Independent Demand Ordering Systems

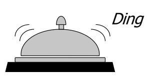
Chapter 11

When to Place an Order

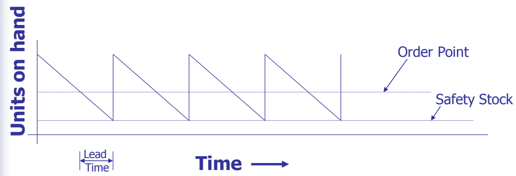
- Not ordered soon enough
  - potential stockout
  - loss in customer service
- Order too early
  - excess inventory
- Need to balance the cost of extra inventory with the cost of a stockout

When to Place an Order

- 3 basic systems
  - Order Point System
  - Periodic Review System
  - MRP (for dependent demand systems)



Order Point System



Order Point

- An is order placed when the on-hand inventory reaches a predetermined level (order point)
- Often used with the EOQ model
- Must allow enough stock to satisfy demand during the lead time (DDLT)

Order point = demand during lead time + safety stock

OP = DDLT + SS

Order Point - Example Problem

Demand is 200 units per week, the lead time is three weeks, and the safety stock is 300 units. Calculate the order point.

OP = DDLT + SS
= 200/wk x 3 weeks + 300
= 900 units

Order when the inventory falls below 900 units

Order Point

Points to Remember

- Order quantities are usually fixed
- Order intervals may vary
- If the demand or the lead time changes the order point must be changed (or the safety stock will change)

$$\text{Average inventory} = \frac{\text{order quantity}}{2} + \text{safety stock}$$

Average Inventory - Example Problem

The order quantity is 1,000 units and the safety stock is 300 units. What is the average inventory?

$$\text{Average inventory} = \frac{Q}{2} + \text{safety stock} = \frac{1{,}000}{2} + 300 = 800 \text{ units}$$

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Determining Safety Stock

- Protection against uncertainty
  - in supply
  - in demand
- Safety Stock
  - covers uncertainty in quantity
- Safety Lead Time
  - covers uncertainty in timing (late) delivery
- Both increase inventory

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Determining Safety Stock

- Amount of Safety Stock Depends on:
  - Variability of demand (during the lead time)
  - Order frequency
  - Desired service level
  - Lead time
    - the longer the lead time the more safety stock
    - keep the lead time to a minimum

Demand Variation About the Average

Week	Item A	Item B
1	1200	400
2	1000	600
3	800	1600
4	900	1300
5	1400	200
6	1100	1100
7	1100	1500
8	700	800
9	1000	1400
10	800	1100
Total Demand	10,000	10,000
Average Demand	1000	1000

Variation about an Average

- Most demand patterns are predictable
- Most follow a normal distribution
- Pattern can be described by
  - Shape
  - Center
  - Spread

The Normal Distribution

- Also called the bell curve
- Predictable
- Most values are centered about the average
- Stable
- Different for different products

Normal Distribution

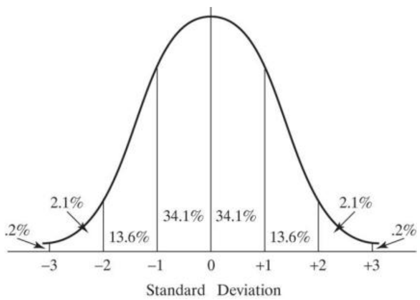

Figure 11.4 Normal distribution

Average

- Most values are centered about the average
- Represented by $\overline{x}$ (x bar)

$$\overline{x} = \frac{\Sigma x}{n}$$

n = the number of data
x = the individual readings

Calculating the Average

Period	Actual Demand
1	1200
2	1000
3	800
4	900
5	1400
6	1100
7	1100
8	700
9	1000
10	800
Total	10,000

$$\text{Average} = \frac{\Sigma x}{n}$$

$$= \frac{10{,}000}{10}$$

$= 1000$ units

Dispersion

- A measure of how closely the actual demands cluster about the average
- Measure in:
  - a range (highest - lowest reading)
  - mean absolute deviation (MAD) *see chpt 8*
  - standard deviation

