Data Analytics in Business

Operations Management

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Inventory Basics

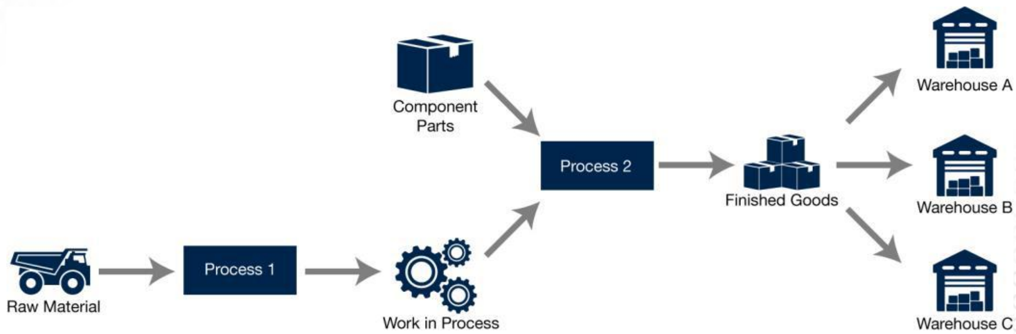
Learning Objectives

At the end of this lesson, you should be able to:

- Discuss the different types of inventory
- Investigate pressures to keep inventory
- Investigate pressures to not keep inventory
- Identify key inventory management decisions

What is Inventory?

- Inventory is the raw material, component parts, work in process, or finished goods that are held at a location in the supply chain



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The Key Activity in Inventory Management

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Gap Store

With Clothes Piling Up, Gap Leans on Heavy Discounts to Clear Stores
Executives said operational issues delayed the timing of new items, not because customers disliked the company's fashions - by Maria Armental – WSJ **May 24, 2018** 7:15 p.m. ET

Gap Inc. executives said they had to resort to heavy discounting to move unsold clothes that had piled up at stores, moves that weighed on profit in the first quarter and could carry over into the current period.

"If you have too much inventory or the wrong inventory, holding on to it does not make it better," Chief Executive Art Peck said on a conference call Thursday. "And so we were very decisive on that and took those actions. It wasn't without pain, but we believe it was absolutely the right thing to do to continue to clean up the business and position it for better performance."

Executives blamed operational issues that delayed the timing of new items and disrupting the assortment of products, but said the weak demand wasn't the result of customers disliking the company's styles or fashions.

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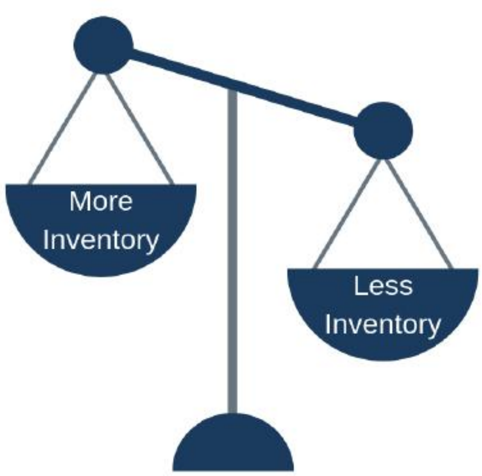
How Much Inventory Should You Keep?



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Why Keep More Inventory?

- Protects against spikes in demand (uncertain demand)
- Protects against supply disruptions
- Can get a quantity discount on ordering

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Why Hold Less Inventory?

- Inventory can become obsolete
- If it is a perishable, it can spoil
- Shrinkage
- Holding Costs
  - Insurance, security, warehouse costs, etc..
- Opportunity Costs

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The Two I.M. Decisions:

1. HOW MUCH should we order?

2. WHEN should we order more?

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Summary

1. Different kinds of inventory
2. Key Ops objective is to match supply with demand
3. There are pressure to keep and not keep inventory
4. An inventory management policy comes down to how much to order and when to order.

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EOQ

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Learning Objectives

At the end of this lesson, you should be able to:

- Explain Economic Order Quantity

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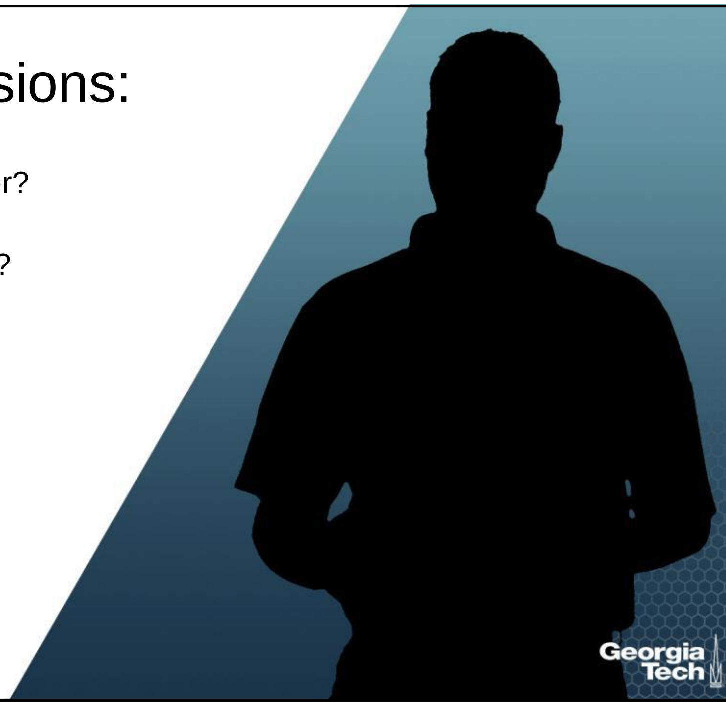
The Two I.M. Decisions:

1. **HOW MUCH** should we order?

2. When should we order more?



Economic Order Quantity

*Tries to balance the scale

Total Cost = Ordering Cost + Inventory Cost

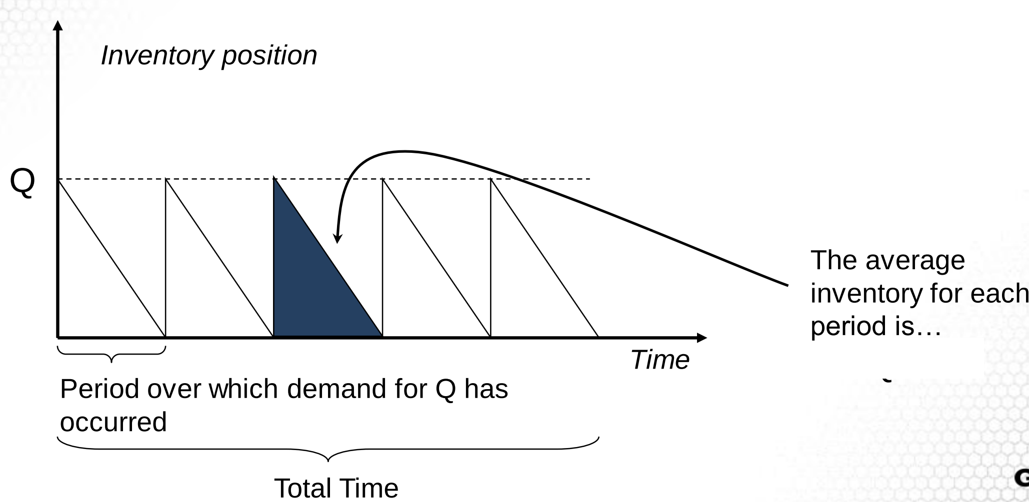
- Ordering Cost = (number of orders per year) X (cost per order)
- Inventory Cost = (average inventory) X (holding cost per year)

Assumptions:

Supplier → Retailer → Demand

- Demand is known and constant: **D** units/yr
- We have a known ordering cost, **S**, and immediate replenishment
- No limit on order quantity
- Annual holding cost of average inventory is **H** per unit
- Assume Ordering and Inventory costs only relevant costs

Say We Order in Batches of **Q**



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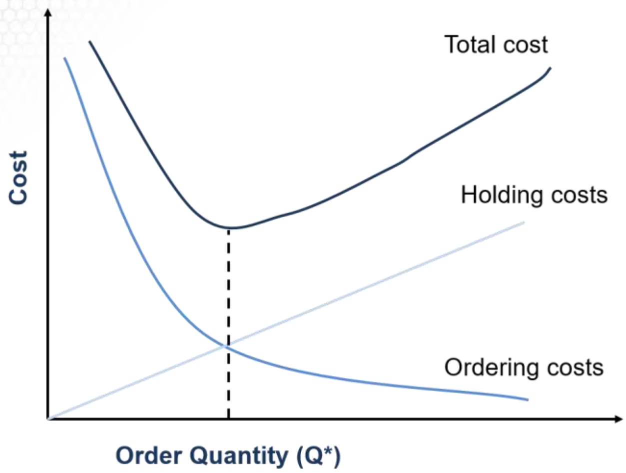

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Economic Order Quantity = HOW MUCH

- Set Ordering costs equal to Holding cost:

$$\frac{D}{Q} \times S = \frac{Q}{2} \times H$$

- Solve for Q. We will call this Q* (because it is the Q where Ordering cost equals Holding cost)

$$Q^* = \sqrt{\frac{2SD}{H}}$$

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How Many Orders Per Year?

