Managing Economies of Scale in the Supply Chain: Cycle Inventory

Why do we have inventory?

**Pros:**
- To overcome the time and space lags between producers and consumers
- To meet demand/supply uncertainty
- To achieve production/transportation economies/flexibility
- To take advantage of quantity purchase discounts
- To improve service level (?)
- ... 
  So, the more, the better?

**Cons:**
- Significant cost
  - Space, capital, risk, ...
  So, the less, the better?

**Issues:**
- Overstocking vs. under-stocking
- Supply chain responsiveness vs. efficiency

1. Understanding Inventory

- **What types of inventory?**
  - raw materials
  - WIP, parts, assembly components
  - finished goods ...
- **Where do we hold inventory?**
  - Suppliers and manufacturers
  - warehouses and distribution centers
  - Retailers
  - Central location ...
- **When to have inventory?**
- **How much inventory should be held?** ...

Inventory Decisions

- **Inventory decision is affected by**
  - Demand characteristics
  - Lead time
  - Number of products
  - Objective (service level, min costs, or the both?)
  - Cost structure
  - ...
- **Goal:**
  - Optimal matching supply and demand
  - 5 "R" principle
- **Decision criteria:**
  - Traditional view: better tradeoff between customer service level and inventory investment (cost)
  - Recent emphasis: increasing customer service AND reducing inventory investment
Cost structure of inventory:

- **Order costs**
  - Fixed
  - Variable

- **Inventory costs**
  - Capital costs
  - Inventory service costs
  - Storage space costs

- **Maintenance & handling costs**

- **Inventory carrying costs**

- **Inventory investment costs**
  - Insurance
  - Taxes
  - Plant warehouses
  - Public warehouses
  - Rented warehouses

- **Inventory risk costs**
  - Obsolescence
  - Damage
  - Pilferage
  - Relocation costs

---

Is it possible to reduce cost AND improve service?

- It can be achieved through
  - Effective inventory management
    - How to order?
    - When to order?
    - What to order?
    - How much to order? ...
  - Supply chain management strategies

---

**INVENTORY MANAGEMENT AT INTERNET COMPANIES**

The Internet has opened a realm of business opportunities that even dreamers about 10 years ago. Many Internet companies, however, were formed under the assumption that customers, vendors, manufacturers, distributors, and service providers can be linked electronically in a wide area network, thereby eliminating the need for costly warehouses and retail stores. They thought that inventory management and distribution could be outsourced to someone else; that if there was a problem with some major Internet companies going against this conventional Internet wisdom! For example, Amazon.com (www.amazon.com) invested $350 million for 4 million square feet of warehouse space.

The answer is that Internet companies are learning the lessons learned earlier by brick-and-mortar (-ers)—economize, customer service, quality, control over inventories. The Christmas of 1999 was a winner for many “-sters.” Enjoy the holiday season, while achieving on-time delivery for 90 percent of its orders, will get a bonus for shipping thousands of orders fast. New Rite Aid investor conference by increasing local revenues and profitability. Its stock fell 90 percent in one year placing its viability in question. Amazon.com (www.amazon.com) was unable to ship any orders on time, which prompted the Federal Trade Commission to impose a fine to not interfering with customers of the affected physicians. Low revenues from Internet operations brought Vivantes to the brink of bankruptcy. Amazon.com’s inventory investment and management dilemma is the focus of this chapter. The alliance between the two firms produced the idea of using the Internet to handle customer service and order processing for Amazon.com.

**MANAGERIAL PRACTICE**

Improving Customer Service Through Inventory Management at Amazon.com

- **Increased warehouse capacity quickly.** Hosted millions of square feet of warehouse capacity in less than a year, which allowed Amazon to develop the appropriate amount of cycle stock and inventory to service its customers.
- **Increased use of automation and mechanization.** The warehouses are efficient and flexible enough to move items in container sizes, pallet sizes, or lot sizes of one, thereby reducing handling costs.