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Standard Deviation (sigma), σ

1. Calculate the deviation (difference) of each period from the average
2. Square each deviation
3. Add the squares of the deviations
4. Divide the sum found in step 3 by the number of periods
5. Calculate the square root of the value found in step 4

$$\sigma = \sqrt{\frac{\Sigma (x - \overline{x})^2}{n}}$$

* This is a standard feature on most calculators

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Calculating the Standard Deviation - Example Problem

Period	Actual Demand	Average	Actual - Average	$(Act - Avg)^2$
1	1200	1000	200	40,000
2	1000	1000	0	0
3	800	1000	-200	40,000
4	900	1000	-100	10,000
5	1400	1000	400	160,000
6	1100	1000	100	10,000
7	1100	1000	-100	10,000
8	700	1000	-300	90,000
9	1000	1000	0	0
10	800	1000	-200	40,000
	10,000			400,000

sigma = $\sqrt{400{,}000/10} = \sqrt{40{,}000} = 200$

Calculating the Standard Deviation - Example Problem Continued

Period	Actual Demand
1	1200
2	1000
3	800
4	900
5	1400
6	1100
7	1100
8	700
9	1000
10	800
	10,000

If σ = 200 we should expect:

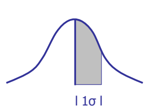
68% of the demands to be between 800 -1200 units

98% of the demands to be between 600 -1400 units

99.88% of the demands to be between 400 - 1600 units

Determining the Safety Stock and Order Point

- The normal curve is symmetrical about the average
- Half the time demand is greater than average
- Half the time demand is less than average
- A safety stock of zero has a service level of 50%
- The error will exceed the average by one sigma 34% of the time



Safety Stock and Order Point - Example Problem

Use the values from the previous problem.

Sigma = 200 units, lead time = 1 period.

a. Calculate the safety stock and order point for an 84% service level.

b. If safety stock of two standard deviations is carried, calculate the safety stock and order point.

Answer

a. Safety stock = 1 sigma = 1 x 200 = 200 units
   Order point = DDLT + SS = 1000 + 200 = 1200 units

b. Safety stock = 1 sigma = 2 x 200 = 400 units
   Order point = DDLT + SS = 1000 + 400 = 1400 units

Safety Factor

- The service level is directly related to the number of standard deviations needed and is called the safety factor
- The safety factor is found on the following table from the corresponding desired service level

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Table of Safety Factors

Service Level (%)	Safety Factor
50	0.00
75	0.67
80	0.84
85	1.04
90	1.28
94	1.56
95	1.65
96	1.75
97	1.88
98	2.05
99	2.33
99.86	3.00
99.99	4.00

Figure 11.5 Table of safety factors

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Safet Stock and Order Point - Example Problem

If the standard deviation is 200 units, what safety stock should be carried to provide a service level of 90%? If the expected demand during the lead time is 1500 units, what is the order point?

Safety factor for 90% service level = 1.28 (from table)

Safety stock = sigma x safety factor
= 200 x 1.28
= 256 units

Order point = DDLT + SS
= 1500 + 256
= 1756 units

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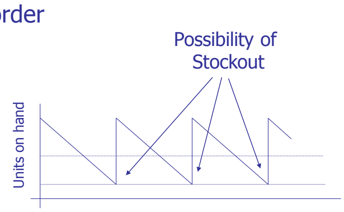
Service Level

- Percentage of time that no stockout occurs
- Stockouts can only occur when we place an order



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Safety Stock - Example Problem

What is the safety stock for an item with a demand of 80 units per month, a lead time of one month and standard deviation of 20 units?

Management wants a service level of 96%.

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Safety Stock - Example Problem Solution

From the table, for a service level of 96% the safety factor = 1.75

Safety Stock = S.F. x Sigma
= 1.75 x 20
= 35

Safety Stock and Order Point - Example Problem

An item has a lead time of 1 month and demand of 200 units per month. If the standard deviation of demand during the month is 40 units what is the safety stock and order point for this item if management needs a 90% service level?