- Expected number of orders:

$$N = \frac{D}{Q^*}$$

- Expected time between orders:

$$T = \frac{\text{Number of working days per year}}{N}$$

Summary

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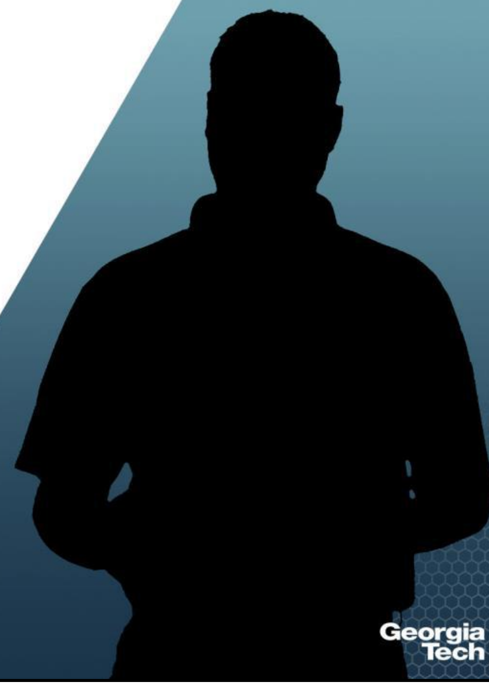
EOQ with Quantity Discount



Learning Objectives

At the end of this lesson, you should be able to:

- Examine quantity discounts in the Economic Order Quantity model

How Can We Account for a Quantity Discount in the EOQ Model?

Quantity Discounts					
1	2-9	10-49	50-99	100-499	500+
$20	$18	$16	$14	$12	$10

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How Can we Account for a Quantity Discount?

1. Expand equation for Total Cost to capture purchase price

- $Expanded\ Total\ Cost\ (ETC) = \frac{D}{Q} * S + \frac{Q}{2} * H + \boldsymbol{P} * \boldsymbol{D}$

D = annual Demand
Q = Quantity Ordered
S = Setup/Order Cost
H = Holding Cost per unit per year
P = Prices per unit

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How Can we Account for a Quantity Discount?

2. Calculate an EOQ for each price point

$$EOQ = \sqrt{\frac{2*D*S}{I*P}}$$

I = holding cost as a percent of unit price

3. Adjust EOQ for each price point up or down if needed to hit that discounts quantity range

Discount Number	Discount Quantity	Discount (%)	Discount Price (P)
1	0 to 999	no discount	$5.00
2	1,000 to 1,999	4	$4.80
3	2,000 and over	5	$4.75

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How Can we Account for a Quantity Discount?

4. Determine an Expanded Total Cost for each "adjusted" EOQ

5. Pick the lowest Total Cost

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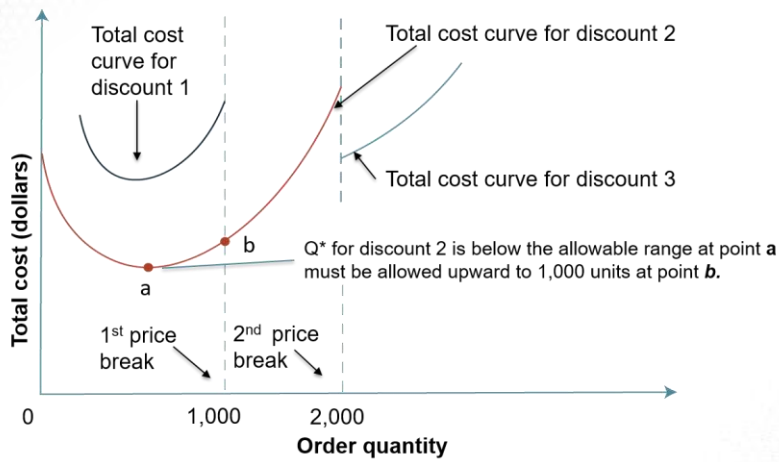
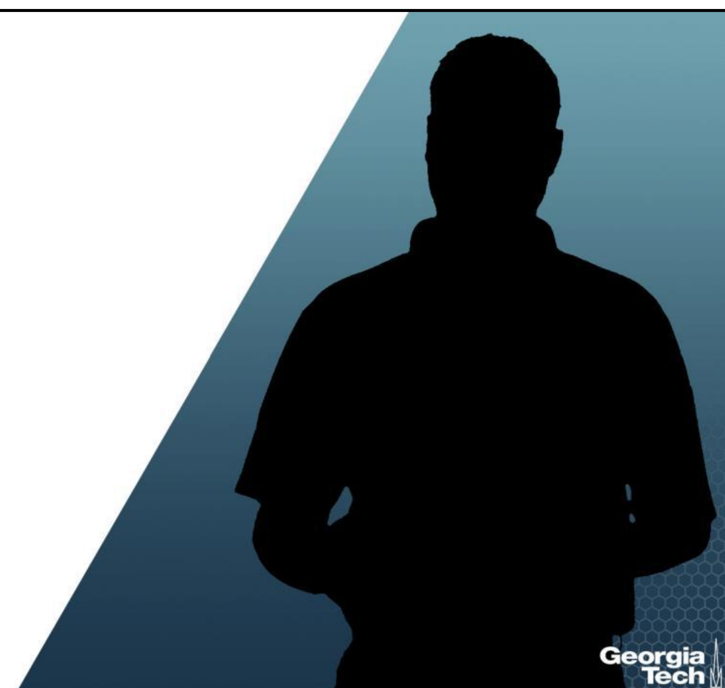
Graphic Example