2. The measure of inventory level

- **Cycle Inventory**
  - The average inventory that builds up in the SC when produced or purchased lots are larger than those demanded by customer.

- **Lot, or batch size:**
  - Quantity that a supply chain stage either produces or orders at a given time.
  - \( Q = \) lot or batch size of an order
  - \( D = \) demand per unit time

- **Cycle inventory** = \( Q/2 \) (depends directly on lot size)
- **Average flow time** = Avg inventory / Avg flow rate
- **Average flow time from cycle inventory** = \( Q/(2D) \)

---

Example:

\[ Q = 1000 \text{ units} \]
\[ D = 100 \text{ units/day} \]

- Cycle inventory = \( Q/2 = 1000/2 = 500 \) = Avg inventory level from cycle inventory
- Avg flow time = \( Q/(2D) = 1000/(2)(100) = 5 \text{ days} \)

- Cycle inventory adds 5 days to the time a unit spends in the supply chain
- Lower cycle inventory is better because:
  - Average flow time is lower
  - Working capital requirements are lower
  - Lower inventory holding costs

---

Role of Cycle Inventory

- Cycle inventory is held primarily to take advantage of economies of scale in the supply chain.
- Supply chain costs influenced by lot size:
  - Material cost = \( C \)
  - Fixed ordering cost = \( S \)
  - Holding cost = \( H = hC \) (\( h = \) cost of holding $1 in inventory for one year)

- Primary role of cycle inventory is to allow different stages to purchase product in lot sizes that minimize the sum of material, ordering, and holding costs.
- Ideally, cycle inventory decisions should consider costs across the entire supply chain, but in practice, each stage generally makes its own supply chain decisions - increases total cycle inventory and total costs in the supply chain.

---

How to decide lot size?

- **Lot sizing for a single product -- EOQ**
- Aggregating multiple products in a single order
- **Lot sizing with multiple products or customers**
  - Lots are ordered and delivered independently for each product
  - Lots are ordered and delivered jointly for all products
  - Lots are ordered and delivered jointly for a subset of products
**EOQ: Optimal lot size and reorder interval**

- **TC** = Order cost + Holding Cost + Purchasing Cost
  \[ TC = \frac{R}{Q}S + \frac{Q}{2}hC + CR \]

- **Min TC**
  \[ \frac{d(TC)}{dQ} = \frac{DS}{Q^2} + \frac{hC}{2} = 0 \]

- **EOQ model**:
  \[ Q^* = \sqrt{\frac{2DS}{H}} \]
  \[ T^* = \sqrt{\frac{2S}{DhC}} \]
  \[ n^* = \frac{D}{Q^*} = \sqrt{\frac{DhC}{2S}} \]

**Example 10.1**
The Deskpro computer at Best Buy.

- **Demand**, \( D = 12,000 \) computers per year
- **Unit cost**, \( C = $500 \)
- **Holding cost**, \( h = 0.2 \)
- **Fixed cost**, \( S = $4,000/\text{order} \)

**By EOQ model**:

- The optimal order quantity: \( Q^* = \sqrt{\frac{2DS}{H}} = 980 \text{ units} \)
- Cycle Inventory = \( \frac{Q^*}{2} = 490 \text{ units} \)
- Flow time = \( \frac{Q^*}{2d} = \frac{490}{12000} \times 12 \text{ weeks} = 0.49 \text{ weeks} \approx 15 \text{ days} \)
- Reorder interval: \( T^* = \frac{DS}{DhC} = 0.98 \text{ weeks} \)

**EOQ model**

- **Questions answered**: How much to order? When to order?

- **Optimal order quantity** - \( Q \)
  - The most economic order quantity (EOQ)

- **Min TC**

**Assumptions under the simple EOQ model**

- A continuous, constant, and known rate of demand.
- A constant and known replenishment cycle or lead time.
- A constant purchase price that is independent of the order quantity or time.
- A constant transportation cost that is independent of the order quantity or time.
- The satisfaction of all demand (no stockouts are permitted).
- Only one item in inventory, or at least no interaction among items.
- No limit on capital availability...

