Safety Inventories

Chapter 11 of Chopra
Why to hold Safety Inventory?

- Desire for product availability
  - Ease of search for another supplier
  - “I want it now” culture

- Demand uncertainty
  - Short product life cycles

- Safety inventory
Measures

◆ Measures of demand uncertainty
  – Variance of demand
  – Ranges for demand
◆ Delivery Lead Time, L
◆ Measures of product availability
  – Stockout?
    » Backorder (patient customer, unique product or big cost advantage) or Lost sales.
  – Cycle service level \((CSL)\), % of cycles
  – Product fill rate \((fr)\), % of products
  – Order fill rate, % of orders
    » Equivalent to product fill rate if orders contain one product
Service measures: CSL and fr are different

![Graph showing inventory over time with CSL and fr differences](utdallas.edu/~metin)
Replenishment policies

- When to reorder?
- How much to reorder?
  - Most often these decisions are related.

**Continuous Review**: Order fixed quantity when total inventory drops below Reorder Point (*ROP*). ROP meets the demand during the lead time *L*. One has to figure out the ROP. Information technology facilitates continuous review.
Demand During Lead time

\( D_i \) demand in period \( i \). Mostly \( D_i \sim Normal(R_i, \sigma_i^2) \)

\( f_i, F_i \) probability density and cumulative density functions for \( D_i \)

\[
R_i = E(D_i) = \int D_i f_i(D_i) dD_i \quad Var(D_i) = \sigma_i^2 = E\{(D_i - R_i)^2\} = \int (D_i - R_i)^2 f_i(D_i) dD_i
\]

\[
\text{cov}(D_i, D_j) = \sigma_{i,j}^2 = E\{(D_i - R_i)(D_j - R_j)\} = \int \int (D_i - R_i)(D_j - R_j) f_{i,j}(D_i, D_j) dD_i dD_j
\]

\[
\rho = \frac{\sigma_{i,j}}{\sigma_i \sigma_j} \quad \text{correlation coefficient}
\]

\[
E(\sum_{i=1}^{L} D_i) = \sum_{i=1}^{L} R_i \quad \text{by the linearity of integration}
\]

\[
Var(\sum_{i=1}^{L} D_i) = \sum_{i=1}^{L} \sum_{j=1}^{L} \text{cov}(D_i, D_j) = \sum_{i=1}^{L} \sigma_i^2 + \sum_{i=1}^{L} \sum_{j=1, j \neq i}^{L} \text{cov}(D_i, D_j)
\]
Normal Density Function

Excel statistical functions:
Density function (pdf) at x: normdist(x, mean, st_dev, 0)
Cumulative function (cdf) at x: normdist(x, mean, st_dev, 1)
Cumulative Normal Density

Excel statistical functions:
Cumulative function (cdf) at x: `normdist(x, mean, st_dev, 1)`
Inverse function of cdf at "prob": `norminv(prob, mean, st_dev)`
Demand During Lead Time Determines ROP

Suppose that demands are identically and independently distributed. For identically and independently distributed use iid.

\[
E\left(\sum_{i=1}^{L} D_i\right) = LR \quad \text{and} \quad Var\left(\sum_{i=1}^{L} D_i\right) = L \sigma^2
\]

If \( D_i \sim N(R, \sigma^2) \) then \( \sum_{i=1}^{L} D_i \sim N(LR, L\sigma^2) \)

\[
P\left(\sum_{i=1}^{L} D_i \leq a\right) = \text{Normdist}(a, LR, \sqrt{L} \sigma, 1) = F(a; LR, \sqrt{L} \sigma)
\]

Coefficient of variation of \( D \): \( cv = \sqrt{Var(D) / E(D)} \)
Optimal Safety Inventory Levels

An inventory cycle

inventory

ROP

Q

time

Lead Times
Shortage
Cycle Service Level

Cycle service level: percentage of cycles with stock out

For example consider 10 cycles:

\[ CSL = \frac{1+1+0+1+1+1+0+1+0+1}{10} \]

Write 0 if a cycle has stockout, 1 otherwise

\[ CSL = 0.7 \]

\[ CSL = 0.7 = \text{Probability that a single cycle has sufficient inventory} \]

[Sufficient inventory] = [Demand during lead time ≤ ROP]

