Inventories and their Management

“Inventories” = ?
New Car Inventory Sitting in Parking Lots
Types of Inventory

1. Materials
   - A. Raw material
   - B. WIP
   - C. Finished Goods
Types of Inventory

1. Components
   • A. Subassemblies
   • B. Purchased parts that “go into”

2. Distribution inventories
   • A. Sometimes called “pipeline” inventories
   • B. In a warehouse or in transit

3. “MRO”
   • A. Maintenance items
   • B. Repair parts
   • C. Operating supplies
A Material-Flow Process

Production Process

Raw Materials

Work in process

Work in process

Work in process

Finished goods

Vendors

Customer
What is inventory and Inventory management?

- Inventory: a stock of materials used to facilitate production or to satisfy customer demand

- Managing the flow of goods into, through, and out of an organization
Inventory

• One of the most expensive assets of many companies representing as much as 50% of total invested capital
• Operations managers must balance inventory investment and customer service
Purpose of Inventories

• To protect against *uncertainties*
  - in demand
  - supply
  - lead times
  - schedule changes
  - Reduction: shorten throughput times
Types of Inventory

- External
- Internal
Types of Inventory (external)

Pipeline inventory
inbound or outbound
stock in transit
Types of Inventory (internal)

Raw Material
product which has not yet undergone any transformation

Work-in-process (WIP)
inventory which has already undergone some transformation but not yet completed

Finished Goods
inventory which has undergone all transformations and is ready to be passed on to the customer
Negative Aspects of Inventory

• Financial cost of carrying too much inventory

• Risk of obsolescence or damage

• Large inventories hide operational problems
Holding (or Carrying) Cost

1. Cost to carry one unit of stock for one unit of time, e.g., $2 / unit / year
   - A. Varies with the inventory level

2. Notation: H

3. Components:
   - A. Capital costs or Opportunity costs
   - B. Storage cost
   - C. Insurance & Taxes
   - D. Risk costs
     - a. Pilferage & Obsolescence

4. Sometimes derived from:
   - A. holding cost “rate”, e.g., 25% per year
   - B. Multiplied by the unit value
Inventory Cost Structures
How the 35 percent carrying cost is distributed

- Cost of Capital—9-20 percent
- Obsolescence—2-5 percent
- Storage—2-5 percent
- Material Handling—1-3 percent
- Shrinkage—1-3 percent
- Taxes & Insurance—1-3 percent

Source: Mark Williams, APICS Instructor Listserv, 22 January 2001
Inventory Cost Structures

- Shrinkage
  - “…’shrinkage’…cost U.S. retailers about $41.6 billion last year.” This is more than the combined total from other crimes such as robberies, auto theft and larceny.

Inventory Cost Structures

• Stock out cost (back order or lost sales)
  • record maintenance
  • lost income
  • customer dissatisfaction
  • Typically expressed as a fixed cost per backorder or as a function of aging of backorders.
Hidden Costs of Inventory

- Longer *lead times*
- Reduced *responsiveness*
- Underlying *problems* are hidden rather than being exposed and solved
- *Quality* problems are not identified immediately
- No incentive for *improvement* of the process
Two Forms of Demand

- Independent demand (this chapter)
  - finished goods, spare parts,
  - based on market demand
  - requires forecasting
  - managed using ‘replenishment philosophy’, i.e. reorder when reach a pre-specified level.
Two Forms of Demand

- Dependent demand (next chapter)
  - parts that go into the finished products
  - dependent demand is a known function of independent demand
  - calculate instead of forecast
  - Managed using a ‘requirements philosophy’, *i.e.* only ordered as needed for higher level components or products.
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)

Finished product

Component parts
Basic Inventory Management Issues And Decisions

1. For which items should inventory be carried?
2. Where should inventory be stored?
3. What is the right inventory level for each product?
4. How can we control inventories?
5. How can we evaluate inventory performance?

*Inventory Decisions Involve Trade-Offs!*
Inventory Systems

1. An inventory system provides the structure and operating policies for maintaining and controlling goods to be stocked in inventory.

