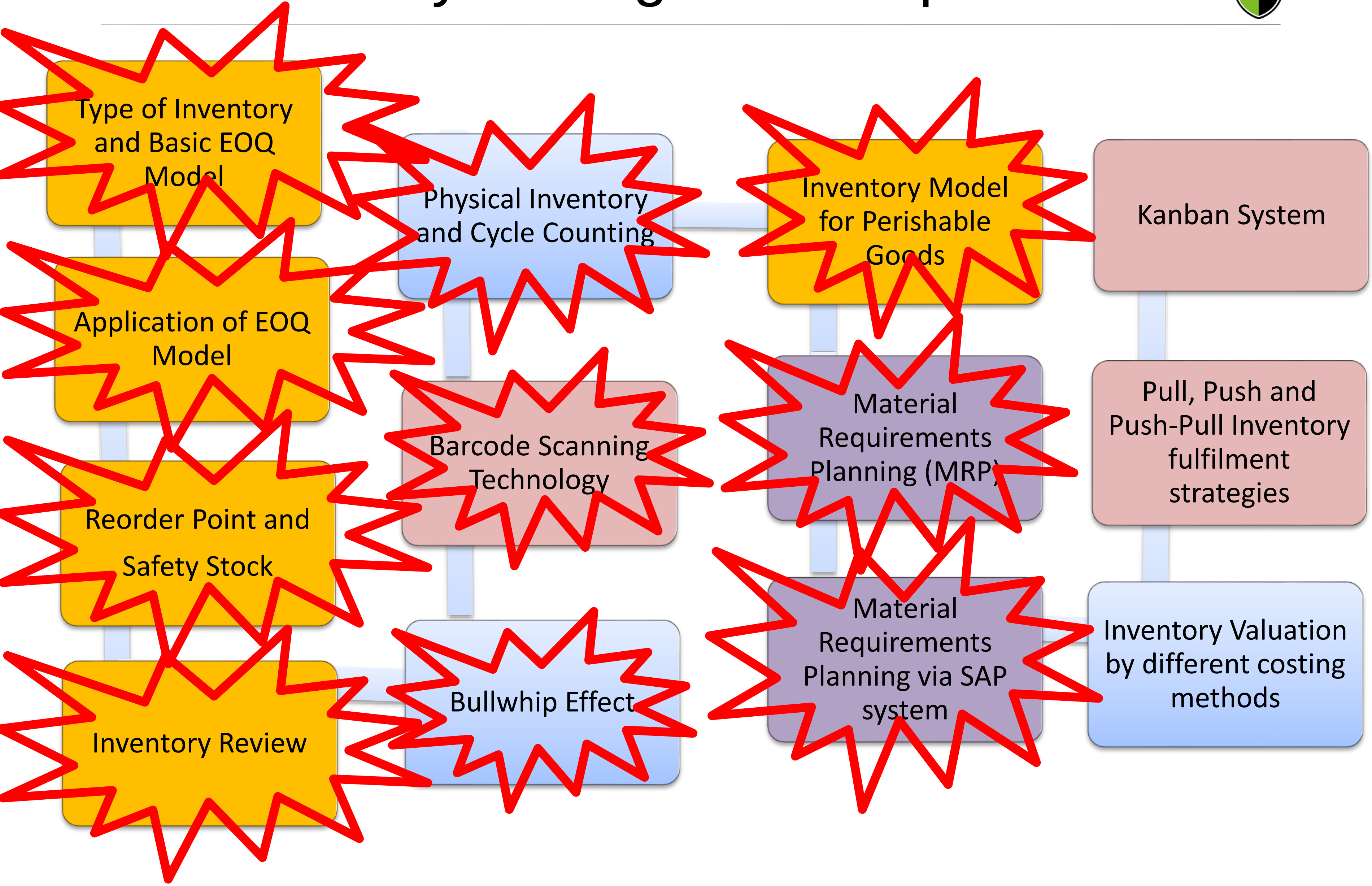
Use Md61 to add in 300 at 21st Aug

Additional PlOrd of 300 at 21st Aug. All other components also increase accordingly.

Learning Objectives

- Understand the key building blocks of SAP ERP
- Overview of Production Planning module
- Describe the organizational levels of PP module
- Describe the different Master Data used by PP
- Create the Material Master & BOM
- Perform MPS & MRP run in SAP
- Interpret MRP outputs by using stock/requirement list
- Convert MRP outputs into either Purchasing Requisition or Production Order

E217 Inventory Management Topic Flow



Problem 11

What is the cost?

E217 – Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

E217 Inventory Management

- **Strategic Role** of Inventory Management
  - Physical Inventory and Cycle Counting
  - Bullwhip Effect
  - Inventory Valuation
- **Inventory Control Methods**
  - **Independent-Demand Items**
    - Basic EOQ Model
    - Application of EOQ Model
    - Safety Stock and Reorder Point
    - Inventory Review Policies
    - Inventory Model for Perishable Goods
  - **Dependent-Demand Items**
    - Material Requirements Planning (MRP)
    - Material Requirements Planning (MRP) via SAP
- **Inventory Control System**
  - Barcode Scanning Technology
  - Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
  - Kanban System

Strategic Role of Inventory

- **Inventory as a buffer**
  - Smooth operations as stock provides a buffer between production and sales or supply and sales.

- **Inventory is money**
  - Financial performance of company is affected by stock holdings and valuation of stocks

Depending on demand of stock

Methods to Value Inventory - FIFO

First-In-First-Out (FIFO)

- Oldest items (those that are first purchased) are assumed to be the ones to be sold first
- For example, perishables like fresh milk, fresh cheese, fresh fruits and vegetables with expiry dates
- Assigns:
  - *Oldest costs to COGS*
  - *Recent costs to ending inventory*

Methods to Value Inventory - LIFO

Last-In-First-Out (LIFO)

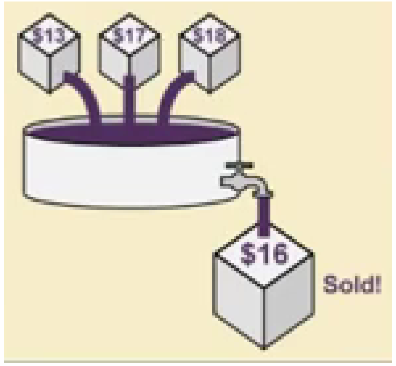
- Newest items (those that are most recently purchased) are assumed to be the first sold.
- For example, people who enter the lift last will be the ones to get out of the lift first
- Other examples include raw materials or components that do not have expiry dates and are kept in such a way that those stored recently are usually retrieved first.
- Assigns:
  - *Most recent costs to COGS*
  - *Oldest costs to ending inventory*

Methods to Value Inventory – Average Costing

Average Costing Method

- This method is quite straightforward.
- Regardless new or old, items are retrieved randomly or mixed and taken out together, e.g. anything in the form of liquid
- The average cost is based on the *weighted average* of all units available for sales during the accounting period.

$$\text{Average Costing in a period} = \frac{\text{Total Cost of Goods Available for Sale in this period}}{\text{Total Quantity of Goods Available for Sale in this period}}$$



Income Statement & Cost Of Goods Sold

- The Profit & Loss statement (P&L), also known as the Income Statement, is a company's financial statement that indicates how the revenue is transformed into net income.
- The purpose of the P&L is to show managers and investors whether the company made or lost money during the period being reported.
- COGS reflects the cost of obtaining raw materials and producing finished goods or services that are sold to consumers.
  - Equal to the beginning inventory plus the cost of goods purchased during some period minus the ending inventory.
  - Or simply add up all the costs of the products sold
  - It is also called “cost of sales” and listed on the Income Statement

Revenue

- **Revenue** is the income that a company receives from its normal business activities, usually from the sale of goods and services to customers.

- Revenue for FY 2016

  = ∑ (sales quantity x selling price)

  = $**481,500**

Selling quantity	Selling price
25	$900
30	$900
45	$900
35	$900
50	$900
20	$900
45	$900
40	$900
65	$900
60	$900
70	$900
50	$900
Total Revenue	481500

COGS by Using FIFO - Method 1

	FIFO Method										
	Units In (Bought)			Units Out (Sold)				Ending Inventory		
	# Units	Cost/Unit	Total Cost	# Units		Cost/Unit	Total Cost	# Units	Total Cost	
Apr-16	30	$550	$16,500	25	25	$550	$13,750	5	$2,750	5@$550
May-16	45	$560	$25,200	30	5	$550	$2,750	45	$25,200	
					25	$560	$14,000	20	$11,200	20@$560
Jun-16	40	$560	$22,400	45	20	$560	$11,200	40	$22,400	
					25	$560	$14,000	15	$8,400	15@$560
Jul-16	50	$550	$27,500	35	15	$560	$8,400	50	$27,500	
					20	$550	$11,000	30	$16,500	30@$550
Aug-16	30	$550	$16,500	50	30	$550	$16,500	30	$16,500	
					20	$550	$11,000	10	$5,500	10@$550
Sep-16	60	$545	$32,700	20	10	$550	$5,500	60	$32,700	
					10	$545	$5,450	50	$27,250	50@$545
Oct-16				45	45	$545	$24,525	5	$2,725	5@$545
Nov-16	70	$550	$38,500	40	5	$545	$2,725	70	$38,500	
					35	$550	$19,250	35	$19,250	35@$550
Dec-16	50	$560	$28,000	65	35	$550	$19,250	50	$28,000	
					30	$560	$16,800	20	$11,200	20@$560
Jan-17	60	$560	$33,600	60	20	$560	$11,200	60	$33,600	
					40	$560	$22,400	20	$11,200	20@$560
Feb-17	60	$550	$33,000	70	20	$560	$11,200	60	$33,000	
					50	$550	$27,500	10	$5,500	10@$550
Mar-17	65	$570	$37,050	50	10	$550	$5,500	65	$37,050	
					40	$570	$22,800	25	$14,250	25@$540
	560		$310,950		COGS1:		$296,700			
					COGS2:		$296,700			

COGS calculated by Method 1
→ sum up all the total cost (Sold)

COGS: $296,700

Ending Inventory Cost

COGS by Using FIFO - Method 2

	FIFO Method										
	Units In (Bought)			Units Out (Sold)				Ending Inventory		
	# Units	Cost/Unit	Total Cost	# Units		Cost/Unit	Total Cost	# Units	Total Cost	
Apr-16	30	$550	$16,500	25	25	$550	$13,750	5	$2,750	5@$550
May-16	45	$560	$25,200 A	30	5	$550	$2,750	45	$25,200	
					25	$560	$14,000	20	$11,200	20@$560
Jun-16	40	$560	$22,400	45	20	$560	$11,200	40	$22,400	
					25	$560	$14,000	15	$8,400	15@$560
Jul-16	50	$550	$27,500	35	15	$560	$8,400	50	$27,500	
					20	$550	$11,000	30	$16,500	30@$550
Aug-16	30	$550	$16,500	50	30	$550	$16,500	30	$16,500	
					20	$550	$11,000	10	$5,500	10@$550
Sep-16	60	$545	$32,700	20	10	$550	$5,500	60	$32,700	
			B		10	$545	$5,450	50	$27,250	50@$545
Oct-16				45	45	$545	$24,525	5	$2,725	5@$545
Nov-16	70	$550	$38,500	40	5	$545	$2,725	70	$38,500	
					35	$550	$19,250	35	$19,250	35@$550
Dec-16	50	$560	$28,000	65	35	$550	$19,250	50	$28,000	
					30	$560	$16,800	20	$11,200	20@$560
Jan-17	60	$560	$33,600	60	20	$560	$11,200	60	$33,600	
					40	$560	$22,400	20	$11,200	20@$560
Feb-17	60	$550	$33,000	70	20	$560	$11,200	60	$33,000	
					50	$550	$27,500	10	$5,500	10@$550
Mar-17	65	$570	$37,050	50	10	$550	$5,500	65	$37,050	
					40	$570	$22,800	25	$14,250	C 25@$540
	560		$310,950	COGS1:			$296,700			
				COGS2:			$296,700			

COGS calculated by Method 2
→beginning inventory plus the cost of goods purchased minus the ending inventory (A + B – C)

COGS: $296,700

Results by Using LIFO

					LIFO Method					
	Units In (Bought)				Units Out (Sold)			Ending Inventory		
	# Units	Cost/Unit	Total Cost	# Units		Cost/Unit	Total Cost	# Units	Total Cost	
Apr-16	30	$550	$16,500	25	25	$550	$13,750	5	$2,750	5@$550
May-16	45	$560	$25,200	30	30	$560	$16,800	20	$11,150	5@$550; 15@$560
Jun-16	40	$560	$22,400	45	40	$560	$22,400	20	$11,150	
					5	$560	$2,800	15	$8,350	5@$550; 10@$560
Jul-16	50	$550	$27,500	35	35	$550	$19,250	30	$16,600	5@$550; 10@$560; 15@$550
Aug-16	30	$550	$16,500	50	30	$550	$16,500	30	$16,600	
					15	$550	$8,250	15	$8,350	
					5	$560	$2,800	10	$5,550	5@$550; 5@$560
Sep-16	60	$545	$32,700	20	20	$545	$10,900	50	$27,350	5@$550; 5@$560; 40@$545
Oct-16				45	40	$545	$21,800	10	$5,550	
					5	$560	$2,800	5	$2,750	5@$550
Nov-16	70	$550	$38,500	40	40	$550	$22,000	35	$19,250	5@$550; 30@$550
Dec-16	50	$560	$28,000	65	50	$560	$28,000	35	$19,250	
					15	$550	$8,250	20	$11,000	5@$550; 15@$550
Jan-17	60	$560	$33,600	60	60	$560	$33,600	20	$11,000	5@$550; 15@$550
Feb-17	60	$550	$33,000	70	60	$550	$33,000	20	$11,000	
					10	$550	$5,500	10	$5,500	5@$550; 5@$550
Mar-17	65	$570	$37,050	50	50	$570	$28,500	25	$14,050	5@$550; 5@$550, 15@$540
	560		$310,950							

COGS1: $296,900

COGS2: $296,900

COGS: $296,900

Comparison of FIFO and LIFO

FIFO Method

Oldest cost	Goes into	Cost of Goods Sold
Recent cost	Goes into	Ending Inventory

LIFO Method

Recent cost	Goes into	Cost of Goods Sold
Oldest cost	Goes into	Ending Inventory

Results Using Average Costing Method

					Average Costing Method				
	Units In (Bought)				Units Out (Sold)			Ending Inventory	
	# Units	Cost/Unit	Total Cost		# Units	Cost/Unit	Total Cost	# Units	Total Cost
Apr-16	30	$550	$16,500.00		25	$555.27	$13,882	5	$2,776
May-16	45	$560	$25,200.00		30	$555.27	$16,658	20	$11,105
Jun-16	40	$560	$22,400.00		45	$555.27	$24,987	15	$8,329
Jul-16	50	$550	$27,500.00		35	$555.27	$19,434	30	$16,658
Aug-16	30	$550	$16,500.00		50	$555.27	$27,763	10	$5,553
Sep-16	60	$545	$32,700.00		20	$555.27	$11,105	50	$27,763
Oct-16					45	$555.27	$24,987	5	$2,776
Nov-16	70	$550	$38,500.00		40	$555.27	$22,211	35	$19,434
Dec-16	50	$560	$28,000.00		65	$555.27	$36,092	20	$11,105
Jan-17	60	$560	$33,600.00		60	$555.27	$33,316	20	$11,105
Feb-17	60	$550	$33,000.00		70	$555.27	$38,869	10	$5,553
Mar-17	65	$570	$37,050.00		50	$555.27	$27,763	25	$13,882
Total	560		$310,950.00		COGS1:		$297,068		
					COGS2:		$297,068		

Average:	$555.27

= $310,950/560

= $555.27

COGS: $297,068

Recommendations for Today's problem

- Gross Profit is the difference between revenue and the cost of making a product or providing a service, before deducting overhead, payroll, taxation, and interest payments.
- Gross Profit = Revenue – COGS
- Profit Before Taxes = Gross Profit – Expenses
- Profit After Tax (After Tax Income) = Profit Before Tax - Tax

Income Statement	FIFO	LIFO	Avg. Costing Method
Revenues	$481,500	$481,500	$481,500
Less: Cost of Goods Sold (COGS)	$296,700	$296,900	$297,068
Gross profit	$184,800	$184,600	$184,432
Less: Selling, General & Administrative Expenses	$2,200	$2,200	$2,200
Depreciation & Amortization Expenses	$1,100	$1,100	$1,100
Goodwill Expenses	$2,000	$2,000	$2,000
Profit Before Taxes	$179,500	$179,300	$179,132
Less: Company Tax (assuming 17%)	$30,515	$30,481	$30,452
Profit After Taxes (After Tax Income)	$148,985	$148,819	$148,679

- The *highest* Profit After Taxes is obtained by using *FIFO* method as FIFO has the *lowest COGS.*

Further Considerations

- If purchasing price keeps going *up* all the time
  - Companies choosing to minimize their taxable income can choose the LIFO method to value inventories.
  - Companies choosing to maximize their reported income typically select FIFO or other non-LIFO method, such as Average Costing Method.