ROP: Reorder point

\[ CSL = \text{Cycle Service Level} = F(ROP; R \cdot L, \sqrt{L \sigma}) \]
Continuous Review Policy: Safety Inventory and Cycle Service Level

\[ CSL = F(ROP, R \cdot L, \sqrt{L} \sigma_R) \]
\[ ROP = F^{-1}(CSL, R \cdot L, \sqrt{L} \sigma_R) \]

safety stock = \( ss := ROP - R \cdot L \)

For normally distributed demand:

\[ ss = F^{-1}(CSL, R \cdot L, \sqrt{L} \sigma_R) - R \cdot L \]
\[ = F^{-1}(CSL;0, \sqrt{L} \sigma) = F^{-1}(CSL;0,1) \cdot \sqrt{L} \sigma \]

The last two equalities are by properties of the Normal distribution.

**Average Inventory** = \( Q/2 + ss \)
Example Continuous Review Policy

\( R = 2,500 \text{ /week}; \sigma = 500 \)

\( L = 4 \text{ weeks}; Q = 10,000; ROP = 16,000 \)

Stdev of demand during lead time = \( \sigma \sqrt{L} = \)

\( ss = ROP - L \cdot R = \)

Average Inventory =

Average Flow Time = Average inventory/Thruput =

Cycle service level, \( F(ROP; L \cdot R, \sqrt{L \sigma}) = \)
Finding Safety Inventory for given CSL

\[ R = 2,500/\text{week}; \sigma = 500 \]
\[ L = 2 \text{ weeks}; Q = 10,000; \text{CSL} = 0.90 \]

\[ ss = F^{-1}(\text{CSL};0,1)\sqrt{L\sigma} = \]
\[ ROP = L \cdot R + ss = \]

Factors driving safety inventory
- Replenishment lead time
- Demand uncertainty
Towards the fill rate:

**Expected shortage per cycle**

- ESC is the expected shortage per cycle
- ESC is not a percentage, it is the number of units, also see next page

\[
\text{Shortage} = \begin{cases} 
\text{Demand} - \text{ROP} & \text{if} \quad \text{Demand} \geq \text{ROP} \\
0 & \text{if} \quad \text{Demand} \leq \text{ROP}
\end{cases}
\]

\[
ESC = E(\max\{\text{Demand during lead time} - \text{ROP}, 0\})
\]

\[
ESC = \int_{x=\text{ROP}}^{\infty} (x - \text{ROP}) f(x) dx
\]

- If demand is normal:

\[
ESC = -ss\left(1 - \text{normdist}\left(\frac{ss}{\sqrt{L\sigma}}, 0, 1, 1\right)\right) + \sqrt{L\sigma} \cdot \text{normdist}\left(\frac{ss}{\sqrt{L\sigma}}, 0, 1, 0\right)
\]

- Does ESC decrease or increase with ss, L, stdev of Demand?
- Does ESC decrease or increase with expected value of demand?
Shortage and Demand during Lead Time

\[ \text{Shortage} = x - \text{ROP} \]

\[ \text{x: Demand During LT} \]

\[ \text{Shortage} = x - \text{ROP} \]

\[ \text{ROP} \]
Fill Rate

- Fill rate: Proportion of customer demand satisfied from stock
- $Q$: Order quantity

$$fr = 1 - \frac{ESC}{Q}$$
Evaluating Fill Rate

\( \sigma = 500; \; L = 2 \; \text{weeks}; \; ss=1000; \; Q = 10,000; \)

Fill Rate \((fr) = ? \)

\[
ESC = -ss\left(1 - \text{normdist}\left(\frac{ss}{\sqrt{L\sigma}},0,1,1\right)\right) + \sqrt{L\sigma} \cdot \text{normdist}\left(\frac{ss}{\sqrt{L\sigma}},0,1,0\right)
\]

\[
ESC = -1000(1 - \text{normdist}(1000 / 707,0,1,1)) + 707\text{nomdist}(1000 / 707,0,1,0)
\]

\[
ESC = 25.13
\]

\[
fr = \frac{(Q - ESC)}{Q} = \frac{(10,000 - 25.13)}{10,000} = 0.9975.
\]
Finding Safety Inventory for a Desired Fill Rate

If desired fill rate is \( fr = 0.975 \), how much safety inventory should be held?