2. The system is responsible for ordering, tracking, and receiving goods.

3. There are two essential questions to answer that define a policy:
   - 1. How much or *what quantity* of an item to order
   - 2. *When* should an order for that item be placed?
Two Types of Systems

- **1. Continuous review system**: an inventory system that always orders the same quantity of items but has differing periods of time between orders

  ![Continuous Review System Diagram]

- **2. Periodic review system**: an inventory system that has a fixed time between orders but has different order quantities from order to order

  ![Periodic Review System Diagram]
Order or Setup Cost

1. Cost to place an order or to initiate a production run, e.g., $10 / order
   - A. A fixed cost

2. Notation: $S$

3. Components:
   - Order Cost -> Time of personnel, receiving, inspection, etc.
   - Setup Cost -> Opportunity cost, waste, etc.
Shortage Cost

1. Also known as *stockout* cost
   - A. Occurs when inventory not sufficient to meet demand

2. Could result in:
   - A. Back order
   - B. Lost sale

3. Direct, and indirect, dollar consequences:
   - A. Downtime of operations
   - B. Premiums for expediting
   - C. Extra transportation and handling
   - D. Lost of customer goodwill
EOQ

1. You want to review your inventory *continually*

2. You want to replenish your inventory when the level falls below a minimum amount, and order the same $Q$ each time

3. Typical of a retail item, or a raw material item in a manufacturer
How to Determine Q

- Use the “EOQ” formula

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

- D = Demand
- S = Order or Setup Cost
- H = Holding Cost
EOQ Assumptions

1. For the Square Root Formula to Work Well:
   A. Continuous review of the inventory position
   B. Demand is known & constant … no safety stock is required
   C. Lead time is known & constant
   D. No quantity discounts are available
   E. Ordering (or setup) costs are constant
   F. All demand is satisfied (no shortages)
   G. The order quantity arrives in a single shipment
EOQ Inventory Behavior

Inventory Level
Starts at Q

Q

Inventory Depletes
at Constant Rate

Reorder Point Hit
R

0

Inventory Runs Out &
Order of Size Q Arrives

Process Repeats
Where the EOQ formula comes from:

- Find the $Q$ that minimizes the total annual inventory related costs:
  - Annual number of orders: $N = \frac{D}{Q}$
  1. Annual Ordering Cost: $S \times \left(\frac{D}{Q}\right)$
  2. Annual Carrying Cost: $H \times \frac{Q}{2}$
How the costs behave:

![Graph showing the relationship between Order Quantity (Q) and Annual cost ($) in a blank graph.](image-url)
How the costs behave:

Ordering Cost = $\frac{SD}{Q}$

Annual cost ($) vs. Order Quantity, $Q$
How the costs behave:

- **Carrying Cost**: $\frac{HQ}{2}$
- **Ordering Cost**: $\frac{SD}{Q}$

Annual cost ($) vs. Order Quantity, $Q$
How the costs behave:

- **Annual cost ($)**
- **Total Cost**
- **Carrying Cost**
- **Ordering Cost**

Minimum total cost at **Optimal order $Q_{opt}$** with a slope of **0**.
How the Costs Behave

• Total Cost (TC)

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

• 1. Total Cost Function Has Slope of Zero at Best (Optimal) Value of Q

• 2. Taking First Derivative of \( TC \) and Setting Equal to Zero Gives the Square Root Equation
Example: *Papa Joe’s Pizza* (Atlanta store)

- Uses 18,000 pizza cartons / year
- Ordering lead time is 1 month

**Decisions:**

1. How many cartons should Papa Joe order? i.e., $Q$
2. When should Papa Joe order? $R$
Data:

• Inventory carrying cost is $0.022 carton / year

• Ordering cost is $10 / order
EOQ for Papa Joe’s

\[ EOQ = \sqrt{\frac{2 \times 10 \times 18,000}{0.022}} = 4,045.2 \]

\[ Q = 4,045 \]

\[ TC(4,045) = \frac{180,000}{4,045} + 0.011 \times 4,045 \]

\[ = \$88.99 \text{ / year} \]

\[ TC(4,000) = \frac{180,000}{4,000} + 0.011 \times 4,000 \]

\[ = \$89.00 \text{ / year} \]
Reorder Point

Q

R

0

Lead Time
Reorder Point Calculation

1. \( D \times L = \text{demand during lead time} \)