Safety Stock = S.F x Sigma
= 1.28 x 40
= 51.2 or 51
Order Point = DDLT + SS
= 200 + 51 = 251

Determining Service Levels

- Carry enough safety stock so the cost of carrying inventory and the cost of stockouts is a minimum
- Stockouts cost money
  - backorder costs
  - lost sales
  - lost customers

Exposures to Stockout

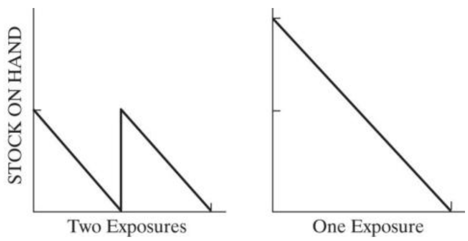


Figure 11.6 Exposures to stockout

Safety Stock and Order Point - Example Problem

Suppose mangement stated that it could only tolerate one stockout per year for a specific item.

For this particular item, the annual demand is 52,000 units, it is ordered in quantities of 2600, and the standard deviation of demand during lead time is 100 units. The lead time is one week. Calculate:

a. Number of orders per year.

b. Service level.

c. Safety stock.

d. Order point.

Safety Stock and Order Point - Example Problem Solution

a. Number of orders per year $= \dfrac{\text{annual demand}}{\text{order quantity}}$

$= \dfrac{52{,}000}{2600}$

= 20 orders per year

b. Since one stockout per year is allowed, there must be no stockouts (20 - 1) = 19 times per year.

Service level $= \dfrac{20 - 1}{20} = 95\%$

Safety Stock and Order Point - Example Problem Solution

c. From the table of safety factors
Safety factor (95%) = 1.65

Safety Stock = safety factor x sigma
= 1.65 x 100 = 165 units

d. DDLT = (52,000 / 52 weeks per yr) = 1000 units

Order point = DDLT + SS
= 1000 + 165
= 1165 units

Service Level Example

What is the service level for an item with annual demand of 25,000 units and an order quantity of 5,000 units? Management will tolerate only 1 stockout per year.

N= 25,000 / 5,000 = 5

What if the order Quantity was 1,000?

$$S.L. = \frac{5-1}{5} \times 100\% = 80\%$$

96%

Different Forecast and Lead Time Intervals

- Many items in inventory have different lead times
- Sales records and forecasts are usually made on a weekly or monthly interval
- The standard deviation will change as the interval changes
  - the longer the interval the higher the variation
- Need to adjust the standard deviation for the lead time

Lead Time vs Forecast Interval

- The standard deviation is measured over the lead time
- If the lead time and the forecast interval i.e. (sales interval) are different:

$$\sigma_{LTI} = \sigma_{FI}\sqrt{\frac{\text{Lead Time Interval}}{\text{Forecast Interval}}}$$

*LTI = Lead Time Interval
*FI = Forecast Interval

Lead Time Interval - Example Problem

The forecast interval is 4 weeks, the lead time interval is 2 weeks, and sigma for the forecast interval is 150 units. Calculate the standard deviation for the lead time interval.

$$\sigma_{LTI} = 150\sqrt{\frac{2}{4}} = 150 \times .707$$

$$= 106 \text{ units}$$

Lead Time Interval - Example Problem

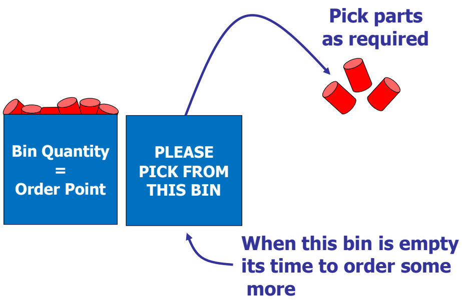
- Sales are collected and recorded every 4 weeks and the standard deviation of demand over the 4 weeks is 32 units.
- What is the standard deviation of demand if the lead time is 3 weeks?
- $MAD_{LTI} = 32 \times \sqrt{\frac{3}{4}} = 27.7$ or **28**

