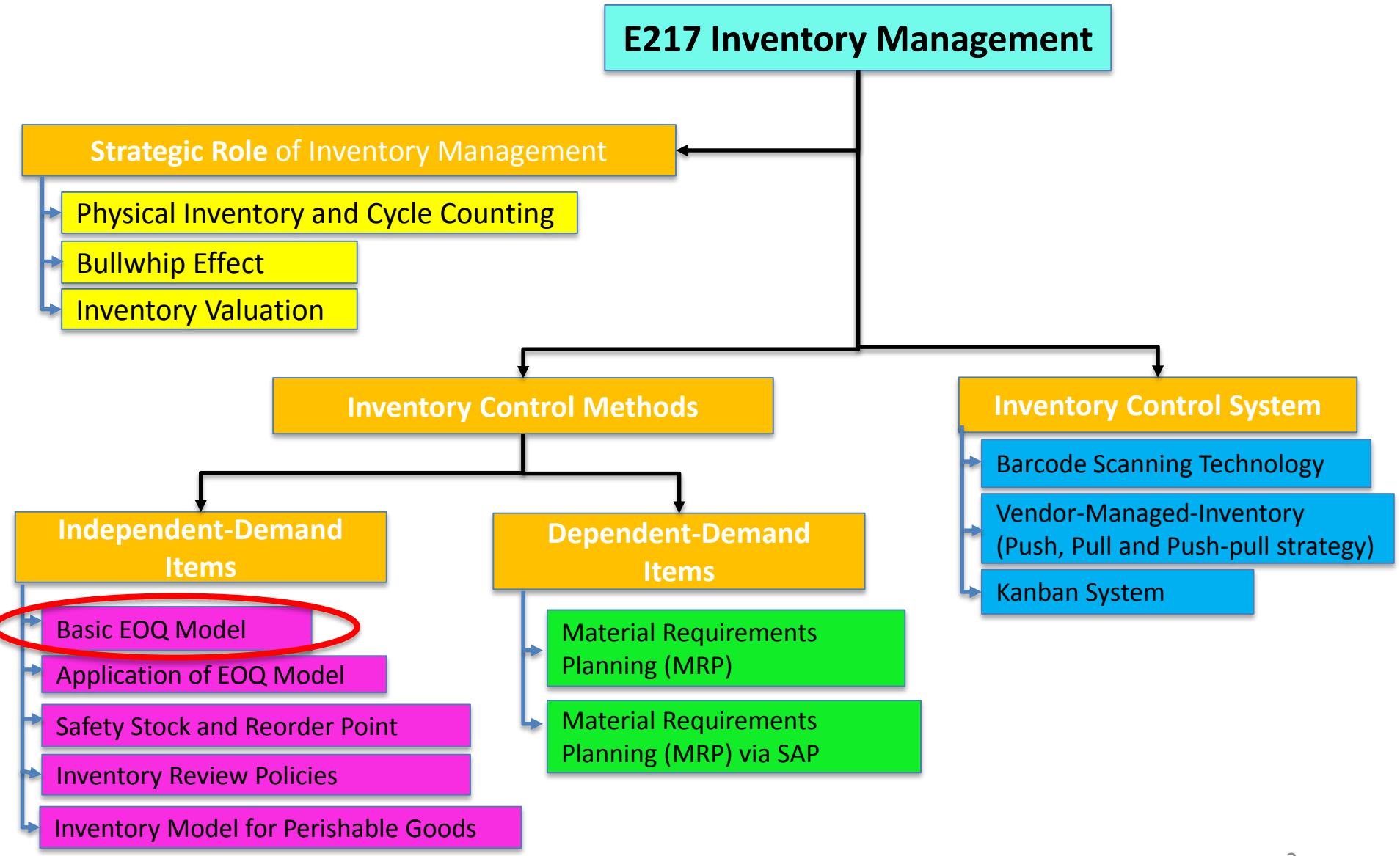
Problem 01

A smarter way to order

E217 – Inventory Management

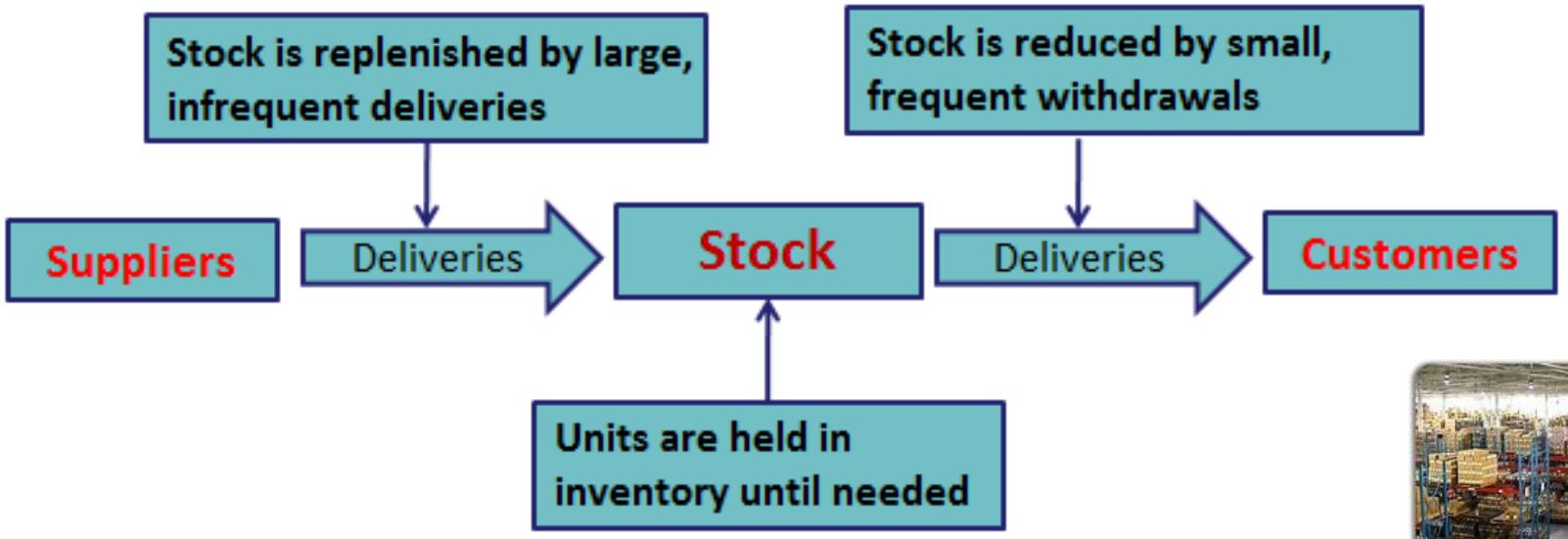
SCHOOL OF ENGINEERING

