OUTLINE

Products & processes (I)

Forecasting (V)

Aggregate planning and Master Production Schedule (MPS) (II)

Material Requirement Planning (MRP) (III)

Planned Work Orders

=> Capacity?

=> Slacks?

=> Shortage?

Work Orders

CONTROL

Planned Requisition

Purchasing

INVENTORY (IV)

SALES ORDER SHIPPING
<table>
<thead>
<tr>
<th>ITEM</th>
<th>SELECT</th>
<th>CODE</th>
<th>LABEL</th>
<th>WAREHOUSE</th>
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<th>Lot sizing</th>
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<tbody>
<tr>
<td>Manufactured</td>
<td>ARM100</td>
<td>Armoire de 100cm</td>
<td>Finished Products</td>
<td>3 days</td>
<td>4</td>
<td>20</td>
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<td></td>
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<tr>
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<td>Armoire de 200cm</td>
<td>Finished Products</td>
<td>3 days</td>
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<td>30</td>
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<td>Etagère de 100cm</td>
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<td>Etagère de 200cm</td>
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<tr>
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<td>Panneau d’étagère de 100cm</td>
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<td>2 days</td>
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</table>
WORKCENTERS

To manufacture ARM 100 and ARM 200, you need in average:

<table>
<thead>
<tr>
<th>WORK CENTERS</th>
<th>ARM 100</th>
<th>ARM 200</th>
<th>Number of workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEC</td>
<td>7 minutes</td>
<td>30 minutes</td>
<td>1 Full Time Equivalent (FTE)</td>
</tr>
<tr>
<td>USI</td>
<td>15 minutes</td>
<td>1 hour</td>
<td>2 FTE/ (1FTE by shift)</td>
</tr>
<tr>
<td>ASE</td>
<td>3 minutes</td>
<td>3 minutes</td>
<td>0.5 FTE</td>
</tr>
<tr>
<td>ASF</td>
<td>9 minutes</td>
<td>9 minutes</td>
<td></td>
</tr>
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</table>

PLANT CALENDAR

- A shift: 8 hours a day, 40 hours a week, 1 month = 20 days.
BILLS OF MATERIALS:

**ARM100**

1 ARM100

2 PANLAT 1 PANA100 4 PROFIL 3 ETA100

0.333 BOIS002 0.25 BOIS002 0.25 LIN40 0.083 BOIS010 4 TAQ000

**ARM200**

1 ARM200

2 PANLAT 1 PANA200 4 PROFIL 3 ETA200

0.333 BOIS002 0.5 BOIS002 0.25 LIN40 0.166 BOIS010 4 TAQ000
## ROUTINGS
Production times for different types of organisation

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<tr>
<th>ITEM</th>
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<th>Label</th>
<th>Mach ine</th>
<th>Set up time (hours)</th>
<th>Operating time (run time) (hours / unit)</th>
<th>Transfer time (hours)</th>
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</thead>
<tbody>
<tr>
<td>ARM100</td>
<td>AR</td>
<td>010</td>
<td>Montage de l’armoire Montage final de l’armoire</td>
<td>ASF</td>
<td>0</td>
<td>0.16 0.133 0.15</td>
<td>0.01 0.001 3</td>
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<td>AR</td>
<td>020</td>
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<tr>
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<td>0.016 0.01 0.013</td>
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<tr>
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</table>

1 Individual organisation  
2 Line organisation  
3 Job-shop organisation
## FORECASTING

<table>
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<th>DATES</th>
<th>SALES FORECAST ARM100</th>
<th>SALES FORECAST ARM200</th>
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<td>10/01</td>
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<td>30/04</td>
<td>320</td>
<td>180</td>
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<td>31/05</td>
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<td>180</td>
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<td>30/06</td>
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<td>31/07</td>
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<tr>
<td>31/08</td>
<td>400</td>
<td>300</td>
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</tbody>
</table>
SESSIONS TP

SESSION I : Conception de Systèmes de production

SESSION II : Planification à moyen terme

SESSION III : Planification à court terme

SESSION IV : Gestion des stocks

SESSION V : Prévisions
SESSION I : Conception des systèmes de production

1.1. Operations sequence
Based on the composition of the finished products (Bill of Material) and the data in table 1, determine the sequence(s) of operations of the production process.

1.2. Individual organisation
One worker is in charge of all the different tasks, and finishes completely one unit before starting another one (the lot size is a single unit).

a) Describe the operations sequence by a Gantt chart.
b) Compute the minimal number of machines needed.
c) Based on the above table, compute for « étagère 100 »:
   - the flowtime,
   - the production rate,
   - the work in progress,

d) How would these indicators change if we produce by lots (lot size > 1) ?
e) How would these indicators change if we hire a second worker ?