Clearly \( ESC = (1 - fr)Q = 250 \)

Use goal seek of Excel to solve

\[
250 = -ss \left[ 1 - \text{normdist} \left( \frac{ss}{707}, 0, 1, 1 \right) \right] + 707 \text{normdist} \left( \frac{ss}{707}, 0, 1, 0 \right)
\]
Evaluating Safety Inventory For Given Fill Rate

<table>
<thead>
<tr>
<th>Fill Rate</th>
<th>Safety Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.5 %</td>
<td>67</td>
</tr>
<tr>
<td>98.0 %</td>
<td>183</td>
</tr>
<tr>
<td>98.5 %</td>
<td>321</td>
</tr>
<tr>
<td>99.0 %</td>
<td>499</td>
</tr>
<tr>
<td>99.5 %</td>
<td>767</td>
</tr>
</tbody>
</table>

Safety inventory is very sensitive to fill rate. Is fr=100% possible?
Factors Affecting Fill Rate

◆ **Safety inventory**: If Safety inventory is up,
  - Fill Rate is up
  - Cycle Service Level is up.

◆ **Lot size**: If Lot size is up,
  - Cycle Service Level does not change. Reorder point, demand during lead time specify Cycle Service Level.
  - Expected shortage per cycle does not change. Safety stock and the variability of the demand during the lead time specify the Expected Shortage per Cycle. Fill rate is up.
To Cut Down the Safety Inventory

◆ Reduce the Supplier Lead Time
  – Faster transportation
    » Air shipped semiconductors from Taiwan
  – Better coordination, information exchange, advance retailer demand information to prepare the supplier
    » Textiles; Obermeyer case
  – Space out orders equally as much as possible

◆ Reduce uncertainty of the demand
  – Contracts
  – Better forecasting to reduce demand variability
Lead Time Variability

Supplier’s lead time may be uncertain:

\[ L = \text{Average lead time.} \quad s^2 = \text{Variance of lead time} \]

\[
E(\sum_{i=1}^{L} D_i) = LR \quad \text{Var}(\sum_{i=1}^{L} D_i) = L \cdot \sigma^2 + R^2 \cdot s^2 =: \sigma_L^2
\]

The formulae do not change:

\[
ss = F^{-1}(CSL;0,1) \cdot \sigma_L = F^{-1}(CSL;0,1) \cdot \sqrt{L \cdot \sigma^2 + R^2 \cdot s^2}
\]

\[
ESC = -ss \left[1 - \text{normdist} \left( \frac{ss}{\sigma_L};0,1,1 \right) \right] + \sigma_L \cdot \text{nomdist} \left( \frac{ss}{\sigma_L};0,1,0 \right)
\]
Impact of Lead Time Variability, $s$

$\bar{R} = 2,500/\text{day}; \sigma = 500$

$L = 7 \text{ days}; Q = 10,000; \text{CSL} = 0.90$

<table>
<thead>
<tr>
<th>$s$</th>
<th>$ss$</th>
<th>Jump in ss</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1695</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>3625</td>
<td>1930</td>
</tr>
<tr>
<td>2</td>
<td>6628</td>
<td>3003</td>
</tr>
<tr>
<td>3</td>
<td>9760</td>
<td>3132</td>
</tr>
<tr>
<td>4</td>
<td>12927</td>
<td>3167</td>
</tr>
<tr>
<td>5</td>
<td>16109</td>
<td>3182</td>
</tr>
<tr>
<td>6</td>
<td>19298</td>
<td>3189</td>
</tr>
</tbody>
</table>
Order at fixed time intervals (T apart) to raise total inventory (on hand + on order) to Order up to Level (OUL)

OUL must cover the Demand during $T + LT$

$LT$ $LT$ $T$
Periodic Review Policy: Safety Inventory

T: Reorder interval

$\sigma_R$: Standard deviation of demand per unit time

$\sigma_{L+T}$: Standard deviation of demand during L+T periods

$OUL$: Order up to level

\[
R_{T+L} = (T + L)R \\
\sigma_{T+L} = \sigma \sqrt{L + T} \\
ss = F^{-1}(CSL;0,1) \cdot \sigma_{T+L} \\
OUL = R_{T+L} + ss
\]
Example: Periodic Review Policy

\[ R = 2,500/\text{week}; \sigma_R = 500 \]

\[ L = 2 \text{ weeks}; T = 4 \text{ weeks}; CSL = 0.90 \]

