REPUBLIC POLYTECHNIC

P03
Prevent Stock-out

E217 – Inventory Management

SCHOOL OF ENGINEERING

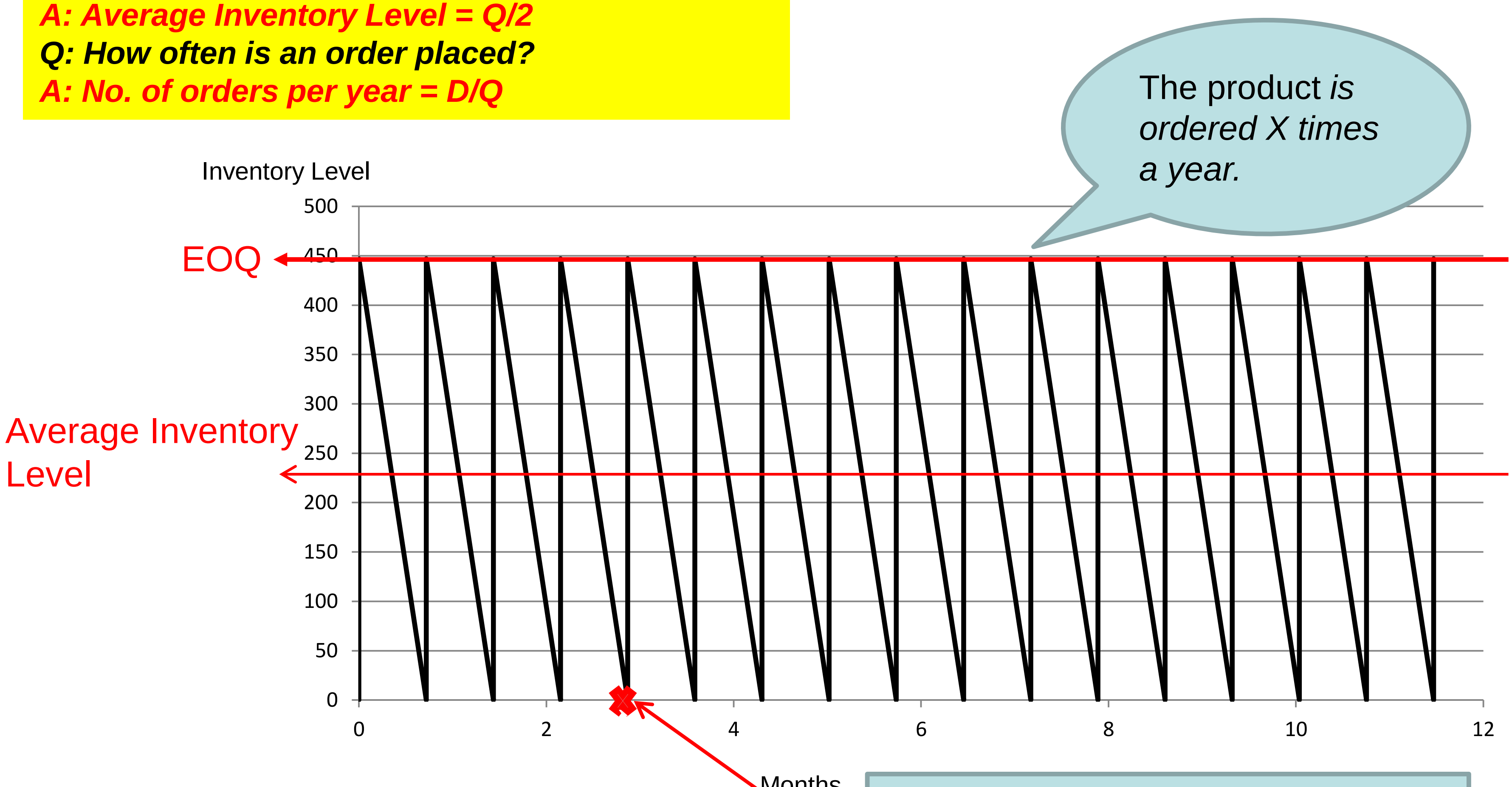
E217 Inventory Management Topic Tree

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



Note that the inventory drops to 0 just before the new stock arrives! But when to place the order ??

