Planning and Managing Inventories

SCM614

WEEK 4

Agenda

Ukraine cases – share info

PP on sustainability

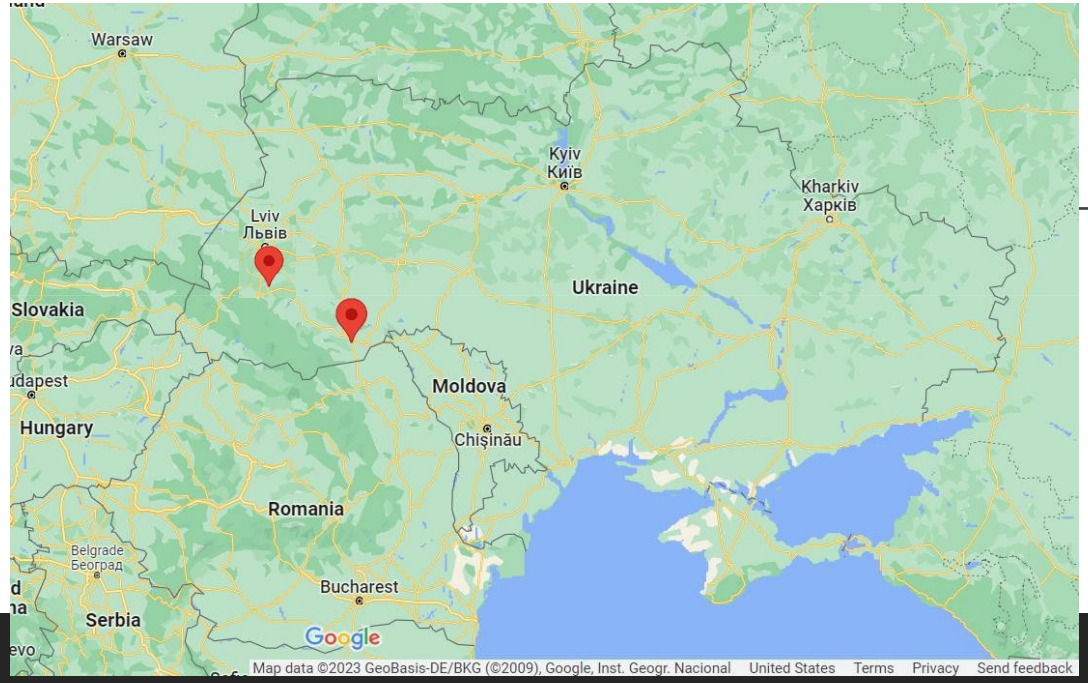
Lecture & Excel

- Inventory types/functions/goals
- Inventory cycle/costs
- Economic Order Quantity
- Economic Production Quantity
- Quantity Discounts
- fieorder Point: many wonderful iterations of such!

What's next: homework

Ukraine's wedding dress industry

- A product that just cannot be late
- Made to order gown LT = 1 yr. from order to fit (standard)
- Interrupted at start of war due to workers fleeing
  - Chernivtsi employees have returned to area/work
  - Lviv Milla Nova moved some production to Warsaw
- Export through fiomania or Poland with no change in outbound SC
- Import materials: silk China, lace France, crystals Austria
- In 2014, shifted exports from fiussia to EU/NA
  - Crimea invasion, ruble drop, working relationships deteriorated



Breakout (PP)
Supply Chain Initiatives: Focus on Sustainability

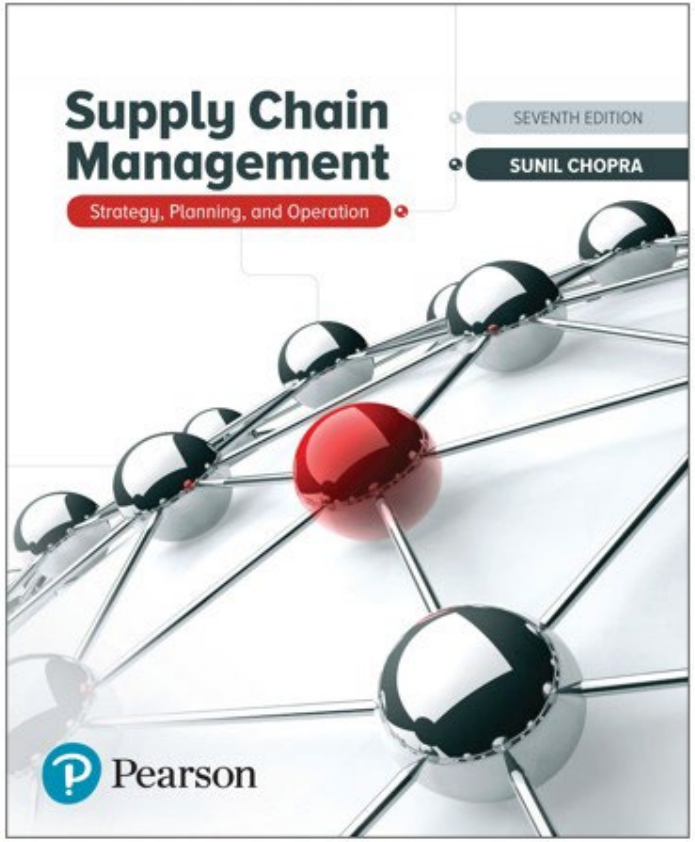
Investigate these resources in your teams and prepare to report back to the class.

- What is CDP? What do they offer? What are the reasons they list for starting the sustainability journey? What areas do they focus on? Look up an “A” business. Any surprise you? https://www.cdp.net/en/
- fieport out on the Sustainable Development Goals (SDGs) from the UN. (I recommend showing the diagram) How can firms work towards these goals? https://sdgs.un.org/goals
- fiead the Clif Bar case study. What did they do and what was their outcome? What are they working with their suppliers to achieve? See content/module 3/week 3/reading
- Find a company that is actively working to address sustainability. Describe the firm and its supply chain (briefly) and what specific actions have taken place, measurements, and results.

https://www.netclipart.com/isee/hmhJiJ_team-huddle-clip-art-huddle-clip-art/

Supply Chain Management: Strategy, Planning, and Operation

Seventh Edition



Chapter 11

Managing Economies of Scale in a Supply Chain Cycle Inventory

Inventory

https://www.reviso.com/blog/inventory-management/

Inventory

- A stock or store of goods

Independent demand items

- Items that are ready to be sold or used

Inventories are a vital part of business because:

(1) necessary for operations

(2) contribute to customer satisfaction

A "typical" firm has roughly 30% of its current assets and as much as 90% of its working capital invested in inventory

Types of Inventory

Cycle inventory

fiaw materials and purchased parts

Work-in-process (WIP)