Discount	Quantity	Price
1	<1,000	$5.00
2	1,000+	$4.80
3	2,000+	$4.75

Summary



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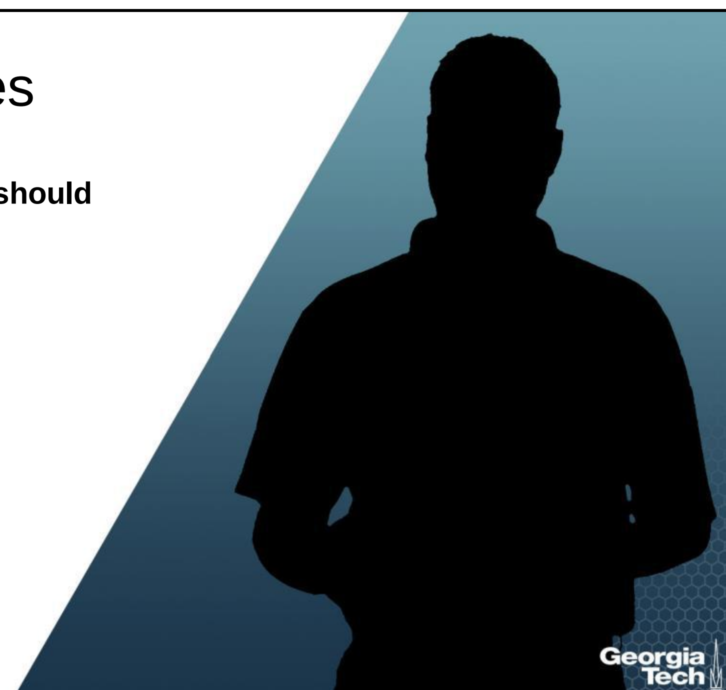
Re-Order Point

Learning Objectives

At the end of this lesson, you should be able to:

- Explain Re-order point

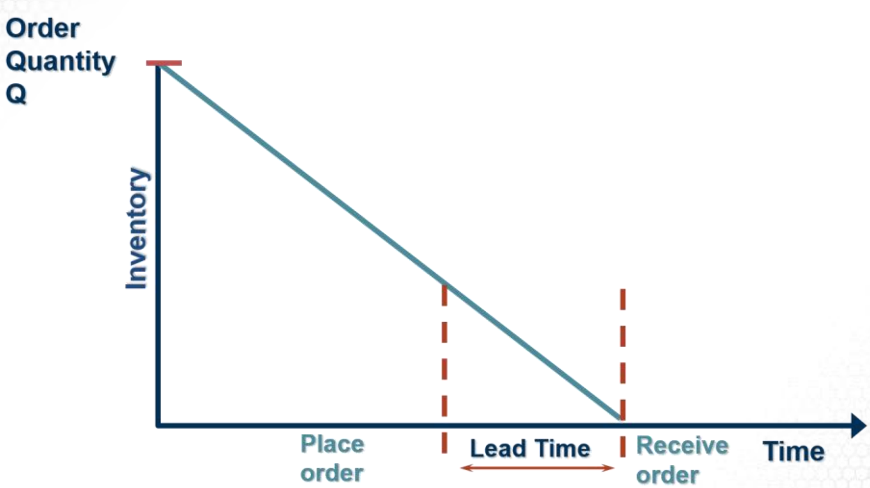


The Two I.M. Decisions:

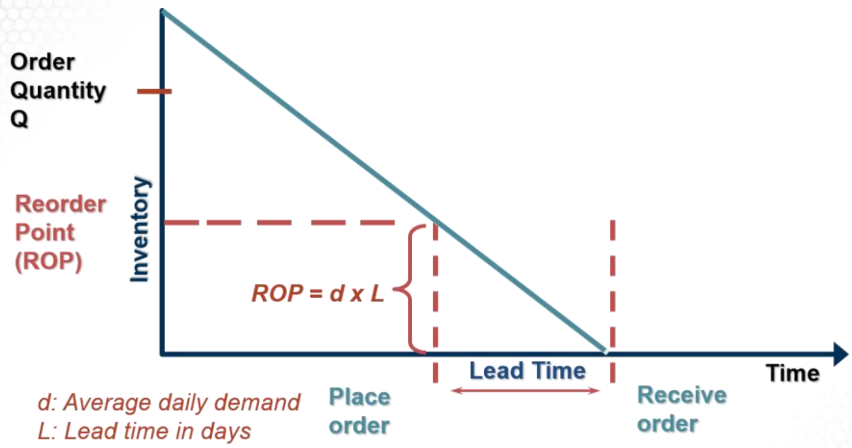
1. How much should we order?

