Inventory

- Inventory is the stock of any item or resource used in an organization and can include:
  - raw materials
  - finished products
  - component parts
  - supplies
  - work-in-process

Ref: Parts/inventory at Wahburn Guitar: PS10.avi

Inventory System

- An inventory system is the set of policies and controls that
  - monitor levels of inventory
  - determines what levels should be maintained
  - when stock should be replenished
  - how large orders should be

Purposes of Inventory

1. To maintain independence of operations
2. To meet variation in product demand
3. To allow flexibility in production scheduling
4. To provide a safeguard for variation in raw material delivery time
5. To take advantage of economic purchase-order size
Inventory Costs

- **Holding (or carrying) costs**
  - Costs for storage, handling, insurance, etc
- **Setup (or production change) costs**
  - Costs for arranging specific equipment setups, etc
- **Ordering costs**
  - Costs of someone placing an order, etc
- **Shortage costs**
  - Costs of canceling an order, etc

Ref: Inventory Cost: MI1.avi

Independent vs. Dependent Demand

- **Independent Demand** (Demand for the final end-product or demand not related to other items)
- **Dependent Demand** (Derived demand items for component parts, subassemblies, raw materials, etc)

Inventory Systems

- **Single-Period Inventory Model**
  - One time purchasing decision
  - Example: vendor selling t-shirts at a football game
  - Seeks to balance the costs of inventory overstock and under stock
- **Multi-Period Inventory Models**
  - Fixed-Order Quantity Models
    - Event triggered (Example: running out of stock)
  - Fixed-Time Period Models
    - Time triggered (Example: Monthly sales call by sales representative)

Single-Period Inventory Model

\[ P \leq \frac{C_u}{C_o + C_u} \]

Where:

- \( C_o \) = Cost per unit of demand over estimated
- \( C_u \) = Cost per unit of demand under estimated
- \( P \) = Probability that the unit will be sold
**Single Period Model Example**

- Our college basketball team is playing in a tournament game this weekend. Based on our past experience, we sell on average 2,400 shirts with a standard deviation of 350. We make $10 on every shirt we sell at the game, but lose $5 on every shirt not sold. How many shirts should we make for the game?

\[ C_u = $10 \text{ and } C_s = $5; \]
\[ P \leq \frac{10}{10 + 5} = .667 \]

Now, we need to find the point on our demand distribution that corresponds to the cumulative probability of 0.667:

\[ Z_{.667} = .432 \text{ (use NORMSINV(.667) or Appendix E)} \]

Therefore we need 2,400 + .432(350) = 2,551 shirts

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**Multi-Period Models: Fixed-Order Quantity Model Model Assumptions**

- Demand for the product is constant and uniform throughout the period
- Lead time (time from ordering to receipt) is constant
- Price per unit of product is constant
- Inventory holding cost is based on average inventory
- Ordering or setup costs are constant
- All demands for the product will be satisfied (No back orders are allowed)

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**Cost Minimization Goal**

By adding the item, holding, and ordering costs together, we determine the total cost curve, which in turn is used to find the \( Q_{opt} \) inventory order point that minimizes total costs.
Basic Fixed-Order Quantity (EOQ) Model Formula

\[ TC = DC + \frac{D}{Q} S + \frac{Q}{2} H \]

- **Total Annual Cost**
- **Annual Purchase Cost**
- **Annual Ordering Cost**
- **Annual Holding Cost**

- \( TC \) = Total annual cost
- \( D \) = Demand
- \( C \) = Cost per unit
- \( Q \) = Order quantity
- \( S \) = Cost of placing an order or setup cost
- \( R \) = Reorder point
- \( L \) = Lead time
- \( H \) = Annual holding and storage cost per unit of inventory

Deriving the EOQ

Using calculus, we take the first derivative of the total cost function with respect to \( Q \), and set the derivative (slope) equal to zero, solving for the optimized (cost minimized) value of \( Q_{\text{opt}} \).

\[ Q_{\text{opt}} = \sqrt{\frac{2DS}{H}} = \sqrt\frac{2(\text{Annual Demand})(\text{Order or Setup Cost})}{\text{Annual Holding Cost}} \]

We also need a reorder point to tell us when to place an order:

\[ R = dL \]

- \( d \) = average daily demand (constant)
- \( L \) = Lead time (constant)

EOQ Example (1) Problem Data

Given the information below, what are the EOQ and reorder point?