- If purchasing price keeps going *down* all the time
  - Companies choosing to maximize their taxable income have to select LIFO method due to lowest COGS

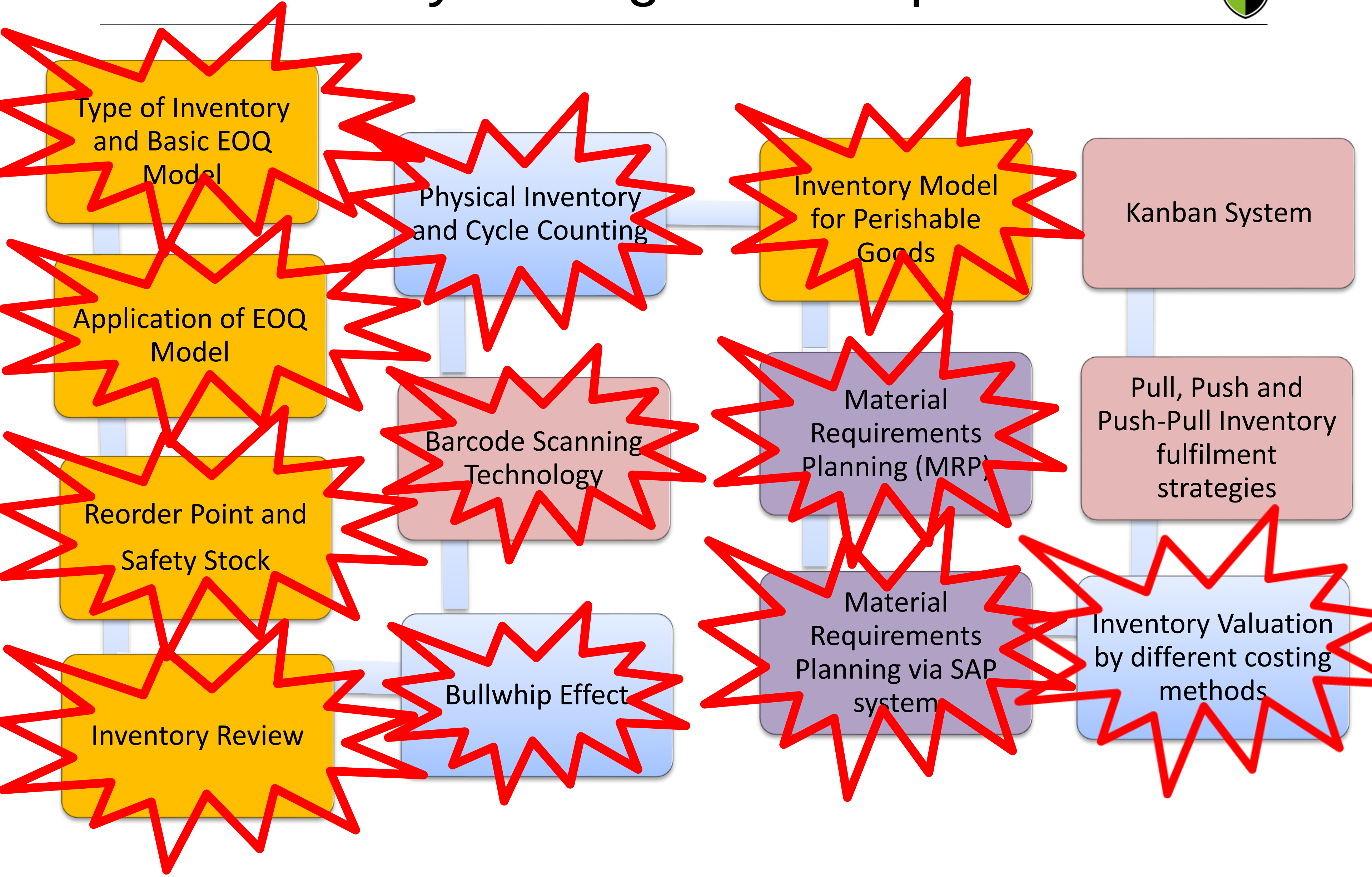
- Other factors to consider when choosing the valuation methods:
  - Expiry dates, usage, fixed shelf-life, storage and material flow systems will also affect the inventory movement & valuation policy.
  - Accounting standards allowed in each country
    - E.g. to use LIFO in Singapore, you need to apply to IRAS

Learning Objectives

- Describe the concepts of First-In-First-Out (FIFO), Last-In-First-Out (LIFO) and Average Costing
- Explain the Cost of Goods Sold (COGS)
- Perform inventory valuations by using FIFO, LIFO and Average Costing respectively:
  - ❖ Calculate COGS
  - ❖ Calculate Revenue
  - ❖ Calculate Gross Profit
  - ❖ Calculate After Tax Income

- Describe the impact of different inventory valuation methods on the Profit and Loss (P&L) Account

E217 Inventory Management Topic Flow



Problem 12

A New Way to Manage Inventory

E217 – Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

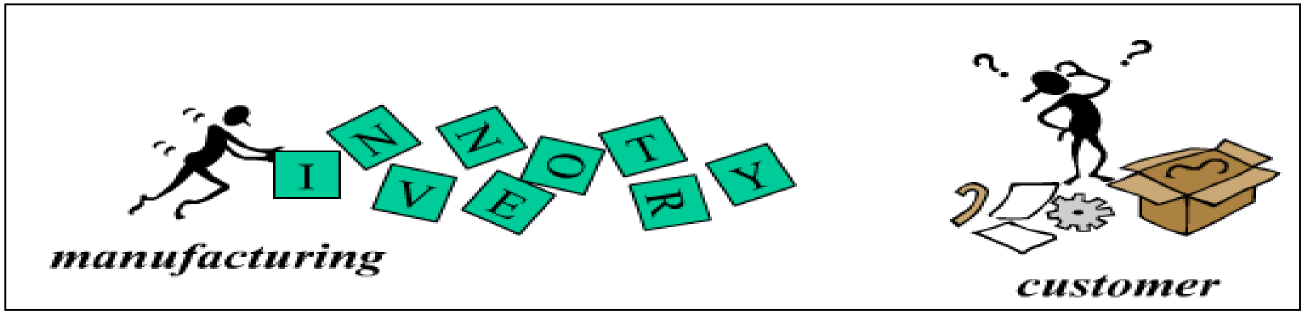
- **E217 Inventory Management**
  - **Strategic Role** of Inventory Management
    - Physical Inventory and Cycle Counting
    - Bullwhip Effect
    - Inventory Valuation
  - **Inventory Control Methods**
    - **Independent-Demand Items**
      - Basic EOQ Model
      - Application of EOQ Model
      - Safety Stock and Reorder Point
      - Inventory Review Policies
      - Inventory Model for Perishable Goods
    - **Dependent-Demand Items**
      - Material Requirements Planning (MRP)
      - Material Requirements Planning (MRP) via SAP
  - **Inventory Control System**
    - Barcode Scanning Technology
    - Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
    - Kanban System

Push & Pull Strategy

- Processes in a supply chain are divided into two categories depending on whether they are executed in response to a customer order (pull) or in anticipation of a customer order (push).
- Push-Based Supply Chain
- Pull-Based Supply Chain
- Push-Pull Supply Chain

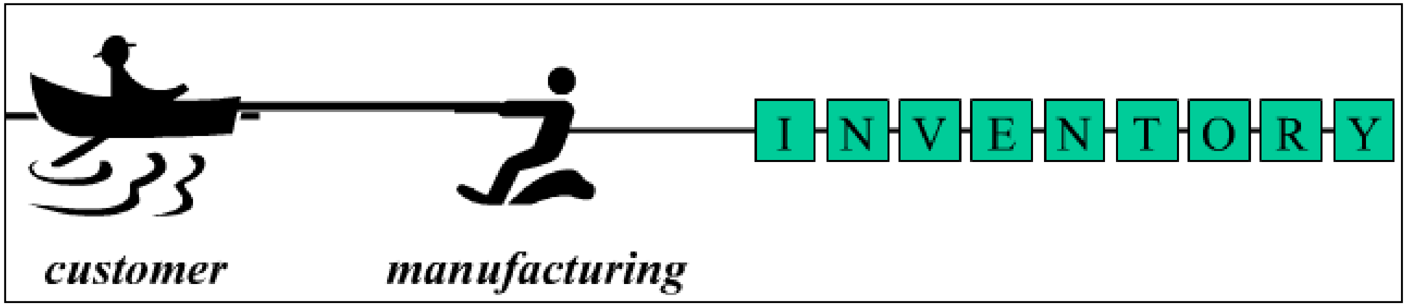
Push-based Supply Chain

- **"Push"** implies that you are pushing inventory into the system with the hopes that someone is going to buy it
- Scale of economies can be enjoyed
- In a **push-based** supply chain, the production and distribution decisions are based on long-term forecasts.
  - *Take a longer time to reach the changing customer demands*
  - *Results in high production cost, high inventory cost and high transportation cost because companies would like to have buffer at every stage of the supply chain (higher risk of product obsolescence)*
- Example: Diet Coke, Rice, Tissue Paper, etc.



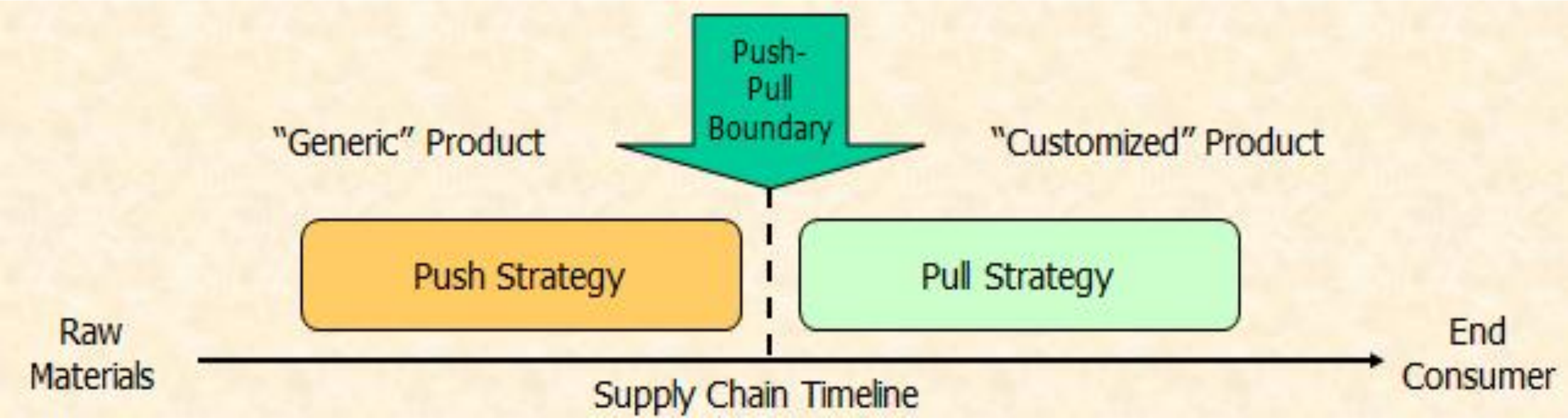
Pull-based Supply Chain

- **"Pull"** implies that items are only manufactured after an actual customer order is placed
- Suitable if there is high demand uncertainty
- In a **pull-based** supply chain, the production and distribution decisions are demand driven
  - *Significant reduction in lead time, inventory levels and costs.*
  - *Better response to changing customer demands*
  - *However, it is difficult to implement the pull system especially when lead-times are long (too slow to react to changing customer demands).*
- Example: Dentures, Build-To-Order (BTO) flats, etc.



Push-Pull Supply Chain

- This has led to companies to use the push-pull strategy (to take advantage of the best of both worlds).
- Typically the initial stages of a supply chain are designed to be pushed-based (replenishment is based on long-term forecasts) while the remaining stages are pull-based (based on actual customer demand).
- The interface between the push and pull stages is known as the push-pull boundary.



Conventional Inventory Management

Customer

- monitors inventory levels and places orders

Vendor

- manufactures/purchases products
- assembles order
- loads vehicles and makes deliveries

Problems with Conventional Inventory Management:

- Large variation in demands on production and transportation workload balancing
- utilization of resources
- unnecessary transportation costs
- urgent V.S. non-urgent orders
- setting priorities

You order – We haul!

History of Vendor Managed Inventory (VMI)

- In 1987, P&G and Wal-Mart pioneered in Continuous Replenishment Process (CRP). With CRP, P&G makes the main inventory replenishment decisions for Wal-Mart.

- P&G monitors Wal-Mart's inventory levels (physically or via electronic messaging) and makes periodic resupply decisions regarding order quantities, shipping, and timing. Transactions customarily initiated by Wal-Mart (like purchase orders) are initiated by P&G instead.

- CRP between Wal-Mart and P&G is best-known as the vendor-managed inventory program.

