Hewlett-Packard Co.
Deskjet Printer Supply Chain
About HP

Major product lines include personal computing devices, enterprise servers, related storage devices, as well as a diverse range of printers and other imaging products.

Other product lines, including electronic test equipment and systems, medical electronic equipment, solid state components and instrumentation for chemical analysis were spun off as Agilent Technologies in 1999.
HP posted US$ 118.4 Billion in annual revenue in 2008

Now, HP (Compaq) is the largest worldwide seller of personal computers, surpassing rival Dell,

Prior to 1980’s, Apple -> IBM-> Dell -> HP
Supply Chain Characteristics (Cont’d)

DC

- Three DCs: US, European, Far East
- Make-to-stock => maintain high availability
  - Esp. European DC and Far East DC (far from the factory)
- Inventory = forecasted sales + safety stock
- Management stress: DC’s role is as warehouse
  - Simple, standardized process.
  - No MRP, BOM or component procurement expertise.
The Inventory/Service Crisis

- Happened at European DC
- Inventory level
  - Some models too many while some stock-out
  - Millions of dollars in slow moving inventory
- Service level
  - Desire high level of product availability
    i.e. keep higher inventory level
The Cause of Inventory/Service Crisis

- Poor forecast system
  - The forecast errors especially alarming in Europe
  - Quite common of product shortage from some countries when other models kept piling up

- Improper safety stock calculation
  - In the past, rule of thumb
  - Now, difficult to get accurate forecast => Need to revisit
The Cause of Inventory/Service Crisis (Cont’d)

- Long lead time
  - 4 to 5 weeks to ship the printers to Europe and Asia

- Inventory imbalance
  - Wide variety of models and localized inventory
  - Difficult to forecast the demand for the varied products
Causes of product differences

- Power connections (socket)
- Languages (EU required to provide the language of destined country: 12 of them): 100 pages x 12?

...
Proposed solutions for the crisis at HP

- **Reduce service:**
  - Not acceptable.

- **Reduce lead time from production to demand:**
  - European factory:
    - Eliminates long lead time, but involves significant risk and capital.
  - Air shipments:
    - Too costly to do for all products (when $h = 24\%$)
    - Maybe worth doing with some portion of demand, especially as end-of-life approaches (since then $h > 24\%$)

- **Improve forecasts**

- **Unidentified alternative: postponement strategy- reduce uncertainty:**
  - Use a generic printer and customize only in Europe.
  - Call this “delayed differentiation” or “postponement”
Modified Supply Chain

Factory at VV -> European DC

Finished Printers: Model A

Localization of Goods:
- Model A + power cord + manual + ...

Regional Resellers
- Model A: Germany version
- Model A: France version
- Model A: England version

Inventories are aggregated here. Product differentiation delayed.
Preliminary Analysis

Parameters

- Target Service Level (in-stock prob.) = 98%
- Lead Time = 4 Weeks
- Review Period = 1 Week (every week)

Assumption

- Demand follows Normal Distribution
- Unmet demand is “backlogged”/backordered
What determines the inventory level?

For example, consider delivery of orders takes 2 periods

We are now here
Periodic Review with a Leadtime of 2 Periods

Given: an order of 20 placed 2 period ago; an order of 25 units was placed 1 period ago.
Your current decision affects period $t+L$ --- covering $L+1$ periods

1. Receipt of order $z_{t-1}$
2. On-hand inv. $x_t$
3. Place an order $z_t$
4. Inv. Position
   $$S_t = x_t + z_{t-1} + z_t$$
5. Demand $D_t$ arrives
6. Hold/shortage cost $x_t - D_t$

1. Receipt of order $z_{t-1}$
2. On-hand inv. $x_{t+1}$
   $$= x_t + z_{t-1}$$
3. Place an order $z_{t+1}$
4. Inv. Position
   $$S_{t+1} = x_{t+1} + z_t + z_{t+1}$$
5. Demand $D_{t+1}$ arrives
6. Hold/shortage cost $x_{t+1} - D_{t+1}$

1. Receipt of order $z_t$
2. On-hand inv. $x_{t+2}$
3. Place an order $z_{t+2}$
4. Inv. Position
   $$S_{t+2} = x_{t+2} + z_{t+1} + z_{t+2}$$
5. Demand $D_{t+2}$ arrives
6. Hold/shortage cost $x_{t+2} - D_{t+2}$

Ending inv. $= x_t - D_t + z_{t-1} - D_{t+1} + z_t - D_{t+2}$

$$= S_t - (D_t + D_{t+1} + D_{t+2})$$

On-hand inv. $x_{t+2} = x_t - D_t + z_{t-1} - D_{t+1} + z_t = S_t - (D_t + D_{t+1})$
What determines the inventory level?

**Short answer:**

- *Inventory level* at the end of a period = $S_t$ minus demand over $L + 1$ periods (2+1).

\[
\text{Inventory level at the end of period } t+2 = S_t - D_t - D_{t+1} - D_{t+2}
\]

Keep in mind:

- At the start of a period the inventory level + On-order equals $S$.
- All inventory on-order at the start of period $t$ arrives before the begin. Of period $t+2$
- Nothing ordered in periods $t+1$, ..., arrives by the begin. of period $t+2$
- If all demand is satisfied in period $t+2$, no shortage; o/w, shortage occurs
Actually, at the beginning of period t, we do not know what will happen in demand in periods t, t+1, t+2!

We set $S_t = \text{order-up-to level such that the cycle service level (in-stock probability) in period t+2 to be met}$.
How About the Continuous Review System?

“Attention” is drawn upon only when something occurs.

Review interval is relatively small – demand comes in small quantity – one or a few units each time interval.