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 problem case, convert all the information to weeks

DAYS
WEEKS
MONTHS

LEAD TIME

$$ROP = d \times L$$

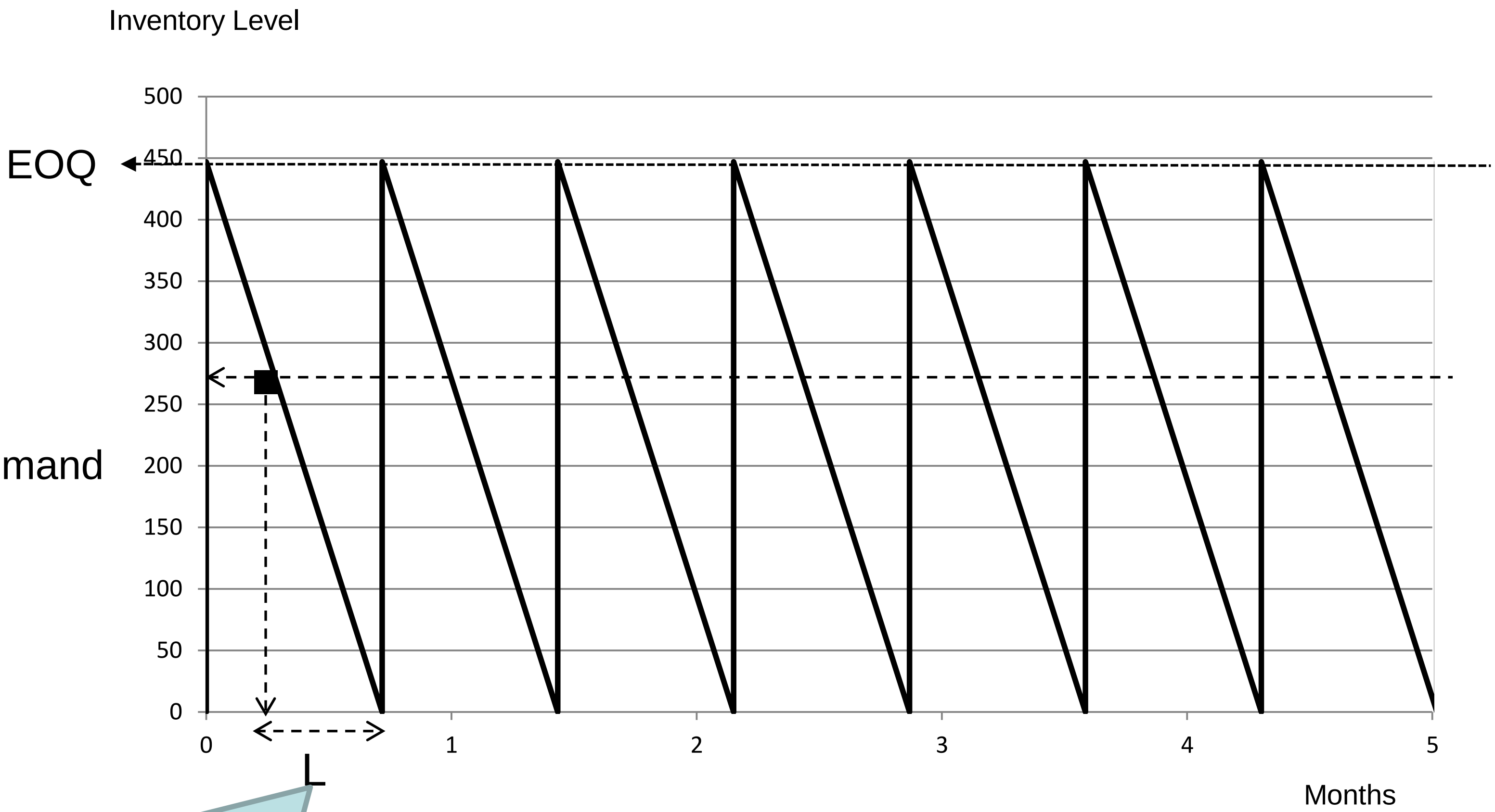
DAILY
WEEKLY
MONTHLY

DEMAND