2. WHEN should we order more?

WHEN Should We Order More?



WHEN Should We Order More?



Note Some Similar Assumptions as EOQ

- Demand is known and constant
- Lead time is known and constant

$$ROP = \bar{d} \times L$$

Summary

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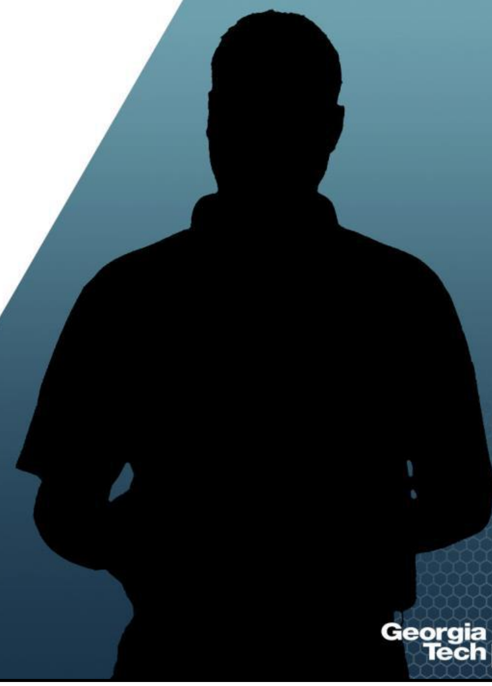
ROP When Demand Varies

Learning Objectives

At the end of this lesson, you should be able to:

- Explain re-order point when demand can vary

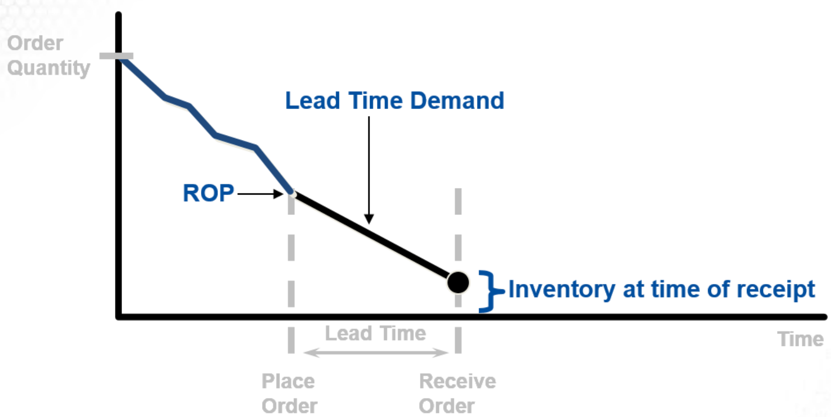


What if We Relax the Constraint on Demand?

- Assume demand is **NOT** constant
- Assume that demand can be modeled with a probability distribution
- Will add a buffer of extra inventory and call it “safety stock” (ss)
  - Size of safety stock will depend on:
    - Lead time
    - Demand uncertainty
    - How strong the desire to NOT stock out

If Actual Demand Less than Expected Demand

Excess Inventory (holding costs too high)



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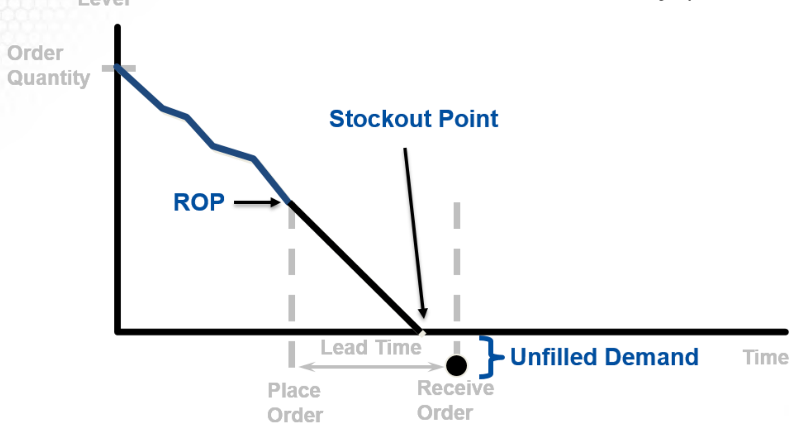
If Actual Demand greater than Expected Demand