E217 Inventory Management Topic Tree

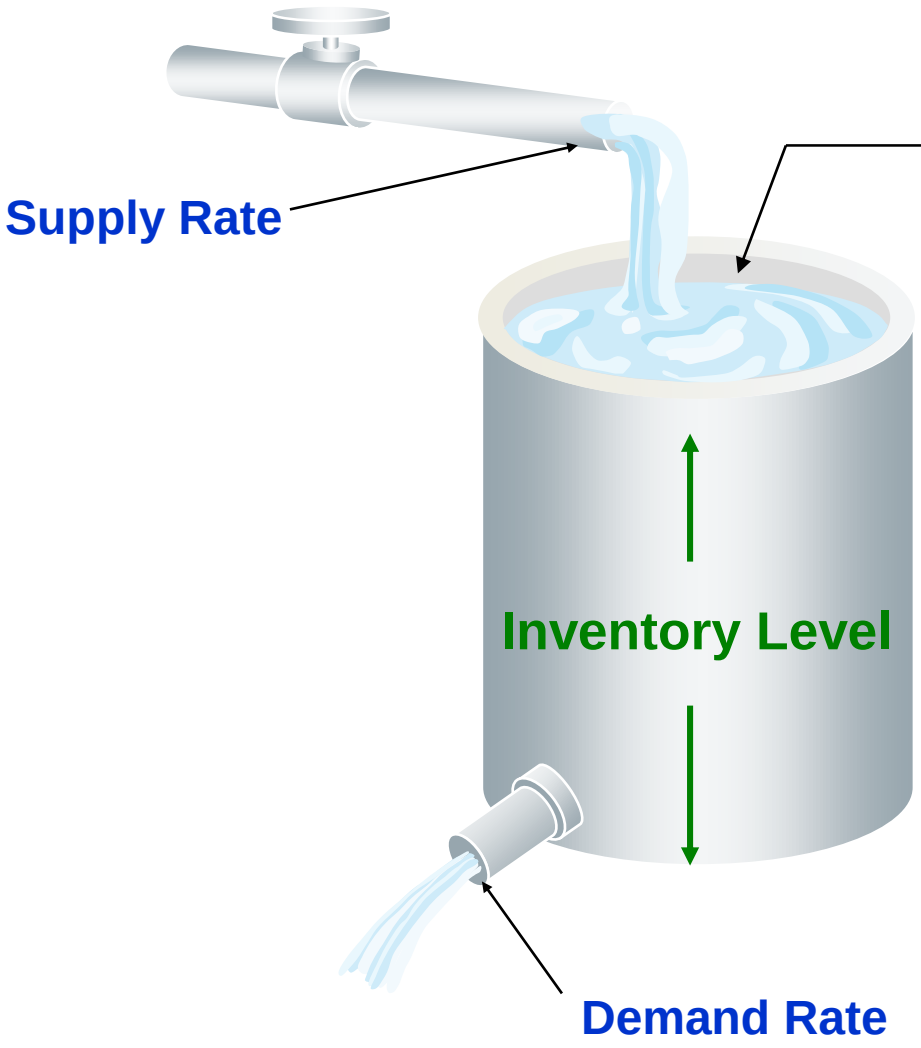


Inventories Everywhere

- 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?

