Ordering Systems for Independent Demand

- Important for all types of enterprises

- Independent versus Dependent demand

- Holding Costs
  “out-of-pocket” opportunity or financial

- Transactions Costs

- Shortage Costs

- Marginal, Variable and Average Costs?
ABC Analysis

A 20% of SKUs, 80% of Annual Dollar Volume

B 30% of SKUs, 15% of Annual Dollar Volume

C 50% of SKUs, 5% of Annual Dollar Volume

Inventory position is: On Hand + Ordered but not yet received - Backlog

Inventory Record Keeping

• None

• Periodic Review

• Perpetual Inventory

Physical Inventory Reconciliation

• Increasingly important with increased automation

• Annual

• Cycle
Regular
Event based
Random
Combination
Higher rate for A items than for C

• Accounting Consequences

• Service Consequences
The economic order quantity problem is to find the optimal number of items to order each time, $Q^*$.

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

$$Q^* = \sqrt{\frac{2DS}{H}}$$

NOTES:

- Combine items from a single vendor if they can share order costs.
- Sensitivity analysis can be done by trying other values of the data.
- Notice square root relationship. Also, you can at least check to see if the implied order costs makes sense and/or is consistent across items.
EOQ Example

A construction supply firm, called ABC Corp., buys cement in large quantities from a single factory and then re-sells it to various contractors who use the cement for mortar and concrete. When the cement is delivered they must rent a forklift with an operator for the day at a cost of $200 dollars in order to unload the cement and place it in their warehouse. The hourly rate for the forklift is so high that they always rent it for the day, even if it only takes a few hours to unload. It also costs about $20 to process the paperwork associated with the order and the invoice, including telephone calls for FAX’s. The cost of capital (internal rate of return) used by ABC Corp is 25% per year. The demand for cement varies from day to day, but the annual demand is about 7000 pallets and each pallet costs ABC $160. How much should ABC plan to order each time?

- $H = (0.25)(160) = 40/\text{year}$
- $S = 200 + 20 = 220$
- $D = 7000/\text{year}$

$$Q^* = \sqrt{\frac{2(7000)(220)}{40}} = 277$$

$$n^* = \frac{7000}{277} = 25/\text{year}$$

So ABC Corp should plan to order cement every two weeks.
Setting the Safety Stock

The EOQ is a deterministic model that assumes everything necessary is known. This is a reasonable model for determining roughly how many times to order each year, but we would be foolish if we followed the plan blindly. Once we know approximately how often we should plan to order \( n^* = D/Q^* \) times per year) we can use a more sophisticated model to determine a detailed policy. (We may not use the EOQ to find \( Q^* \), but we still might want to use the next model to find a re-order point).
Important Formula

Formulas for the mean and variance of demand during the lead time are important:

\[ d\bar{LT} = \bar{d}\bar{LT} \]

and

\[ \text{var} dLT = (\text{var} d)(\bar{LT}) + (\text{var} LT)(\bar{d})^2 \]

Let \( \sigma_{dLT} \) be \( \sqrt{\text{var} dLT} \). It is common to set the safety stock as

\[ SS = z\sigma_{dLT} \]

where \( z \) is set to achieve the desired number of stockouts per year. We re-order when the inventory gets down to \( R \) units with

\[ R = d\bar{LT} + z\sigma_{dLT} \]

If we assume that \( DDLT \) follows a normal distribution, we can look up \( z \) in a normal table.
Periodic Review with review period $T$

Very similar to the models that we have developed, but safety stock most also be adequate to cover the extra variance due to the “time when you’re not looking.”
More Issues:

- The book looks at both methods of setting $z$: stockouts per cycle and service level. Service level is much more common.

- The concepts for Fixed-Order-Interval are very similar.

- The table in the book is lovely!
Newsboy

Stock out Prob =

\[
\frac{\text{cost} - \text{salvage value}}{\text{net revenue} + \text{shortage cost} + \text{cost} - \text{salvage value}}
\]

(e.g., use this prob to pick a value for \( z \))

Re-arrange to get implied shortage cost, which is a useful thing to do.
Inventory Discussion

- This is a simple model, but it gives a good starting point for a policy. Of course, if ABC Corp knew that its supplier was going to be late with a shipment, they might begin to ration their cement supply to avoid angering too many customers too much. Other kinds of adjustments are also possible, but the optimum policy from our simple model gives good rules for managers to start with.