Insufficient Inventory (lost sales)



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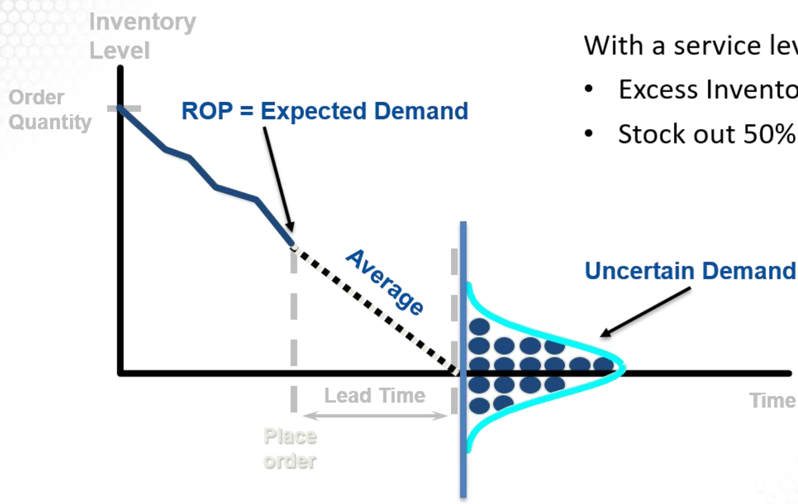
Uncertain Demand – Service Level



With a service level of 50%:

- Excess Inventory 50% of time
- Stock out 50% of time

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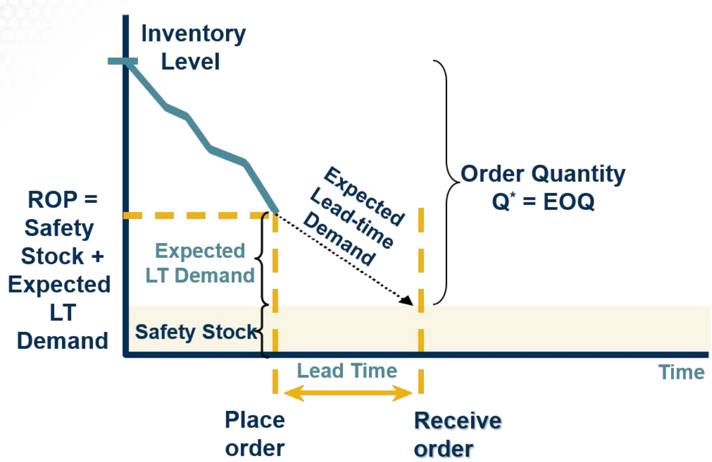
Safety Stock: Reduce the Probability of a Stockout



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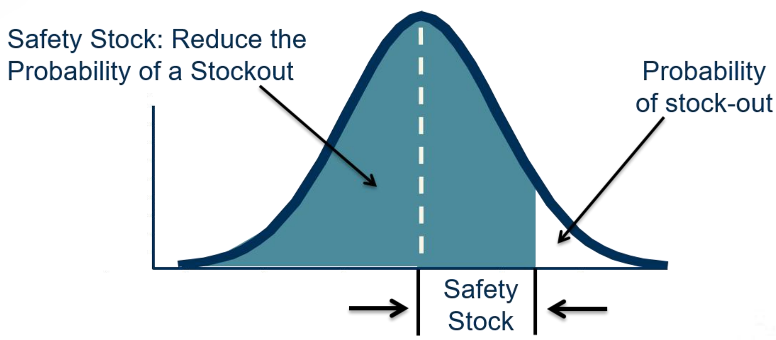
Service Level

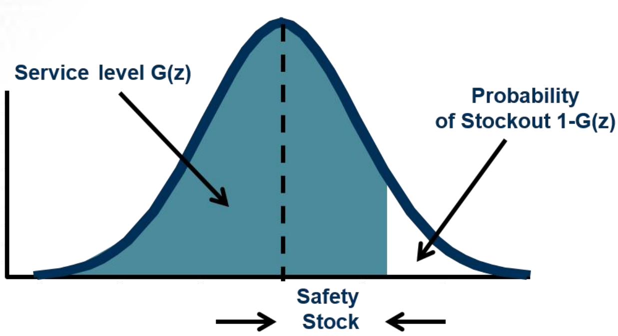
- Service level = probability of NOT stocking out (probability of satisfying all demand)
- The service level will determine the safety stock



Safety Stock

Safety Stock = (safety factor) x (std. dev. in LT demand)

$SS=(z) \times (s_{LT})$



Read z from Standard Normal table for a given service level; Service level is $G_{(z)}$

Standard Deviation in LT Demand

Variance over multiple periods = the sum of the variances of each period (assuming independence)

