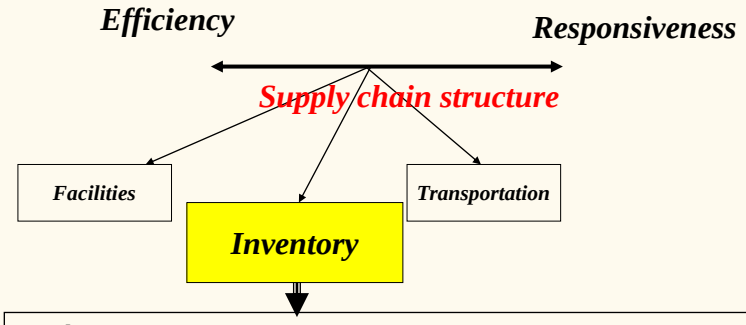
Drivers of Supply Chain Performance



- Cycle Inventory
  - Why hold cycle inventory? How to reduce cycle inventory?
    - Basic EOQ and Lessons; Aggregation and Quantity Discount
- Safety Inventory
- Level of Product Availability

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Issues when Aggregating

- Aggregation across customers/suppliers
  - Customers/suppliers are of different size
- Aggregation across products
  - Demand varies across products

How does diversity across products, customers, suppliers affect the value of aggregation?

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Lot Sizing with Multiple Products: Example

Data

- Demand per year
  - D_L = 12,000; D_M = 1,200; D_H = 120
- Common transportation cost, S = $4,000
- Product specific order cost
  - s_L = $1,000; s_M = $1,000; s_H = $1,000
- Holding cost, h = 0.2
- Unit cost
  - **C_L = $500; C_M = $500; C_H = $500**

Source: Examples 11.3 – 11.4

No Aggregation - Order each Product Independently

	Litepro	*Medpro*	*Heavypro*
Demand per year	**12,000**	**1,200**	**120**
Fixed cost / order	**$5,000**	**$5,000**	**$5,000**
Optimal order size	**1,095**	**346**	**110**
Order frequency	**11.0 / year**	**3.5 / year**	**1.1 / year**
Annual holding (=order) cost	**$54,772**	**$17,321**	**$5,477**
Annual cost	**$109,544**	**$34,642**	**$10,954**

Annual cost: holding/order = $77,570; Total = $155,140

How might aggregation help reduce costs?

Source: Examples 11.3 – 11.4

Lot Sizing with Multiple Products: Complete Aggregation
Order all Products Jointly

	Litepro	*Medpro*	*Heavypro*
Demand per year	**12,000**	**1,200**	**120**
Order frequency	**9.75/year**	**9.75/year**	**9.75/year**
Optimal order size	**1,230**	**123**	**12.3**
Annual holding cost	**$61,512**	**$6,151**	**$615**

$$n^* = \sqrt{\frac{\sum_{i=1}^{k} D_i h C_i}{2S^*}}$$

$$S^* = 4,000 + 3 \times 1,000 = 7,000$$

Annual order cost = 9.75 × $7,000 = $68,250
Annual total cost = $136,558

Can we further reduce costs in any way?

Source: Examples 11.3 – 11.4

Tailored Aggregation: Order Selected Subsets

	Litepro	*Medpro*	*Heavypro*
Demand per year	**12,000**	**1,200**	**120**
Order frequency	**11.47/year**	**5.74/year**	**2.29/year**
Optimal order size	**1,046**	**209**	**52**
Annual holding cost	**$52,307**	**$10,461**	**$2,615**

Annual order cost = $ 65,383
Total annual cost = $130,767

Source: Examples 11.6

Impact of Product Specific Order Cost on Performance of Aggregation Strategies

	Product specific order cost = $1000	Product specific order cost = $3000	Product specific order cost = $300
No Aggregation	**$155,140**	**$183,564**	**$143,871**
Complete Aggregation	**$136,528**	**$186,097**	**$114,252**
Tailored Aggregation	**$130,767**	**$165,233**	**$112,900**