2. Set reorder point, \( R \), equal to demand during lead time

3. \( R = D \times L \)

4. For Papa Joe’s
   
   A. \( R = (18,000 \text{ cartons} / \text{yr}) \times (1 / 12 \text{ yr}) \)
      
      \[ = 1,500 \text{ cartons} \]

5. State Inventory Policy As:
   
   A. Order 4,000 cartons When the Inventory Level Reaches 1,500 cartons
Variable Demand & Safety Stock

- Order Placed
- Order Received
- Demand during lead time
- Stockout

Q, R
The Relationship Between SS, R, & L

1. \( R = \) enough stock to cover:

A. What you *expect* to happen during a lead time plus

B. What *might* happen during the lead time

C. \( R = dL + SS \)
EOQ with Discounts

- Many companies offer discounted pricing for items that they sell.

Procedure:

- Arrange the prices from lowest to highest. Starting with the lowest price, calculate the EOQ for each price until a feasible EOQ is found.
  - If the first feasible EOQ is for the lowest price, this quantity is optimal and should be used.
  - If not, proceed until feasible EOQ found.
  - If feasible EOQ found, check ALL breakpoints above the value of the feasible Q
EOQ w/ Quantity Discounts

- Example
  - \(D = 16,000\) boxes of gloves/year
  - \(S = $5/\text{order}\)
  - \(h = 0.25\) (25% of cost)
  - \(C = \text{cost per unit}\)
    - $5.00 for 1 to 99 boxes
    - $4.00 for 100 to 499 boxes
    - $3.00 for 500+ boxes

\[
Q = \sqrt{\frac{(2)(16,000)(5)}{(0.25)(3)}} = 461.9
\]

\(C = $3.00\)

Not Feasible

\[
Q = \sqrt{\frac{(2)(16,000)(5)}{(0.25)(4)}} = 400
\]

\(C = $4.00\)

Feasible
EOQ w/ Quantity Discounts

For Q = 400

\[ TC = \frac{16,000}{400} (5) + \frac{400}{2} (0.25)(4) + (4)(16,000) = \$64,400 \]

For Q = 500

\[ TC = \frac{16,000}{500} (5) + \frac{500}{2} (0.25)(3) + (3)(16,000) = \$48,347.5 \]

Decision: Buy with Q = 500 for Lowest Possible Cost
EPQ

- You want to review your inventory continually
- You want to replenish your inventory when the level falls below a minimum amount, and order the same Q each time
- Your replenishment does *NOT* occur all at once
- Typical of a WIP item, typical of manufacturing
Papa Joe’s Pizza

- Joe orders in batches of $Q = 4000$ cartons at a time
- He uses a “low bid” vendor (cheap)
  - It takes about 1 month to get the order in
  - Due to limited staffing, only 1000 cartons can be made and sent to Joe each week

How is the inventory build up different than the Base Case (EOQ scenario)?
EPQ Inventory Behavior

- Inventory Level Starts at $I_{\text{max}}$
- Inventory Depletes at Constant Rate
- Reorder Point Hit ($R$) (Prepare Production Run)
- Inventory Runs Out & Production Begins
- Production Stops at $I_{\text{max}}$
- Inventory Produced at Constant Rate
- Process Repeats

Major Difference: Maximum Inventory Level
EPQ Equations

• Total cost:
  \[ TC = \left( \frac{D}{Q} S \right) + \left( \frac{I_{\text{MAX}}}{2} H \right) \]

• Maximum inventory:
  • \( d = \) avg. daily demand rate
  • \( p = \) daily production rate
  \[ I_{\text{MAX}} = Q \left( 1 - \frac{d}{p} \right) \]

• Calculating EPQ:
  \[ Q = \sqrt{\frac{2DS}{H \left( 1 - \frac{d}{p} \right)}} \]
EPQ Example
And when should Papa Joe reorder his cartons?

\[ R = \text{Demand during the resupply lead time} = d \times L \]

Reorder point is determined in the same way as for the EOQ policy.
Other Types of Inventory Systems

Variations on the basic types of continuous and periodic reviews:

- ABC Systems
- Bin Systems
- Can Order Systems
- Base Stock Systems
- The Newsvendor Problem
1. **ABC systems**: inventory systems that utilize some measure of importance to classify inventory items and allocate control efforts accordingly.