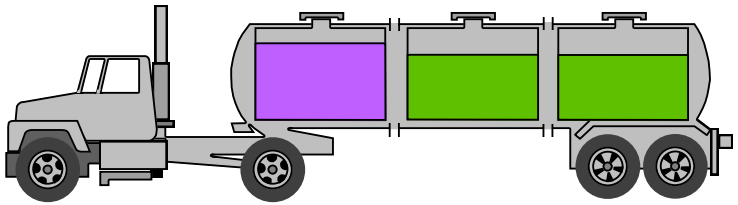
- Inventory is the largest factor in manufacturing costs, and efficient Inventory Management has the greatest potential for increasing profitability
  - *Example: For a typical US manufacturer, 60% of corporate income goes towards the purchase of materials*
- Inputs to be considered
  - Objectives of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

- Transit Inventory (pipeline inventory, merchandise shipped by truck or rail or air)
- Buffer inventory (safety stock)
- Average 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

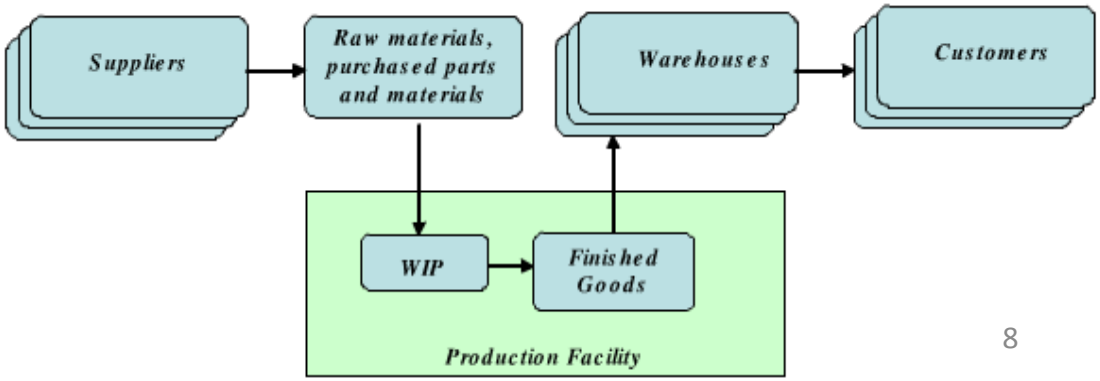
Major Types of Inventory

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. Bamboo Fibre 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

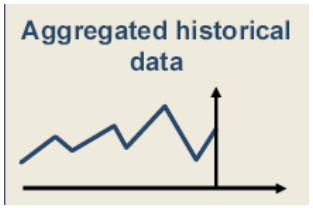
Major Inventory Costs

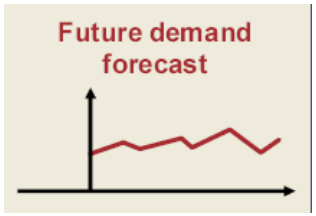
- Holding/Carrying Costs
  - *Cost of holding items in inventory*
  - *Examples: insurance, damage, warehousing, etc.*
- Ordering Costs
  - *Costs of receiving an order, verifying inventory availability, invoicing and payment, etc.*
- Setup costs
  - *Cost to prepare a machine or process for manufacturing 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