Basic EOQ Model Recap

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

ROP
= Weekly demand
x Lead Time



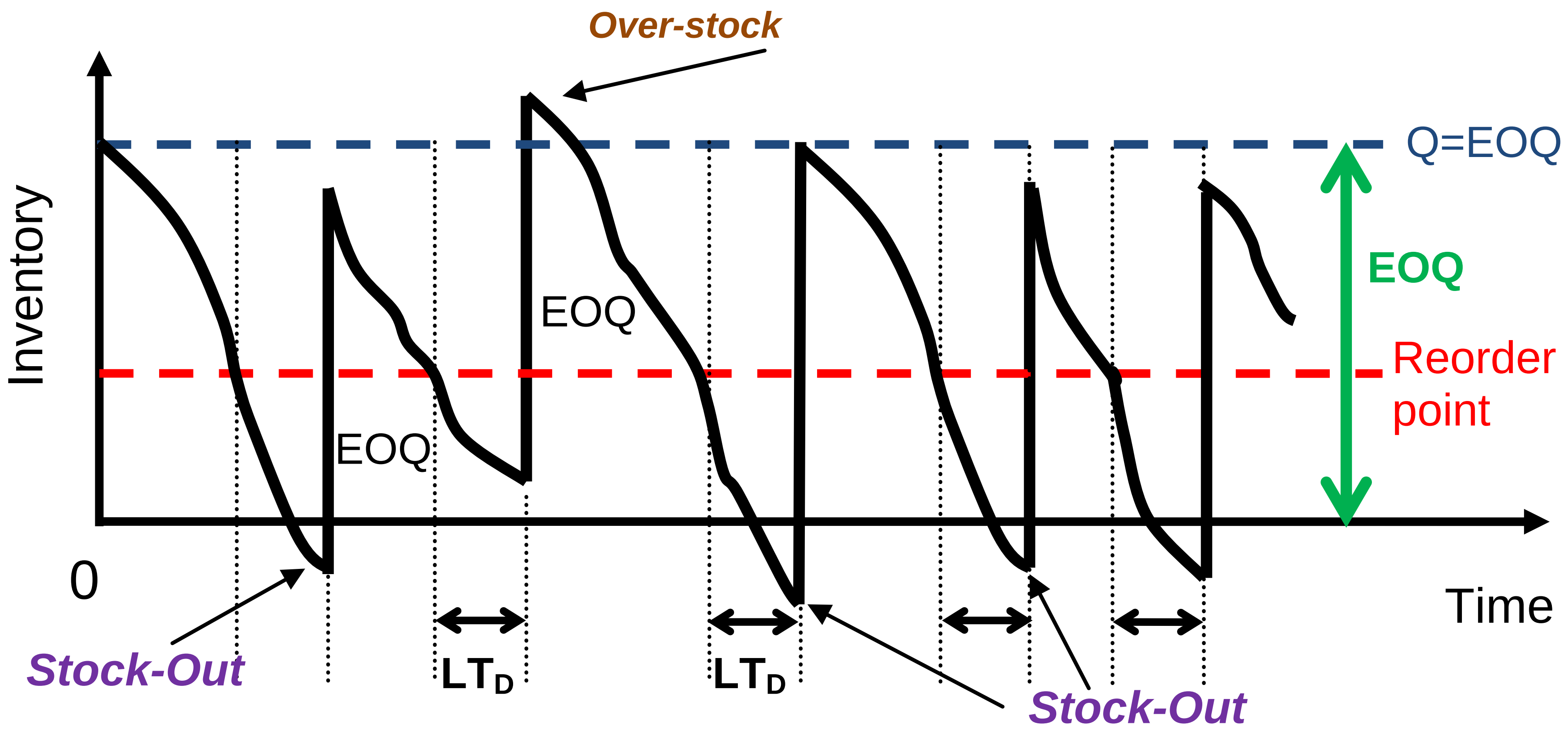
Reorder Point / Daily Demand
= L weeks (this is exactly the replenishment lead-time)