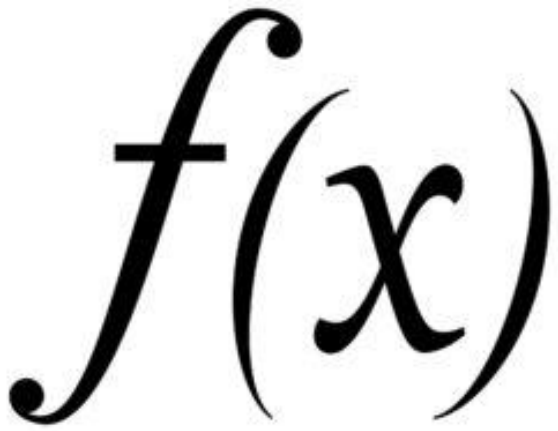
Finished goods inventories or merchandise

Tools and supplies

Maintenance and repairs (MfiO) inventory

Goods-in-transit to warehouses or customers (pipeline inventory)

Inventory Functions



Inventories serve a number of functions such as:

1. To meet anticipated customer demand
2. To smooth production requirements
3. To decouple operations
4. To protect against stockouts
5. To take advantage of order cycles
6. To hedge against price increases
7. To permit operations
8. To take advantage of quantity discounts

Objectives of Inventory Control

Inventory management has two main concerns:

1. Level of customer service
   - Having the **right goods** available in the **right quantity** in the **right place** at the **right time (+ right quality)**
2. Costs of ordering and carrying inventories
   - The overall objective of inventory management is to achieve satisfactory levels of customer service while keeping inventory costs within reasonable bounds
     - Measures of performance
     - Customer satisfaction
       - ✓ Number and quantity of backorders
       - ✓ Customer complaints
     - Inventory turnover

Effective Inventory Management

fiequires:

1. A system keep track of inventory
2. A reliable forecast of demand
3. Knowledge of lead time and lead time variability
4. fieasonable estimates of
   - Holding costs
   - Ordering costs
   - Shortage costs
5. A classification system for inventory items

https://www.shopkeep.com/blog/how-to-keep-track-of-inventory

Inventory Counting Systems

Periodic system

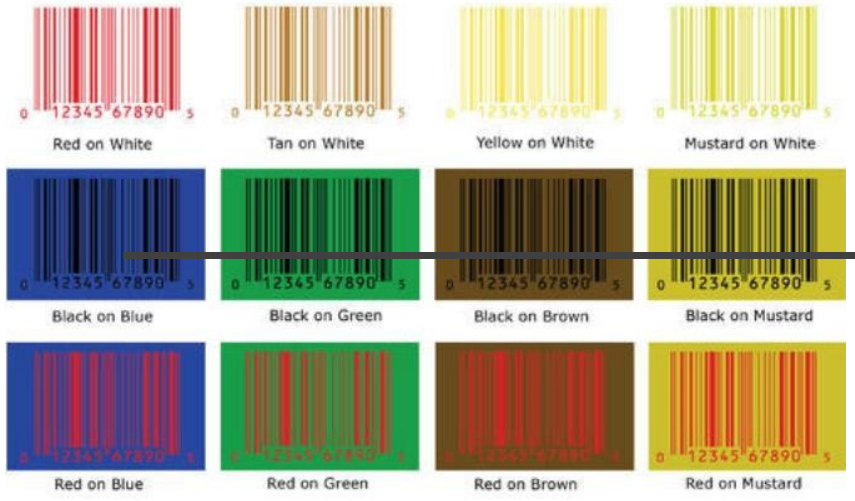
- Physical count of items in inventory made at periodic intervals

Perpetual inventory system

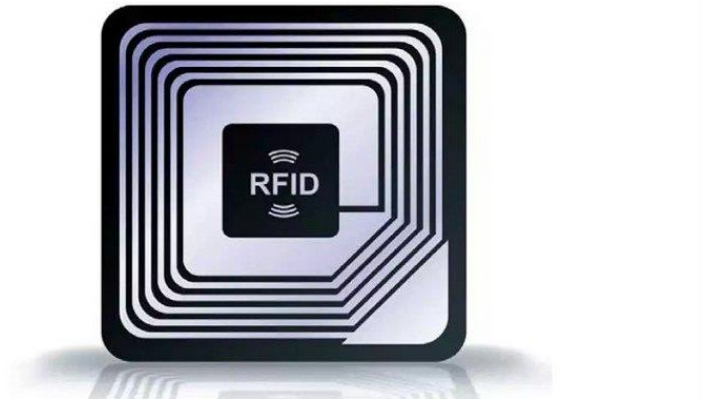
- System that keeps track of removals from inventory continuously, thus monitoring current levels of each item
  - An order is placed when inventory drops to a predetermined minimum level
    - ✓ **Two-bin system (Kanban)**
      - Two containers of inventory; reorder when the first is empty

https://www.horiba.com/en_en/products/detail/action/show/Product/batch-processing-1681/; https://www.creativemechanisms.com/gears

Inventory Counting Technologies



https://www.indiamart.com/proddetail/upc-non-scannable-barcode-label-



https://www.rfsmart.com/blog/you-down-with-rfid-yeah-you-know-me

Universal product code (UPC)

- Bar code printed on a label that has information about the item to which it is attached

Radio frequency identification (RFID) tags

- A technology that uses radio waves to identify objects, such as goods, in supply chains

Inventory Costs

Purchase cost: The amount paid to buy the inventory

Holding (carrying) costs: Cost to carry an item in inventory for a length of time, usually a year