- Removing some of the assumptions -- Variations of EOQ:
  - EOQ with backlog
  - EOQ with quantity discount
  - EOQ with continuous replenishment
  - Stochastic inventory models
  - ...
Question: Can we further reduce the TC by reducing Q?

- If lot size reduces to \( Q = 200 \) units,
  \[ \text{Annual inventory cost} = \left( \frac{D}{Q} \right)S + \left( \frac{Q}{2} \right)hC = \$250,000 \]
  - which is higher than \( TC = \$97980 \) when \( Q^* = 980 \) units

(Example 10.2)
- To make it economically feasible to reduce lot size, the fixed cost associated with each lot would have to be reduced
- If desired lot size \( Q = 200 \) units,
  
  \[ \text{The desired ordering cost}, S = hCQ^*/2d = \$166.70 \]
  -- The store manager would have to reduce the ordering cost per lot from \( \$4000 \) to \( \$166.70 \)
  for a lot size of 200 to be optimal.

Observation: \( Q < Q^* \)
  \[ \Rightarrow \text{Fixed cost} \uparrow \]
  \[ \Rightarrow \text{TC} \uparrow \]

Key Points from lot sizing by EOQ
- In deciding the optimal lot size, the trade off is between order (setup) cost and holding cost.
- If demand increases by a factor of \( k \), it is optimal to increase batch size by a factor of \( (k^{1/2}) \) and produce (order) a factor of \( (k^{1/2}) \) as often. Flow time attributed to cycle inventory should decrease by a factor of \( (k^{1/2}) \).
- If lot size is to be reduced, one has to reduce fixed order cost. To reduce lot size by a factor of \( k \), order cost has to be reduced by a factor of \( (k^2) \).

3. Strategies to improve SC performance while lowering cycle inventory

1) Aggregation (across products, supply points, delivery points)
2) Lot sizing with aggregation strategies
3) Quantity discounts
4) Short term discounting: trade promotions

Successful cases
- Wal-Mart: 3 day replenishment cycle
- 7-11 Japan: Multiple daily replenishment

Aggregating Multiple Products in a Single Order
- Transportation is a significant contributor to the fixed cost per order
- Can possibly combine shipments of different products from the same supplier
  - same overall fixed cost
  - shared over more than one product
  - effective fixed cost is reduced for each product
  - lot size for each product can be reduced
- Can also have a single delivery coming from multiple suppliers or a single truck delivering to multiple retailers
- Aggregating across products, retailers, or suppliers in a single order allows for a reduction in lot size for individual products because fixed ordering and transportation costs are now spread across multiple products, retailers, or suppliers
Example: Aggregating Multiple Products in a Single Order

- Suppose there are 4 computer products in the previous example: Deskpro, Litepro, Medpro, and Heavpro. Assume demand for each is 1000 units per month
- If each product is ordered separately:
  - Q* = 980 units for each product
  - Total cycle inventory = 4(Q/2) = (4)(980)/2 = 1960 units
- Aggregate orders of all four products:
  - Combined Q* = 1960 units
  - For each product: Q* = 1960/4 = 490
  - Cycle inventory for each product is reduced to 490/2 = 245
  - Total cycle inventory = 1960/2 = 980 units
  - Average flow time, inventory holding costs will be reduced

Lot Sizing with Aggregation Strategy

Why?
- In practice, the fixed ordering cost is dependent at least in part on the variety associated with an order of multiple models
  - A portion of the cost is related to transportation (independent of variety)
  - A portion of the cost is related to loading and receiving (not independent of variety)
- Aggregating across products, retailers, or suppliers in a single order allows for a reduction in lot size for individual products because fixed ordering and transportation costs are now spread across multiple products, retailers, or suppliers.
- Service?