Vendor Managed Inventory (VMI)

Customer

- trusts the vendor to manage the inventory

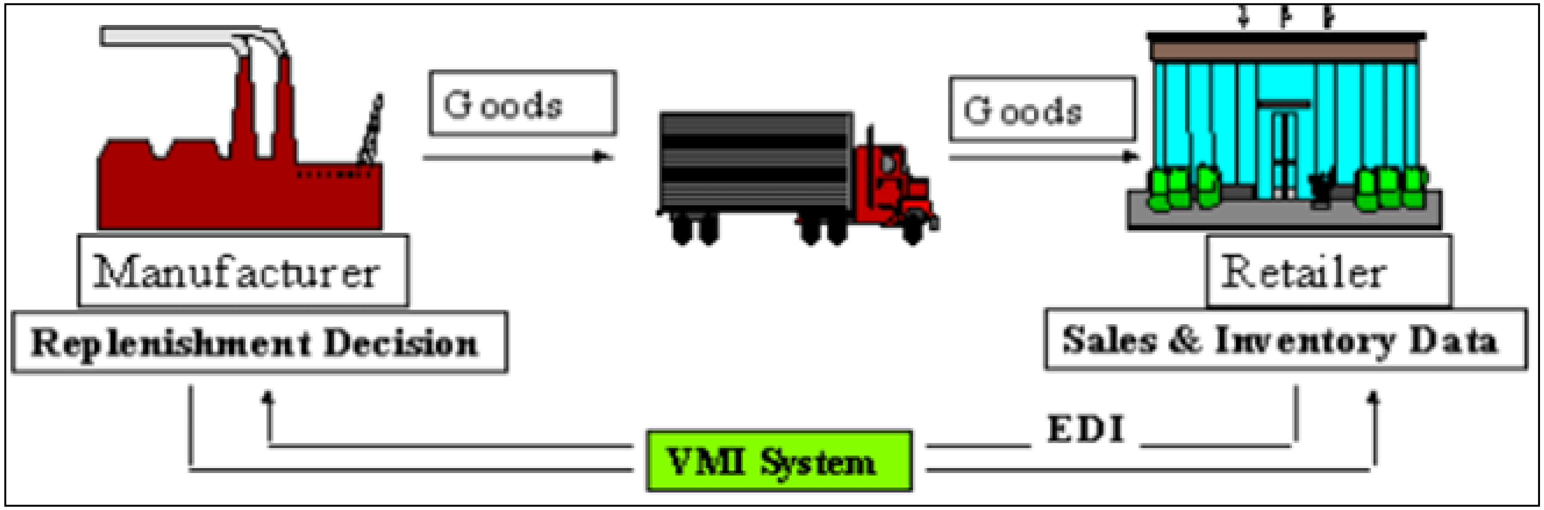
Vendor

- monitors customers' inventory
- controls inventory replenishment & decides
  - when to deliver
  - how much to deliver
  - how to deliver

You rely – We supply!

Vendor Managed Inventory (VMI)

- An approach to inventory and order fulfillment in the way that supplier, not the customer, is responsible for managing and replenishing inventory.
- The supplier creates the purchase orders based on the demand information exchanged by the customer.
- The supplier is responsible for maintaining the customer inventory management



Vendor Managed Inventory (VMI)

- VMI provides visibility across the supply chain
  - Enables both parties to reduce inventory significantly
  - Improve production planning
  - Improve inventory turnover
  - Improve stock availability.
  - Lower operations cost

- VMI does not simply stand for:
  the passing of the customer’s consumption history for a specific item to the supplier, who will follow-up the customer’s stock level and generates a purchasing order to replenish the stock.

- VMI in fact stands for:
  Granting inspection of the sales profile of a specific item to the supplier, who will optimize the replenishment policy and ensure the pre-defined service level towards his customer.

How Does VMI Work? (1)

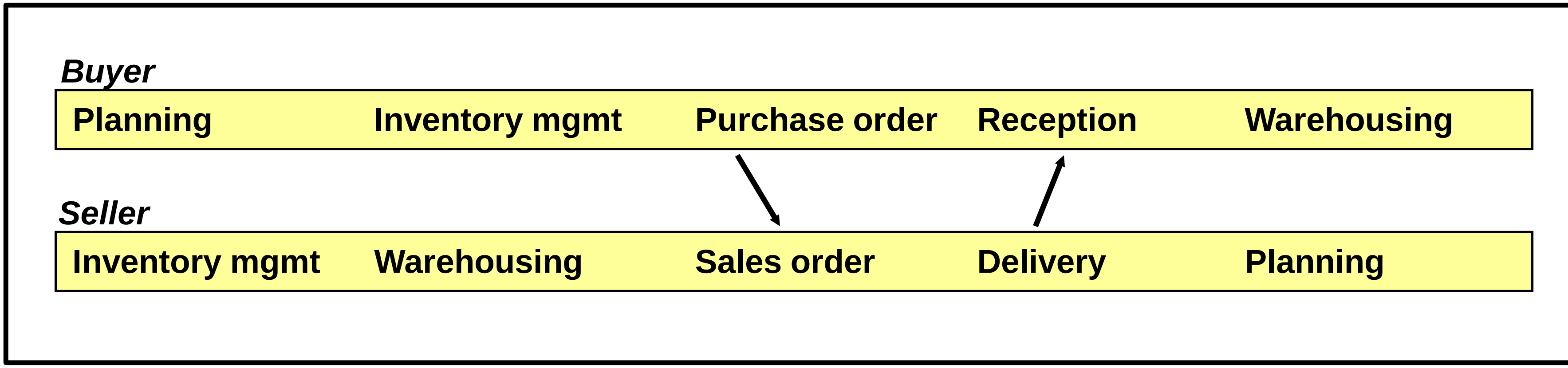
VMI may cover a single task or any combination of tasks as below:

- Vendor shows up at customer’s facility and physically reviews inventory levels, immediately replenishes with inventory he has with him (physically stocks the inventory on the customer’s shelves).
- Vendor shows up at customer’s facility and physically reviews inventory levels, places an order for replenishment inventory that will be delivered at a later date
- Customer periodically (e.g. weekly) provides vendor with current inventory levels. Vendor reviews inventory levels and creates replenishment orders. Replenishment orders are shipped to customer.

How Does VMI Work? (2)

- Vendor has direct access to customer’s inventory system and can get real-time information related to on-hand levels, open orders, forecasts, production schedules, etc. Vendor makes replenishment decisions based on this data and ships orders to customer.
- Vendor provides on-site inventory planner that works full-time at the customer’s facility managing the inventory supplied by that vendor.
- Vendor leases space within the customer’s facility and runs their own warehouse and inventory planning operation with their own employees within the customer’s facility.

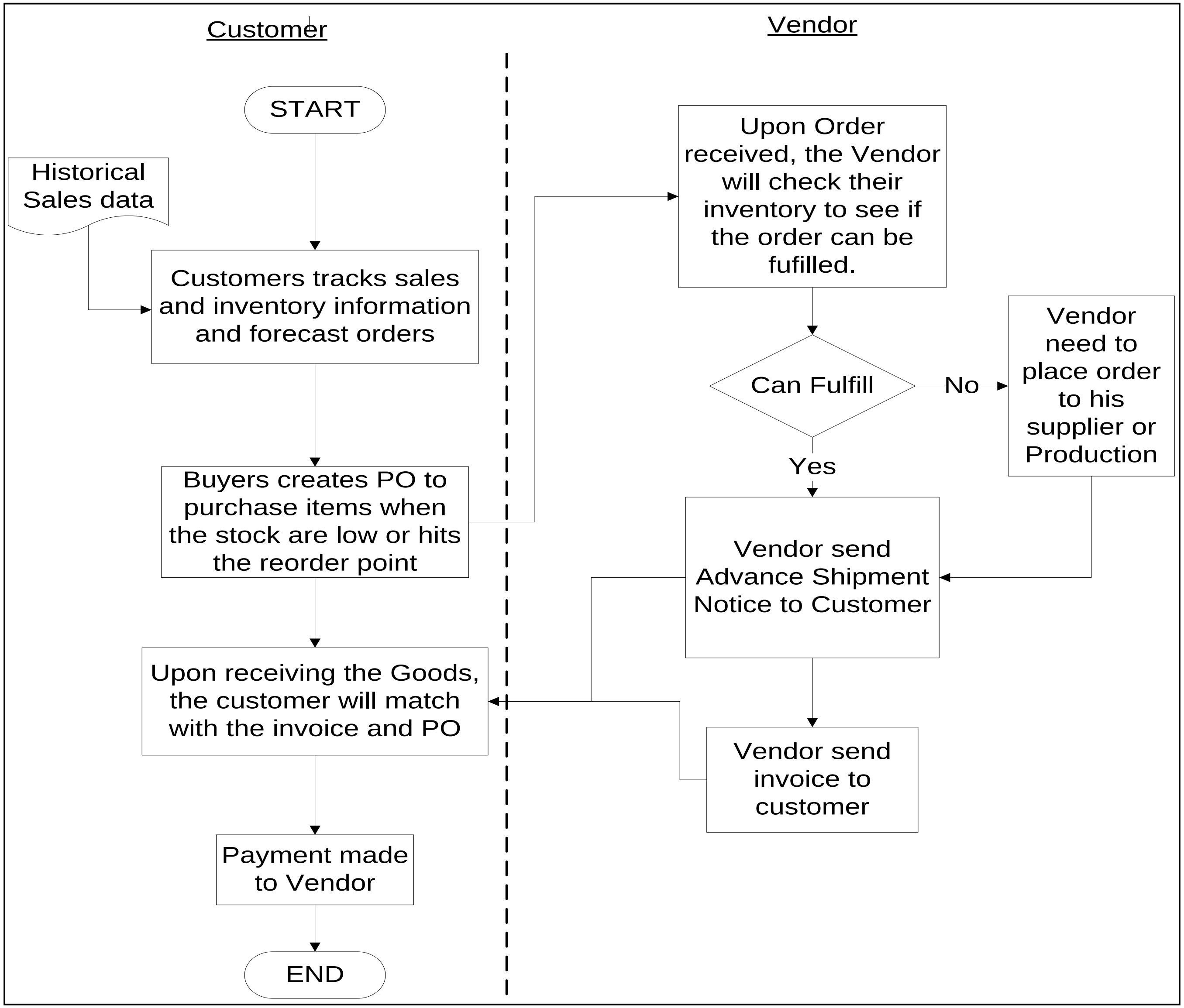
Conventional Fulfillment Process



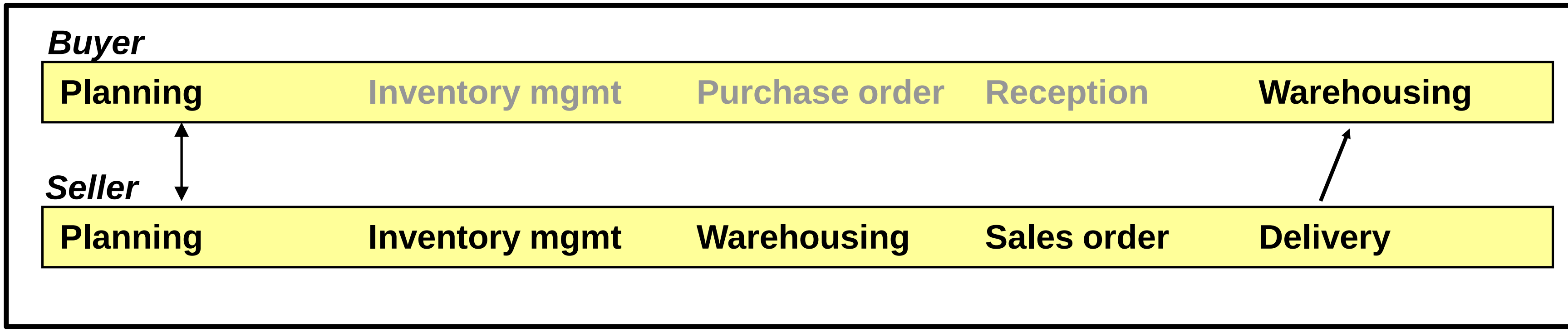
Under the typical business model:

- When a retailer needs product, they place an order against a manufacturer.
- The retailer is in total control of the timing and size of the order being placed. The retailer maintains the inventory plan.

A Typical Conventional Fulfillment Process

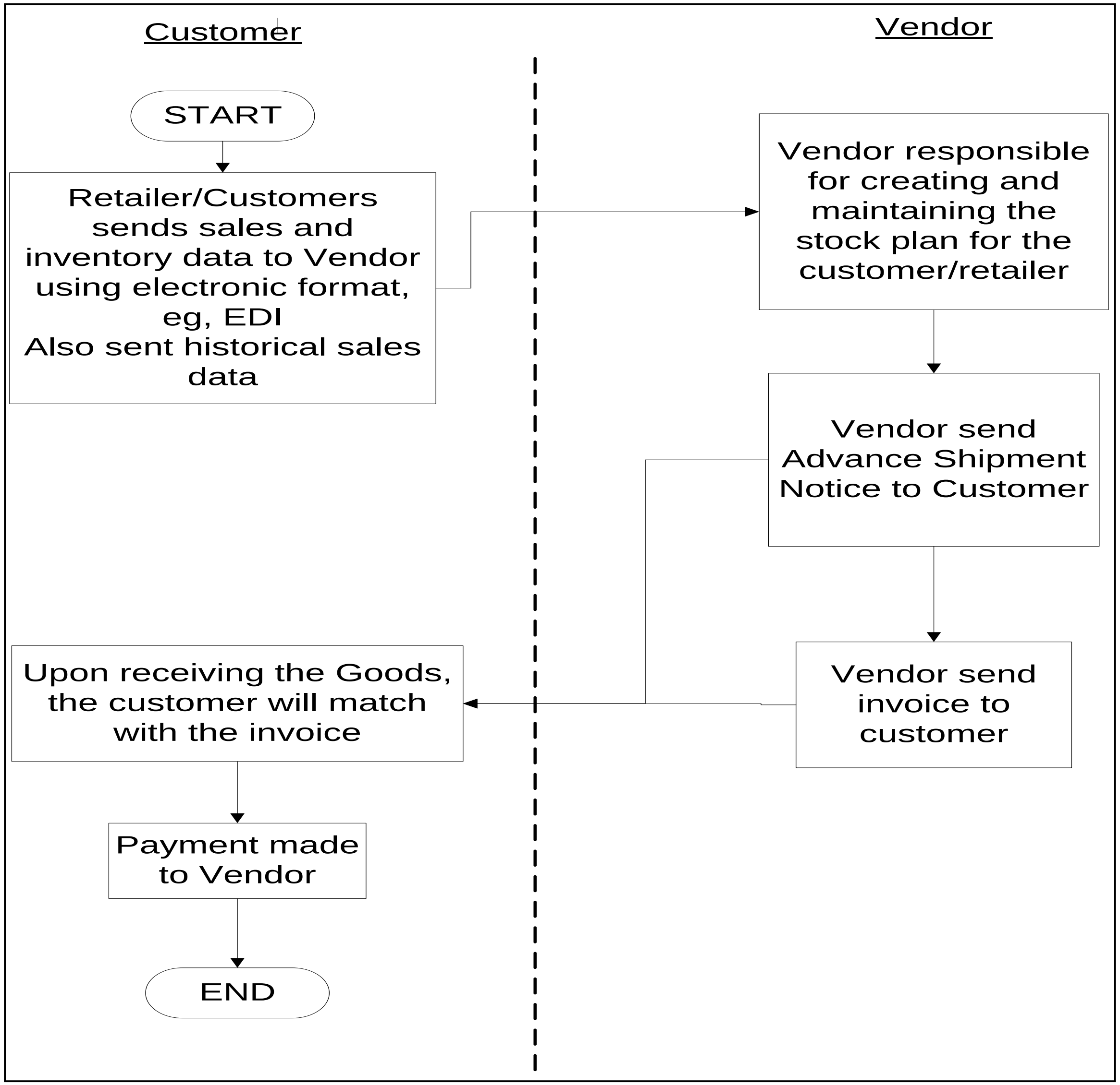


VMI Fulfillment Process (Example)



- The manufacturer receives electronic data (usually EDI or via internet) that tells him the retailers sales and stock levels.
- The manufacturer can view every item that the retailer carries as well as true point of sale data.
- The manufacturer is responsible for creating and maintaining the inventory plan.
- Under VMI, the manufacturer generates the order, not the retailer. VMI does not change the “ownership” of inventory.