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Aggregation Strategies: Lessons

- Aggregation allows firm to lower lot size without increasing cost
- **Complete aggregation** is effective if product specific fixed cost is a small fraction of joint fixed cost (*in other words, production and distribution are lean and can cost effectively handle variety and small batches)*
- **Tailored aggregation** is effective if product characteristics are different and product specific fixed cost is large fraction of joint fixed cost *(in other words, production and distribution are not flexible. In this case, complete aggregation may be worse than no aggregation)*

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Economies of Scale Due to Quantity Discounts

- Quantity Discounting Schemes
  - Lot size based: All units vs. marginal units
  - Volume based
- Faced with such a scheme, how should buyer react?
- What are the implications for the supply chain?
- What are appropriate discounting schemes?

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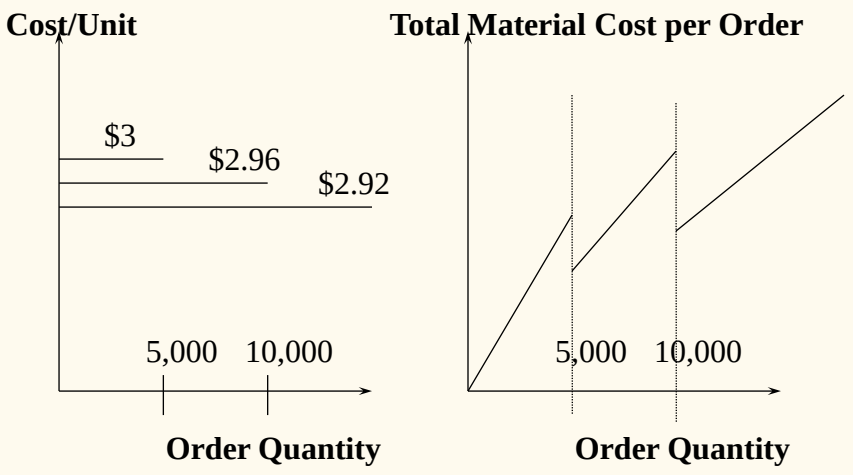
All-Unit Quantity Discounts



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Data: All-Unit Quantity Discounts (Continued)

- Demand: 10,000 per month
- Fixed order placement, transportation, and receiving costs: $100 per each order
- Holding cost: 20% of the purchase costs

Q1: What is the optimal order quantity for each order?

Q2: What happens if we reduce the fixed cost from $100 to $4?

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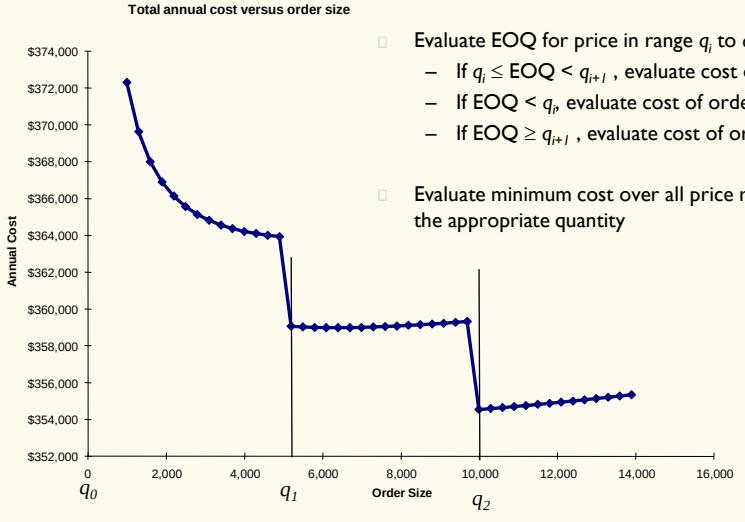
All-Unit Quantity Discounts: How Should the Buyer React?