- Annual Demand = 1,000 units
- Days per year considered in average daily demand = 365
- Cost to place an order = $10
- Holding cost per unit per year = $2.50
- Lead time = 7 days
- Cost per unit = $15

EOQ Example (1) Solution

\[ Q_{\text{opt}} = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(1,000)(10)}{2.50}} = 89.443 \text{ units or 90 units} \]

\[ d = \frac{1,000}{365} = \frac{2.74 \text{ units}}{\text{day}} \]

Reorder point, \( R = dL = 2.74 \text{ units/day} \times 7 \text{ days} = 19.18 \text{ or 20 units} \)

In summary, you place an optimal order of 90 units. In the course of using the units to meet demand, when you only have 20 units left, place the next order of 90 units.
**EOQ Example (2) Problem Data**

Determine the economic order quantity and the reorder point given the following:

- **Annual Demand**: 10,000 units
- **Days per year considered in average daily demand**: 365
- **Cost to place an order**: $10
- **Holding cost per unit per year**: 10% of cost per unit
- **Lead time**: 10 days
- **Cost per unit**: $15

**EOQ Example (2) Solution**

\[
Q_{opt} = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(10,000)(10)}{1.50}} = 365.148 \text{ units, or 366 units}
\]

\[
\bar{d} = \frac{10,000 \text{ units / year}}{365 \text{ days / year}} = 27.397 \text{ units / day}
\]

\[
R = \bar{d} L = 27.397 \text{ units / day} \times 10 \text{ days} = 273.97 \text{ or 274 units}
\]

Place an order for 366 units. When in the course of using the inventory you are left with only 274 units, place the next order of 366 units.

**Fixed-Time Period Model with Safety Stock Formula**

\[
q = \bar{d} (T + L) + Z \sigma_{T+L} + I
\]

Where:
- \(q\): quantity to be ordered
- \(\bar{d}\): average demand daily forecast
- \(T\): number of days between reviews
- \(L\): lead time in days
- \(\bar{d}\): average daily demand
- \(Z\): number of standard deviations for a specified service probability
- \(\sigma_{T+L}\): standard deviation of demand over the review and lead time
- \(I\): current inventory level (includes items on order)

**Multi-Period Models: Fixed-Time Period Model: Determining the Value of \(\sigma_{T+L}\)**

\[
\sigma_{T+L} = \sqrt{\sum_{i=1}^{n} \sigma_i^2}
\]

Since each day is independent and \(\sigma_i\) is constant,

\[
\sigma_{T+L} = \sqrt{(T + L)\sigma_i^2}
\]

The standard deviation of a sequence of random events equals the square root of the sum of the variances.
Example of the Fixed-Time Period Model

Given the information below, how many units should be ordered?

Average daily demand for a product is 20 units. The review period is 30 days, and lead time is 10 days. Management has set a policy of satisfying 96 percent of demand from items in stock. At the beginning of the review period there are 200 units in inventory. The daily demand standard deviation is 4 units.

Example of the Fixed-Time Period Model: Solution (Part 1)

\[
\sigma_{T+L} = \sqrt{(T + L)\sigma_d^2} = \sqrt{(30 + 10)(4)^2} = 25.298
\]

The value for “z” is found by using the Excel NORMSINV function, or as we will do here, using Appendix D. By adding 0.5 to all the values in Appendix D and finding the value in the table that comes closest to the service probability, the “z” value can be read by adding the column heading label to the row label.

So, by adding 0.5 to the value from Appendix D of 0.4599, we have a probability of 0.9599, which is given by a \( z = 1.75 \).

