Multi Stage Inventory Optimization in EIS
Supply Chain Network Representation

- Traditional modeling approach

- It is the representation of the actual facilities and distribution options.
Supply Chain Inventory Model Representation
Tandem or Series Supply Chain

- Simplest model
- Node vs. Stocking Point
- Single vs. Multi-Stage (Echelon)
- Upstream vs. Downstream
- “Pull” and demand propagation

- Calculation (single stage)
- Optimization (multi stage)
Process and Distribution Supply Chains

Bill of Material (BOM) Matching of input to outputs

- Warehouse
- Distribution Center
- Multi-sourcing
Multi-Stage Dilemma

Customer-facing (CF) node satisfying external demand
- Service Level is 95% (NSP)
- Forecasts are moderately good

Internal warehouse (WH) staging inventory
- Holding cost is half as expensive as CF

How should we allocate safety stock buffers across the stages?

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How should we allocate safety stock buffers across the stages?

1. As much as possible to WH
2. Shared, more to WH
3. Shared, more to CF
4. As much as possible to CF
5. I have no earthly idea
Multi-Stage Dilemma

Customer-facing (CF) node satisfying external demand
- Service Level is 95% (NSP)
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Internal warehouse (WH) staging inventory
- Holding cost is half as expensive as CF

How should we allocate safety stock buffers across the stages?

Different stages should optimally share the risk
- Propagate demand from downstream to upstream
- Model the impact of internal service level (ISL) decision of the upstream stage at the downstream stage

Demand = 100 +/- 50
Capturing Interactions Between Stages

In multi-stage supply chains, stages are all linked together.

Orders placed by the customer-facing node create demand for product upstream.
Upstream service level have an impact on ability to meet service level downstream.

Multi-stage models allow the internal service level of the upstream stage to be modeled at the downstream stage and ensure that service level targets are met.
Multi-stage Example

Two Single Stages

- LT=2
- SS= 267 units
- Cost=$267

- LT=1
- SS= 116 units
- Cost=$232

Cooperative Multi Stage

- LT=2
- SS= 111 units
- Cost=$111

- LT=1
- SS= 124 units
- Cost=$248

Total Cost = $499
Achieved Service Level = 95%

Total Cost = $343
Achieved Service Level = 93%

Total Cost = $359
Achieved Service Level = 95%

Internal Service Level Causes Shortages of 4 +/- 16 units

Increase of 8 units of safety stocks due to internal service level

Decrease of 156 units of safety stocks
Multi-stage Example

### Two Single Stages

- **SS = 267 units**
- **ISL = 99.9%**
- **Cost = $267**
- **LT = 2**
- **PBR = 1**
- **SL = 95%**
- **Demand = 100 +/- 50**

- **SS = 116 units**
- **Cost = $232**
- **LT = 1**
- **PBR = 1**
- **SL = 95%**
- **Demand = 100 +/- 50**

### Cooperative Multi Stage

- **SS = 111 units**
- **ISL = 90%**
- **Cost = $111**
- **LT = 1**
- **PBR = 1**
- **Variability from Internal Service Level Causes Shortages of 4 +/- 16 units**

- **SS = 124 units**
- **Cost = $248**
- **PBR = 1**
- **SL = 95%**
- **Demand = 100 +/- 50**

### Ultra Lean WH Node

- **SS = 0 units**
- **ISL = 50%**
- **Cost = $0**
- **LT = 1**
- **PBR = 1**
- **Variability from Internal Service Level Causes Shortages of 34 +/- 50 units**

- **SS = 178 units**
- **Cost = $356**
- **PBR = 1**
- **SL = 95%**
- **Demand = 100 +/- 50**

- **Total Cost = $499**
- **Decrease of $140**

- **Total Cost = $359**

- **Total Cost = $356**

- **Achieved Service Level = 95%**

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Two-Stage Example: Internal Service Level Impact on Safety Stock Costs

Safety Stock Costs

Optimal ISL = 0.72
Example: Optimal

ISL=99.9%

- SS= 267 units  
  Cost=$267

- SS= 116 units  
  Cost=$232

- Total Cost = $499

Optimal ISL=72%

- SS= 50 units  
  Cost=$50

- SS= 144 units  
  Cost=$288

- Total Cost = $338

- Achieved Service Level = 95%
## Optimal Internal Service Levels Versus Holding Costs

<table>
<thead>
<tr>
<th>Holding Costs</th>
<th>Optimal Internal Non-Stockout Probability</th>
<th>Optimal Internal Fill Rate</th>
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<tbody>
<tr>
<td>CF</td>
<td>WH</td>
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<tr>
<td>2</td>
<td>0.2</td>
<td>93%</td>
</tr>
</tbody>
</table>

- **CF**: Customer Fill
- **WH**: Warehouse
- **LT**: Lead Time
- **PBR**: Performance-Based Rating
- **SL**: Service Level
- **Demand**: 100 +/- 50
- **Holding Costs**: 2%
Multi-Stage Logic for Complex Supply Chains

- Simple search works well for simple supply chains
- For complex supply chains, complete enumeration of all possible combinations is simply not practical
- Simultaneously searching for all optimal internal service levels requires refined optimization mechanisms
- SAP tools embed and employ fast and sophisticated optimization techniques
Safety Stock buffers for all the forms of uncertainty in the supply chain

Safety Stock Key Drivers:

1. **Forecast error variability**
   - Should capture error and bias around forecasts
   - Should reflect demand classification (frequent seller, intermittent, etc.) other characteristics

2. **Service variability**
   - Should capture less-than-perfect service from internal replenishment points

3. **Lead time variability**
   - Should capture variations in lead times due to natural, external forces
   - Should not include the effects of expediting and advance order placements
   - Should not include effects of upstream material unavailability

4. **Supply quantity variability**
   - Should capture variations in received quantities due to natural, external forces
   - Can also account for chronic over- or under-production

- Demand: 100 +/- 25
- PBR: 1, Lead Time: 2
- Service Level = 95%
Thank you