1.3. Line organisation
One production line is dedicated for each product (étagère 100 et 200).

a) Represent graphically the line layout.
b) Describe the operations sequence by a Gantt chart.
c) Compute the minimal number of machines needed.
d) If you look at the figures in table 1, you will notice that operating times for the line organisation are smaller than for the two other types of organisations. Which reasons could explain such a difference ?
e) Based on the above table, compute for « étagère 100 »:
   - the flowtime,
   - the production rate,
   - the work in progress,
f) If operating times were random, what would be the advantage of using buffers ? Where would you place them preferentially ?
g) If you could replace a machine with a faster one, which one would you choose ? Why ?

1.4. Job – Shop organisation
All similar tasks are grouped in workshops (ASE, ASF, USI, DEC). At each workshop, a production lot-size and a transfer lot-size are defined.

a) Represent graphically the job-shop layout and the transfers between workshops.
b) Compute the minimal number of machines needed.
c) Explain why it is more difficult to compute the production rate, flow-time and work-in-progress. How could you approximate it ?

1.4. General aspects
Compare the different kinds of organisations with respect to the following points :
   - Necessary equipment
   - Flexibility (for example, if demand suddenly increases, or if the product mix changes)
   - Quality
   - Human aspects
SESSION II : Planification à moyen terme.

The Picasso firm produces two kinds of cupboards: small cupboards 100 centimeters (ARM100) and large cupboards 200 centimeters (ARM200) and wants to make an aggregate planning. From a human resource plan, overtime is no more used.

1. GENERAL ASPECTS
   a. What is the purpose of an aggregate planning?
   b. Which aggregate unit do you propose? How can you obtain this information?

2. DEMAND
   a. Which data do you need to build your aggregate plan for the next eighth months?
   b. Fill the next table and convert forecasting demands $D_t$ in aggregate units for each month. Find the cumulative net requirements $ND_t$ for these months. Represent these cumulative net requirements in a graph.

<table>
<thead>
<tr>
<th>Months</th>
<th>$F_t$ Arm100</th>
<th>$F_t$ Arm200</th>
<th>$D_t$ Arm100</th>
<th>$D_t$ Arm200</th>
<th>$D_t$</th>
<th>$S_t$</th>
<th>$ND_t$</th>
<th>$ND_t$</th>
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<tr>
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<td></td>
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<td>February</td>
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<td>March</td>
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</tbody>
</table>

3. ‘LEVEL’ STRATEGY
   a. Find a constant rate production plan from January to May.
   b. What is the required capacity? At the bottleneck, how many workers should be hired and/or how many machines should we buy?
   c. Find a constant rate production plan from June to August.
   d. Show graphically your production plan.
   e. What is the required capacity?
   f. Your stock capacity is limited to 200 units, is this constraint satisfied? Show graphically your stock level for each period.
   g. One unit cannot stay in stock more than 2 months, is this constraint always satisfied from January to August? Show graphically the minimum and maximum time that units stay in stock.

4. ‘CHASE’ STRATEGY
   a. Determine a production plan that minimizes stock. What is the required capacity? Compare with the results obtained with the constant production plan.
   b. Represent graphically this plan.
   c. How does your plan change if you can not hire more than 2 workers at the bottleneck?
   d. Represent graphically this plan.
The scheduled sales of the two finished products for the next 2 weeks are the following. From the aggregate planning, you have to create a stock of 32 ARM200 for future forecasted demand increase.

<table>
<thead>
<tr>
<th>Periods</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
<th>Day 8</th>
<th>Day 9</th>
<th>Day 10</th>
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<tr>
<td>ARM100</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<td>ARM200</td>
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<td>7</td>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

GENERAL ASPECTS

1. Are these forecasts consistent with those given in Aggregate Planning? How could you explain the stock created only for ARM200?
2. What is the purpose of a MRP? Compare this purpose with those of an aggregate planning and a Master Production Schedule.
3. Your job is to build a MRP. To achieve this goal, which information is needed?
4. Based on the BOM of ARM100 and ARM200, could you give the products for which demand is dependent and products for which demand is independent? Explain the difference between these demands. How could you obtain these two demands?

MRP

1. How many tag000 are used to build 1 ARM100?
2. Could you find for the next 8 days the MRP records to determine how many and when to order PROFIL. Fill by mean of the enclosed tables.

Receipts are scheduled for:

<table>
<thead>
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<th>Scheduled Receipts</th>
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<tbody>
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<td>ARM100</td>
</tr>
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</tr>
<tr>
<td>5, period 2</td>
</tr>
<tr>
<td>5, period 3</td>
</tr>
<tr>
<td>ARM200</td>
</tr>
<tr>
<td>38, period 1</td>
</tr>
<tr>
<td>8, period 2</td>
</tr>
<tr>
<td>8, period 3</td>
</tr>
<tr>
<td>PROFIL</td>
</tr>
<tr>
<td>100, period 1</td>
</tr>
<tr>
<td>ETA200</td>
</tr>
<tr>
<td>20, period 1</td>
</tr>
<tr>
<td>PLET100</td>
</tr>
<tr>
<td>30, period 1</td>
</tr>
<tr>
<td>PLET200</td>
</tr>
<tr>
<td>50, period 1</td>
</tr>
</tbody>
</table>

3. Assume that a particular worker performs transports and that workers at the USI workshop are exclusively responsible for setup and operating jobs. Which data are needed to control the capacity at the USI workshop (CRP)? Could you check if capacity for the first day is sufficient?