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

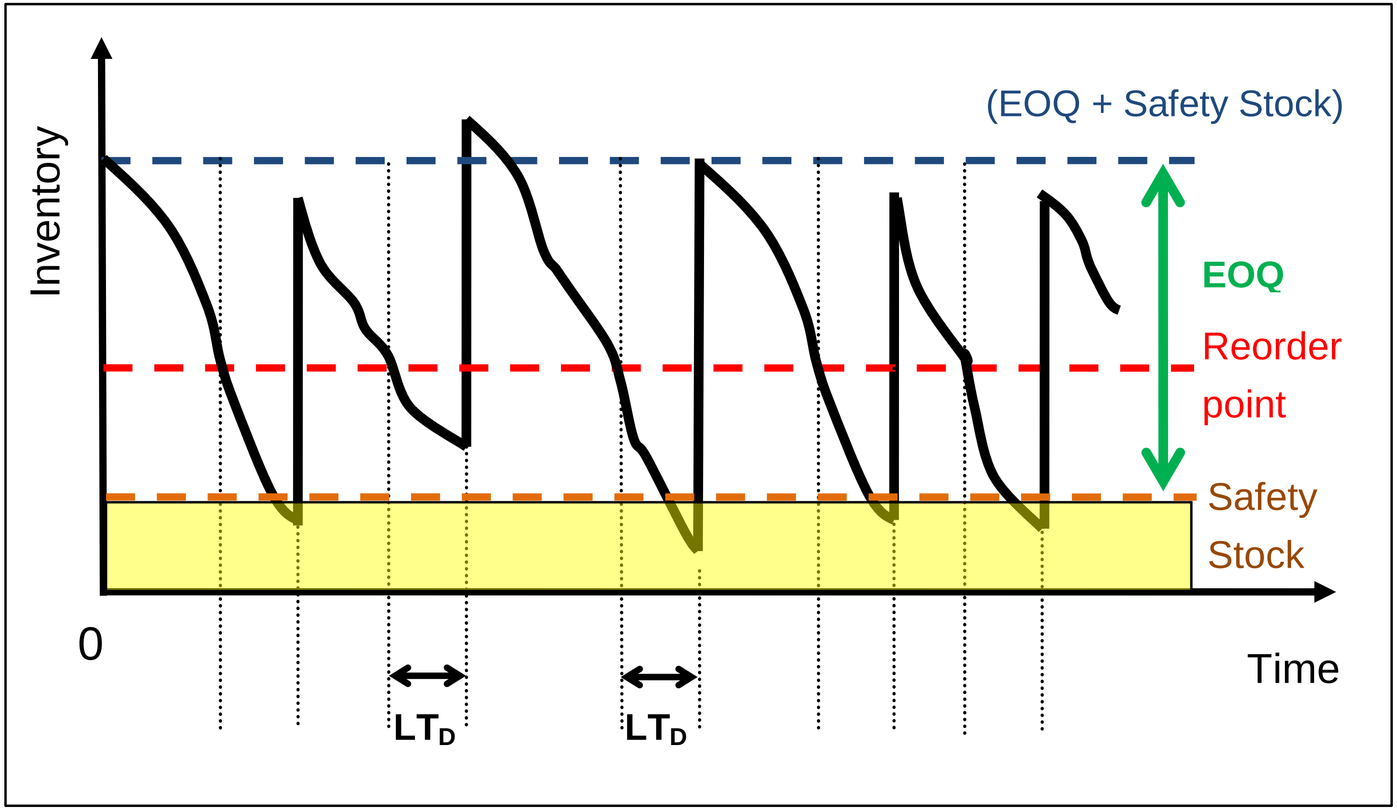


Real Life - Uncertain Customer Demand

- 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 due to the need to have extra storage space in warehouse.
- Under normal circumstances:
  - *Tony needs not target to fulfil all customer demands, e.g. 100% service level*
  - *Instead, he can aim to fulfil customers' orders within a desired 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.

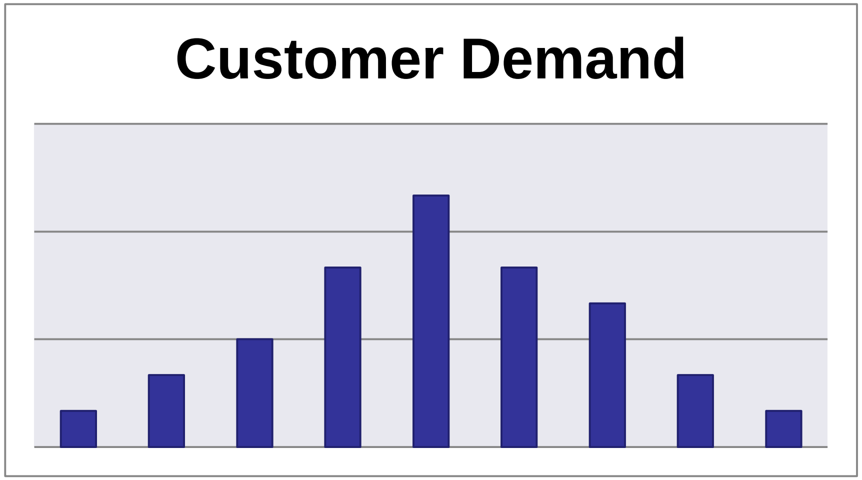
Demand Frequency & Probability

- 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	3	0.0577	0.115
126	130	4	0.0769	0.192
131	135	5	0.0962	0.288
136	140	6	0.1154	0.404
141	145	7	0.1346	0.538
146	150	7	0.1346	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	1.0000	