2. They take advantage of what is commonly called the 80/20 rule, which holds that 20 percent of the items usually account for 80 percent of the value.
   - A. Category **A** contains the most important items.
   - B. Category **B** contains moderately important items.
   - C. Category **C** contains the least important items.
ABC Systems

1. **A** items make up only 10 to 20 percent of the total number of items, yet account for *60 to 80 percent of annual dollar value.*

2. **C** items account for 50 to 70 percent of the total number of items, yet account for only *10 to 20 percent of annual dollar value.*

3. **C** items may well be of high importance, but because they account for relatively little annual inventory cost, it may be preferable to order them in large quantities and carry excess safety stock.
Bin Systems

1. **Bin system**: a type of inventory system that uses either one or two bins to hold a quantity of the item being inventoried; an order is placed when one of two bins is empty or a line on a single bin is reached.
Can Order & Base Stock Systems

1. Can order system: a type of inventory system that reviews the inventory position at fixed time intervals and places orders to bring the inventory up to an expected target level, but only if the inventory position is below a minimum quantity, similar to the reorder point in a continuous review system.

2. Base stock system: a type of inventory system that issues an order whenever a withdrawal is made from inventory.
“Newsvendor” Problem

1. Order inventory for only a one-time stocking of an item
   the “Single-Period” Inventory model

2. Examples:
   - A. Xmas tree lots
   - B. Newspaper stands

3. Objective: maximize profit

4. Why not just stock as many units as possible?
Example:

Tee shirts are purchased in multiples of 10 for a charity event for $8 each. When sold during the event the selling price is $20. After the event their salvage value is just $2. From past events the organizers know the probability of selling different quantities of tee shirts within a range from 80 to 120:

<table>
<thead>
<tr>
<th>Customer Demand</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob. Of Occurrence</td>
<td>.20</td>
<td>.25</td>
<td>.30</td>
<td>.15</td>
<td>.10</td>
</tr>
</tbody>
</table>

How many tee shirts should they buy and have on hand for the event?
## Payoff Table: Setup

<table>
<thead>
<tr>
<th>Purchase Qty</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Payoff Table: Cell Calculations

Profit = Revenues – Costs + Salvage

- Revenues = \textbf{Selling Price} (p) \times \textbf{Amount Sold}
- Costs = \textbf{Purchase Price} (c) \times \textbf{Purchase Qty}
- Salvage = \textbf{Salvage Value} (s) \times \textbf{Amount Leftover}

\textbf{Amount Sold} = \text{min} (\text{Demand, Purchase Qty})
\textbf{Amount Leftover} = \text{max} (\text{Purchase Qty} – \text{Demand}, 0)
Payoff Table: Cell Calculations

Let $Q = \text{Purchase Qty}$ and $D = \text{Demand}$

Case 1. $Q \leq D$
Profit = $[p \times Q] - [c \times Q] + [s \times 0] = (p - c) Q$

Case 2. $Q > D$
Profit = $[p \times D] - [c \times Q] + [s \times (Q - D)]$
Payoff Table: Cell Calculations

Have $p = $20, $c = $8, and $s = $2.

Compute Profit when $Q = 90$ and $D = 110$.
Profit = $[p \times Q] - [c \times Q] + [s \times 0] = (p - c) Q = 12(90) = 1080$

Compute Profit when $Q = 100$ and $D = 100$.
Profit = $[p \times Q] - [c \times Q] + [s \times 0] = (p - c) Q = 12(100) = 1200$

Compute Profit when $Q = 110$ and $D = 80$.
Profit = $[p \times D] - [c \times Q] + [s \times (Q - D)]$
= $20(80) - 8(110) + 2(30) = 1600 - 880 + 60 = 780$
## Payoff Table Values

<table>
<thead>
<tr>
<th>Purchase Qty</th>
<th>Demand</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td>960</td>
</tr>
<tr>
<td>90</td>
<td>900</td>
<td>1080</td>
<td>1080</td>
<td>1080</td>
<td>1080</td>
</tr>
<tr>
<td>100</td>
<td>840</td>
<td>1020</td>
<td><strong>1200</strong></td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>110</td>
<td><strong>780</strong></td>
<td>960</td>
<td>1140</td>
<td>1320</td>
<td>1320</td>
</tr>
<tr>
<td>120</td>
<td>720</td>
<td>900</td>
<td>1080</td>
<td>1260</td>
<td><strong>1440</strong></td>
</tr>
</tbody>
</table>
Getting the Final Answer