What is the required safety inventory?

\[ s_s = F^{-1}(CSL;0,1) \cdot \sigma_{T+L} = 1570 \]

Factors driving safety inventory

– Demand uncertainty
– Replenishment lead time
– Reorder interval
Periodic vs Continuous Review

- Periodic review ss covers the uncertainty over $[0,T+L]$, $T$ periods more than ss in continuous case.
- Periodic review ss is larger.
- Continuous review is harder to implement, use it for high-sales-value per time products.
Methods of Accurate Response to Variability

- Physical Centralization
- Information centralization
  - Virtual aggregation, Barnes&Nobles stores
- Specialization, what to aggregate
- Product substitution
- Raw material commonality - postponement
Inventory Pooling

Which of two systems provides a higher level of service for a given safety stock? Consider demands:

\[(R_1, \sigma_1) \quad (R_2, \sigma_2)\]

\[(R_3, \sigma_3) \quad (R_4, \sigma_4)\]

\[R^C = \sum_{i=1}^{k} R_i; \quad (\sigma^C_R)^2 = \sum_{i=1}^{k} \sigma_i^2 + 2 \sum_{i \neq j} \text{cov}(i, j)\]
Sum of Identical Random Variables

\[ \sigma^C_R \leq \sum_{i=1}^{k} \sigma_i \]  
When they are independent

\[ \sigma^C_R = \sum_{i=1}^{k} \sigma_i \]  
When they are perfectly positively correlated

\[ \sigma^C_R = 0 \leq \sum_{i=1}^{k} \sigma_i \]  
When they are perfectly negatively correlated
Factors Affecting Value of Aggregation

◆ Demand Correlation, aggregation is helpful almost always except when products are positively correlated.

◆ Coefficient of Variation of demand: Do not bother to aggregate if the variance is relatively small to begin with.
Impact of Correlation on Aggregated Safety Inventory (4 outlets)

Benefit = SS after aggregation / SS before aggregation
EX 11.8: W.W. Grainger a supplier of Maintenance and Repair products

- About 1600 stores in the US
- Produces large electric motors and industrial cleaners
- Each motor costs $500; Demand is Normal(20,40x40)
- Each cleaning can costs $30; Demand is Normal(1000,100x100)
- Which demand has a larger coefficient of variation?
- How much savings if motors inventoried centrally? How much savings if cleaners inventoried centrally?
EX. 11.8: Specialization: Impact of cv on Benefit From 1600-Store Aggregation, \( h=0.25 \)

<table>
<thead>
<tr>
<th></th>
<th>Motors</th>
<th>Cleaner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean demand/wk</td>
<td>20</td>
<td>1,000</td>
</tr>
<tr>
<td>SD of demand</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>Disaggregate cv</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Value/Unit</td>
<td>$500</td>
<td>$30</td>
</tr>
<tr>
<td>Disaggregate ss value</td>
<td>$105,600,000</td>
<td>$15,792,000</td>
</tr>
<tr>
<td>Aggregate cv</td>
<td>0.05</td>
<td>0.0025</td>
</tr>
<tr>
<td>Aggregate ss value</td>
<td>$2,632,000</td>
<td>$394,770</td>
</tr>
<tr>
<td>Inventory cost savings</td>
<td>102,968,000</td>
<td>15,397,230</td>
</tr>
<tr>
<td>Holding Cost Saving</td>
<td>$25,742,000</td>
<td>$3,849,308</td>
</tr>
<tr>
<td>Saving / Unit</td>
<td>$7.74</td>
<td>$0.046</td>
</tr>
</tbody>
</table>
Slow vs Fast Moving Items

- Low demand = Slow moving items, vice versa.
- Slow moving items have high coefficient of variation, vice versa.
- Stock slow moving items at a central store

Buying a best seller at Amazon.com vs. a Supply Chain book vs. a Banach spaces book, which has a shorter delivery time?

- “Case Interview” books are not in our sku list. You must check with our central stores.
  - Store keeper at Barnes and Nobles at Collin Creek, March 2002.
Product Substitution

- Manufacturer driven
- Customer driven

Consider: The price of the products substituted for each other and the demand correlations

- One-way substitution
  - Army boots. Aggregate?
- Two-way substitution:
  - Grainger motors; water pumps model DN vs IT.
  - Similar products, can customer detect specifications.