Ordering costs: Costs of ordering and receiving inventory

Setup costs: The costs involved in preparing equipment for a job

- Analogous to ordering costs

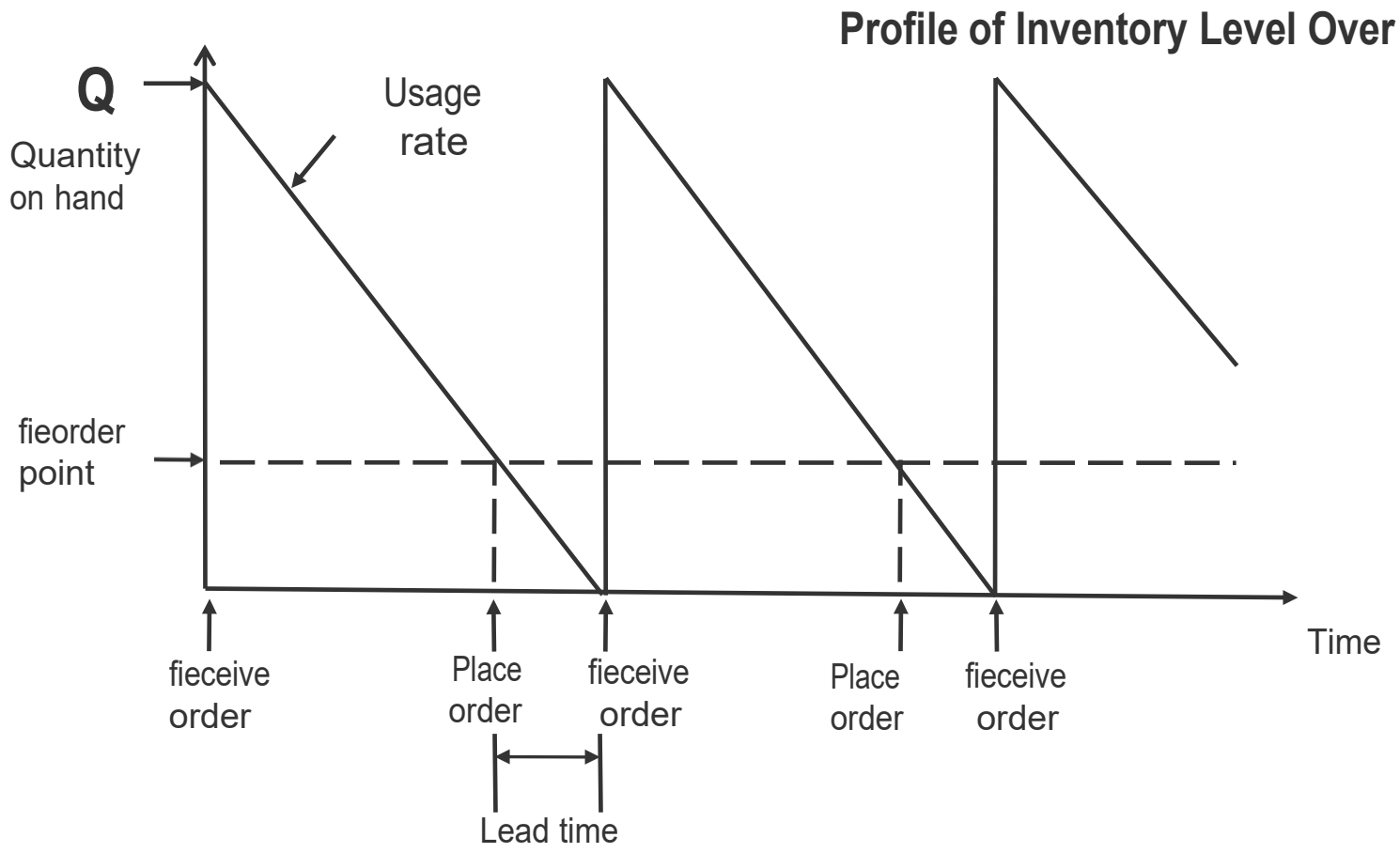
Shortage costs: Costs resulting when demand exceeds the supply of inventory; often unrealized profit per unit

https://www.flaticon.com/free-icon/bag-with-dollar-sign_1349

The Inventory Cycle

$$\text{Average inventory} = \frac{Q}{2}$$

$$\text{Length of order cycle} = \frac{Q}{D}$$



Total Annual Cost

$$\text{Total Cost} = \text{Annual Holding Cost} + \text{Annual Ordering Cost}$$

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

where

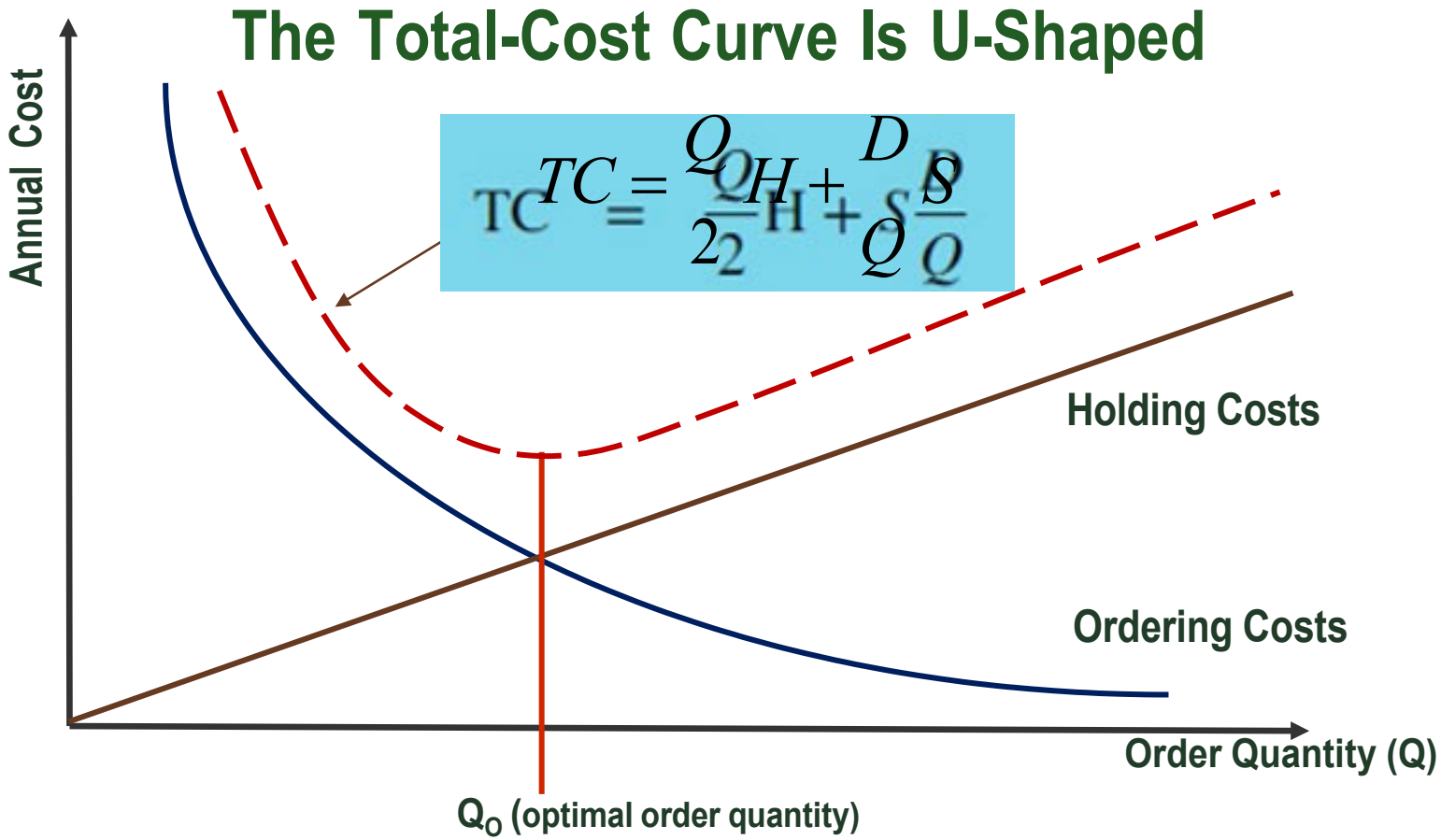
Q = Order quantity in units

H = Holding (carrying) cost per unit, usually per year

D = Demand, usually in units per year

S = Ordering cost per order

Goal: Total Cost Minimization



How Much to Order: EOQ Models

Economic order quantity models identify the optimal order quantity by minimizing the sum of annual costs that vary with order size and frequency