A Typical VMI Fulfillment Process (Example)



What’s Needed to Make VMI Work

- **Management and Staff Commitment**

  - Strategic initiative (top down)
  - Communicated to the organisation especially the inventory and replenishment planners.
  - Management must understand the concept of VMI and ready to let 3rd party handle the inventory.
  - The support of inventory analysts, e-business analysts and replenishment planners are very essential for the success

What's Needed to Make VMI Work

- **Setting up Information Management systems, e.g. EDI, ERP system, etc.**
  - Information system is the enabler for VMI (Technology)
  - Product data, code and other catalog information must match between customer and vendor.
  - Prior to start up, all product data must be audited and difference must be resolve.
  - Vendor must be in the information system
  - The information system must be tested to ensure correct and accurate data are able to be transmitted to the Vendor.

What's Needed to Make VMI Work

- **Agreement**
  - On Inventory Turnover
  - Fill rates
  - Frequency of replenishment
  - Payment terms
  - Quality

- **Data Exchange**
  - One time exchange of sales history (Retailer/customer)
  - On-going product activity data (on-hand inventory, sales volume, backorders, returns, etc)

What's Needed to Make VMI Work

- **Ordering and Invoicing**

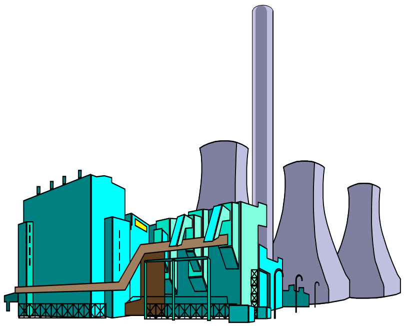
  - Vendor does the ordering on behalf of the customer.
  - The PO will be acknowledged electronically by the customer.
  - Reorder point, order quantity, frequency will be determined by the vendor depending on the agreement.
  - Advance shipping order needs to be sent to the customer via electronic means (EDI or internet).
  - Customer upon receiving the invoice and goods, will need to do a matching before processing payment to vendors

What's Needed to Make VMI Work

- **Performance Measurement**

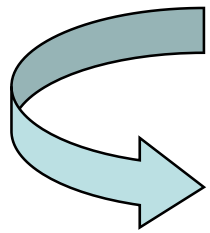
  - KPIs must be established during the agreement stage
  - Vendors will be subjected to audit based on these KPIs
  - A formal measuring process should be in place for effective measurement of the vendor using the agreed KPIs.

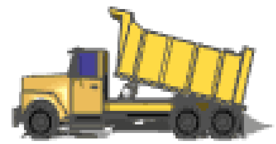
Benefits of Implementing VMI



Vendor

- Better forecasts (POS)
- Lower inventory
- Less errors in orders placed
- Leveling of production capacity





- Full truck load
- Efficient route planning

Customer

- Less stock-out
- Lower inventory
- Better service level
- Lower planning & ordering costs

Benefits of VMI to Vendor

- Better coordination of inventory levels at different customers
- Better coordination of deliveries to decrease transportation cost (reduce the rush-order and related high cost)
- Reduce Bullwhip Effect with increased supply chain visibility (real-time availability of customers' demand information and stock level)
- Improve production scheduling and forecast with better information, reducing WIP and inventory levels
- Lock in customers with deeper partnership and collaborations
- Reduce errors in orders as now the orders are done by the vendor, thus reducing returns.

Benefits of VMI to Customer

- Customers only have to supervise the stocks, instead of drawing up a detailed analysis for the placing of orders.
- Reduce the time interval between receiving goods and making them available for consumption or sales.
- Stocks with customer will be reduced, because the uncertainty due to variability in the supplier's periods of delivery will drop.
- Reduce risk and cost of stock-outs, Vendor is responsible to track inventory movement, level and replenishment to meet agreed service level.
- Increase in sales due to less stock-outs and giving customer the confidence to come back.

Limitations & Challenges of VMI

- High resource commitment during implementation and startup
- Overall level of collaboration will be limited if companies view it as ‘inventory outsourcing’ where the responsibility to generate orders and meet inventory targets belongs to the vendor
- Insufficient or poor system integration will result in poor visibility and poor data sharing.
- Lack of commitment from staff will hinder the progress and successfulness of the VMI program. E.g., resistance from sales force because of commission earned from high volume sales.
- Most manufacturers fail to leverage customer-specific data effectively for planning production. Instead, they continue to make to stock. In some cases, reserving finished goods inventory in the manufacturer’s distribution centers actually causes shortages to other customers.

Limitations & Challenges of VMI

- There are many advantages of going for VMI, but the journey is not simple. Much effort is required:
  - *Commitment*
  - *High level of Trust*
  - *Sharing of data*
  - *Performance measures*
  - *Agreement in place*

- A successful VMI requires a high level of trust and is a form of joint business development requiring active communication, information sharing and joint problem solving. Most companies are not committed to that level of partnership.
- VMI may not always be the best solution. If the customer wants to do a better job in forecasting the demand and achieving high service level without the high cost, then VMI may not be the way to go.

VMI in Practice (Examples)

Retail store – Visual & POS

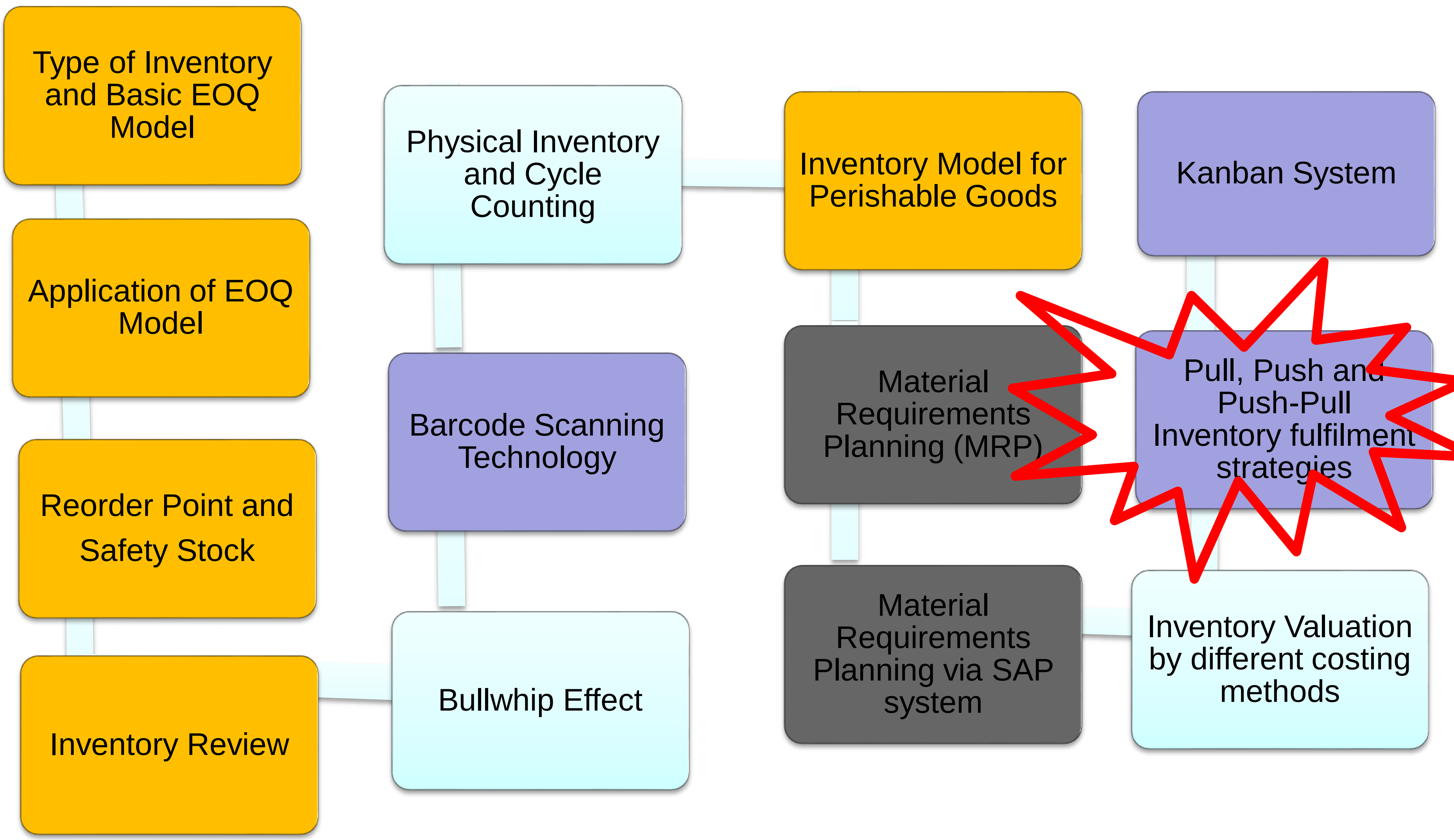
Parts vending machine typically with IOT

Digital weighing scale with visual or IOT

Variations From VMI

1. Consignment Inventory is in the possession of the customer, but is still owned by the supplier. In other words, the supplier places some of his inventory in his customer's possession (in their store or warehouse) and allows them to sell or consume directly from his stock. The customer purchases the inventory only after he has sold or consumed it.
2. You can have VMI that is not consignment inventory, or consignment inventory that is not VMI, and you can have inventory that is both consignment and VMI.
3. VMI + Consignment – Vendor Owned Inventory where goods ownership belongs to supplier, until buyer sells the goods or draw the goods form warehouse.
4. VMI + Buy back – VMI where ownership of goods belongs to buyer, but supplier agrees to buy back stock, if the inventory is not moved for an agreed period of time (E.g. Walmart)
5. VMI + shared wastage cost – Shared risk between buyer and supplier where ownership belongs to buyer, but when goods become obsolete or spoilt after an agreed period of time, to share the burden of goods wastage cost

E217 Inventory Management Topic Flow



Learning Objectives

- Describe the push, pull and push-pull strategies
- Describe the conventional fulfilment process
- Describe the Vendor Managed Inventory (VMI) fulfilment process
  - ✓ History of VMI
  - ✓ VMI Process Requirement
  - ✓ Benefits of Implementing VMI (for Customer)
  - ✓ Benefits of Implementing VMI (for Vendor)
  - ✓ Limitations & Challenges of VMI

Lesson 13

Streamline by Cards

E217 – Inventory Management

SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

- **E217 Inventory Management**
  - **Strategic Role** of Inventory Management
    - Physical Inventory and Cycle Counting
    - Bullwhip Effect
    - Inventory Valuation
  - **Inventory Control Methods**
    - **Independent-Demand Items**
      - Basic EOQ Model
      - Application of EOQ Model
      - Safety Stock and Reorder Point
      - Inventory Review Policies
      - Inventory Model for Perishable Goods
    - **Dependent-Demand Items**
      - Material Requirements Planning (MRP)
      - Material Requirements Planning (MRP) via SAP
  - **Inventory Control System**
    - Barcode Scanning Technology
    - Vendor-Managed-Inventory (Push, Pull and Push-pull strategy)
    - Kanban System

Scenario – Production and Distribution of Fans

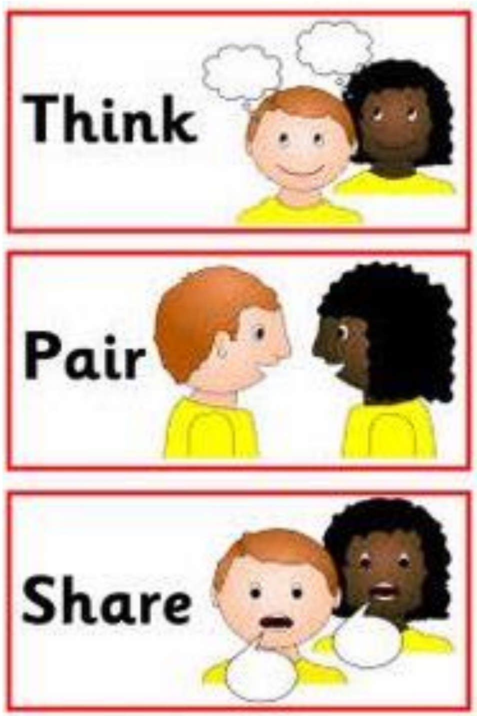
- Fans.com is a distributor and original equipment manufacturer (OEM) of portable fans
- Ricky, the warehouse supervisor manages the inventory of the portable fans.
- Ricky normally places orders based on his experience when the stock level is low.
- The demand from customers is about 50 units a day, and he can get the supplies from factory next day.
- One day, Ricky was on urgent leave and would be away for about one week. His colleague John walked into the warehouse and had no idea on whether he should reorder and how many he should reorder for the products.
- During the week, there are a few stock-out situations for certain SKUs due to demand increase

Scenario – Task of the day

John is frustrated in understanding the numbers recorded in Ricky's spreadsheet, because he has to take actions as fast as possible. He is wondering whether there is a way to achieve better visibility, in order to

- See which SKUs are required to order from factories internally and how many to order?
- Find which SKUs are producing at factories now and will come to the warehouse soon?
- Ensure no overstock and understock situations
- Minimize inventory holding cost

Activity 1: Think-Pair-Share



Based on your prior knowledge, answer the following questions through **think by yourself**, **exchange your thoughts with your neighbour** and **share your ideas within your team**:

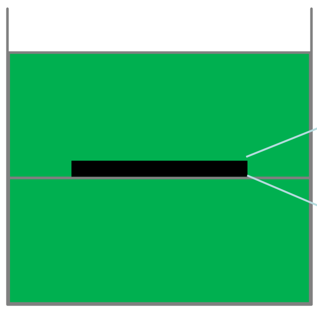
1. What information should John have before he can make decision on what, when and how many to order for certain SKUs?
2. How long do you think John needs to find, understand and make use of the information?
3. Any suggestions for John to speed up the decision making process?