1. For Each Purchase Quantity:
   A. Calculated the Expected Profit

2. Choose Purchase Quantity With Highest Expected Profit.

3. Expected Profit for a Purchase Quantity:
   A. Multiply Each Payoff by Its Probability, Then Sum

4. Example:
   A. For Purchase Quantity = 100
   B. Expected Profit = (840)(0.2) + (1020)(0.25) + (1200)(0.3) + (1200)(0.15) + (1200)(0.1) = $1083
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>purchase price</td>
<td>8 $ / tee shirt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>selling price</td>
<td>20 $ / tee shirt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>salvage value</td>
<td>2 $ / tee shirt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Customer demand</td>
<td>80 90 100 110 120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Prob (demand)</td>
<td>0.20 0.25 0.30 0.15 0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Profit Calculations</td>
<td>= selling price*(amt sold) - purchase price*(purchase qty) + salvage value*(amt leftover)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Purchase Qty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>90</td>
<td>900</td>
<td>1080</td>
<td>1080</td>
<td>1080</td>
<td>1080</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>100</td>
<td>840</td>
<td>1020</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>110</td>
<td>780</td>
<td>960</td>
<td>1140</td>
<td>1320</td>
<td>1320</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>120</td>
<td>720</td>
<td>900</td>
<td>1080</td>
<td>1260</td>
<td>1440</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```excel
=CS3*MIN(B14,C12)-CS2*B14+CS4*MAX(B14-C12,0)
```
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>purchase price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>selling price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>salvage value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Customer demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Prob (demand)</td>
<td>0.20</td>
<td>0.25</td>
<td>0.30</td>
<td>0.15</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Profit Calculations</td>
<td>= selling price*(amt sold) - purchase price*(purchase qty) + salvage value*(amt leftover)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Demand</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Purchase Qty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>80</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>90</td>
<td>900</td>
<td>1080</td>
<td>1080</td>
<td>1080</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>100</td>
<td>840</td>
<td>1020</td>
<td>1200</td>
<td>1200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>110</td>
<td>780</td>
<td>960</td>
<td>1140</td>
<td>1320</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>120</td>
<td>720</td>
<td>900</td>
<td>1080</td>
<td>1260</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

=SUMPRODUCT($C$7:$G$7,C14:G14)
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DATA</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>purchase price</td>
<td>8</td>
<td>$ / tee shirt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>selling price</td>
<td>20</td>
<td>$ / tee shirt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>salvage value</td>
<td>2</td>
<td>$ / tee shirt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Customer demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Prob (demand)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.20</td>
<td>0.25</td>
<td>0.30</td>
<td>0.15</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Profit Calculations</td>
<td>= selling price * (amt sold) - purchase price * (purchase qty) + salvage value * (amt leftover)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Demand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Purchase Qty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td>960</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>90</td>
<td>900</td>
<td>1080</td>
<td>1080</td>