Shorter the Lead Time ➡ The Lower σ

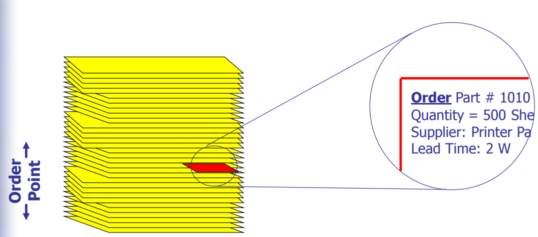
Determining When the Order Point is Reached

- Need a mthod to show when the quantity on hand has reached the order point
- Two basic systems:
  - Two - bin system
    - used with 'C' items
  - Perpetual inventory system

Two Bin System



Red-Tag Method



Perpetual Inventory Record System

- A continual account of inventory transactions
  - **balance on hand**
  - quantity on order (not yet received)
  - quantity allocated (not issued)
  - available balance
  - Issued
  - Received
- Should be accurate and up to date
  - Often done on a computer

Perpetual Inventory Record System

426254 SCREW				ORDER QUANTITY 500		ORDER POINT 100
DATE	ORDERED	RECEIVED	ISSUED	ON HAND	ALLOCATED	AVAILABLE
01				500		500
02				500	400	100
03	500			500		100
04			400	100	0	100
05		500		600	0	600

Figure 11.7 Perpetual inventory record

Perpetual Inventory Record

- Permanent Information *(does not change frequently)*
  - part number, name, description
  - storage location
  - order point
  - order quantity
  - lead time
  - safety stock
  - supplier(s)

Perpetual Inventory Record

- Variable information (*changes with each transactions)*
  - quantities ordered: dates, order number
  - quantities received: dates, order number
  - quantities issued: dates, order number
  - balance on hand
  - allocated: dates, order number
  - **available balance**

Periodic Review System

- Economic Order Quantity
  - quantity ordered is constant
  - the time between orders varies
- Periodic Review System
  - the time between orders is constant
  - the order quantity varies

Periodic Review System

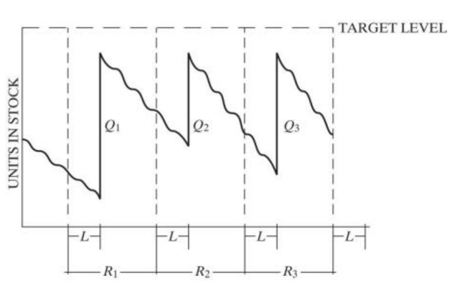


Figure 11.8 Periodic review system: units in stock versus time

Target Level or Maximum Inventory Level

- Total of the:

  demand (D) during the review period (R)
  + demand (D) during the lead time (L)
  + safety stock (SS)

$$T = D(R + L) + SS$$

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Periodic Review - Order Quantity

- When it is time to place an order
  - Order the difference between the target level (T) and the quantity on hand (I).

$$Q = T - I$$

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Periodic Review System

- Used when:
  - there are many small issues from stock e.g. grocery stores
  - many items are ordered from one source
  - many items are ordered together to fill a truck or a production run

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Periodic Review - Example Problem

A harware company stocks nuts and bolts and orders them from a local supplier once every two weeks (10 working days). Lead time is two days. The company has determined that the average demand for 1/2 inch bolts is 150 per week (5 working days), and it wants to keep a safety stock of three day's supply on hand. An order is to be placed this week, and stock on hand is 130 bolts.

a. What is the target level?

b. How many 1/2 inch bolts should be ordered this time?

Let: D= demand per unit time = 150 / 5 = 30 per working day
L = lead time = 2 days
R = review period = 10 days
SS = safety stock = 3 day's supply = 90 units
I = inventory on hand = 130 units

Periodic Review - Example Problem Continued

Target level T = D(R + L) + SS
= 30(10 + 2) + 90
= 450 units

Order quantity Q = T - I
= 450 - 130
= 320 units

Place an order now for 320 units which will arrive in 2 days.