1. The basic economic order quantity model
2. The economic production quantity model
3. The quantity discount model

Basic EOQ Model

The basic EOQ model is used to find a fixed order quantity that will minimize total annual inventory costs

Assumptions:

1. Only one product is involved
2. Annual demand requirements are known
3. Demand is even throughout the year
4. Lead time does not vary
5. Each order is received in a single delivery
6. There are no quantity discounts

Deriving EOQ

Using calculus, we take the derivative of the total cost function and set the derivative (slope) equal to zero and solve for *Q*.

The total cost curve reaches its minimum where the carrying and ordering costs are equal.

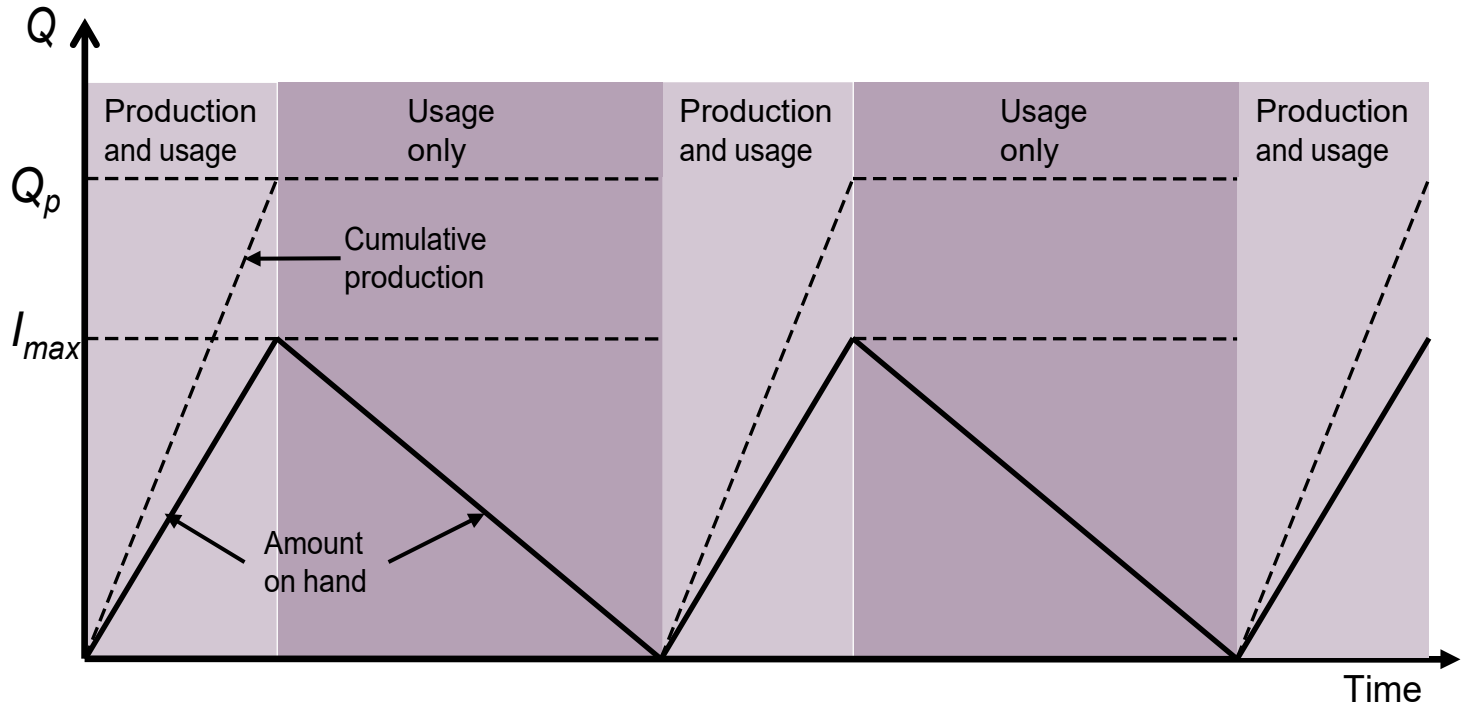
$$Q_{\mathrm{O}} = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(\text{annual demand})(\text{order cost})}{\text{annual per unit holding cost}}}$$

Economic Production Quantity (EPQ)

The batch mode is widely used in production. In certain instances, the capacity to produce a part exceeds its usage (demand rate).

- **Assumptions**
  1. Only one item is involved
  2. Annual demand requirements are known
  3. Usage rate is constant
  4. Usage occurs continually, but production occurs periodically
  5. The production rate is constant
  6. Lead time does not vary
  7. There are no quantity discounts

EPQ: Inventory Profile



EPQ – total cost, run size Q_p

$$TC_{min} = \text{Carrying Cost} + \text{Setup Cost}$$

$$= \left(\frac{I_{max}}{2}\right)H + \frac{D}{Q}S$$

where

I_{max} = Maximum inventory

$$= \frac{Q_p}{p}(p-u)$$

p = Productionor delivery rate

u = Usage rate

$$Q_p = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}}$$

Cycle time	$= \frac{Q}{u}$
Run time	$= \frac{Q}{p}$
I_{max}	$= \frac{Q_0}{p}(p-u)$
Average inventory	$= \frac{I_{max}}{2}$

Practice!

Harry & David sells boxed fruit. Maybe you have heard of them. They offer 4 different boxes as follows:

Box name	Profit ($/box)	Envy apple	Granny Smith apple	Bosch Pear	Tangerine	Lemon
qty	--	200	400	150	150	300
Surprise!	10	1	1	1	1	1
Tangy	12		2		2	1
Martini garnish	13			1	1	3
An Apple a day	12	2	3			

Make boxes with the mixes as shown to maximize profits.