“L+1” is not needed.

Thus, you can see the cal. differs for periodic and continuous review systems.
Safety Stock Calculation
Example Europe AB

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Weekly Demand</td>
<td>3656</td>
<td>Monthly / 4.33</td>
<td></td>
</tr>
<tr>
<td>Std. Dev</td>
<td>2703</td>
<td>Monthly/(4.33)^.5</td>
<td></td>
</tr>
<tr>
<td>Lead Time</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std. Dev of Demand Period</td>
<td>6044</td>
<td>2703*(5)^.5</td>
<td></td>
</tr>
<tr>
<td>Safety Factor</td>
<td>1.9</td>
<td>98% service</td>
<td></td>
</tr>
<tr>
<td>Safety Stock</td>
<td>11483</td>
<td>1.9*6044</td>
<td></td>
</tr>
</tbody>
</table>

\[ \text{Safety Stock} = z \times \text{STD} \times \sqrt{\text{LT}+1} \]
Analysis of Findings – Safety Stock

<table>
<thead>
<tr>
<th>Europe Options</th>
<th>Nov</th>
<th>…</th>
<th>Oct</th>
<th>Wkly mean D'd (wk)</th>
<th>STDV (wk)</th>
<th>Safety Stock</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>80</td>
<td>…</td>
<td>42</td>
<td>10</td>
<td>16</td>
<td>72</td>
</tr>
<tr>
<td>AA</td>
<td>400</td>
<td>…</td>
<td>273</td>
<td>98</td>
<td>98</td>
<td>451</td>
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<tr>
<td>AB</td>
<td>20,572</td>
<td>…</td>
<td>9,792</td>
<td>3,681</td>
<td>2,712</td>
<td>12,434</td>
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<tr>
<td>AQ</td>
<td>4,008</td>
<td>…</td>
<td>2,961</td>
<td>535</td>
<td>564</td>
<td>2,583</td>
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<tr>
<td>AU</td>
<td>4,564</td>
<td>…</td>
<td>6,153</td>
<td>978</td>
<td>1,063</td>
<td>4,874</td>
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<tr>
<td>AY</td>
<td>248</td>
<td>…</td>
<td>234</td>
<td>71</td>
<td>50</td>
<td>228</td>
</tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>5574</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total 20,642</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Europe Options</th>
<th>Nov</th>
<th>…</th>
<th>Oct</th>
<th>Wkly Mean D'd</th>
<th>Wkly Std Dev</th>
<th>Safety Stock</th>
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</thead>
<tbody>
<tr>
<td>Total</td>
<td>29,872</td>
<td>…</td>
<td>19,455</td>
<td>5,374</td>
<td>3,011</td>
<td>13,803</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>Total 13,803</td>
</tr>
</tbody>
</table>

Safety Stock Saving ~ 7,000

Assuming localization takes zero time ~ negligible time 33%
Calculate Safety Stock (SS) using European Data

\[ SS = z_{0.98} \sigma \]
Delayed differentiation at HP

**Costs**
- Investments to install localization capability at DCs:
  - Final assembly may be less efficient at DC than Factory.
- Possible delays in responding to demand.
- Quality assurance: who is responsible for quality failure?
- Procurement of localization materials.
- Stocks of localization materials must be high at DCs.

**Benefits**
- Less forecast uncertainty for total demand than demand for each version: leads to lower overall inventory.
- Easier to manufacture a generic printer at factory.
- Lower value of transit inventory, cheaper transportation cost.
- Customs and duties implications.
What happened in HP?

“Localization and customization are manufacturing tasks, not really the resp. of distribution. We are best at moving products.

- Who is going to be resp. for the testing & the ultimate quality of the products?
- Paying the investment to set up the location line? ...
- Training?
- Procuring all power modules and manuals and install software?
- We do not have the system to support all these functions.”

“We have all been engaged in eliminating bon-value-added steps from our supply chain. The printer is shipped in its final form. Your idea would mean that we would have to reopen the carton upon receipt, unpack, perform the localization, test, ... That is simply a lot of non-value-added activities. “

“Why not to `do it right the first time,’ i.e., have the whole thing done at your end, so that we do not have to reopen and reseal the box?”
What happened at HP

- DeskJet Printer was redesigned to be localized at the European DCs.
- Substantial savings reported.
- Service improved substantially.
- New packaging method more than halved the shipping costs (packaging was also done at DCs) – why?
- Duty costs down, supplementing the value of local content.
- Localization now part of design strategy.
- This is a showcase for design for localization.
- Best practice spreads to other HP divisions, and beyond – won many industry awards.
Last few words

- Tradeoff in inventories between manufacturing end and demand end

- Get near-finished/non-customized products at an upper SC location v.s. Finished products at the lower SC location?
Ready to Customization (Configure to Orders)  

Leadtime = 3 wks  

Many SKUs  

The base models made ready  

May carry them for many weeks  

Assembly to Orders  

Leadtime = 3 wks  

Many SKUs
Pet Electronics
ABC Analysis – 4 product categories

No of SKU => 100
A Postponement Strategy

“Currently”: Assemble-to-order: stocking finished varieties in the US DC
- 70 – 90 days of leadtime

Postponement – stocking base models in CM in Shenzhen
- They are stored in CM site
- Final assembly/test is done when orders received
Many SKUs

Leadtime = 3 wks

Many SKUs

2 wks

The base models made ready

May carry them for many weeks

Ready to Customization (Configure to Orders)

7-12 wk

Leadtime = 3 wks

Many SKUs

Assembly to Orders

Many challenges for CM and OEM. Even they belonged to the same company, some challenges remain...