Pulling Inventory using Kanban

- *When does your family replenish the toilet paper?*

Pulling Inventory using Kanban

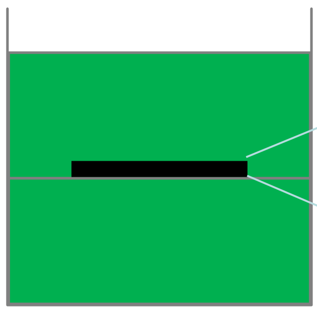
- Kanban
  - Visualize when to reorder, what to reorder, how much to reorder



Reorder Finished Goods	
Part Number	: PPUF228
Part Description	: Metal USB Fan
Reorder Quantity	: 1 Carton
Quantity per Container	: 12 Pieces
Location	: 02-18-01
Lead Time	: 1 Days

Pulling Inventory using Kanban

- Kanban
  - Visualize when to reorder, what to reorder, how much to reorder



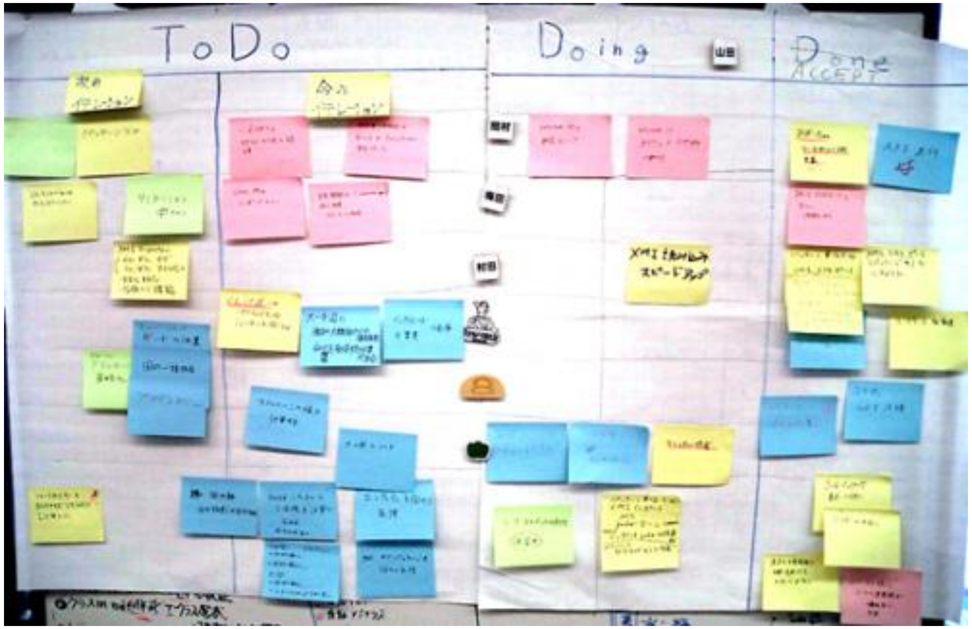
Reorder Finished Goods	
Part Number	: PPUF228
Part Description	: Metal USB Fan
Reorder Quantity	: 1 Carton
Quantity per Container	: 12 Pieces
Location	: 02-18-01
Lead Time	: 1 Days

Waiting for Finished Goods Arrival	
Part Number	: PPUF228
Part Description	: Metal USB Fan
Reorder Quantity	: 1 Carton
Quantity per Container	: 12 Pieces
Location	: 02-18-01

Kanban Concept

https://youtu.be/5izyN66PTxs

Examples Incorporating Kanban Concept



Kanban on Products

- Good location and/or packaging labels help to quickly identify the product and make less mistakes
- Facilitates logical, more detailed product search from left to right, or/and up and down
- The use of contrasts, underline, bold and font types are also low costs ways to improve product, packaging and location labels

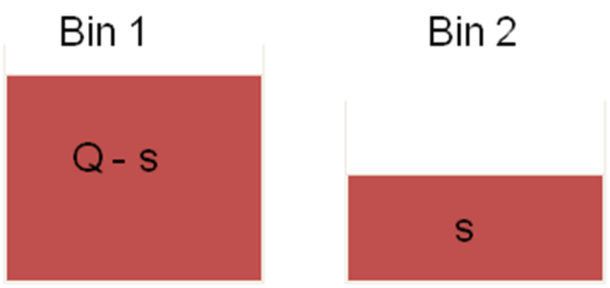
Kanban for Products

H&M uses both colours and number of pieces for their changing rooms

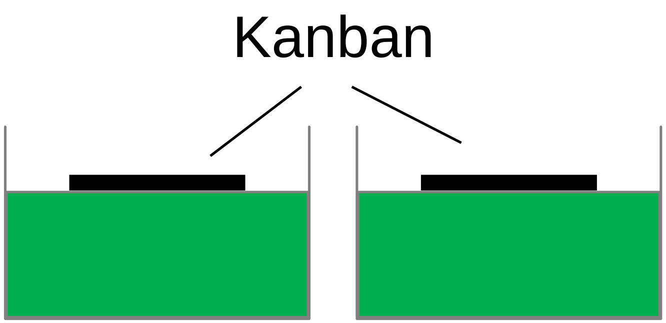
Visual Management of what is a new style vs older style

The Origin Of Kanban

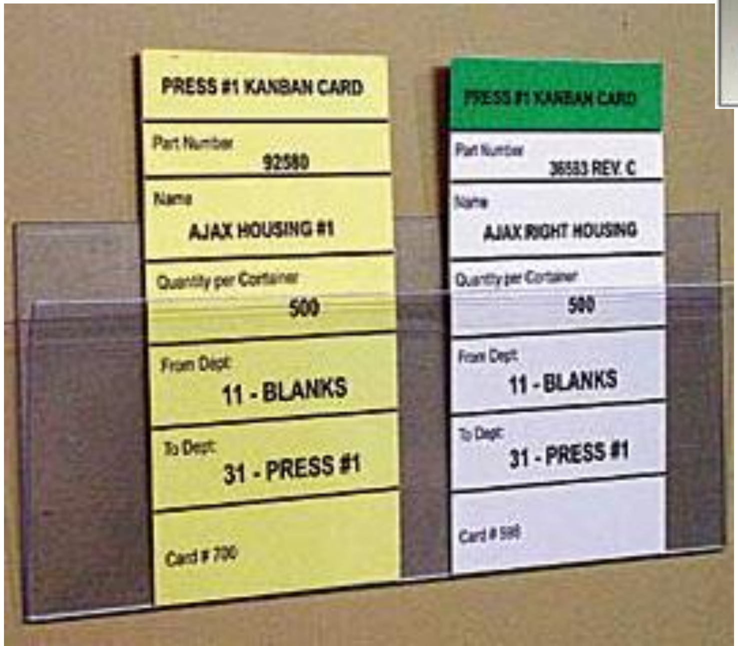
Two-bin inventory system

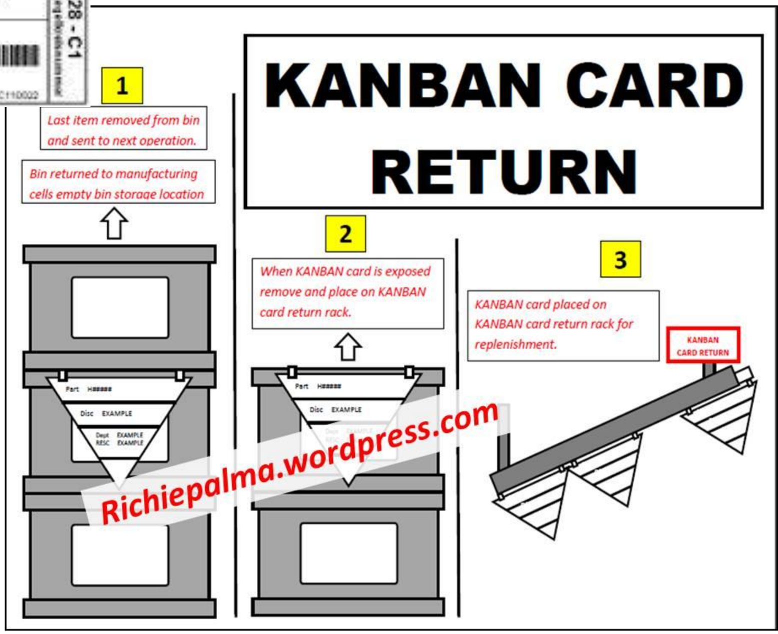


Kanban Inventory System



Q = order quantity
s = reorder point
= demand during lead time





Kanban Inventory Control

- Kanban (Japanese): Card or Visual Record
- It contains any information necessary to describe what, where, when and how much is needed for the process.
- Kanbans are signals used to replenish the inventory of items used repetitively in a facility
- Consists of an information *Card* and *Container* that holds a standard quantity of items
- Kanban maintains discipline of *pull* production, which is based on actual demand.
- No station is permitted to produce more than what is immediately required by the succeeding station, thereby it reduces waste (inventory)

Essential Rules for Kanban System

- ✓ ***Each container /product must have a card***
- ✓ ***Downstream station always withdraws from a station upstream (pull system)***
- ✓ ***Containers/product cannot be moved without a Kanban***
- ✓ ***Containers should contain the same number of parts***
- ✓ ***Only good parts are passed along***
- ✓ ***Production should not exceed authorized production quantity***

Activity 2: Poll

1. Will the Kanban system will _________ the average inventory level of the product
   - **A. Increase**
   - **B. Reduce**
   - **C. Not Change**

2. The product with ____________ demand is suitable for Kanban system
   - **A. Low and intermittent**
   - **B. High and consistent**
   - **C. Moderate and fluctuated**

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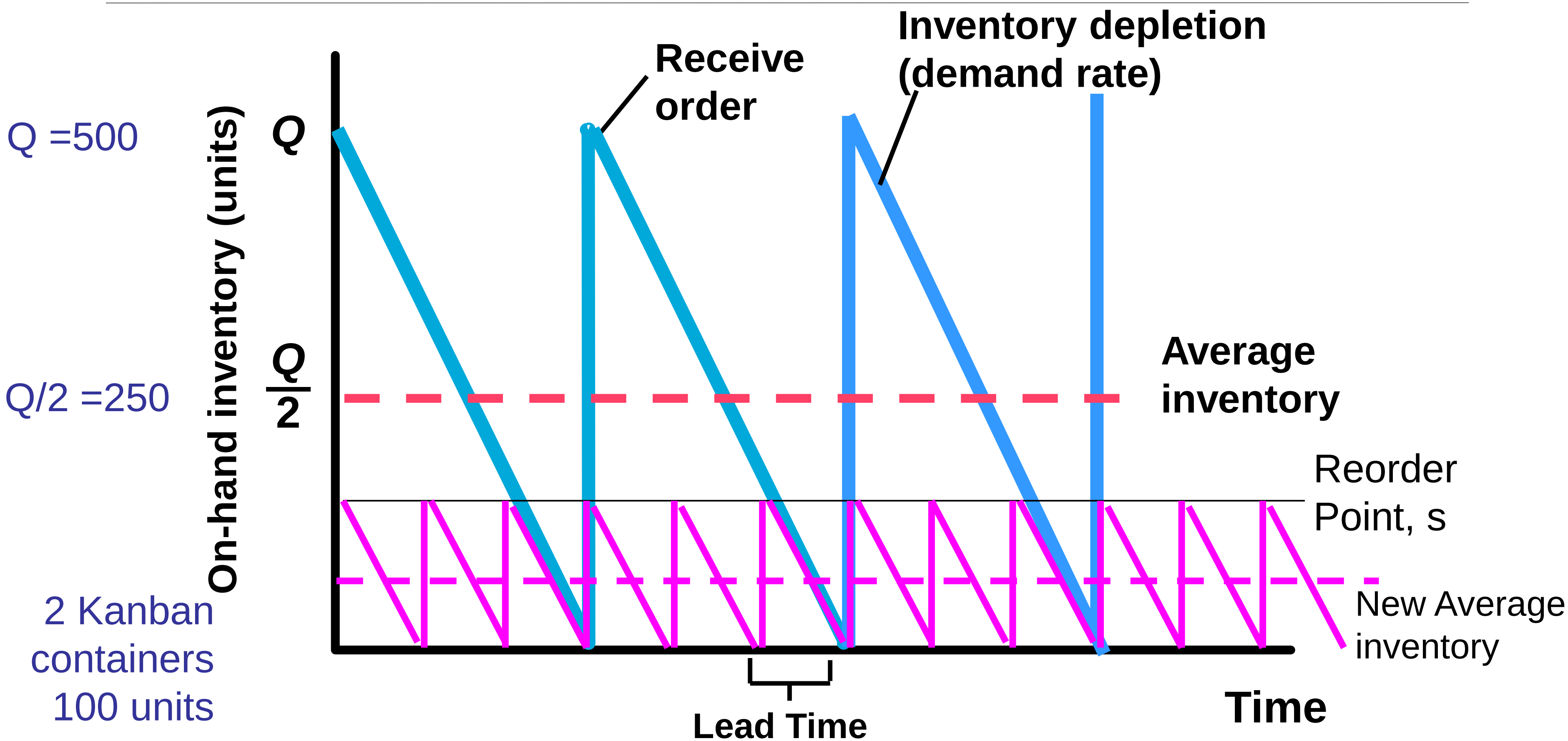
Lower Inventory with Kanban by Example

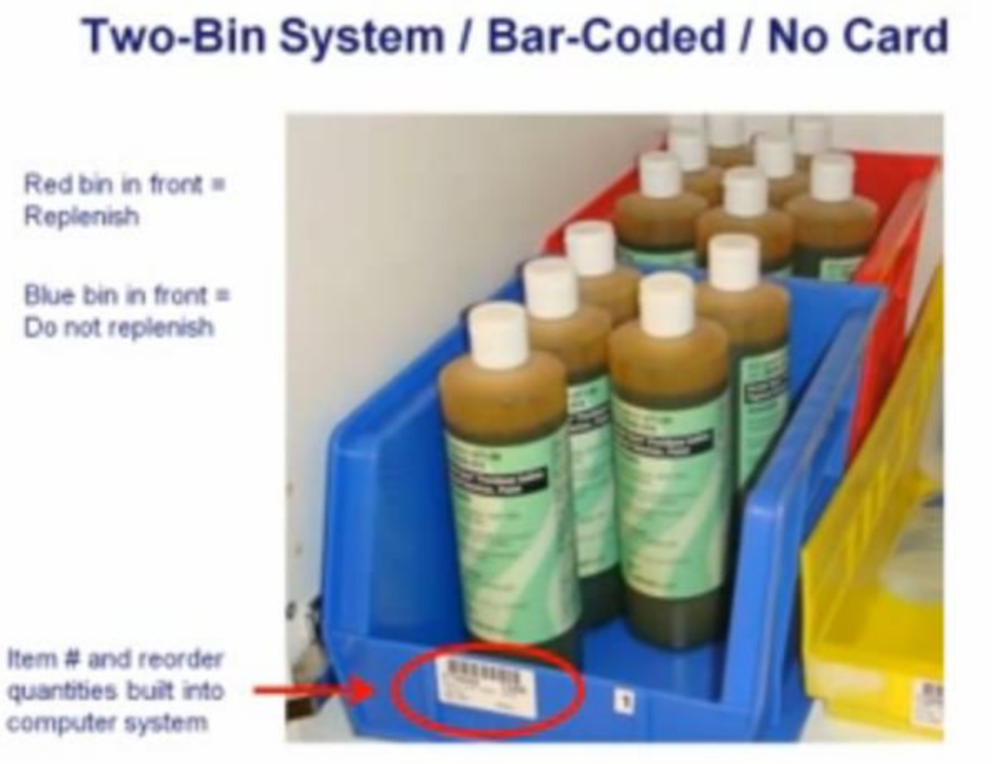


- For example, two-bin system (reorder point system), Q =500, so average inventory is 250 and reorder point is 50.
- If we replace with Kanban system with 2 containers, 50 units in each, the maximum inventory is 50 and average inventory is 25 units, which is much lower than the two-bin system. This saves **space**, and **capital locked in inventory**
- Same demand rate