Standard deviation over multiple periods is the square root of the sum of the variances, not the sum of the standard deviations!!!

$$\sigma_{LT} = \sqrt{(L)x(\sigma_D)^2} = \sigma_D\sqrt{L} \neq \sigma_D \; x \; L$$

Putting it Together

ROP = [(average daily demand) * LT] + SS

$$\boldsymbol{ROP = Expected\ Demand\ during\ lead\ time + Z\sigma_D\sqrt{LT}}$$

Z = Number of standard deviations (get from a Z table)
σ_D = standard deviation of demand
LT = Lead Time

Summary

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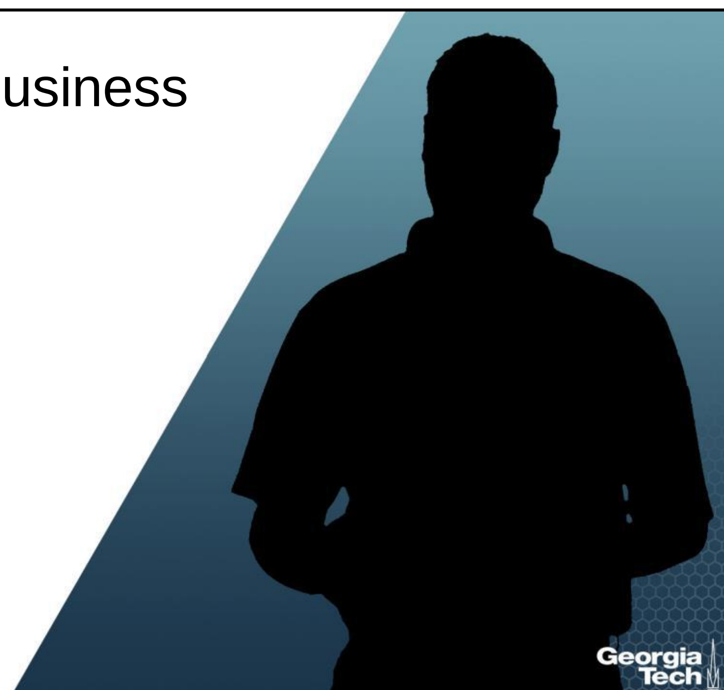
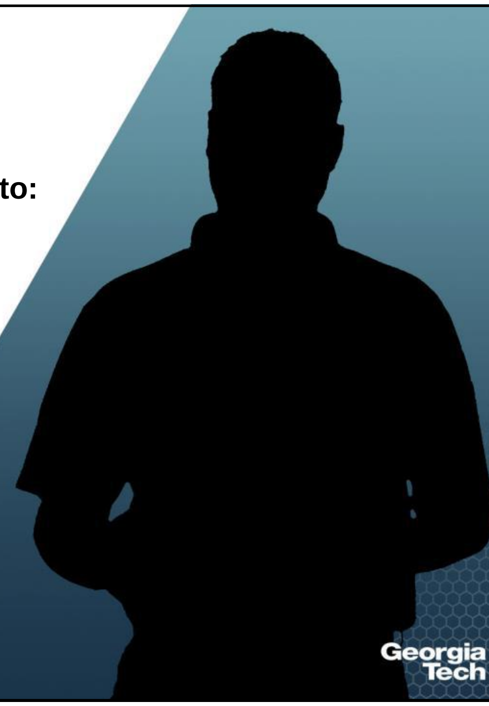
ROP When Demand Varies
Example



Learning Objectives



At the end of this lesson, you should be able to:

- Recommend a Re-order point when demand varies

The Situation:

You work at Best Buy in an Inventory Management role. Your boss wants no more than a 10% stock out probability and has asked you to recommend a reorder point for Apple iPads. You review sales data and determine that the average daily demand for iPads is 15 with a standard deviation of 5 units. The lead time from Apple for more iPads is 2 days. What reorder point do you recommend and what portion of that is safety stock?

Solution:

$$ROP = Expected\ Demand\ during\ lead\ time + Z\sigma_D\sqrt{LT}$$

Where: $Expected\ Demand\ during\ lead\ time = Ave\ Demand * LT$

- Ave Demand = 15 units/day
- Lead Time = 2 days
- σ_D = 5 units
- Z = ?