Quantity Discount Model

Quantity discount

- Price reduction for larger orders offered to customers to induce them to buy in large quantities

$$\text{Total Cost} = \text{Carrying Cost} + \text{Ordering Cost} + \text{Purchasing Cost}$$

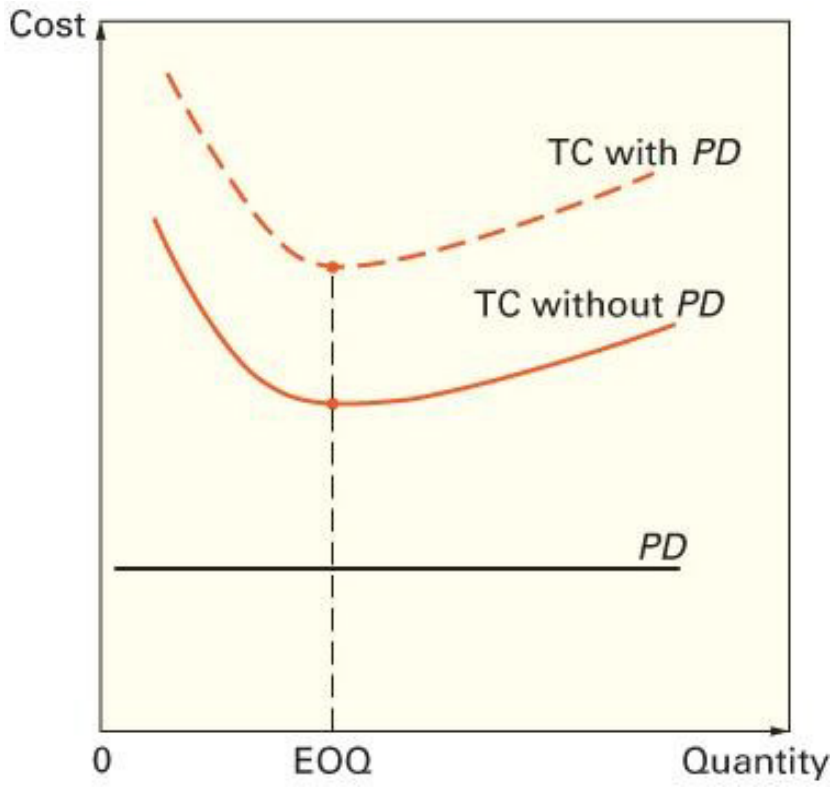
$$= \frac{Q}{2}H + \frac{D}{Q}S + PD$$

where

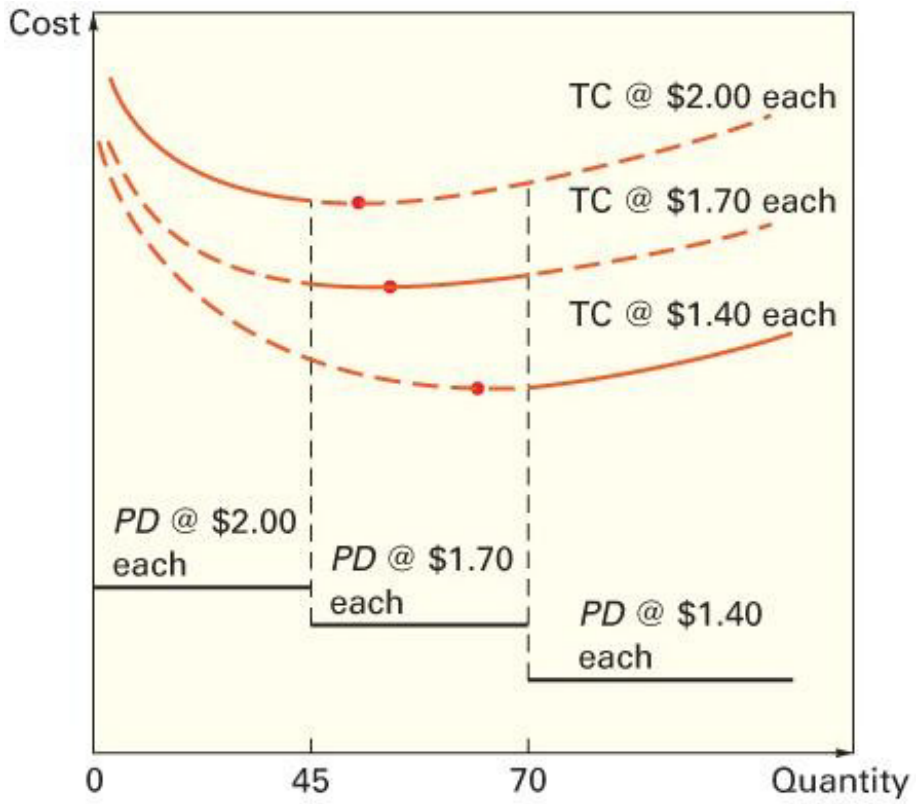
P = Unit price

Quantity Discounts

Adding *PD* does not change EOQ



Quantity Discounts (cont.)



The total-cost curve with quantity discounts is composed of a portion of the total-cost curve for each price

Practice!

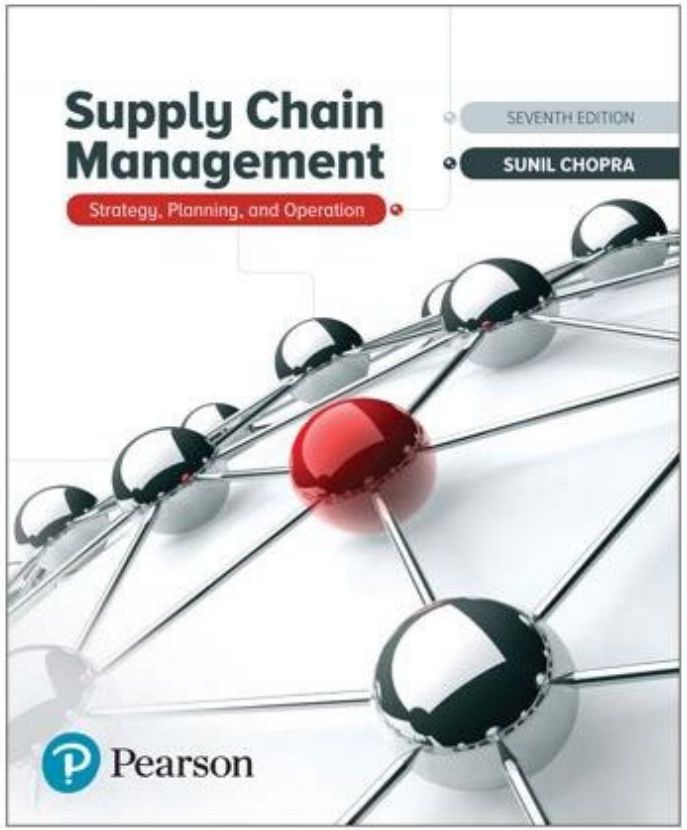
Managerial Levers to Reduce Cycle Inventory

- Factors driving lot sizing decisions: fixed costs & qty discounts
- If buildup is due to large lots associated with fixed costs – reduce fixed costs
  - Decrease changeover times
- If buildup is due to transportation – facilitate aggregation
  - Coordinating orders
  - Using intermediate locations to aggregate from multiple suppliers
  - Use milk runs for pickup and delivery
- If buildup is due to order placement and receiving – employ appropriate technologies
  - Electronic order placement
  - Advanced shipping notices
  - fi F I D
- If buildup is due to lot sizing decisions – check supplier's fixed costs
  - fieduce fixed costs
  - Employ volume-based discounts

https://oneeducatorsopinion.wordpress.com/2014/02/26/brain-breaks-are-good-for-teachers-too/

Supply Chain Management: Strategy, Planning, and Operation

Seventh Edition



Chapter 12

Managing Uncertainty in a Supply Chain Safety Inventory

The Role of Safety Inventory

- **Safety inventory** is carried to satisfy demand that exceeds the amount forecasted Ofi takes longer to arrive from supplier than expected
  - fiaising the level of safety inventory increases product availability and thus the margin captured from customer purchases
  - fiaising the level of safety inventory increases inventory holding costs

Questions:

1. What is the appropriate level of product availability?
2. How much safety inventory is needed for the desired level of product availability?
3. What actions can be taken to reduce safety inventory without hurting product availability?

