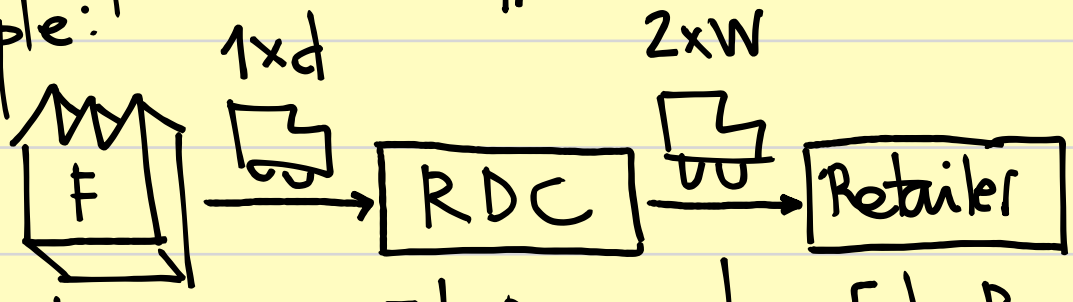
MULTI-ECHELON INVENTORY SYSTEMS & SUPPLY CHAIN OPTIMIZATION

Introduction. Why MEIS? In modern Supply Chains, inventory is often spread across multiple locations, such as central warehouses, regional distribution centers, and retail stores. Managing these inventories across different stages is critical to minimize cost and maintaining high service levels. This process is called MEIS.

1. MEIS.

1.1 Def. What is a MEIS? It refers to a supply chain where inventory is stored at multiple locations, referred as ..echelons". Each echelon represents a different level in the supply chain.

Example:



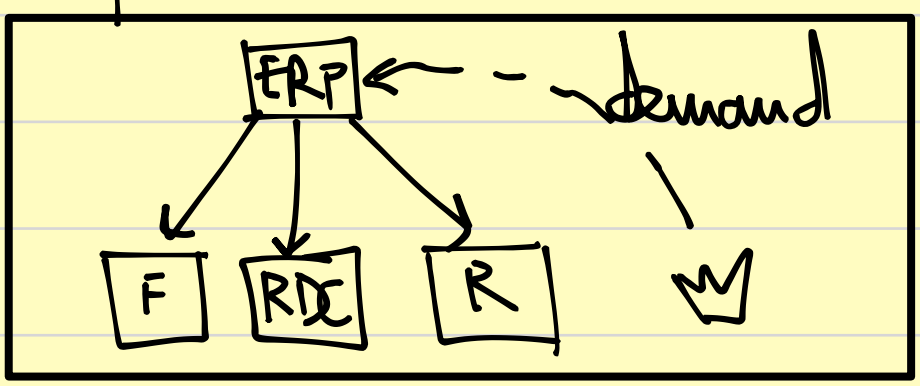
1.2 Key Concepts in MEIS.

1.2.1. **Echelon Stock**. Refers to the total amount of inventory available in all locations upstream of a particular echelon. For instance $ES_R = 1000 + 100.000 + 20.000 = 121.000$

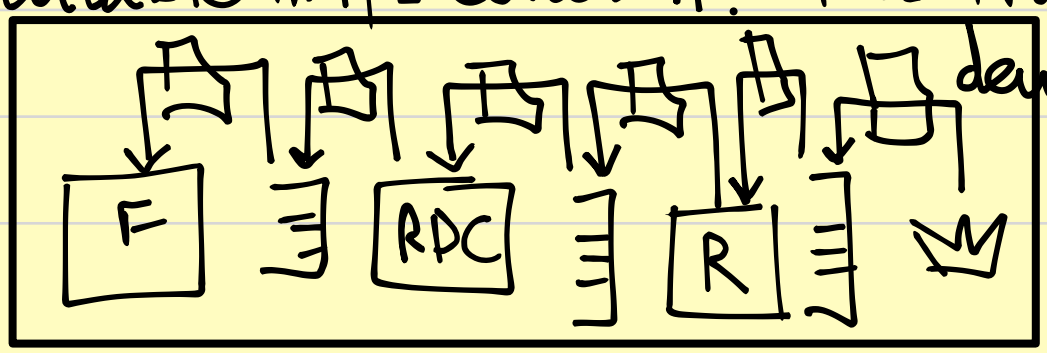
1.2.2. **Echelon Lead Time**. Time it takes to replenish stock at a particular location, considering all upstream echelons. ELT_R = Time delivery RDC to R + Time delivery F to RDC.

1.2.3. **Policies of Inventory Mgmt.**

a) Installation Stock Policies. Each location manages its own stock independently, without considering the stock in upstream echelons. PUSH Process.



b) Echelon Stock Policies. Each location bases its ordering decisions on the total stock available in its echelon. PULL Process.