If products are very similar, why not to eliminate?
Component commonality. Ex. 11.9

◆ Dell producing 27 products with 3 components (processor, memory, hard drive)

◆ No product commonality: A component is used in only 1 product. 27 component versions are required for each component. A total of $3 \times 27 = 81$ distinct components is required.

◆ Max component commonality. Only three distinct versions for each component. Each combination of components is a distinct product. A component is used in 9 products.

◆ Component commonality provides inventory aggregation.
Example 11.9: Value of Component Commonality in Safety Inventory Reduction
Advantages of Standardization

- Fewer parts to deal with in inventory & manufacturing
  - Less costly to fill orders from inventory
- Reduced training costs and time
- More routine purchasing, handling, and inspection procedures
- Opportunities for long production runs, automation
- Need for fewer parts justifies increased expenditures on perfecting designs and improving quality control procedures.
Disadvantages of Standardization

- Decreased variety results in less consumer appeal.
- Designs may be frozen with too many imperfections remaining.
  - US wireless communication standards vs Europe’s
- High cost of design changes increases resistance to improvements
  - Keyboards: We are using a suboptimal qwerty keyboard. Even more interestingly countries using languages other than English also mostly use qwerty keyboard.
Mass Customization

Mass customization:
- A strategy of producing standardized goods or services, but incorporating some degree of customization
- Modular design
- Delayed differentiation
Mass Customization I: Customize Services Around Standardized Products

Warranty for contact lenses:

Source: B. Joseph Pine

- Deliver customized services as well as standardized products and services
- Market customized services with standardized products or services
- Continue producing standardized products or services
- Continue developing standardized products or services

DEVELOPMENT | PRODUCTION | MARKETING | DELIVERY
Mass Customization II: Create Customizable Products and Services

Gillette sensor adjusting to the contours of the face
Customizing the look of screen with windows operating system

DEVELOPMENT | PRODUCTION | MARKETING | DELIVERY

- Develop customizable products or services
- Produce standard (but customizable) products or services
- Market customizable products or services
- Deliver standard (but customizable) products or services
Mass Customization III: Provide Quick Response Throughout Value Chain

Skiing parkas manufactured abroad:

- Reduce development cycle time
- Reduce Production cycle time
- Reduce selection and order processing cycle times
- Reduce Delivery Cycle Times
Mass Customization IV: Provide Point of Delivery Customization

- Paint mixing
- Lenscrafters for glasses.

- Develop products where point of delivery customization is feasible
- Produce standardized portion centrally
- Market customized products or services
- Deliver standardized portion
- Point of delivery customization

DEVELOPMENT  PRODUCTION  MARKETING  DELIVERY
Mass Customization V: Modularize Components to Customize End Products

Computer industry, Dell computers:

- **DEVELOPMENT**: Develop modularized products.
- **PRODUCTION**: Produce modularized components.
- **MARKETING**: Market customized products or services.
- **DELIVERY**: Deliver customized products.

Diagram:

-箭头从左到右表示从开发到生产、再到营销，最终到交付的流程。
Modular Design

*Modular design* is a form of standardization in which component parts are subdivided into modules that are easily replaced or interchanged.

- A bad example: Earlier Ford SUVs shared the lower body with Ford cars

It allows:

- easier diagnosis and remedy of failures
- easier repair and replacement
- simplification of manufacturing and assembly
Types of Modularity for Mass Customization

Component Sharing Modularity, Dell

Cut-to-Fit Modularity, Gutters that do not require seams

Bus Modularity, E-books

Mix Modularity, Paints

Sectional Modularity, LEGO
Inventory–Transportation Costs:
Eastern Electric Corporation: p.427

- Major appliance manufacturer, buys motors from Westview motors in Dallas
- Annual demand = 120,000 motors
- Cost per motor = $120; Weight per motor 10 lbs.
- Current order size = 3,000 motors
- Lead time = 1 + days in transit
- Safety stock carried = 50% of demand during delivery lead time
- Holding cost = 25%
- Evaluating the mode of transportation under all unit discounting based on shipment weight
  