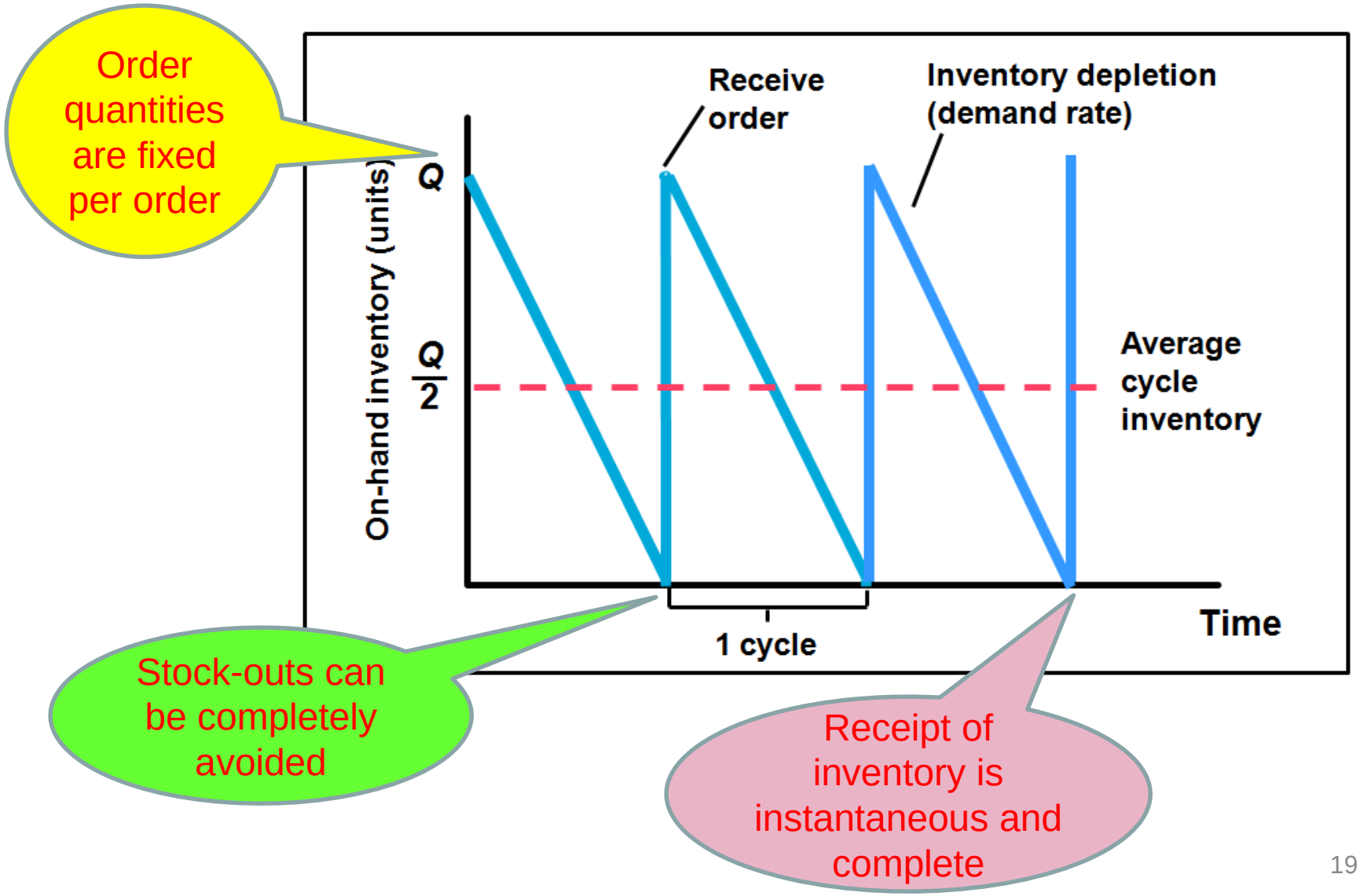
- Ordering in large quantities helps to reduce the inventory ordering cost, but on the other hand, this increases the inventory holding cost; vice verse if ordering in small amount.

  → 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



Economic Order Quantity (EOQ) Model

- Notations for EOQ:

D = Demand rate (units/year)

R = Constant ordering cost ($)

H = Holding cost ($/unit/year)