Preconditions for Kanban system

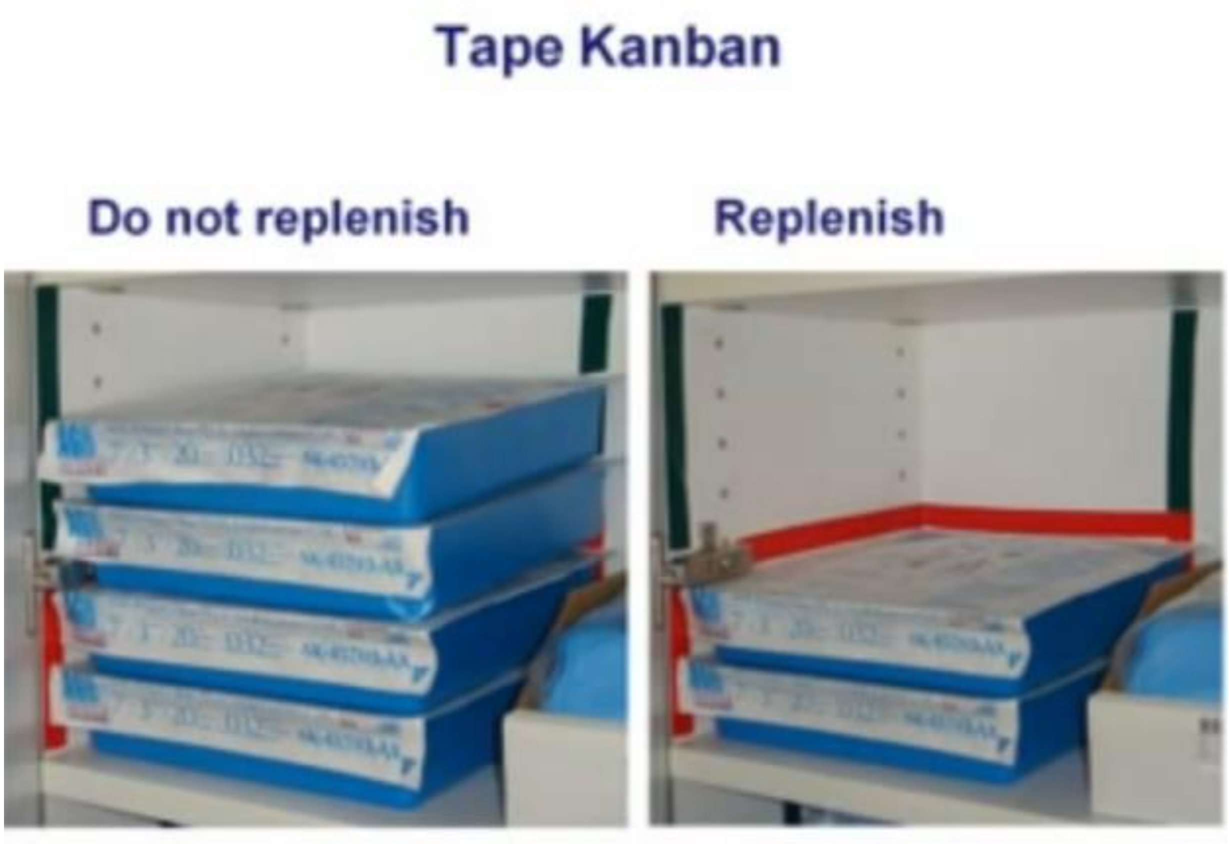
- Quick changeovers
- Repetitive production in small lots
- Balanced manufacturing line and stable process with minimal setup
- Close proximity of different parts of the system
- Scrap/ defects are not present
- Consistent demand (no large fluctuations)

Kanban System Without Cards



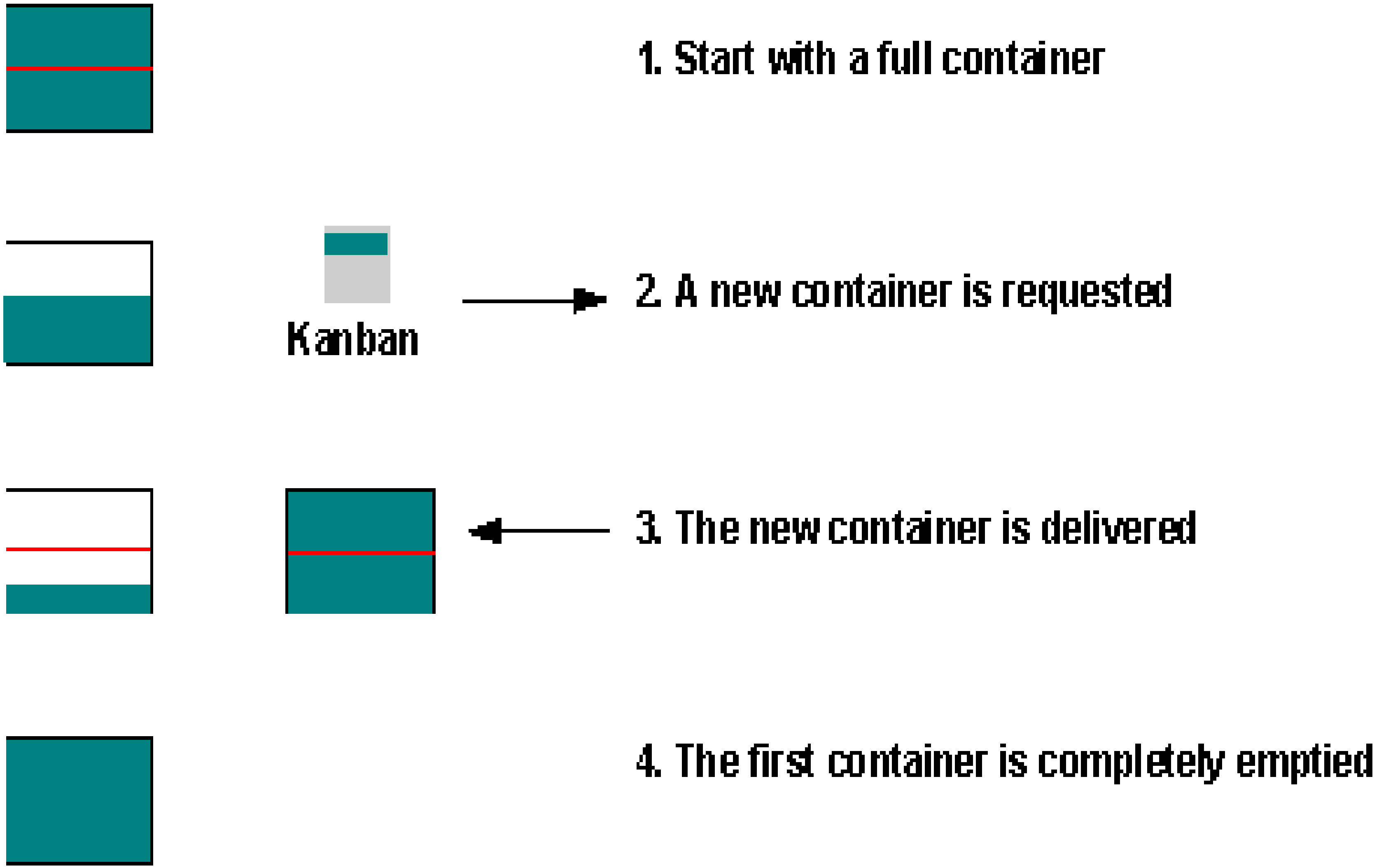
- Add color to visually detect when to order
- When red bin is in front, use the barcode scanner/smart phone with apps to read item to be ordered
- Order information is sent wirelessly to the inventory system
  - **Wireless Kanban**

Kanban System Without Cards



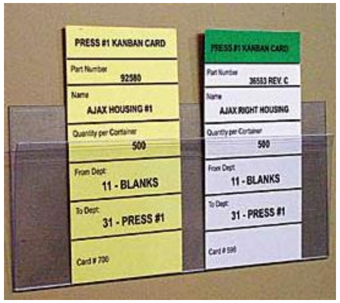
- When the stock gets down to the red tape, it is time to order

Simple Single-Card Kanban System



Generalized Single-Card Kanban System

- In a Single Card Kanban system, the operator of a downstream operation requires a Production/Move Card and the necessary Material to be authorized to begin processing.
- The operator simply removes the Card and sends it back to the upstream process, signaling production to replenish the materials used by the station prior to processing the job.
- Information on a Kanban card:
  - Product name
  - Part code or item number
  - Preceding stage and succeeding stage
  - Card number
  - Item quantity / container size
  - Barcodes, etc.

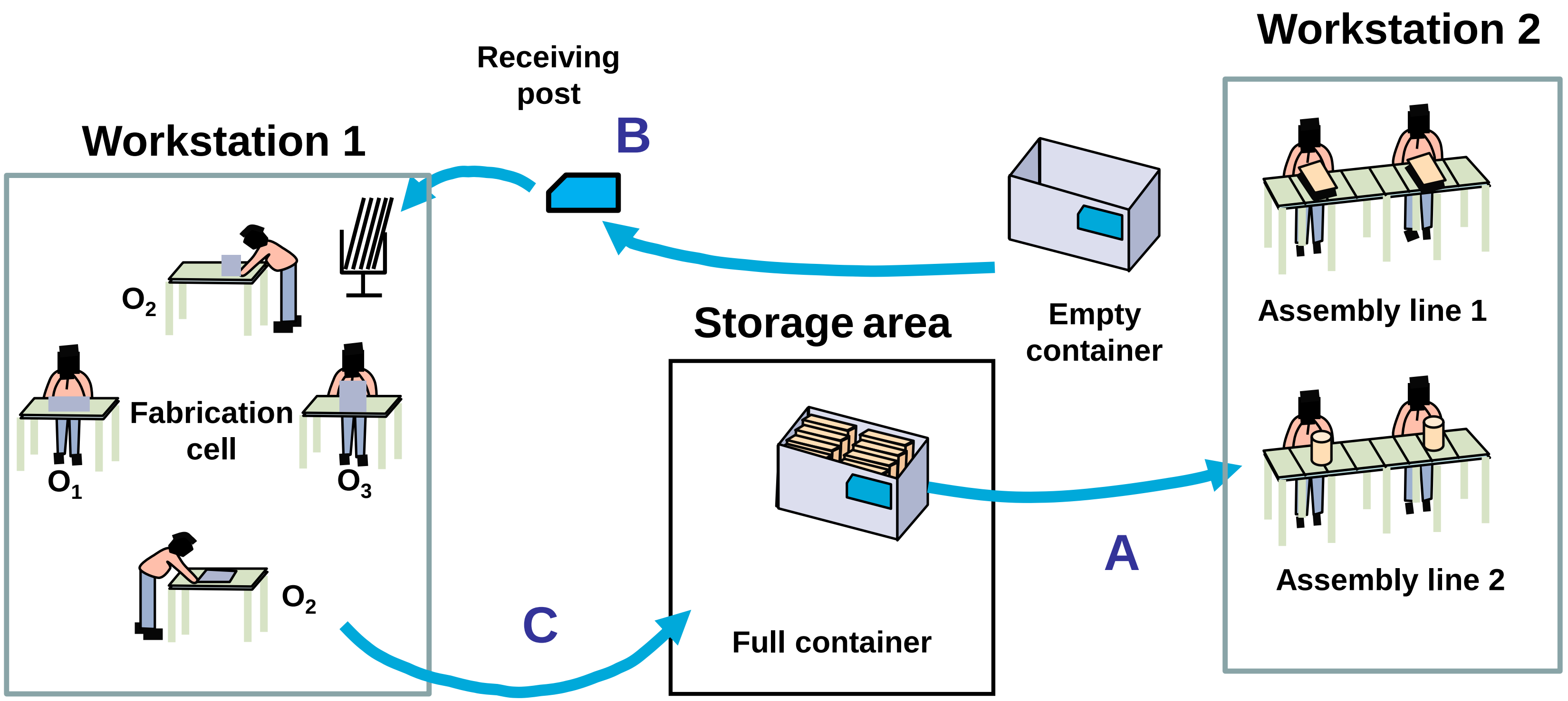


One Example of Single-Card Kanban System

https://youtu.be/tum1lLwy6gE

Single-Card Kanban System

- To “pull” inventory and production processes



After one container is used by Workstation 2

A: Workstation 2 gets the materials from the full container at the storage area.

B: The empty container with Kanban attached is sent to Workstation 1.

C: Full container to replenished to Storage area

Dual-Card Kanban System

- This Kanban system is more commonly referred to as the Toyota Kanban system as Toyota was the first to employ this system in full scale use.
- It is a more useful Kanban technique in large-scale, high variety manufacturing facilities.
- A Two Card Kanban is used when WIP can't be effectively handed from one process to the next, thus necessitating an Inbound Stock Point and an Outbound Stock Point for processing stations.
- Two Cards are used:
  - ➢ Move card (Withdrawal card/ Transport card) :
    - Delivers order for parts from a preceding process
    - Specifies quantity and type of parts to deliver from Location A to Location B
  - ➢ Production Card:
    - Provides production instructions for the work center
    - Tells the workers exactly the quantity and the type of part to produce

Move Card & Production Card

Move Card

Part number : 33311-3501

Container capacity : 50

No. of kanban released : 7 of 12

Downstream work center: K123

Stock location no.: A-12

Stock location no.: A-07

Upstream work center: Y321

Work Center no.: Y321
Part number to be produced: 33311-3501
Container capacity: 50 units
Stock capacity at which to store: A-07

Materials Required:

Material no. 33311-3504
Stock location: A-05

Part no. 33825-2474
Stock location: B-03

Production Card

Move Card

Types of Kanban

Can stop at supplier Kanban around 5 min plus https://youtu.be/NWCPBMDZ7SU

Activity 3: Ten-minute Assignment

Design a Kanban system to help fans.com know clearly when the inventory needs to be produced.

- Write down the necessary information on your Kanban Cards
- Demonstrate how the cards are moved and used

Note: show clearly how the production knows which SKU to produce, how many units to produce at one time, when the finished goods reaches or goes below the Kanban level?