<td>1080</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>100</td>
<td>840</td>
<td>1020</td>
<td>1200</td>
<td>1200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>110</td>
<td>780</td>
<td>960</td>
<td>1140</td>
<td>1320</td>
<td>1320</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>120</td>
<td>720</td>
<td>900</td>
<td>1080</td>
<td>1260</td>
<td>1440</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expected Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>960</td>
</tr>
<tr>
<td>1044</td>
</tr>
<tr>
<td>1083</td>
</tr>
<tr>
<td>1068</td>
</tr>
<tr>
<td>1026</td>
</tr>
</tbody>
</table>
Newsvendor and Overbooking

1. Approximately 50% of Reservations Get Cancelled at Some Point in Time.
2. In Many Cases (car rentals, hotels, full fare airline passengers) There is No Penalty for Cancellations.
3. Problem:
   A. The company may fail to fill the seat (room, car) if the passenger cancels at the very last minute or does not show up.
4. Solution:
   A. Sell More Seats (rooms, cars) Than Capacity (Overbook)
5. Danger:
   A. Some Customers May Have to be Denied a Seat Even Though They Have a Confirmed Reservation.
   B. Passengers Who Get Bumped Off Overbooked Domestic Flights Receive:
      a. Up-to $400 if arrive <= 2 hours after their original arrival time
      b. Up-to $800 if arrive >= 2 hours after their original arrival time
Overbooking at Hyatt

1. The Cost of Denying a Room to the Customer with a Confirmed Reservation is $350 in Ill-Will (Loss of Goodwill) and Penalties.
2. Average Revenue From a Filled Room is $159.
3. Average Number of No Shows Per Night is 8.5
4. How Many Rooms Should be Overbooked (Sold in Excess of Capacity)?
Overbooking at Hyatt

<table>
<thead>
<tr>
<th>No Shows</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0002</td>
</tr>
<tr>
<td>1</td>
<td>0.0017</td>
</tr>
<tr>
<td>2</td>
<td>0.0074</td>
</tr>
<tr>
<td>3</td>
<td>0.0208</td>
</tr>
<tr>
<td>4</td>
<td>0.0443</td>
</tr>
<tr>
<td>5</td>
<td>0.0752</td>
</tr>
<tr>
<td>6</td>
<td>0.1066</td>
</tr>
<tr>
<td>7</td>
<td>0.1294</td>
</tr>
<tr>
<td>8</td>
<td>0.1375</td>
</tr>
<tr>
<td>9</td>
<td>0.1299</td>
</tr>
<tr>
<td>10</td>
<td>0.1104</td>
</tr>
<tr>
<td>11</td>
<td>0.0853</td>
</tr>
<tr>
<td>12</td>
<td>0.0604</td>
</tr>
<tr>
<td>13</td>
<td>0.0395</td>
</tr>
<tr>
<td>14</td>
<td>0.0240</td>
</tr>
<tr>
<td>15</td>
<td>0.0136</td>
</tr>
<tr>
<td>16</td>
<td>0.0072</td>
</tr>
<tr>
<td>17</td>
<td>0.0036</td>
</tr>
<tr>
<td>18</td>
<td>0.0017</td>
</tr>
<tr>
<td>19</td>
<td>0.0008</td>
</tr>
<tr>
<td>20</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

- How to Approach Problem?
  - Payoff Table Would Be Huge (21 by 21 = 441 Cells)
Overbooking at Hyatt

• New Trick
  • Use Critical Ratio
  • Optimal Overbooking Ratio:

\[
\frac{C_u}{C_u + C_o} = \frac{159}{159 + 350} = 0.3124
\]

• \(C_u\) = Cost of Underage
• \(C_o\) = Cost of Overage
• For Hyatt: \(C_u = \$159\) and \(C_o = \$350\)
• Critical Ratio is then:
Overbooking at Hyatt

- Look at Cumulative Probabilities of “No Shows”
- Find First Number of “No Shows” That Exceeds Critical Ratio
- For Critical Ratio of 0.3124
  First Number of “No Shows” With Cumulative Probability That Exceeds is 7
- Overbooking by 7 Rooms Is Optimal Decision

<table>
<thead>
<tr>
<th>No Shows</th>
<th>Cumulative Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0002</td>
</tr>
<tr>
<td>1</td>
<td>0.0019</td>
</tr>
<tr>
<td>2</td>
<td>0.0093</td>
</tr>
<tr>
<td>3</td>
<td>0.0301</td>
</tr>
<tr>
<td>4</td>
<td>0.0744</td>
</tr>
<tr>
<td>5</td>
<td>0.1496</td>
</tr>
<tr>
<td>6</td>
<td>0.2562</td>
</tr>
<tr>
<td>7</td>
<td>0.3856</td>
</tr>
<tr>
<td>8</td>
<td>0.5231</td>
</tr>
<tr>
<td>9</td>
<td>0.6530</td>
</tr>
<tr>
<td>10</td>
<td>0.7634</td>
</tr>
</tbody>
</table>
Summary

• What are the types of inventory
• What are the basic inventory decisions
• What are the basic inventory questions to solve
• What are holding costs
• Understand the shortage costs
• EOQ
• EPQ
• Other types of inventory control