The Role of Safety Inventory

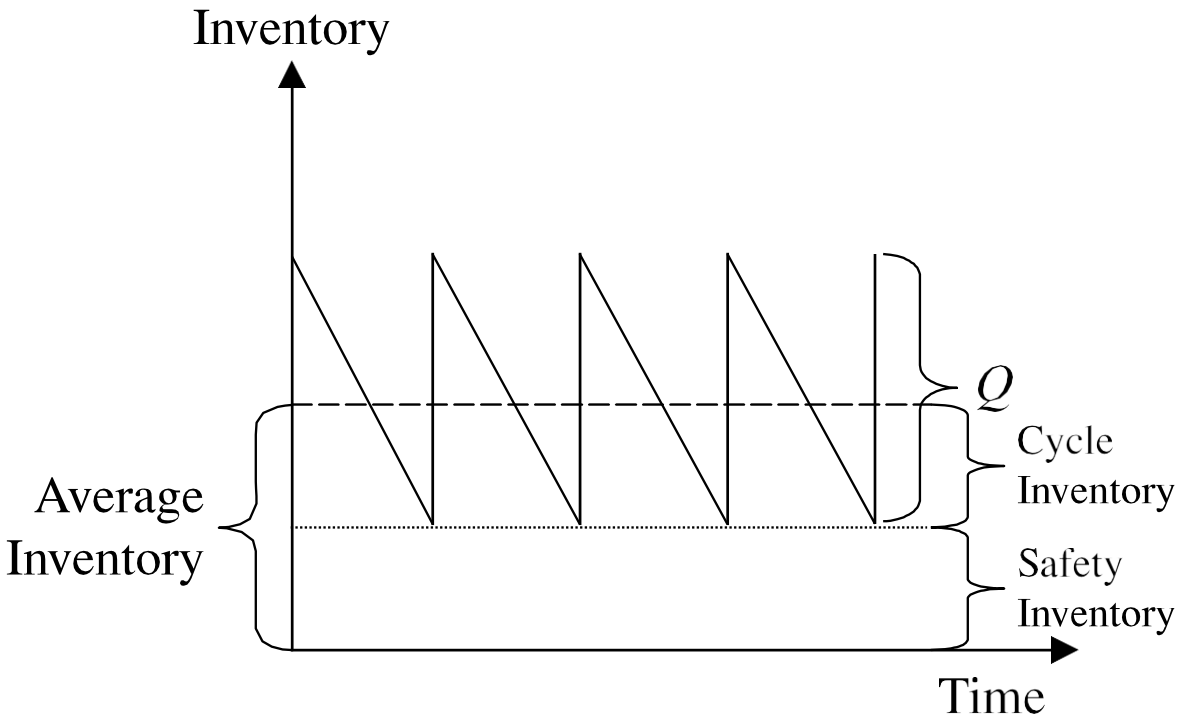


Figure 12-1 Inventory Profile with Safety Inventory

Factors Affecting the Level of Safety Inventory

- The desired level of product availability
- The uncertainty of demand
- The uncertainty of supply
- Inventory replenishment policies

Safety Stock?

As the amount of safety stock carried increases, the risk of stockout decreases.

- This improves customer service level

Service level

- The probability that demand will not exceed supply during lead time
- Service level = 100% - stockout risk

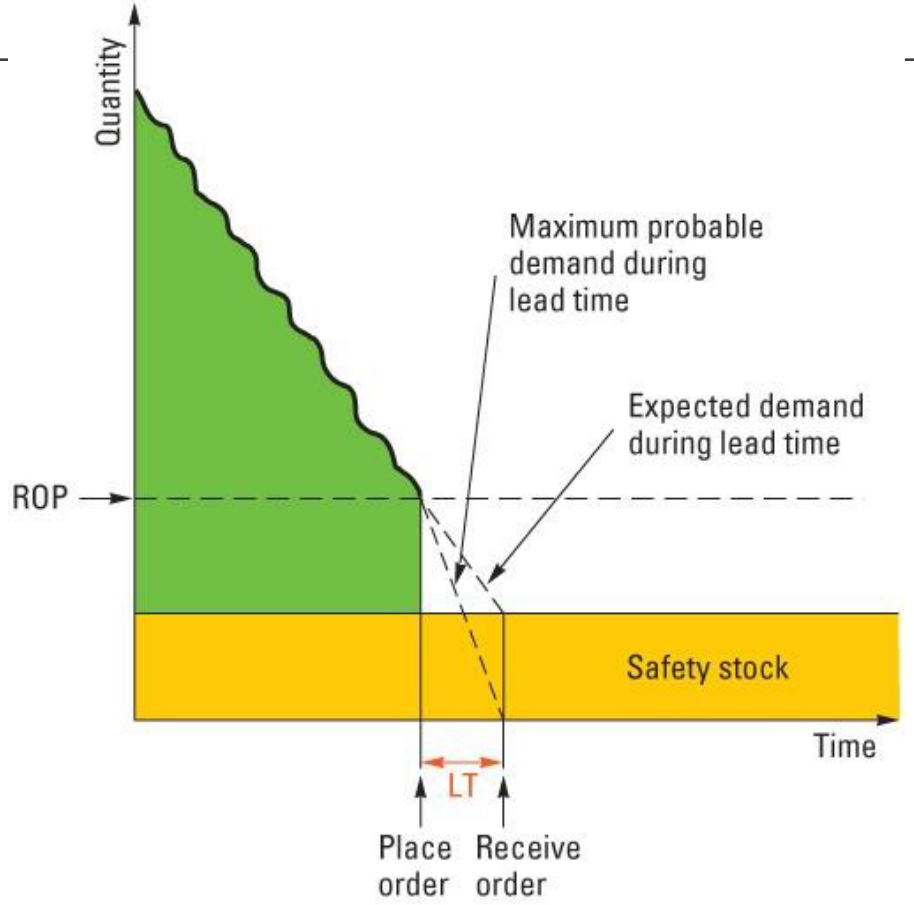
When to Reorder

https://www.slimstock.com/en/inventory-management-solutions/inventory-optimisation-supply-chain/economic-order-quantity/