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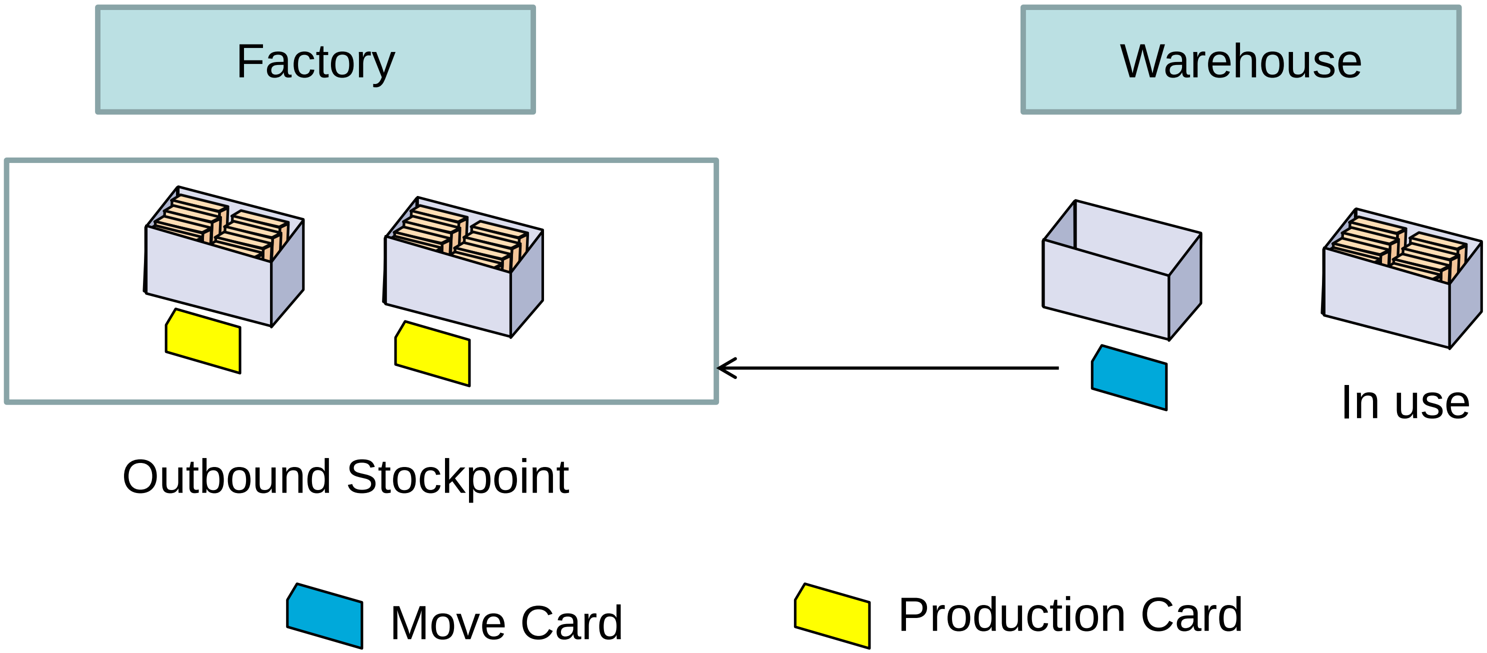
Note: show clearly how the production knows which SKU to produce, how many units to produce at one time, when the finished goods reaches or goes below the Kanban level?

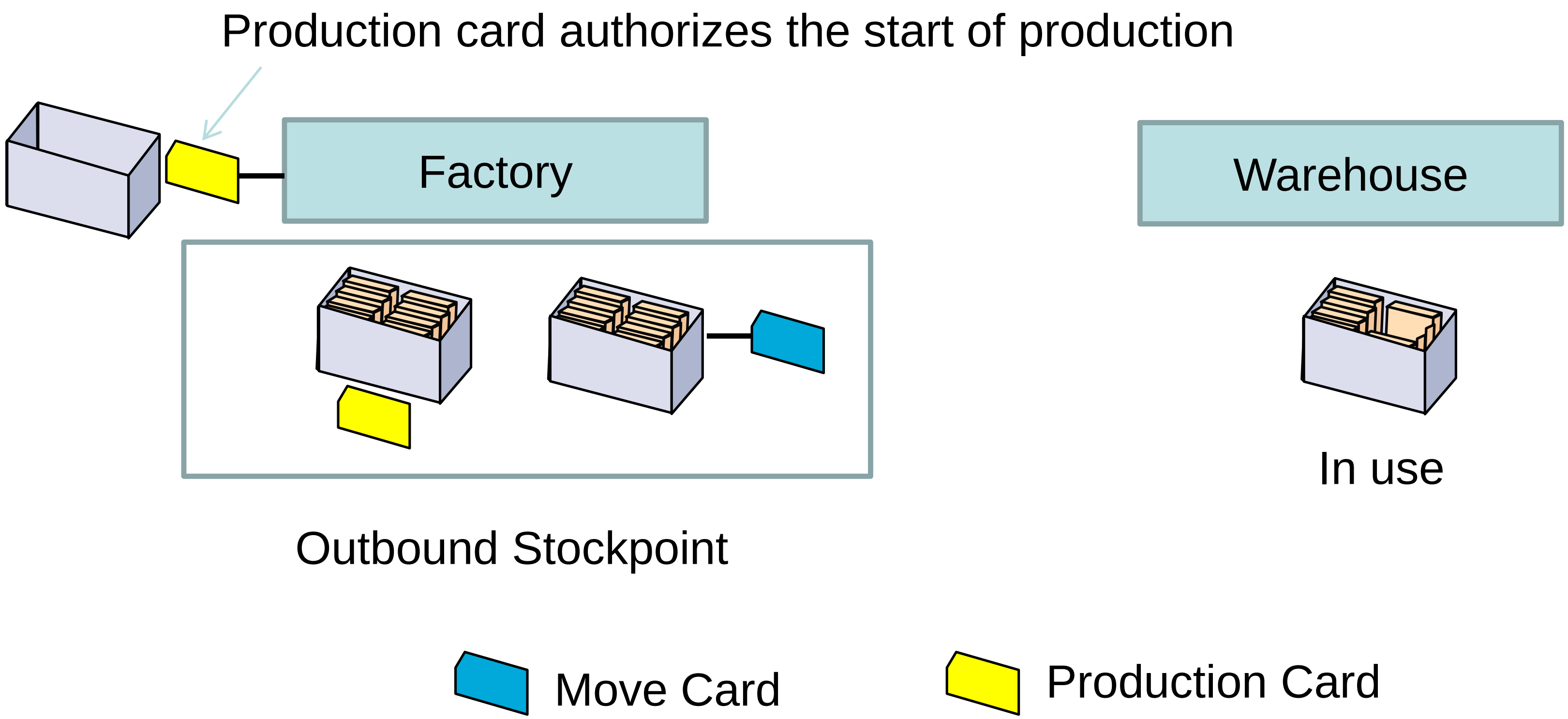
(Allow students have enough time to think, give them the blank cards to simulate the process)
One proposed system is explained in the following slides

Proposed Dual-Card Kanban System (1)



1) When Warehouse consumes the contents of a full container, the move card is sent to Factory.

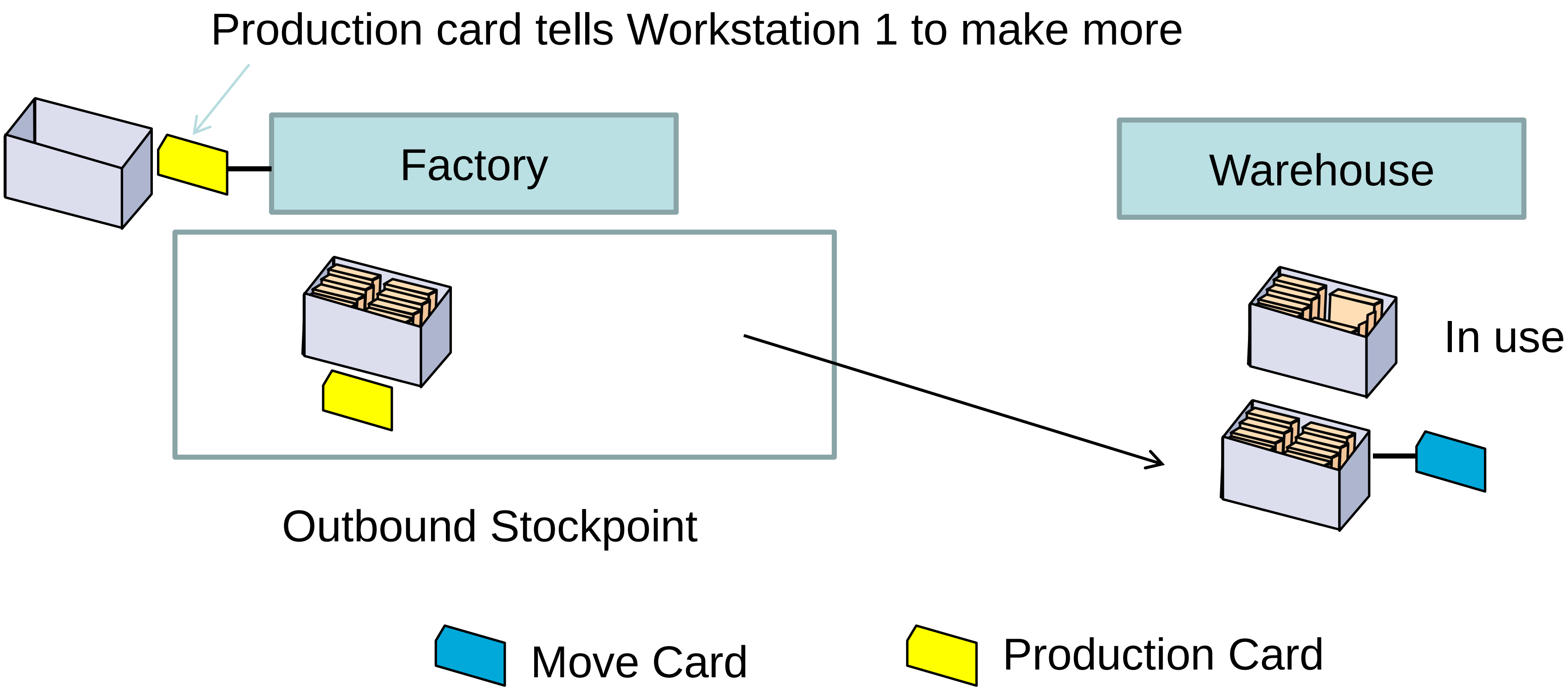
Proposed Dual-Card Kanban System (2)



2) Attach the move card to a full container at the outbound stock point of Factory, this authorizes movement of this container to Warehouse.

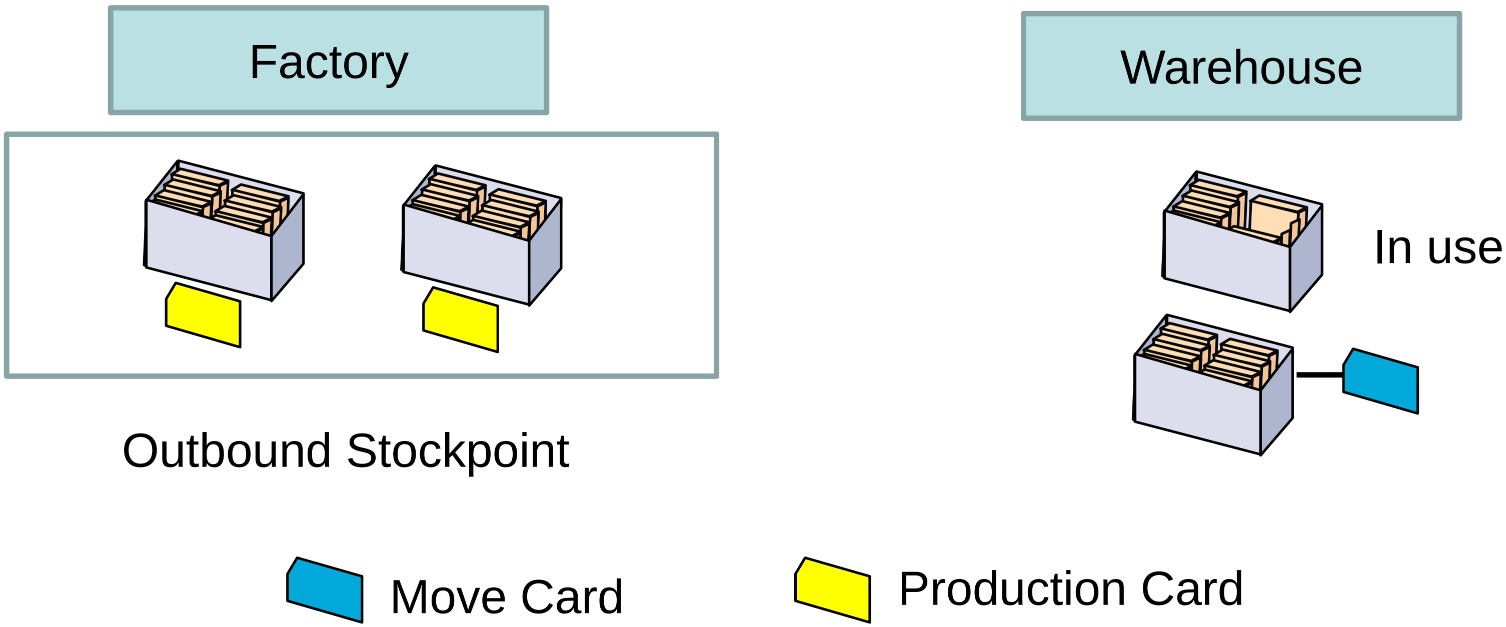
- Production card from the container in factory is detached.
- Factory should now begin to produce parts to fill in an empty container to replace the one that was taken.

Proposed Dual-Card Kanban System (3)



3) Move the full container to Warehouse.

Proposed Dual-Card Kanban System (4)



4) Factory completes its work and fills up the empty container.
Nothing more happens until Warehouse exhausts the “in use” container.

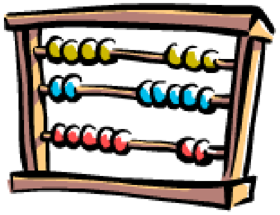
Determining the Number of Kanbans

$$\text{No. of kanbans} = \frac{\text{average demand during lead time} + \text{safety stock}}{\text{container size}}$$

$$N = \frac{dL + S}{C}$$

where

- N = number of Kanbans or containers
- d = average demand over some time period
- L = lead time
- S = safety stock/ buffer stock, set by policy,
  e.g. 10% of dL
- C = container size



Kanban Calculation Example

Given the following information, determine the number of Kanban Cards required:

d = 50 units per day L = 1 day

dL = (50)(1) = 50 S = 10% dL = 10% x 50 = 5

C = 20 units

Solution:

$$N = \frac{dL + S}{C} = \frac{(50 \times 1) + 10\% * 50}{20}$$
$$= 2.75 \text{ kanbans or containers}$$

- Round up to 3 (allow some slack)
- Or round down to 2 (force improvement, but risky)

Activity 4: Test Yourself

To implement a Kanban System, all the necessary information are gathered as follows, calculate the number of Kanban cards required.

Average Monthly Demand	600 units
Standard Deviation of Weekly Demand	40 units
Lead Time	1 month
Target Service level	95%
Container Size	100

Assume 4 weeks per month

Activity 4: Test Yourself - (Answer)

To implement a Kanban System, all the necessary information are gathered as follows, calculate the number of Kanban cards required.