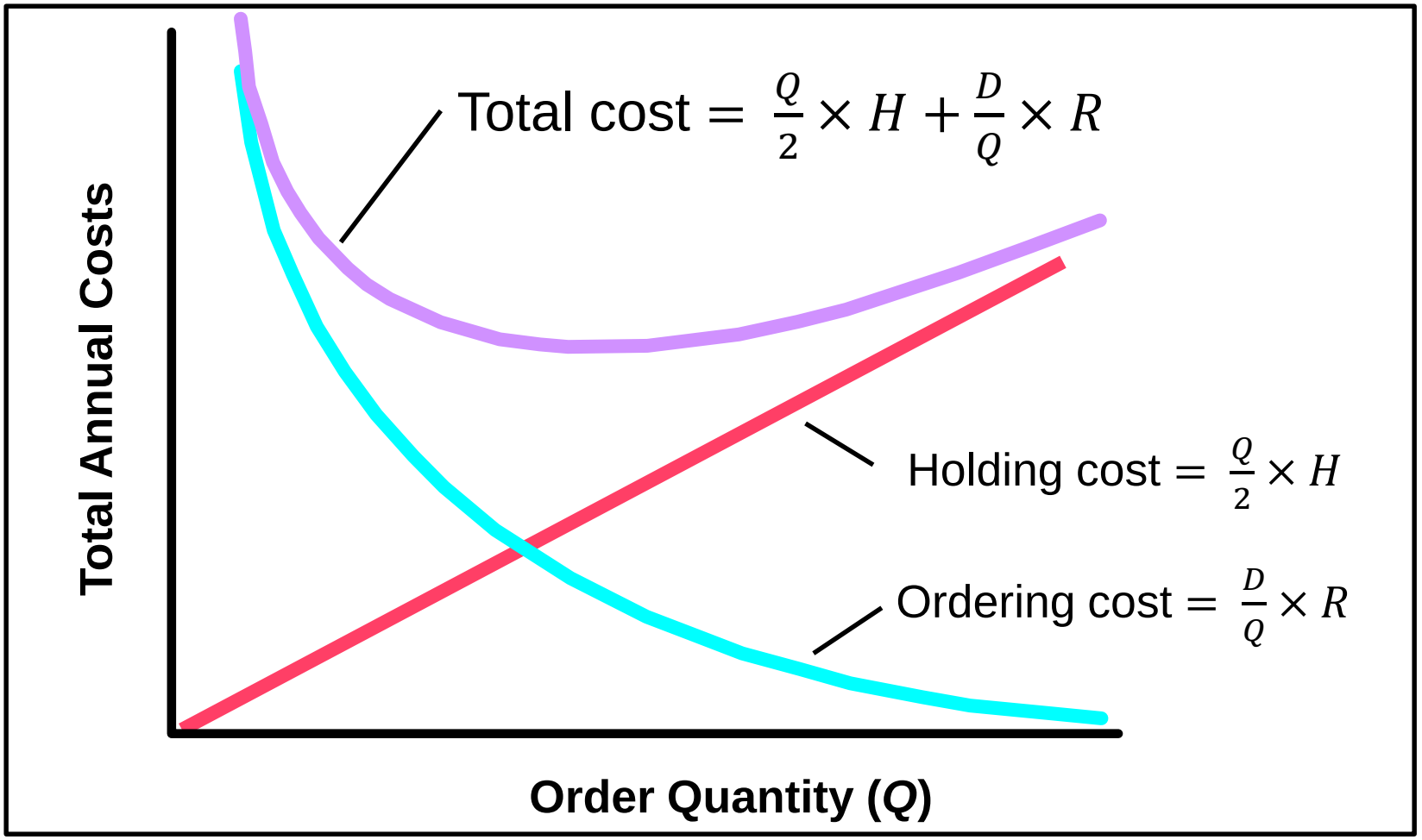
Q = Order Quantity (units)

Q* = Optimal Order Quantity

$$Q^* = \sqrt{\frac{2 \times D \times R}{H}}$$

Economic Order Quantity (EOQ) Model

- Inventory Costs for EOQ:



Today's Problem

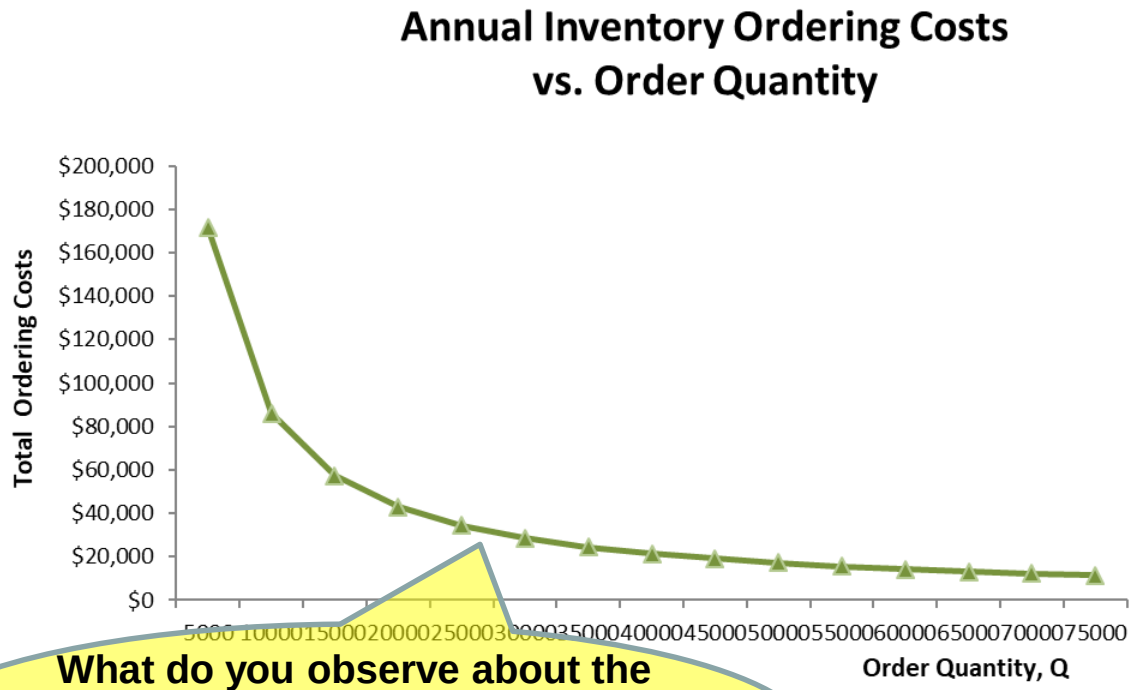
Given Information:

- Annual Demand, D = 716,000 units
- Inventory Ordering Cost, R = $1,200 per order
- Inventory Holding Cost, H = $1.10 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
  = (716,000/Q) * 1,200
  = <u>859,200,000 / Q</u>

Order Quantity, Q	Annual Ordering Costs
5000	$171,840
10000	$85,920
15000	$57,280
20000	$42,960
25000	$34,368
30000	$28,640
35000	$24,549
40000	$21,480
45000	$19,093
50000	$17,184
55000	$15,622
60000	$14,320
65000	$13,218
70000	$12,274
75000	$11,456



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

Annual Inventory Holding Costs

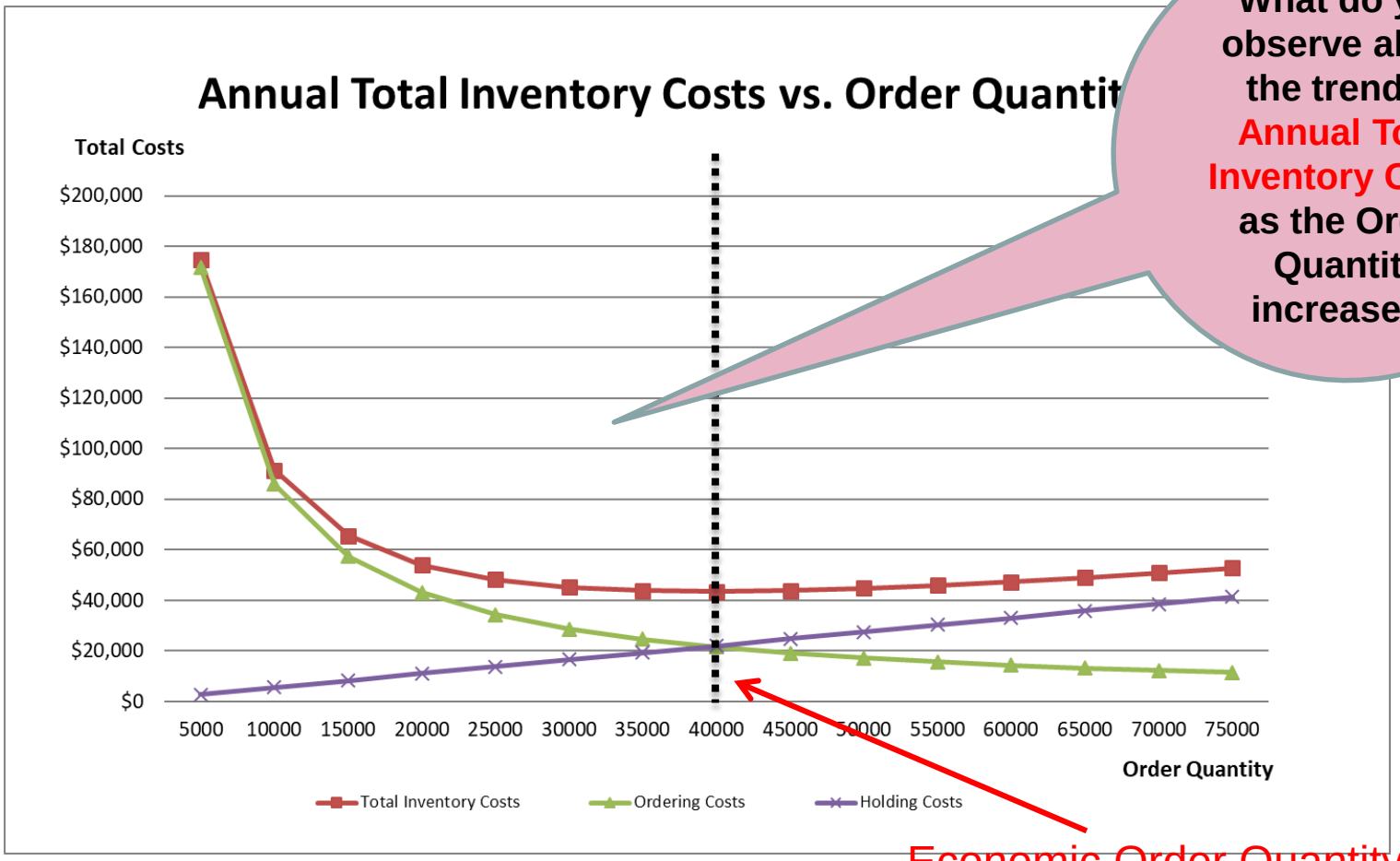
- Annual Inventory Holding Costs
  = (Q/2) * H
  = (Q/2) * 1.1
  = **0.55* Q**

Order Quantity, Q	Annual Holding Costs
5000	$2,750
10000	$5,500
15000	$8,250
20000	$11,000
25000	$13,750
30000	$16,500
35000	$19,250
40000	$22,000
45000	$24,750
50000	$27,500
55000	$30,250
60000	$33,000
65000	$35,750
70000	$38,500
75000	$41,250