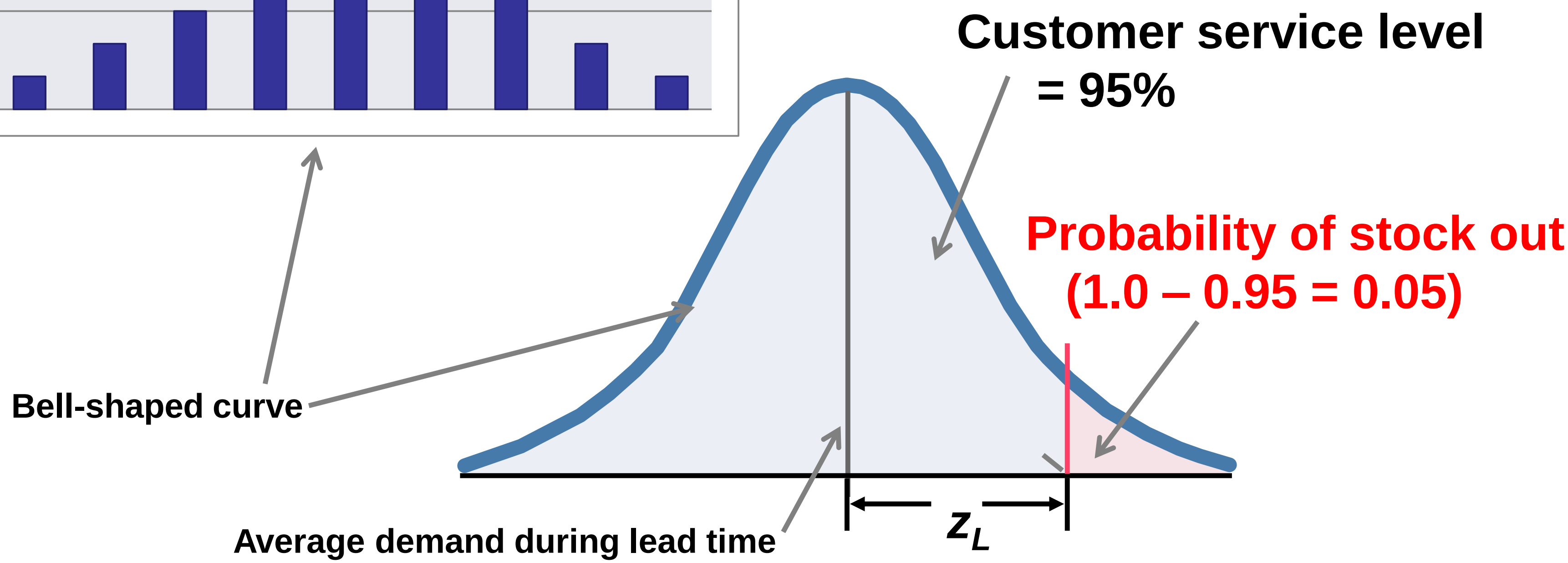
= 6/52
(individual frequency / total frequency)

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:

$$\sigma_{\mathrm{L}} = \sigma_{\mathrm{d}} \sqrt{L}$$

σ_{d} = Standard Deviation of demand during <u>a given period of time</u>

σ_{L} = Standard Deviation of demand during <u>replenishment lead time</u>

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:

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 manage these against expectations?

Given information

- Ordering Cost, R = \$100 per order
- Holding Cost, H = \$150 per unit per year
- Replenishment Lead-time, L = 4 weeks
- No. of operating weeks = 52 weeks per year
- Customer Service Level = 98%

Recommendations for Today's Problem

- Monthly Average Demand, d = **146 units/month**
- Monthly Standard Deviation, STDEV = **21.47 units/month**
- Annual Demand, D = **1745 units/year**
- Economic Order Quantity, Q* ~ **49 units (rounded up)**
- Reorder Point (ROP) **without considering the safety stock**
  = Monthly Average Demand * Replenishment Lead-time
  = 146 * 4 * 12 / 52
  = **135 units (rounded up)**

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

Recommendations for Today's Problem

<u>For customer service level at 98%</u>

- Safety Factor = NORMSINV(0.98) = 2.05

- Safety Stock

  = Safety Factor * STDEV * SQRT (L)