Average Monthly Demand	600 units
Standard Deviation of Weekly Demand	40 units
Lead Time	1 month
Target Service level	95%
Container Size	100
Assume 4 weeks per month	

SS= k*std(L)* sqrt(L) = Normsinv(0.95)* weekly std * sqrt(L)

=1.65*40*sqrt(4)

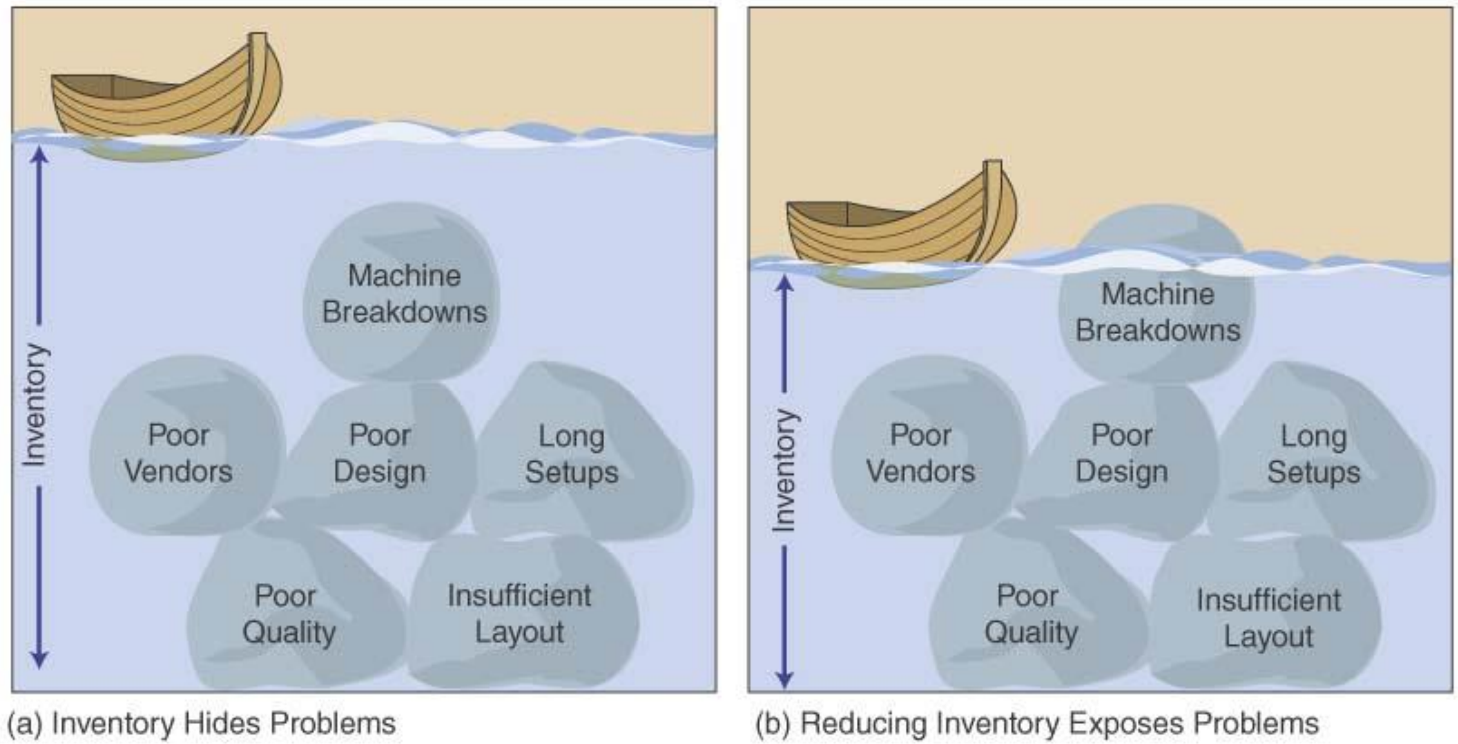
≈132

No. of Kanbans = (DL+SS)/Container Size

= (600*1+ 132)/100

= 732/100 ≈ 8 (round up)

Problems Exposed by Inventory Reduction



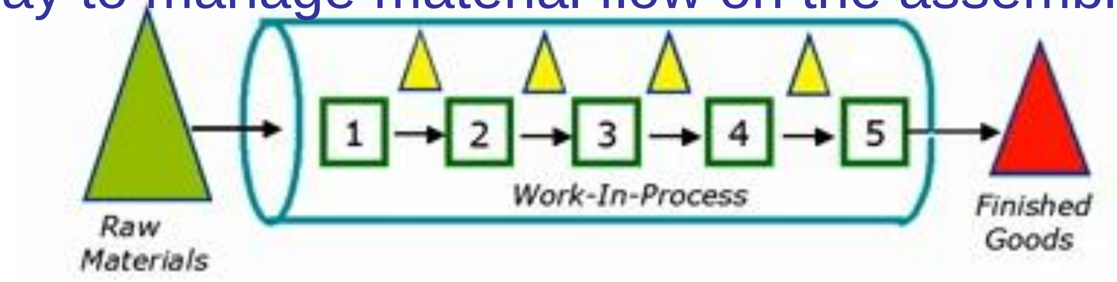
Kanban system helps to reduce inventory level and expose problems and solve it, thus it helps eliminate waste:

- Example 1: Poor vendor, by identifying defective items from a vendor early in the production process, the downstream work is saved
- Example 2: Poor quality, by identifying defective items by employees upstream, the downstream work is saved

Operational Benefits: Kanban System

- ✓ Reduces inventory holding
- ✓ Minimises risk of inventory obsolescence
- ✓ Improves the material flow process
- ✓ Prevents overproduction
- ✓ Low implementation cost
- ✓ Improves responsiveness to changes in demand

Kanban was originally developed at Toyota in the 1950's as a way to manage material flow on the assembly line.



Kanban Implementation Framework

Pre-Implementation Phase

- Data collection & analysis – current state of operations
- Calculate the Kanban size
- Design the Kanban – Signaling mechanism, rules for operating the Kanban system
- Train the people involved in the system – Develop an Operating handbook for ease of reference and for personnel training purposes

Implementation Phase

- Implement the Kanban system

Post Implementation Phase

- Audit and maintain the Kanban – Review and identify shortfalls of the system on a periodic basis (e.g. quarterly)
- Improve the Kanban – Following-up on the shortfalls or issues uncovered

Activity 5: Role Play

- At least 2 persons from every team per scene
- Story background:

  Now, Ricky has come back from his leave. He wants to remain his previous way of managing the inventory while John has proposed the Kanban system to the management. The management is quite happy with John's idea.

Team	Roles	Scene
Team 1 & 2	John	1. John explains to Ricky on the reasons to use Kanban system, however Ricky is quite against it. John wants to convince Ricky with more benefits of using Kanban system, Ricky asks more questions to challenge John
Team 3 & 4	Ricky	
Team 3 & 4	John	2.John seeks the management's support by giving extra bonus for better performance. The management asks how to measure the performance
Team 5	The management	
Team 5	John	3. John tells Ricky the new performance measurements and then Ricky gets motivated and asks how the Kanban system works. now Ricky has been convinced and is willing to change. He invites John to discuss the implementation plan and other potential issues
Team 1&2	Ricky	

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Team	Roles	Scene
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Team 2	Ricky	
Team 3	John	2.John seeks the management's support by giving extra bonus for better performance. The management asks how to measure the performance, John tells Ricky the new performance measurements and then Ricky gets motivated and asks how the Kanban system works. now Ricky has been convinced and is willing to change. He invites John to discuss the implementation plan and other potential issues
Team 4	The management/ Ricky	

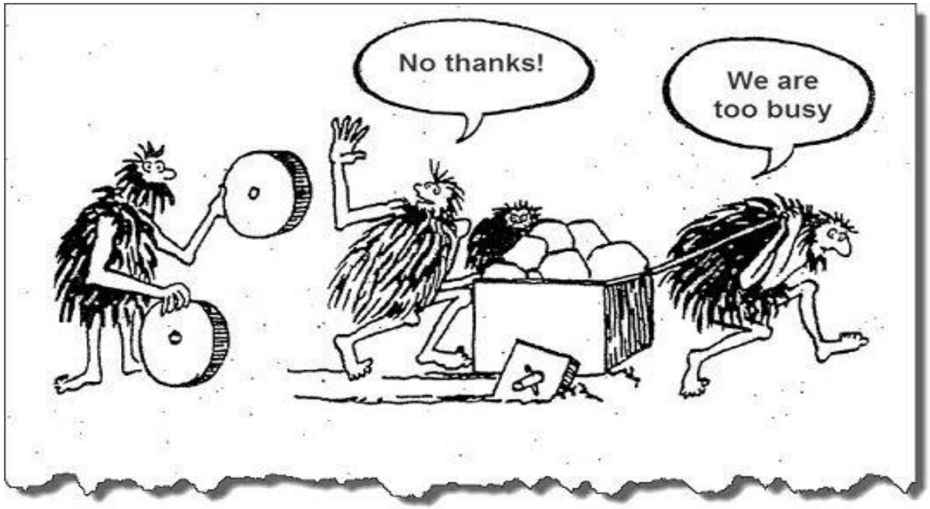
Recommendations to Fans.com

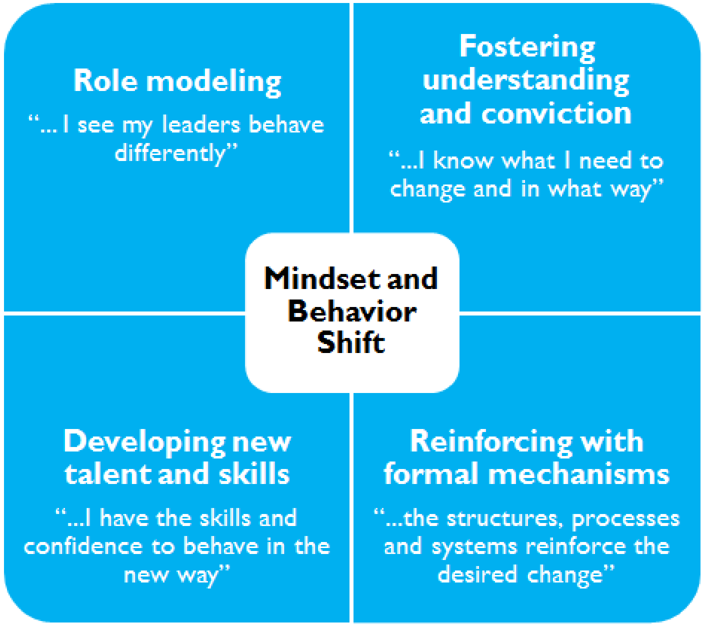
- Telling the supervisor to implement Kanban does not mean he will do it
- He needs to be convinced by how Kanban will help him in his work, and not just the company
  - Mindset Change for Staff
- The company’s management also needs to measure the supervisor differently for him to be motivated to better manage inventory
  - Management Change

Recommendations to Fans.com

Mindset Change for Staff

- Rather than just valuing him for his experience and loyalty, management should measure the supervisor by the average inventory he keeps, and out of stock situations, etc.



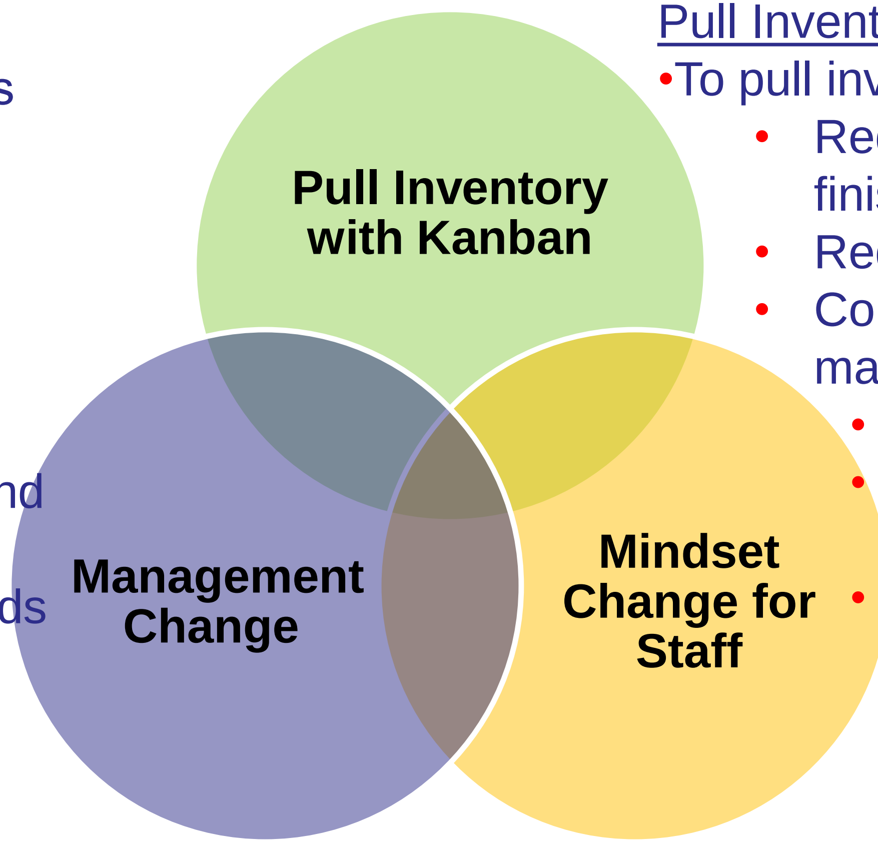


Recommendations to Fans.com

Management Change

- Acknowledge supervisor's experience
- Kanban will help the supervisor in:
  - Tracking when an item needs to be reordered, what is being reordered, and how much to order
  - Handling what needs to be ordered for more different products
  - Tracking what products have already been ordered
  - Training new and temporary staff in reordering finished goods

Recommendations to Fans.com



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Pull Inventory with Kanban

- To pull inventory
  - Reduce overstocking of finished goods
  - Reduce understocking
  - Control using Visual management
    - Anyone can do it
    - What to replenish, when to replenish
    - How much to replenish

Mindset Change for Staff

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MRP V.S. JIT

- MRP is the classic *push* system. The MRP system computes production schedules for all levels based on forecasts of sales of end items. Once produced, subassemblies are *pushed* to next level whether needed or not.
- JIT is the classic *pull* system. The basic mechanism is that production at one level only happens when initiated by a request at the higher level. That is, units are *pulled* through the system by request.
- These methods offer two completely different approaches to basic production planning in a manufacturing environment:
  - ✓ Main Advantage of MRP over JIT: MRP takes forecasts for end product demand into account. In an environment in which substantial variation of sales are anticipated (and can be forecasted accurately), MRP has a substantial advantage.
  - ✓ Main Advantage of JIT over MRP: JIT reduces inventories to a minimum. In addition to saving direct inventory carrying costs, there are substantial side benefits, such as improvement in quality and plant efficiency.

Learning Objectives

- Understand the role of Kanban cards
- Understand how single-card & dual-card Kanban systems work
- Be able to calculate the Kanban size
- Understand the concept of Just In Time (JIT)
- Support mindset change and how management should change how they measure staff performance

E217 Inventory Management Topic Flow