Distribution Inventory

All of the finished goods held anywhere in the distribution system

- to improve customer service
  - store goods near the customer
- to reduce transportation costs
  - allow full truckloads
- to reduce production costs
  - economic lot sizes

Distribution Systems

- Factory - *supports central supply*
- Central supply - *holds goods for the distribution centers*
- Distribution centers - *receive orders from customers*
- Customers - *may be the final customer or some other intermediary*
- Demand may be smooth or lumpy

Lumpy Demand

- Created by the distribution centers using order point systems

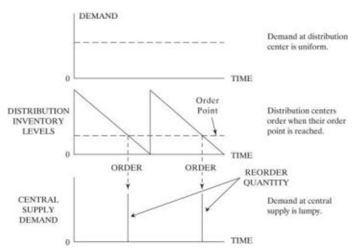

Figure 11.10 Distribution inventory

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Decentralized Systems

- Each distribution center orders as needed disregarding:
  - needs of other centers
  - available inventory at central supply
  - factory production schedule
- Each center is independent
  - reduces communication costs
  - reduces coordination costs

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Decentralized Systems

- Called 'pull systems'
  - goods are pulled through the system
- May cause problems:
  - customer service
  - factory scheduling
  - inventory levels

Centralized Systems

- All forecasts and orders are determined at the central supply
- Stock is 'pushed' into the distribution centers
- Attempt to balance the needs of all the centers
- Coordinates: factory, central supply and distribution centers
- Lacks the ability to respond to local needs

Distribution Requirements Planning

- Forecasts when demands will occur
- Allows planning by the factory and central supply
- Uses MRP logic
- Planned order releases from the distribution centers become the gross requirements of central supply

Distribution Requirements Planning

Distribution Center A
Part 5678

Week	1	2	3
Planned Order Release	200		200

Distribution Center B
Part 5678

Week	1	2	3
Planned Order Release		100	

Central Supply
Part 5678
Lead Time: 2 weeks
Order Quantity: 500

Week		1	2	3
Gross Requirements		200	100	200
Scheduled Receipts				
Projected Available	400	200	100	400
Planned Order Release		500		

Figure 11.11 Distribution requirements planning

DRP - Example Problem

Distribution Center A

Transit Time = 2 weeks
Order Quantity = 100 units

Week		1	2	3	4	5
Gross Requirements		25	30	55	50	30
In Transit			100			
Projected Available	50					
Planned Order Release						

Distribution Center B

Transit Time = 1 weeks
Order Quantity = 200 units

Week		1	2	3	4	5
Gross Requirements		95	85	100	70	50
In Transit						
Projected Available	100					
Planned Order Release						

DRP - Example Problem Solution

Distribution Center A

Transit Time = 2 weeks
Order Quantity = 100 units

Week		1	2	3	4	5
Gross Requirements		25	30	55	50	30
In Transit			100			
Projected Available	50	25	95	40	90	60
Planned Order Release			100			

Distribution Center B

Transit Time = 1 weeks
Order Quantity = 200 units

Week		1	2	3	4	5
Gross Requirements		95	85	100	70	50
In Transit						
Projected Available	100	5	120	20	150	100
Planned Order Release		200		200		

DRP - Example Problem Solution

Central Supply
Lead Time = 2 weeks
Order Quantity = 500 units

Week		1	2	3	4	5
Gross Requirements		200	100	200		
Scheduled Receipts						
Projected Available	400					
Planned Order Release						

DRP - Example Problem Solution

Central Supply
Lead Time = 2 weeks
Order Quantity = 500 units

Week		1	2	3	4	5
Gross Requirements		200	100	200		
Scheduled Receipts						
Projected Available	400	200	100	400		
Planned Order Release		500				

Central Supply needs to place an order for 500 now, scheduled to be received in week 3