  = 2.05 * 21.47 * SQRT (4*12/52)

  = 42.37 units

  ~ **<u>43 units (rounded up)</u>**

- Reorder Point **considering the safety stock**

  = Weekly Average Demand * Replenishment Lead time + Safety Stock

  = 135 + 43

  = **<u>178 units</u>**

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	56	61	67	76	89

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 = **<u>64</u>**

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

- Optimal quantity to be backordered, Qs = **<u>28</u>**

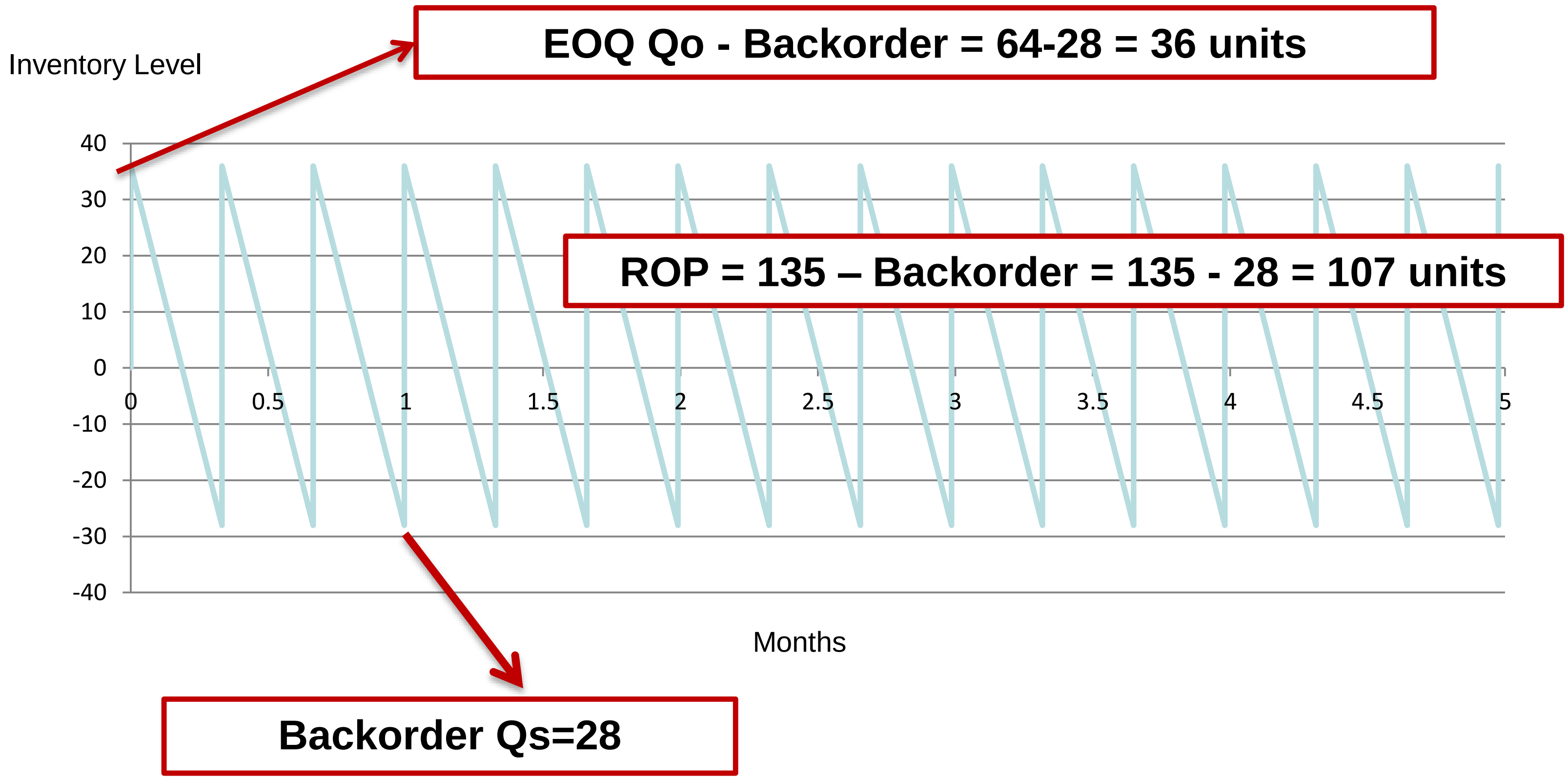
$$Q_s = \sqrt{\frac{2RHD}{B(H+B)}} = Q_o\left(\frac{H}{H+B}\right)$$

- Total Cost per year, TC = **<u>$5,471 (without Safety Stock)</u>**

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

Understanding the Backorder EOQ Model

At replenishment point, 64 units (Qo) arrive and 28 units(Qs) are immediately allocated to fulfill the backorders, leaving 36 units in stock.