How?
- Three scenarios:
  - Lots are ordered and delivered independently for each product
  - Lots are ordered and delivered jointly for all three models
  - Lots are ordered and delivered jointly for a selected subset of models

Example 10.3: Best Buy

The Deskpro computer at Best Buy, three models,
- Demand per year: D_L = 12,000; D_M = 1,200; D_H = 120
- Product specific order cost: s_L = s_M = s_H = $1,000
- Unit cost: C_L = C_M = C_H = $500
- Common transportation cost: S = $4,000
- Holding cost: h = 0.2

Delivery options:
- No Aggregation: Each product ordered separately
- Complete Aggregation: All products delivered on each truck
- Tailored Aggregation: Selected subsets of products on each truck

Option 1: No Aggregation - Order each product independently

<table>
<thead>
<tr>
<th>Example 10.3</th>
<th>Litepro</th>
<th>Medpro</th>
<th>Heavypro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand per year</td>
<td>12,000</td>
<td>1,200</td>
<td>120</td>
</tr>
<tr>
<td>Fixed cost / order</td>
<td>$5,000</td>
<td>$5,000</td>
<td>$5,000</td>
</tr>
<tr>
<td>Optimal order size (Q*)</td>
<td>1,095</td>
<td>346</td>
<td>110</td>
</tr>
<tr>
<td>Cycle inventory (Q*/2)</td>
<td>548</td>
<td>173</td>
<td>55</td>
</tr>
<tr>
<td>Order frequency (n*)</td>
<td>11.0 / year</td>
<td>3.5 / year</td>
<td>1.1 / year</td>
</tr>
<tr>
<td>Annual cost (1C*)</td>
<td>$109,544</td>
<td>$34,642</td>
<td>$10,954</td>
</tr>
</tbody>
</table>

Total cost = $155,140
**Option 2: Complete Aggregation: Order all products jointly**

The combined fixed order cost: 
\[ S^* = S + S_i + S_m + S_h \]

\[ TC = \text{(Annual Order Cost)} + \text{(Annual Holding Cost)} = \min TC = \frac{d(TC)}{dn} = 0 \Rightarrow n^* \]

The optimal ordering frequency, 
\[ n^* = \sqrt{\frac{\sum (DhC_i)}{2S^*}} \]

<table>
<thead>
<tr>
<th>Example 10.4</th>
<th>Litepro</th>
<th>Medpro</th>
<th>Heavypro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand per year</td>
<td>12,000</td>
<td>1,200</td>
<td>120</td>
</tr>
<tr>
<td>Order frequency ( n^* )</td>
<td>9.75/year</td>
<td>9.78/year</td>
<td>9.78/year</td>
</tr>
<tr>
<td>Optimal order size ( Q^* )</td>
<td>1,230</td>
<td>123</td>
<td>12.3</td>
</tr>
<tr>
<td>Cycle inventory ( \frac{Q^*}{2} )</td>
<td>615</td>
<td>61.5</td>
<td>6.15</td>
</tr>
<tr>
<td>Annual holding cost</td>
<td>$61,512</td>
<td>$6,151</td>
<td>$615</td>
</tr>
</tbody>
</table>

**Annual order cost = 9.75 \times 7,000 = $68,250**

**Annual total cost = $136,528**

---

**Option 3: Tailored Aggregation: Ordering Selected Subsets**

Discussion:

**Example 10.5**

<table>
<thead>
<tr>
<th>Product</th>
<th>Litepro</th>
<th>Medpro</th>
<th>Heavypro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand per year</td>
<td>12,000</td>
<td>1,200</td>
<td>120</td>
</tr>
<tr>
<td>Order frequency ( n^* )</td>
<td>10.8/year</td>
<td>5.4/year</td>
<td>2.16/year</td>
</tr>
<tr>
<td>Optimal order size ( Q^* )</td>
<td>1,111</td>
<td>222</td>
<td>56</td>
</tr>
<tr>
<td>Cycle inventory</td>
<td>555.5</td>
<td>111</td>
<td>28</td>
</tr>
<tr>
<td>Annual holding cost</td>
<td>$55,556</td>
<td>$11,111</td>
<td>$2,778</td>
</tr>
</tbody>
</table>