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
  = **859,200,000 / Q + 0.55 * Q**



Optimal Order Quantity, Q* and Total Costs

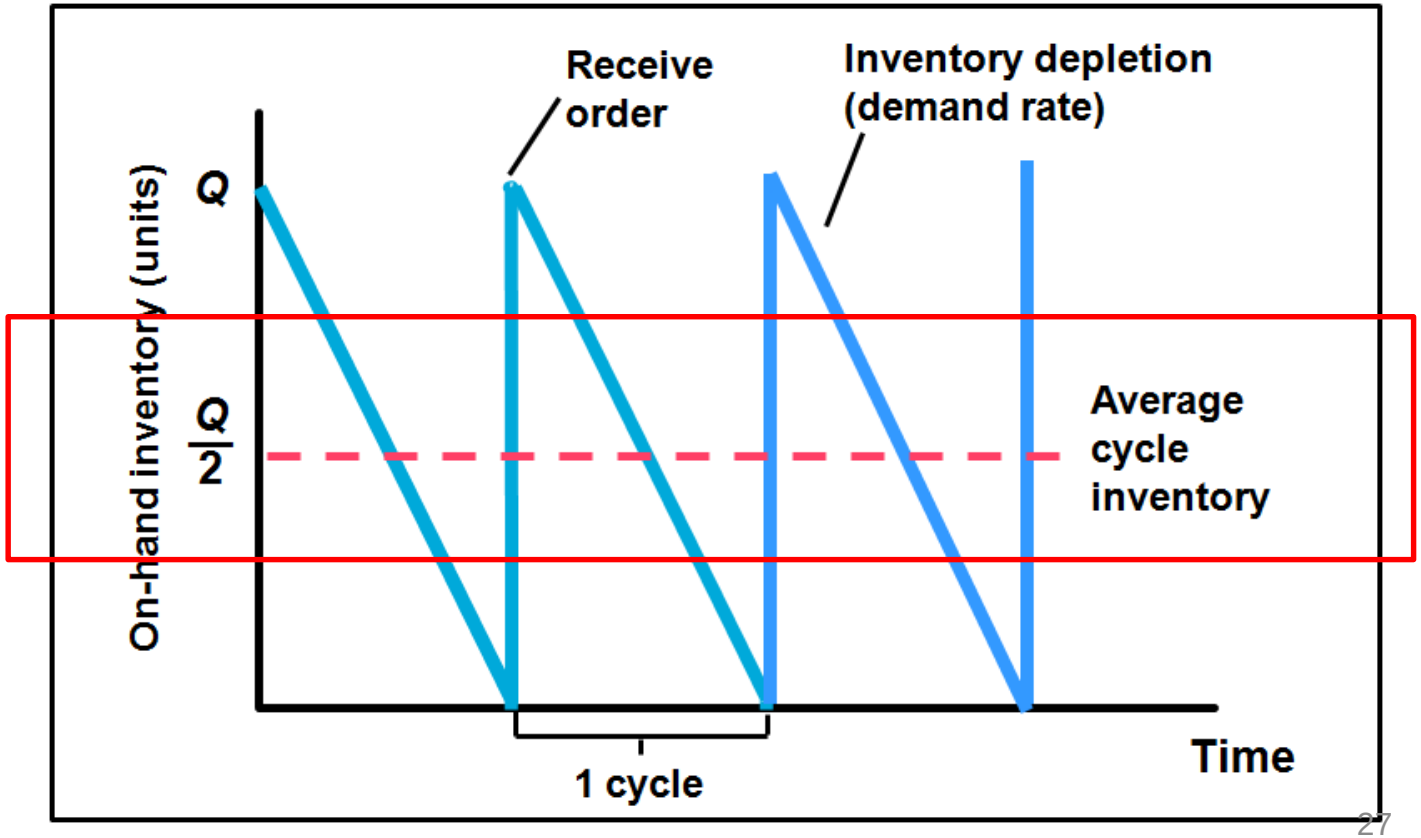
- Optimal order quantity, EOQ (Q*)
  = **39,525 units** (roundup to nearest integer)

$$Q^* = \sqrt{\frac{2RD}{H}} = \sqrt{\frac{2 \times 1200 \times 716000}{1.1}} = 39525$$

- Optimal Total Annual Inventory Costs
  = **859,200,000 / Q + 0.55 * Q**
  = 859,200,000/39,525+ 0.55*39,525
  = **$43,477** (roundup to nearest integer)