Reorder point

- When the quantity on hand of an item drops to this amount, the item is reordered.
- Determinants of the reorder point
  1. The rate of demand
  2. The lead time
  3. The extent of demand and/or lead time variability
  4. The degree of stockout risk acceptable to management

Safety Stock



Reorder Point: Under Certainty

$$\text{ROP} = d \times \text{LT}$$

where

d = Demand rate (u

LT =

Reorder Point: Under Uncertainty

Demand or lead time uncertainty creates the possibility that demand will be greater than available supply

To reduce the likelihood of a stockout, it becomes necessary to carry safety stock

- **Safety stock**
  - Stock that is held in excess of expected demand due to variable demand and/or lead time
  - **Lead time** (*LT*) is the gap between when an order is placed and when it is received

$$\text{ROP} = \begin{matrix}\text{Expected demand} \\ \text{during lead time}\end{matrix} + \text{Safety Stock}$$

Safety Stock equation for ROP: expected demand during the LT & its s.d. is known

The amount of safety stock that is appropriate for a given situation depends upon:

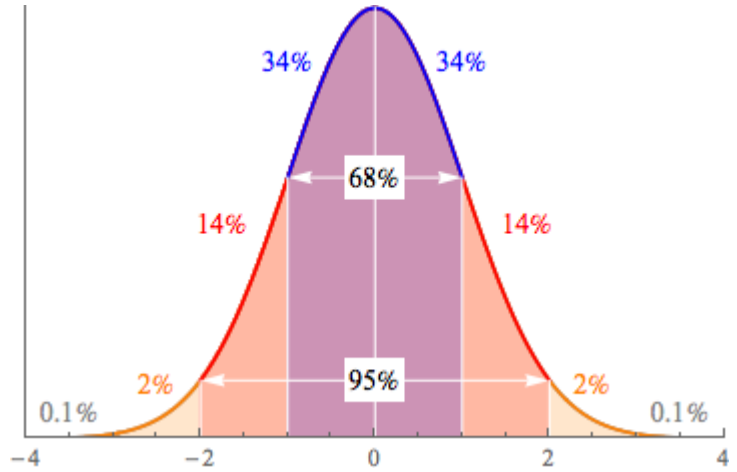
1. The average demand rate and average lead time
2. Demand and lead time variability
3. The desired service level

$$\text{ROP} = \begin{matrix}\text{Expected demand} \\ \text{during lead time}\end{matrix} + z\sigma_{dLT}$$

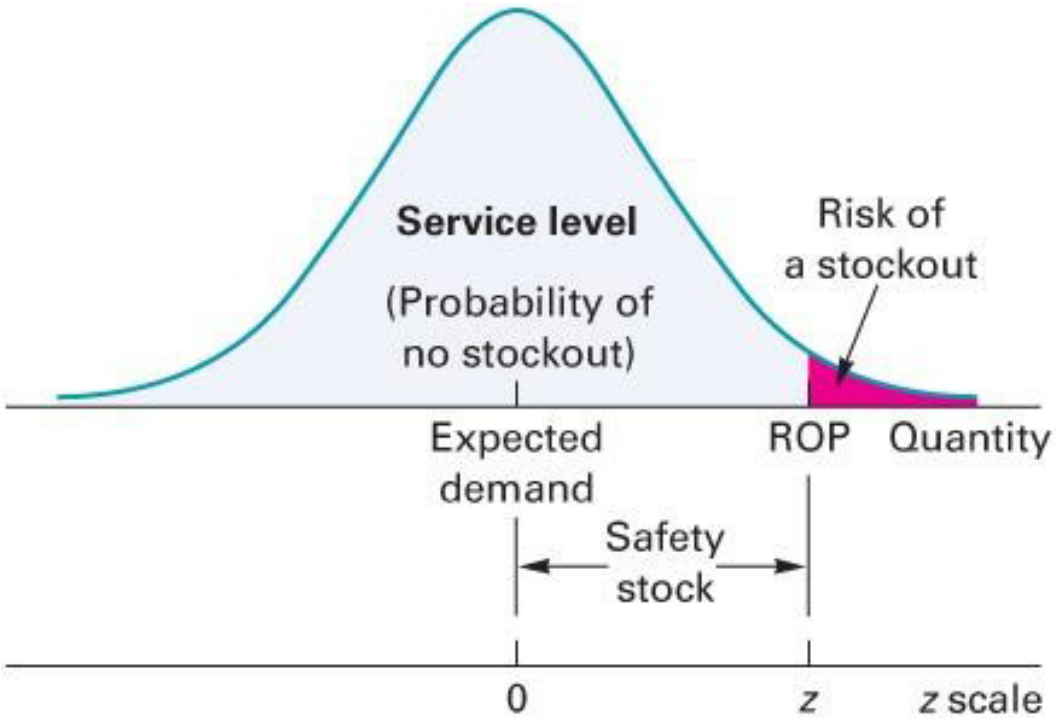
where

z = Number of standard deviations

σ_{dLT} = The standard deviation of lead time demand



Reorder Point



The fiOP based on a normal distribution of lead time demand

$$\text{ROP} = \begin{matrix}\text{Expected demand} \\ \text{during lead time}\end{matrix} + z\sigma_{d\text{LT}}$$

where

z = Number of standard deviations

$\sigma_{d\text{LT}}$ = The standard deviation of lead time demand

Z table

If service level = 97%, then find in table.

Closest is under column .08, row 1.8

The z score is = 1.88 (add row 1.8 with .08)

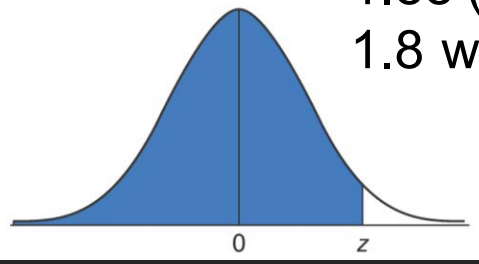


TABLE AREAS UNDER THE STANDARDIZED NORMAL CURVE, FROM $-\infty$ TO $+ Z$

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857

4. Reorder point under: a. Constant demand and lead time b. Variable demand rate c. Variable lead time d. Variable lead time and demand	$ROP = d(LT)$ $ROP = \bar{d}LT + z(\sigma_d)\sqrt{\overline{LT}}$ $ROP = d\overline{LT} + z(\sigma_{LT})d$ $ROP = \overline{dLT} + z\sqrt{\overline{LT}\sigma^2_d + \bar{d}^2\sigma^2_{LT}}$	ROP = Quantity on hand at reorder point d = Demand rate LT = Lead time $\bar{d}$ = Average demand rate σ_d = Standard deviation of demand rate z = Standard normal deviation $\overline{LT}$ = Average lead time σ_{LT} = Standard deviation of lead time

Reorder Point: Lots of various formulas!