**Annual order cost = $61,560**

**Total annual cost = $131,004**

---

**An heuristic procedure for tailored aggregation:**

**Step 1:** Identify most frequently ordered product

\[ \tilde{n}_i = \sqrt{\frac{hc_iD_i}{2(S + S_i)}}, \quad \tilde{n} = \max \{\tilde{n}_i\} \]

**Step 2:** Identify frequency of other products as a multiple

\[ \tilde{m}_i = \sqrt{\frac{hc_iD_i}{2S_i}}, \quad \tilde{m} = \tilde{m}_i, \quad m_i = [\tilde{m}_i] \text{ (closest int. eger)} \]

**Step 3:** Recalculate ordering frequency of most frequently ordered product

\[ n = \sqrt{\frac{\sum hc_iD_i}{2(S + \sum S_i)}}, \text{ Fixed cost per order } = S + \sum \frac{S_i}{m_i} \]

**Step 4:** Identify ordering frequency of all products

\[ \frac{n}{m_i}, \text{ for product } i \]
### Strategy 3: Quantity Discounts

- **Commonly used in B2B transactions**

- **Types of Quantity Discount**
  - Lot size based (based on the quantity ordered in a single lot)
    - All units
    - Marginal unit
  - Volume based (based on the total quantity purchased over a given period)

- **Questions:**
  - How should buyer react?
  - How to determine appropriate discounting schemes?
  - What is the impact of quantity discounts on the supply chain?
  - How to use the QD strategy to improve SC performance?

### Example 10.6 [Review yourself !!!]

**Drugs Online (DO)** - an online retailer of prescription drugs and health supplements

<table>
<thead>
<tr>
<th>Order quantity</th>
<th>Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5,000</td>
<td>$3.00</td>
</tr>
<tr>
<td>5001-10,000</td>
<td>$2.96</td>
</tr>
<tr>
<td>Over 10,000</td>
<td>$2.92</td>
</tr>
</tbody>
</table>

D = 120,000/yr,
S = $100/lot,
h = 0.2

The manager wants to know how many bottles to order in each lot?

By using the EOQ model with quantity discount,

\[ Q^* = 10,001 \text{ units} \] (with the unit price = $2.96)
The Method for All-Unit Quantity Discounts

- Evaluate EOQ for price in range \( q_i \) to \( q_{i+1} \):
  1. If \( q_i \leq \text{EOQ} < q_{i+1} \), evaluate cost of ordering EOQ.
  2. If \( \text{EOQ} < q_i \), evaluate cost of ordering \( q_i \).
  3. If \( \text{EOQ} \geq q_{i+1} \), evaluate cost of ordering \( q_{i+1} \).

- Evaluate minimum cost over all price ranges.

Impacts of Quantity Discounts ...

- (recalling the beer game ...)
  - Quantity discounts encourage large order quantities and lead to a significant buildup of cycle inventory.
  - Retailers are encouraged to increase the size of their orders.
  - Average inventory (cycle inventory) in the supply chain is increased.
  - Average flow time is increased.

So, why quantity discount?

- Quantity discount can be valuable in a SC to improve chain coordination and reduce the total chain cost.

But How?

Coordination for Commodity Products

- Commodity product - the market sets the price and the firms' objective is to lower costs.
- DO makes its lot sizing decisions (of vitamins) based on its own costs.