- Evaluate EOQ for price in range q_i to q_{i+1}
  - If $q_i \leq$ EOQ < q_{i+1} , evaluate cost of ordering EOQ
  - If EOQ < q_i, evaluate cost of ordering q_i
  - If EOQ $\geq q_{i+1}$, evaluate cost of ordering q_{i+1}
- Evaluate minimum cost over all price ranges and order the appropriate quantity

Source: Example 11.7 in C & M

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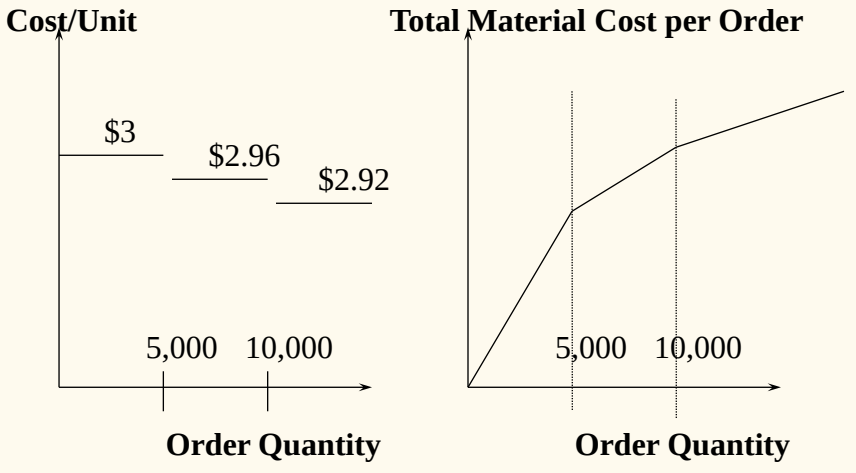
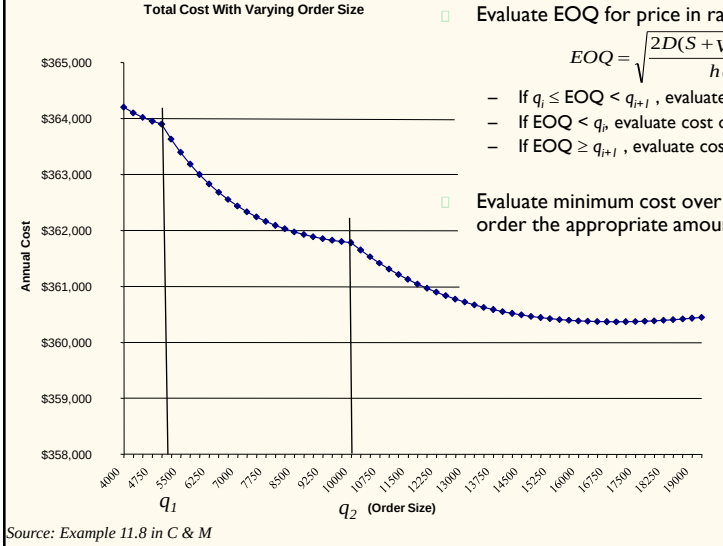
Marginal Unit Quantity Discounts



Marginal-Unit Quantity Discounts: How Should the Buyer React?



- Evaluate EOQ for price in range q_i to q_{i+1}

$$EOQ = \sqrt{\frac{2D(S + V_i - q_i C_i)}{hC_i}}$$

  - If $q_i \le EOQ < q_{i+1}$, evaluate cost of ordering EOQ
  - If $EOQ < q_i$, evaluate cost of ordering q_i
  - If $EOQ \ge q_{i+1}$, evaluate cost of ordering q_{i+1}

- Evaluate minimum cost over all price ranges and order the appropriate amount

Source: Example 11.8 in C & M

Why do Sellers Offer Quantity Discounts?