Average Inventory Level

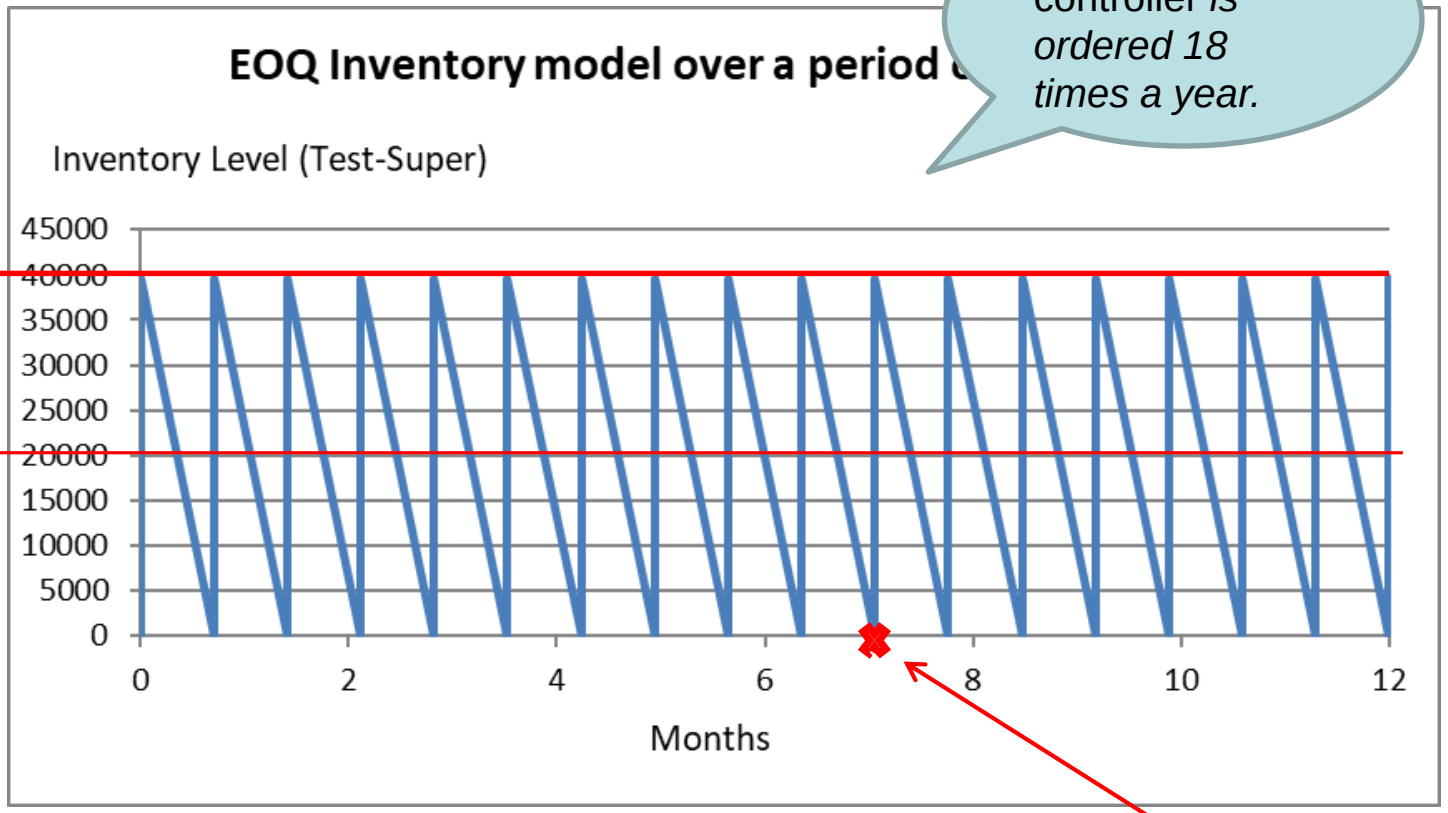
- Average Inventory Level
  = Optimal Order Quantity, Q* / 2
  = 39,525 / 2
  = **19,763 units**



Proposal: a Simple EOQ Ordering System

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

The remote controller *is ordered 18 times a year.*



EOQ = 39,525

Average Inventory Level = 19,763

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 120000 pcs and re-order at 30,000 pcs, the new ordering system by using EOQ model could reduce average inventory level and total inventory cost.

- Average inventory level reduction = 60,000 - 19,763= 40,237
- Expected total inventory cost reduction =$73,160 - $43,477
  =$29,683

	Current practice	EOQ model
Order Quantity (Q)	Q= 120,000 units	Q=EOQ= 39,525 units
Average Inventory (Q/2)	120,000/2=60,000 units	39,525/2 = 19,763 units
Total Inventory Cost (Ordering cost+ holding cost)	= (D/Q)*R + (Q/2)*H = 859,200,000 / Q + 0.55 * Q = 859,200,000/**120,000** + 0.55***120,000** = **$73,160**	= (D/Q)*R + (Q/2)*H = 859,200,000 / Q + 0.55 * Q = 859,200,000/**39,525** + 0.55***39,525** = **$43,477**

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 39,525 units on average instead of keeping 60,000 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