- This type of analysis is often done only for important items.

- Why is it sometimes best to use a vendor who is more reliable than one who has a lower price?

- What about emergency suppliers? Hedging?
Multi-Stage

- Some repetition (or we would say job shop)

- Examples from service businesses?

- Bill of Materials (BOM); Parts; SKUs

- End Items, Independent Demand, (Questions of Perspective)

- Dependent Demand

- Master Schedule

- Routings

- Push versus Pull
BOM

- Product Structure Diagrams
- Indented BOM
- Where Used
- BOM explosion
- Requirements explosion
- Low Level Code
Materials Requirements Planning (mrp)

- Establish Time Buckets (e.g. weeks)

- Establish lead times for each SKU (safety lead time?)

- Establish lot sizes, or a lot sizing rule for each SKU, e.g.
  - lot for lot
  - fixed size
  - safety stock?

- Develop a Master Schedule

- Go through the parts, level by level, bucket by bucket (NOT bucket by bucket, level by level) and determine
  - gross requirements
  - scheduled receipts
  - projected inventory position
  - planned order release (for lower level parts in an earlier bucket)
An mrp Example

1. AJ8172:
   
   Production Lead Time: 2 days  
   Minimum Lot Size: 100  
   Components: 2 - LQ8811, 1 - RN0098  
   Initial Inventory: 90

2. LQ8811:
   
   Production Lead Time: 3 days  
   Minimum Lot Size: 400  
   Components: NN1100, WN7342  
   Initial Inventory: 300

3. RN0098:
   
   Order Lead Time: 4 days  
   Minimum Order Quantity: 100  
   Initial Inventory: 100

4. NN1100:
   
   Order Lead Time: 1 day  
   Minimum Order Quantity: 1  
   Initial Inventory: 0

5. WN7342:
   
   Order Lead Time: 12 days  
   Minimum Order Quantity: 1000  
   Initial Inventory: 900
mrp Mechanics

The demand for AJ8172 in the next eight periods is 20, 30, 10, 20, 30, 20, 30, and 40 so mrp gives the following plan for AJ8172.

<table>
<thead>
<tr>
<th>AJ8172</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>20</td>
<td>30</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Inventory Plan (90)</td>
<td>70</td>
<td>40</td>
<td>30</td>
<td>10</td>
<td>80</td>
<td>60</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>Planned Receipts</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned Releases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The planned releases of orders for AJ8172 creates demand for its components. There will be a need for 200 LQ8811s and 100 RN0098s in day 3 and day 6. The initial inventory of WN7342 is adequate for the eight day planning horizon.

<table>
<thead>
<tr>
<th>LQ8811</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>200</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory Plan (300)</td>
<td>300</td>
<td>300</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Planned Receipts</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned Releases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RN0098</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Inventory Plan (100)</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned Receipts</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned Releases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MRP II

- Add routing and capacity data

- Provide Capacity checks
How it Works

- We will refer to the maximum production by a resource during a time bucket as its *capacity*.

- The list of resources used to produce a particular SKU is known as the *routing* for the SKU.

- Routings and capacities are entered into a database.

- Execute mrp to get a schedule

- For each time bucket each SKU is “followed along its routing” and the utilization of each resource is updated.

- Those resources whose capacity would be exceeded by the mrp schedule are identified.
Now What?

- The user can be given a list of the resources and time buckets along with the SKUs that would use the resources in those time buckets.

- and perhaps the list of the end-items that would use these “offending” SKUs and the time buckets in which the end-items would be produced.

- The planner and/or some software can attempt to change the input data so that a feasible schedule results.

- The most common method is to “repair” the master production schedule (i.e., change the timing of the external demands).

- MRP II add-ons (such as I2 and SAP’s SCO) attempt to find capacity feasible schedules.
Problems with MRP and MRP II

- Lead Times depend more on the state of the facility than on the SKU

- Lot Sizing can result in “nervousness” as time rolls forward

- Fences and frozen zones can result in inflexibility

- Capacities are hard to estimate

- Lead Time vicious cycle
JIT and pull based production

- JIT philosophy and History

- Mechanics of Kanban

- Pull Versus Push Based Production

- Mechanics of CONWIP

- Service Implications