Practice!

The Impossible Burger: Inventory Management

Source image: https://www.softwaresuggest.com/blog/inventory-management-practices-streamline-ecommerce-store/

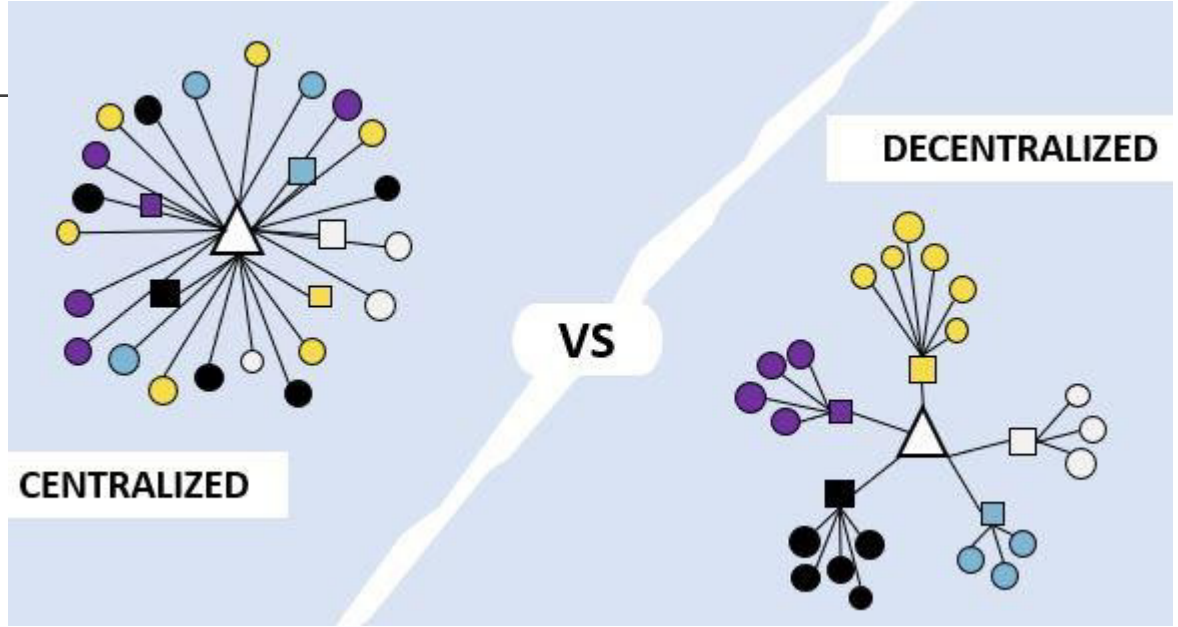
Watch: https://www.youtube.com/watch?v=ng4C2HMH664

fiead in the news: https://www.cnn.com/2019/05/14/business/impossible-whopper-new-markets-trnd/index.html

- **As more places (including Canada) are introducing the impossible burger with high demand (sometimes more than supply), how can Burger King better manage the Impossible Burger product?**
- **Vice versa, if demand suddenly drops?**

To centralize or not centralize – that is the question (definitively not Hamlet)

Advantages	Disadvantages
Lower overall network safety stock → lower facility costs, holding costs	Increase response time for customer order
Can keep additional depth of inventory (slower moving parts at master WH)	Increase transportation cost to customer
Improves product availability without adding to inventories	Increase GHG emissions



https://www.innovisor.com/2020/09/17/the-journey-to-successful-decentralization-starts-with-data/

Impact of Coefficient of Variation on Value of Aggregation

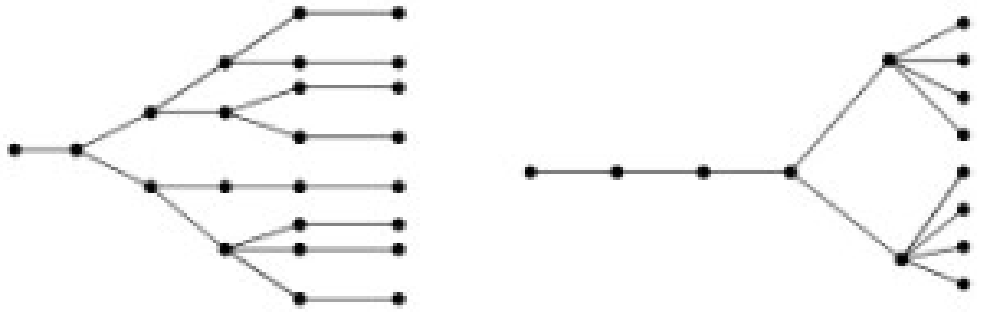
Table 12-4 Value of Aggregation at W.W. Grainger

	Motors	Cleaner
Inventory is stocked in each store		
Mean weekly demand per store	20	1,000
Standard deviation	40	100
Coefficient of variation	2.0	0.1
Safety inventory per store	132	329
Total safety inventory	211,200	526,400
Value of safety inventory	$105,600,000	$15,792,000
Inventory is aggregated at the DC		
Mean weekly aggregate demand	32,000	1,600,000
Standard deviation of aggregate demand	1,600	4,000
Coefficient of variation	0.05	0.0025
Aggregate safety inventory	5,264	13,159
Value of safety inventory	$2,632,000	$394,770

Postponement

Delay product differentiation or customization until closer to the time the product is sold

- Upstream operations can be standardized (common components, tooling)
- Move product differentiation as close to customer as possible
- Can occur at different stages
  - Manufacturing
  - Assembly
  - Packaging
  - Labeling



Managerial Levers to Reduce Safety Inventory

fieduction of supply uncertainty

- Sharing information
- Coordinated demand

fieduction of lead times

- Delays contribute more to lead time than production and transportation time

fieduction of demand uncertainty

- fieduce information distortion through sharing
- Aggregate demand

Assignments

Homework 2 – due 2/16

- Chapter 8: agg planning (rescheduled from HW1)
  - 1 a/b/c compare level and chase strategies
- See LP exercises in content/module 4/week 4/assignment
- Chapter 11: cycle stock, safety stock, EOQ, qty discounts
  - 3, 6, 7, 16
- Chapter 12: fiOP
  - 6 (no CSL), 9, 11 + one other fiOP in content/module 4/week 4/assignment

SCOfi – get familiar with tool

- Complete training through ASCM https://www.ascm.org/corporate-transformation/standards-tools/scor-ds/#freecourse
- Post screen print showing completion to dropbox/SCOfi training