Example of the Fixed-Time Period Model: Solution (Part 2)

\[
q = \bar{d}(T + L) + Z\sigma_{T+L} - I
\]

\[
q = 20(30 + 10) + (1.75)(25.298) - 200
\]

\[
q = 800 + 44.272 - 200 = 644.272, \text{ or 645 units}
\]

So, to satisfy 96 percent of the demand, you should place an order of 645 units at this review period.

Miscellaneous Systems: Optional Replenishment System

Maximum inventory level, \( M = q = M - I \)

Actual inventory level, \( I \)

\( Q = \) minimum acceptable order quantity

If \( q > Q \), order \( q \), otherwise do not order any.
**Miscellaneous Systems:**

**Bin Systems**

**Two-Bin System**

- Full → Order One Bin of Inventory
- Empty

**One-Bin System**

- Order Enough to Refill Bin

**Periodic Check**

Ref: Inventory Control with Kanban: [http://tw.youtube.com/watch?v=Va6UWZl66o](http://tw.youtube.com/watch?v=Va6UWZl66o)

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**ABC Classification System**

- Items kept in inventory are not of equal importance in terms of:
  - dollars invested
  - profit potential
  - sales or usage volume
  - stock-out penalties

So, identify inventory items based on percentage of total dollar value, where “A” items are roughly top 15%, “B” items as next 35%, and the lower 65% are the “C” items.

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**Inventory Accuracy and Cycle Counting**

- **Inventory accuracy** refers to how well the inventory records agree with physical count
- **Cycle Counting** is a physical inventory-taking technique in which inventory is counted on a frequent basis rather than once or twice a year

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**Real Practice**

- Case Study-Microsoft Retail Management System: [http://tw.youtube.com/watch?v=84-P7opRwxk](http://tw.youtube.com/watch?v=84-P7opRwxk)
- ERP Systems: DVD
Question Bowl

The average cost of inventory in the United States is which of the following?

a. 10 to 15 percent of its cost
b. 15 to 20 percent of its cost
c. 20 to 25 percent of its cost
d. 25 to 30 percent of its cost
e. 30 to 35 percent of its cost

Answer: e. 30 to 35 percent of its cost

Question Bowl

Which of the following is a reason why firms keep a supply of inventory?

a. To maintain independence of operations
b. To meet variation in product demand
c. To allow flexibility in production scheduling
d. To take advantage of economic purchase order size
e. All of the above

Answer: e. All of the above (Also can include to provide a safeguard for variation in raw material delivery time.)

Question Bowl

An Inventory System should include policies that are related to which of the following?

a. How large inventory purchase orders should be
b. Monitoring levels of inventory
c. Stating when stock should be replenished
d. All of the above
e. None of the above

Answer: d. All of the above

Question Bowl

Which of the following is an Inventory Cost item that is related to the managerial and clerical costs to prepare a purchase or production order?

a. Holding costs
b. Setup costs
c. Carrying costs
d. Shortage costs
e. None of the above

Answer: e. None of the above (Correct answer is Ordering Costs.)
**Question Bowl**

Which of the following is considered a **Independent Demand** inventory item?

a. Bolts to an automobile manufacturer  
b. Timber to a home builder  
c. Windows to a home builder  
d. Containers of milk to a grocery store  
e. None of the above

Answer: d. Containers of milk to a grocery store

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**Question Bowl**

If you are marketing a more expensive independent demand inventory item, which inventory model should you use?

a. Fixed-time period model  
b. Fixed-order quantity model  
c. Periodic system  
d. Periodic review system  
e. P-model

Answer: b. Fixed-order quantity model

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**Question Bowl**

The basic logic behind the **ABC Classification** system for inventory management is which of the following?

a. Two-bin logic  
b. One-bin logic  
c. Pareto principle  
d. All of the above  
e. None of the above

Answer: c. Pareto principle

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**Question Bowl**

A physical inventory-taking technique in which inventory is counted frequently rather than once or twice a year is which of the following?

a. Cycle counting  
b. Mathematical programming  
c. Pareto principle  
d. ABC classification  
e. Stockkeeping unit (SKU)

Answer: a. Cycle counting