  » cwt=cent weight=100pounds

utdallas.edu/~metin
## Inventory–Transportation trade off: Eastern Electric Corporation, see p.426-8 for details

<table>
<thead>
<tr>
<th>Alternative (Lot size)</th>
<th>Transport Cost</th>
<th>Cycle Inventory</th>
<th>Safety Inventory</th>
<th>Transit Inventory</th>
<th>Inventory Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Rail (2,000)</td>
<td>$78,000</td>
<td>1,000</td>
<td>986</td>
<td>1,644</td>
<td>$108,900</td>
<td>$186,900</td>
</tr>
<tr>
<td></td>
<td>120000(0.65)</td>
<td></td>
<td></td>
<td>120000(5/365)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northeast Trucking (1,000)</td>
<td>$90,000</td>
<td>500</td>
<td>658</td>
<td>986</td>
<td>$64,320</td>
<td>$154,320</td>
</tr>
<tr>
<td>Golden (500)</td>
<td>$96,000</td>
<td>250</td>
<td>658</td>
<td>986</td>
<td>$56,820</td>
<td>$152,820</td>
</tr>
<tr>
<td></td>
<td>120000(0.80)</td>
<td></td>
<td></td>
<td>120000(3/365)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golden (2,500)</td>
<td>$86,400</td>
<td>1,250</td>
<td>658</td>
<td>986</td>
<td>$86,820</td>
<td>$173,220</td>
</tr>
<tr>
<td>Golden (3,000)</td>
<td>$78,000</td>
<td>1,500</td>
<td>658</td>
<td>986</td>
<td>$94,320</td>
<td>$172,320</td>
</tr>
<tr>
<td>Golden (4,000)</td>
<td>$67,500</td>
<td>2,000</td>
<td>658</td>
<td>986</td>
<td>$109,320</td>
<td>$176,820</td>
</tr>
</tbody>
</table>

If fast transportation not justified cost-wise, need to consider rapid response
Physical Inventory Aggregation:
Inventory vs. Transportation cost: p.428

- HighMed Inc. producer of medical equipment sold directly to doctors
- Located in Wisconsin serves 24 regions in USA
- As a result of physical aggregation
  - Inventory costs decrease
  - Inbound transportation cost decreases
    » Inbound lots are larger
  - Outbound transportation cost increases
Inventory Aggregation at HighMed

Highval ($200, .1 lbs/unit) demand in each of 24 territories
  - $\mu_H = 2$, $\sigma_H = 5$
Lowval ($30$/unit, 0.04 lbs/unit) demand in each territory
  - $\mu_L = 20$, $\sigma_L = 5$
UPS rate: $0.66 + 0.26x$ {for replenishments}
FedEx rate: $5.53 + 0.53x$ {for customer shipping}
Customers order $1H + 10L$
## Inventory Aggregation at HighMed

<table>
<thead>
<tr>
<th></th>
<th>Current Scenario</th>
<th>Option A</th>
<th>Option B</th>
</tr>
</thead>
<tbody>
<tr>
<td># Locations</td>
<td>24</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>Reorder Interval</td>
<td>4 weeks</td>
<td>1 week</td>
<td>1 week</td>
</tr>
<tr>
<td>Inventory Cost</td>
<td>$54,366</td>
<td>$29,795</td>
<td>$8,474</td>
</tr>
<tr>
<td>Shipment Size</td>
<td>8 H + 80 L</td>
<td>2 H + 20 L</td>
<td>1 H + 10 L</td>
</tr>
<tr>
<td>Transport Cost</td>
<td>$530</td>
<td>$1,148</td>
<td>$14,464</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$54,896</td>
<td>$30,943</td>
<td>$22,938</td>
</tr>
</tbody>
</table>

If shipment size to customer is 0.5H + 5L, total cost of option B increases to $36,729.
Summary of Cycle and Safety Inventory

Match Supply & Demand

Reduce Buffer Inventory

Economies of Scale
- Reduce fixed cost
- Aggregate across products
- Volume discounts
- Promotion on Sell thru

Supply / Demand Variability
- Quick Response measures
  - Reduce Info Uncertainty
  - Reduce lead time
  - Reduce supply uncertainty
- Accurate Response measures
  - Aggregation
  - Component commonality and postponement

Safety Inventory

Seasonal Variability

Seasonal Inventory