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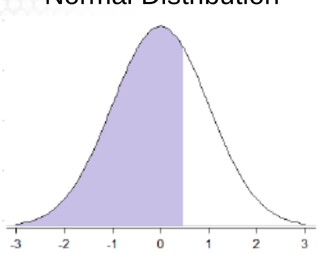
Finding Z:

Normal Distribution



z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
+0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
+0.1	.53983	.54380	.54776	.55172	.55567	.55966	.56360	.56749	.57142	.57535
+0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
+0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
+0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
+0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
+0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
+0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
+0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
+0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
+1	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
+1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
+1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
+1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91308	.91466	.91621	.91774
+1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
+1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
+1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
+1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
+1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
+1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
+2	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169

Almost 90%.
Use this Z
value (1.28)

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Solution:

$$\boldsymbol{ROP = Expected\ Demand\ during\ lead\ time + Z\sigma_D\sqrt{LT}}$$

Where: $Expected\ Demand\ during\ lead\ time = Ave\ Demand * LT$

- Ave Demand = 15 units/day
- Lead Time = 2 days
- σ_D = 5 units
- Z = 1.28

ROP = 15*2 + 1.28*5*SQRT(2) = 30 + 9.02 = **39 iPads left, SS~9**

Summary

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Inventory Policy

Learning Objectives

At the end of this lesson, you should be able to:

- List the two components of an inventory policy
- Recommend an Inventory Policy when demand varies

The Two I.M. Decisions:

1. **HOW MUCH** should we order?

2. **WHEN** should we order more?

The Situation:

You work at GTRI in their IT group. One of your jobs is building minicomputers for use by researchers. Keeping costs down is important. Also important is having the inputs to make minicomputers quickly when requested. Of particular interest are memory chips. Records show 8,000 units a year on average are used with a standard deviation of 400. Each unit costs $10 and holding cost is 5%. Each order for more costs $50 and takes a week to arrive. The current Service Level Agreement (SLA) with R&D is 96%.

What inventory policy do you recommend for this item?

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The Two I.M. Decisions:

1. **HOW MUCH** should we order?

2. WHEN should we order more?

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HOW MUCH?

No quantity discount mentioned, so use standard EOQ

$$EOQ = \sqrt{\frac{2*D*S}{H}} = \sqrt{\frac{2*8{,}000*50}{.5}} = 1264.911 \sim \mathbf{1265\ units}$$

- D = 8,000/year
- S = $50 per order
- H = 5% of $10 = $.5

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The Two I.M. Decisions:

1. HOW MUCH should we order?

2. **WHEN** should we order more?

WHEN?

Demand is described with "average" and "standard deviation", this indicates demand varies

$$ROP = Expected\ Demand\ during\ lead\ time + Z\sigma_D\sqrt{LT}$$
$$ROP = (27.98 * 7) + 1.75 * 400 * \sqrt{7}$$
$$ROP = 153.85 + 1{,}852.02$$
$$\boldsymbol{ROP} = 2{,}005.86 = \mathbf{2{,}006\ chips}$$

- σ_D = 400 chips
- LT = 1 week = 7 days
- d = 8,000/52/7= 27.98
- Z = 1.75

Recommended Inventory Policy

Keep track of quantity of memory chips

When there are <u>2,006 chips left</u>, place an <u>order</u> for <u>1,265 more</u>

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Summary

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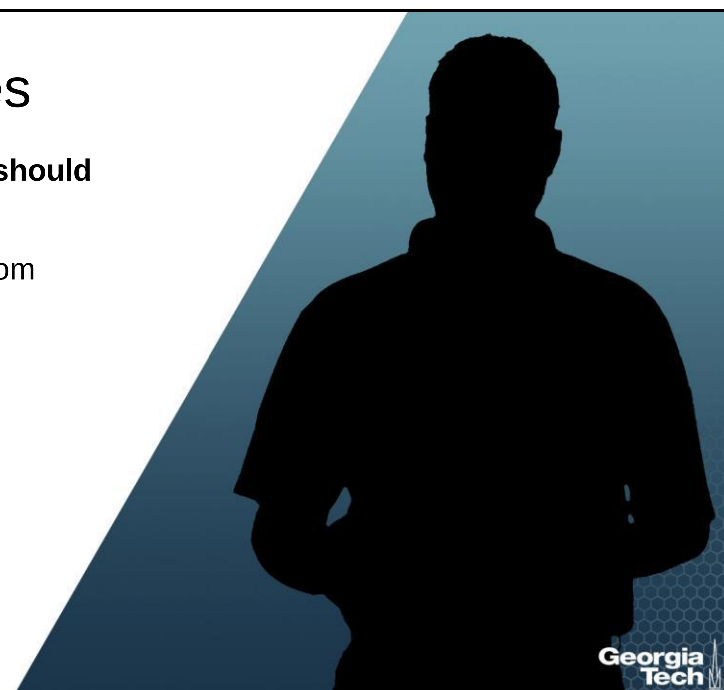
Inventory Management
Recap

Learning Objectives

At the end of this lesson, you should be able to:

- Discuss and recap lessons from this week
- Assess tie back to analytics



Recap

- There are different kinds of inventory.
- Inventory Management is about matching supply with demand.
- Even if demand varies, we can make some optimization decisions.
- We looked at EOQ and ROP to define an inventory policy.