If DO's Order Size = 9165 units

- Supplier side:
  - \( S = $250 \), \( h = 0.2 \), \( C = $2 \)
  - Supplier cost = \( (120,000/6,324) \times 250 + (6,324/2) \times 0.2 = $4,009 \)

- Retail side:
  - \( p = $100 \) per order,
  - \( h = 0.2 \), \( C = $3 \) per bottle
  - Retailer's optimal lot size: \( Q^* = 6,324 \)
  - Retailer cost = \( $3,795 \)

- Supply chain cost = \( 3,795 + 4,009 = $7,804 \)

If DO order 9165, the total chain saves $638 and the supplier saves $902, but retailer pays $624 more!

Observation:
- If DO order 9165, the total chain saves $638 and the supplier saves $902, but retailer pays $624 more!

Question:
- How to convince DO to take the order size of 9165?
Use Quantity Discount Strategy to achieve the Chain Coordination and the Chain Cost Reduction

- The SC Solution:
  - The supplier offers lot size-based quantity discount incentives:
    - For orders less than 9165, the price is $3.
    - For orders of 9165 or more, the price is $2.9978.
  - The resulted optimal order size at DO is 9165, by using EOQ model with quantity discount.
  - The manufacturer returns $264 (=$4059-3795) to DO as material cost reduction to make it optimal for DO to order 9165 bottles.
  - Passing some fixed cost to retailer (enough that he raises order size from 6324 to 9165).

After all:
- Retailer cost = $4,059 - 264 = $3795 (no change).
- Supplier cost = $5,106 + 264 = $5370 (save $639).
- Supply chain cost = $9,165 (save $639).

Key point:
- For commodity products for which price is set by the market, manufacturers can use lot size-based quantity discounts to achieve coordination in the supply chain and decrease supply chain cost.
-Lot size-based discounts, however, increase cycle inventory in the supply chain.

Quantity Discounts When Firm has Market Power

- A new vitamin - Vitaherb, no competitors.
- The sale price at DO will influence demand.
- The demand curve is given by: \[ D = 360,000 - 60,000p \]
- Production cost at the manufacturer \( C_s = $2/\text{bottle} \).
- Manufacturer needs to decide the price to charge DO, \( p_R \), and DO needs to decide the price to charge customers, \( p \).

\[ \begin{align*}
\text{Manufacturer} & \quad p_R=? \quad p=? \\
\text{DO} & \quad (D=360-60p) \\
\text{Customer} & \quad p=? \\
\end{align*} \]

\[ C_s = $2 \quad p_R=? \quad p=? \quad (D=360-60p) \]

**IF the two stages make the pricing decision independently**

- \[ \text{Manufacturer} \]
  \[ C_s = $2 \]
  \[ p_R=? \]
  \[ p=? \]

- \[ \text{DO} \]
  \[ (D=360-60p) \]
  \[ p=? \]

- \[ \text{Customer} \]
  \[ p=? \]

\[ \text{Manufacturer} \]
\[ C_s = $2 \]
\[ p_R=? \]
\[ p=? \]
\[ (D=360-60p) \]

\[ \text{DO} \]
\[ (D=360-60p) \]
\[ p=? \]

\[ \text{Customer} \]
\[ p=? \]

\[ \text{Total Chain Profit} = $180,000, \text{Demand} = 60,000 \]

**IF the two stages coordinate the pricing decisions**

- \[ p=p_R, \text{then } \text{Profit}_f = $60,000, \text{Profit}_w = 180,000, \text{and} \]
- \[ \text{Total Chain Profit} = $240,000 \text{ (increased by $60,000), Demand=120,000} \]
**Question:** How can the manufacturer achieve the coordinated solution and maximize supply chain profit?