2. Mathematical models for MEIS

2.1. MEIS. Continuous Review (CR). We monitor inventory levels at each echelon in real-time and reorder stock when inventory falls below a predetermined Reorder Point (ROP). However, unlike single-echelon systems, the ROP is based on echelon Inventory levels, not just local stock levels.

2.1.1. ROP for MEIS

The ROP at a particular echelon is calculated by considering both: ECHELON LEAD TIME & DEMAND VARIABILITY

$$\text{Variability of Demand} = \sigma_d^2 = \frac{\sum_{i=1}^{n} (d_i - D_e)^2}{n-1}$$

The general formula for the ROP in a MEIS is:

$$ROP_e = D_e \cdot LT_e + SS_e$$

- ROP_e: Reorder Point at echelon e
- D_e: Average Demand at echelon
- LT_e: Echelon Lead Time at echelon
- SS_e: Safety Stock at echelon e based on demand variability.

The key difference is that the LT_e accounts for both the time to receive stock from the immediate upstream echelon

and the time it takes for that echelon to receive stock from its upstream sources.

2.2 Example: Consider a supply chain with two echelons 1 & 2.

Echelon 1. A retail store with De = 50 units/day.

Echelon 2. A RDC that supplies the store and receives stock from a central warehouse.

Lead Times: From RDC to Store: 2 Days.

From CW to RDC: 5 Days.

The RDC keeps a stock of 100 units and the store keeps 50 units. The standard deviation of De at the store is 8 units.

Problem Question: Calculate the $ROP_{Retail\,Store}$

Step 1. Calculate the Echelon Lead Time Retail Store.

$LT_{Retail\,Store}$ is the sum of all lead times from both the RDC and the CW.

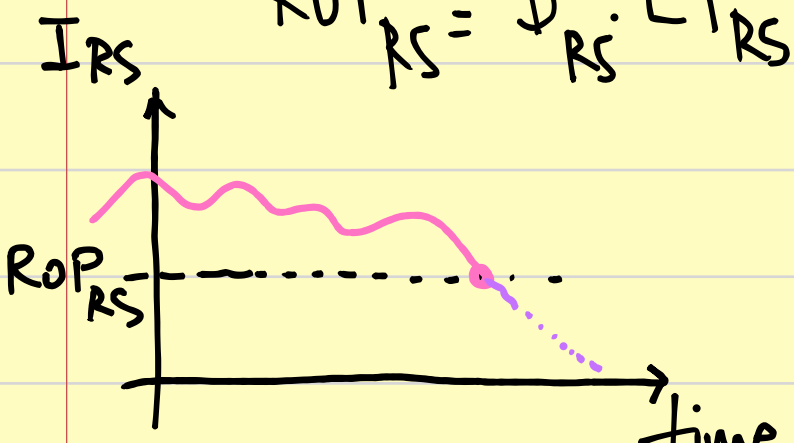
$LT_{RS} = 2\,days + 5\,days = 7\,days$

$LT_{RDC \to Store}$ $LT_{CW \to RDC}$

Step 2. Calculate the ROP_{RS}

ROP_{RS} must cover demand during the entire LT_{RS}.

$$ROP_{RS} = D_{RS} \cdot LT_{RS} + SS_{RS} = 50 \frac{units}{day} \cdot 7 days + 50 units = 400 units$$



1. We get the Z-Value . σ_{RS}
2. We know the $SS_{RS} = 50 units$

2.3. MEIS Periodic Review

Inventory levels are reviewed at set intervals (e.g. weekly) and an order is placed to bring inventory back to a target level. In MEIS we adjust the target level based on echelon stock and lead times.

2.3.1 Order-up-to-level MEIS . (CONWIP)

The order-up-to-level (S) in a MEIS (PR) is the target level of inventory that a location aims to reach after each review. It is calculated by considering the expected demand during both the review period and the echelon lead time, as well as the safety stock required to cover demand variability.

$$S_e = \left[D_e \cdot (T + LT_e) \right] + SS_e$$

Review Period

2.4. Example . Same supply chain as in example 2.2. It uses 30-day Review Period (T) at the retail store.

Calculate Order.Up.to.level(S)?

Step 1. Expected demand during T and LT_e :

$$D_e \cdot (T + LT_e) = 50 \frac{\text{units}}{\text{day}} \cdot [30\text{days} + 7\text{days}] = 1850\text{unit}$$

Step 2. Calculate Order.up.to.level.(S)

$$S = [D_e(T + LT_e)] + SS_e = 1850\text{units} + 50\text{units} =$$

1900 units.

Repeat Ex 2.2 & 2.4 if the SS_{RS} is not known, but we know we aim for 95% safety.

HINT. Z-Score.