- Coordination in the supply chain (Increase supply chain surplus)
  - **Decrease supply chain costs:** Commodity products

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Decreasing Supply Chain Costs
Coordination for Commodity Products

S_S = \$250,
h_S = 0.2, C_S = \$2

S_R = \$100,
h_R = 0.2, C_R = \$3

Solution where retailer optimizes local costs

Retailer's optimal lot size = $\sqrt{\frac{2\times 120,000\times 100}{3\times 0.2}} = 6,324$

Retailer cost = (6,324/2) × 3 × 0.2 + (120,000/6,324) × 100 = \$3,795;
Supplier cost = (6,324/2) × 2 × 0.2 + (120,000/6,324) × 250 = \$6,009

Supply chain cost = 3,795 + 6,009 = \$9,804

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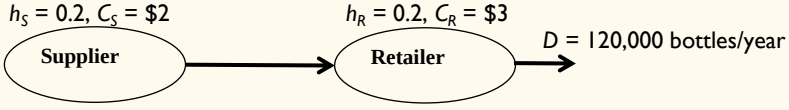
Decreasing Supply Chain Costs

Coordination for Commodity Products

S_S = \$250,
h_S = 0.2, C_S = \$2

S_R = \$100,
h_R = 0.2, C_R = \$3



Solution where retailer optimizes local costs

Retailer's optimal lot size = 6,324 bottles

Retailer cost = \$3,795; Supplier cost = \$6,009; Supply chain cost = \$9,804

Action that minimizes supply chain costs

Coordinated lot size = $\sqrt{\frac{2\times 120,000\times(250+100)}{(2+3)\times 0.2}} = 9,165$

Retailer cost = $(9,165/2)\times 3\times 0.2 + (120,000/9,165)\times 100$ = \$4,059 (4,059 – 3,795 = \$264);

Supplier cost = $(9,165/2)\times 2\times 0.2 + (120,000/9,165)\times 250$ = \$5,106 (6,009 – 5,106 = \$903)

Supply chain cost = 4,059 + 5,106 = \$9,165 (9,804 – 9,165 = \$639).

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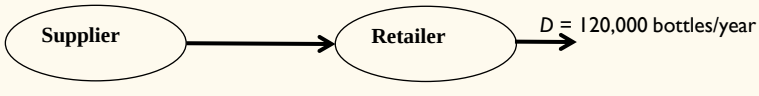
Decreasing Supply Chain Costs

Coordination for Commodity Products

S_S = \$250,
h_S = 0.2, C_S = \$2

S_R = \$100,
h_R = 0.2, C_R = \$3



Difference between action that minimizes supply chain costs and action that minimizes retailer costs

Retailer optimal lot size = 6,324; Coordinated lot size = 9,165

Retailer costs increase by \$264 on ordering 9,165 units (instead of 6,324)

Supplier cost decrease by \$903 if retailer orders 9,165 units (instead of 6,324)

Supply chain costs decrease by \$639 if retailer orders 9,165 units (instead of 6,324)

How can the supplier achieve this outcome with retailer optimizing locally?

- All unit quantity discount

\$ _____ for lots below _____

\$ _____ for lots of _____ or more

- Pass some fixed cost to retailer (enough that he raises order size from 6,324 to 9,165)

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Lessons From Quantity Discount Schemes

- Lot size based discounts increase lot size and cycle inventory in the supply chain
  - Becomes more pronounced as fixed costs are decreased
- Lot size based discounts may make sense to decrease supply chain costs for commodity products when manufacturer's fixed costs are high
  - Much less valuable as fixed costs are reduced

The Role of Inventory and Cycle Inventory: Summary of Lessons

- Cycle Inventory
  - What is its role, why does it build up?
  - How does it affect supply chain performance?
- Levers to Reduce Cycle Inventory Without Hurting Costs
  - Manage economies of scale to reduce lot sizes
    - Reduce fixed cost by aggregating cost across products, customers, suppliers
    - Tailored aggregation
  - Are quantity discounts consistent with operations?
    - Only if manufacturers fixed cost is large