- Design a volume discount scheme (see the text page 161 for detail, if interested) that achieves the coordinated solution.
  - \( Q^* = 120,000 \), \( p^* = 4 \)
  - Following this discount scheme, the DO’s optimal order \( Q^* = 120,000 \) and \( p^* = 4 \)
- Design a two-part tariff that achieves the coordinated solution.
  - Ask DO (1) a up-front cost of $180,000, and (2) \( p_R = 2 \)

**Key Point**
When products for which the firm has market power, two-part tariffs or volume-based quantity discounts can be used to achieve coordination in supply chain and maximize supply chain profit.

**Lessons From Discounting Schemes**
- Lot size based discounts increase lot size and cycle inventory in the supply chain
- Lot size based discounts are justified to achieve coordination for commodity products
- Volume based discounts with some fixed cost passed on to retailer are more effective in general
- When products for which the firm has market power, the approaches of volume-based quantity discounts or two-part tariffs can be used to achieve coordination in supply chain and maximize supply chain profit.

**Strategy 4: Short Term Discounting**

**Goal**
- to influence retailers to act in a way that helps the manufacturer achieve its objective
  - Induce retailers to use price discounts
  - Shift inventory from the manufacturer to the retailer and the customer
  - Defend a brand against competition

**Questions**
- What is the impact of a trade promotion on the behavior of the retailer and the performance of the supply chain?
- How should a retailer react to a trade promotion a manufacturer offers?

**Impact of a trade promotion**
A manufacturer lowers the price of a product

**Size of forward buy?**
How should the retail react?
Forward buy of the retailer

\[ Q^* = \sqrt{\frac{2RS}{hC}} \]

\[ d = \frac{dR}{(C-d)h} + \frac{CQ^*}{C-d} \]

Forward buy = \( Q^d - Q^* \)

Short Term Discounts: Forward buying

Example 10.8

Normal order size, \( Q^* = 6,324 \) bottles
Normal cost, \( C = \$3 \) per bottle
Discount per tube, \( d = 0.15 \)
Annual demand, \( R = 120,000 \)
Holding cost, \( h = 0.2 \)

Before promotion:
Cycle inventory = \( Q^* / 2 = 6324 / 2 = 3162 \) bottles
Average flow time = \( Q^* / 2R = 6234 / (2 \times 120000) = 0.3162 \) mths (≅ 9 days)

Promotion:
\[ Q^d = 38236 \]
Forward buy = \( Q^d - Q^* = 38263 - 6324 = 31912 \) bottles

After promotion:
Cycle inventory = \( Q^d / 2 = 38236 / 2 = 19118 \) bottles (≅ 6 times)

(Opt. Buy for Retailer) Average flow time = \( Q^d / 2R = 1.9118 \) mths (≅ 5 times)

Promotion pass through to consumers

It may be optimal to the retailer to pass through some (not entire) of the discount to the end customer

Demand at retailer:
\[ D = 300,000 - 60,000p \]
Normal supplier price, \( P_s = \$3.00 \)
Max Profit = \( p(300,000 - 60,000p) - (300,000 - 60,000p)P_s \)

Optimal retail price:
\[ p = (300,000 + 60,000P_s) / 120,000 \]

Promotion discount = 0.15, thus \( P_p = \$2.85 \)
Optimal retail price: \( p = \$3.925 \)
Customer demand: \( D = 64,500 \)
Retailer passes through half the promotion discount and demand increases by 7.5%
Key point:

Faced with a short-term discount, it is optimal for retailers to pass through only a fraction of the discount to the customer, keeping the rest for themselves. Simultaneously, it is optimal for the retailer to increase the purchase lot size and forward buy for future period. This lead to an increase of cycle inventory in the supply chain as the result of a trade promotion without a significant increase in customer demand.

Summary of Learning Objectives

- How are the appropriate costs balanced to choose the optimal amount of cycle inventory in the supply chain?
- What are the effects of quantity discounts on lot size and cycle inventory?
- What are appropriate discounting schemes for the supply chain, taking into account cycle inventory?
- What are the effects of trade promotions on lot size and cycle inventory?
- What are managerial levers that can reduce lot size and cycle inventory without increasing costs?