Note: In the backorder EOQ, no safety stock is required, hence the ROP = 135 - backorder

Recommendations – If Backorders are Not Allowed

- Optimal quantity, Q = **49 units**

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

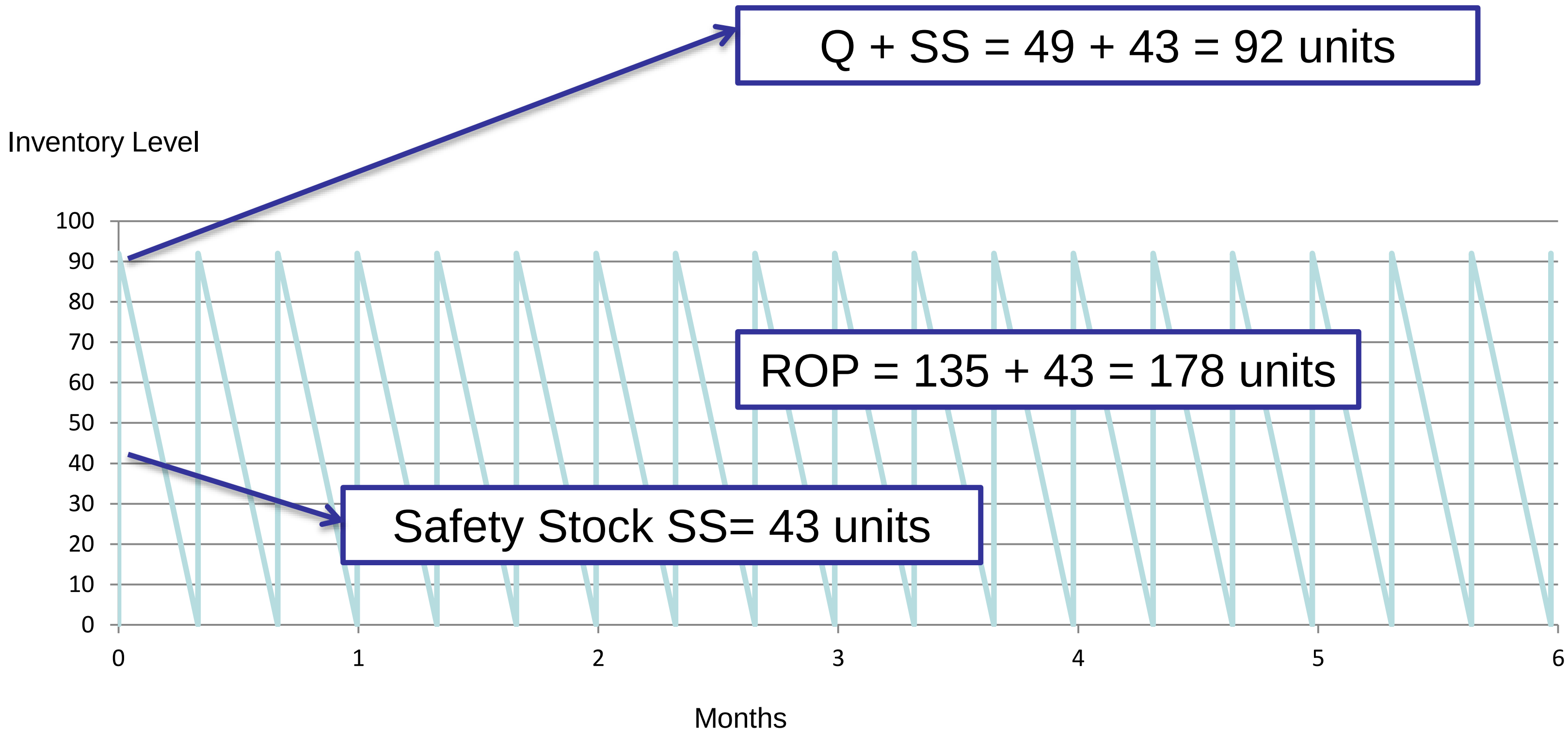
- Total Cost per year= **$13,687 (with Safety Stock)**, this is the optimal total cost for today's problem.

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

Additional carrying cost incurred due to safety stock!

Recommendations – If Backorders are Not Allowed

Stock level with NO backorders

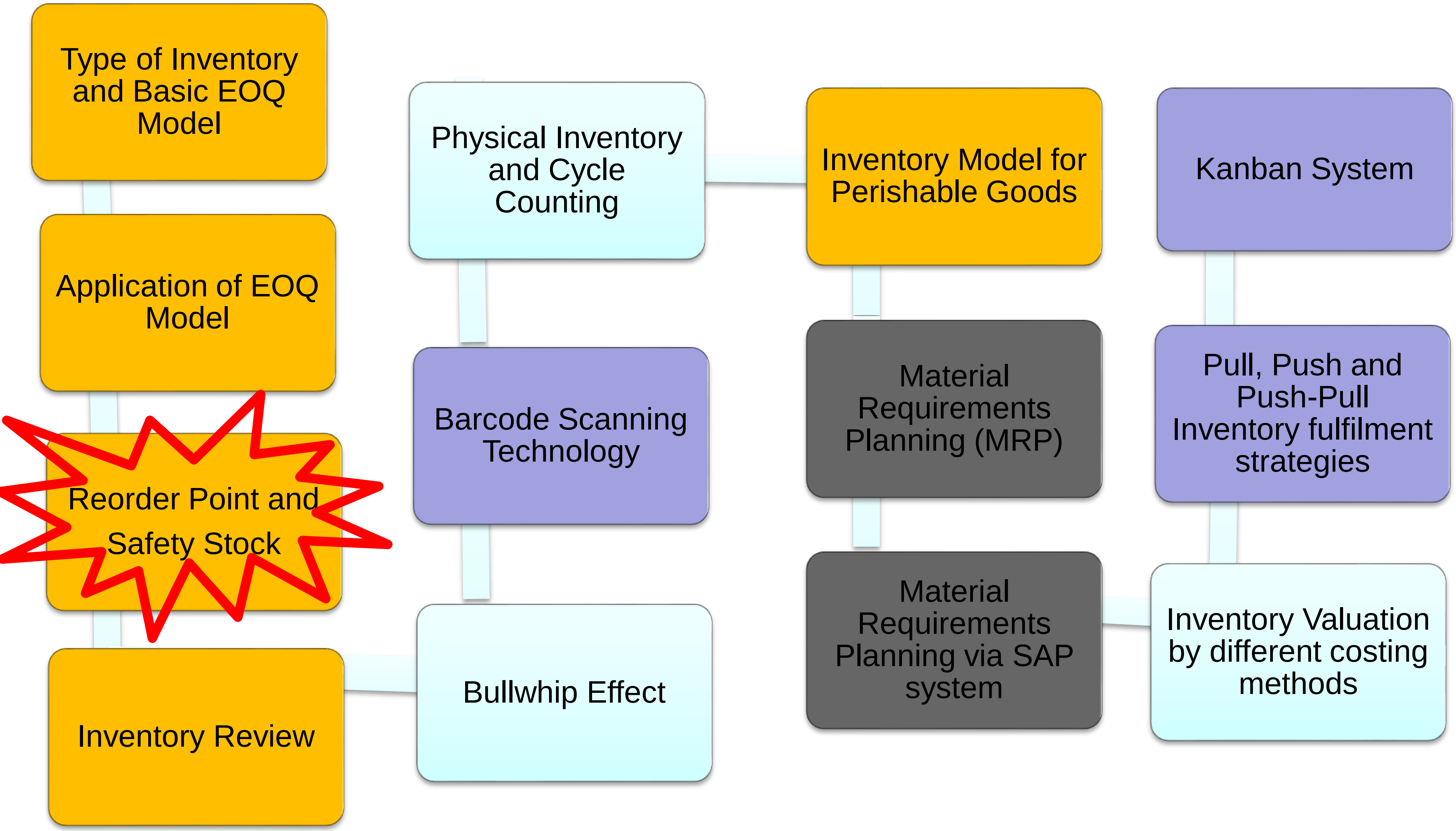


Note: If backorder is not allowed, safety stock is required, hence the ROP = 135 +SS

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 = **$5,471**
- **Not allowing backorders**, total inventory cost, TC = **$13,687**
- Cost savings = **$8,216** (savings if backorders are allowed)

E217 Inventory Management Topic Flow



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