LOT SIZING

1. For several products, a fixed lot size is used as lot sizing technique. In which case, is this technique appropriate? Which other techniques could you use? Demonstrate it with PROFIL.
<table>
<thead>
<tr>
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<th>1</th>
<th>2</th>
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<td>Planned Order Release</td>
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Gross Requirement
Scheduled Receipts
On hand
  Without O.R.
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Net Requirement
Planned Order Release
Session IV: Gestion des stocks

In the previous session (MRP), we analysed how to compute the orders (when and how much) for components and raw materials based on the planned orders. In this session, we will analyse how to compute orders (when and how much) based on a statistical distribution of the demand (mean and standard deviation). We will apply these methods to the LIN40 article.

Annual holding cost: 10 € per unit of LIN40,
Supplier order cost: 250 €

GENERAL DATA

1. Deterministic demand
Assume daily demand for LIN40 is 100 and no stockout is allowed.

1.1. Permanent Review
- compute the Economic Order Quantity (EOQ)
- determine the reorder point (that minimises holding costs)
- Show graphically how the stock level evolves over time
- How many times a year do you place an order ?
- Compare order costs and holding costs

1.2. Periodic Review
A periodic review policy can result either from external constraints (i.e. an order frequency imposed by the supplier) or from internal reasons such as order grouping or low inventory turnover.

1.2.1.
Your supplier imposes you to order exactly once a month.
- How many units do you order ?
- Do you expect total costs (holding and inventory costs) to be greater or lower than in 1.1 ?

1.2.2.
Your supplier imposes you to order at least once a month.
- What period do you choose ?
- How many units do you order ?
- Do you expect total costs (holding and inventory costs) to be greater or lower than in 1.1 ?

1.2.3.
In the case of Picasso, identify a possible reason to use a periodic review with a different period from the one found in 1.2.2.
2. Random demand
Assume now the daily demand is normally distributed with an average of 100 and a standard deviation of 20 (=> coefficient of variation = 20 / 100 = 0.2)

When we face a stochastic demand, uncertainty is tackled by adding a safety stock at the beginning of the vulnerability period\(^4\). Different methods exist to compute the safety stock level.

Stockout frequency
Based on a number of yearly allowed stockouts (regardless of the magnitude of these stockouts), we determine the maximum stockout probability per cycle. Based on this probability and the demand distribution, we compute the minimum safety stock level that satisfies this constraint.

Fill Rate
Based on a target percentage of satisfied demand and on the available quantities per cycle, we compute the maximum number of unsatisfied demand per cycle. Using the demand distribution, we find the minimum safety stock level which satisfies this constraint.

2.1. Permanent Review
- Compute the EOQ
- What is the vulnerability period ?

2.1.1 If we target a frequency of maximum 2 stockouts per year, what is the safety stock level ?
- Determine the associated reorder point
- Show graphically the evolution of the stock level

2.1.2.
- If we target a fill rate of 99 %, what is the safety stock level ?
- Determine the associated reorder point

2.2. Periodic Review
2.2.1. Your supplier imposes you to order exactly once per month.
- On average, how many units do you order ?
- What is the vulnerability period ?
- If we target a frequency of maximum 2 stockouts per year, what is the safety stock level ?
- What is the associated replenishment inventory level ?

2.2.2. Your supplier imposes you to order at least once per month.
- What period do you choose ?
- On average, how many units do you order ?
- What is the vulnerability period ?
- If we target a frequency of maximum 2 stockouts per year, what is the safety stock level ?
- Why is it different from the safety stock computed in 2.1.1. ?

\(^4\) At the beginning of the cycle if we are in a periodic review; when we place an order if we are in a permanent review.
3. Optional Questions

- Assume we have two products, X and Y. Both demands follow a normal distribution: \( \mu_x = 100, \sigma_x = 20; \mu_y = 10, \sigma_y = 5 \). As an inventory manager, which product do you prefer (base your reasoning on the average stock level and the annual sales volume) ?

- What are the hidden costs of a permanent review system ?

- Is it possible to have a negative safety stock ? Explain.

- If you determine your safety stock by a maximum stockout frequency, how can you know the corresponding fill rate ?

- Does it make sense to target a 100% fill rate ?

Comparison with MRP

- For which kind of demand is EOQ best suited ?

- For which kind of products is MRP best suited ?
Session V : Prévisions

1.
- What are the main models used in demand forecasting ?
- What the main methods ?

2. Assume demand during the last 12 period is the following:

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- Which model best suits these observations ?
- Assume the three following methods:
  - A linear regression with $a_{12} = 50$ and $b = 0$
  - An exponential smoothing with $\alpha = 0.3$ and $F_{12} = 49$
  - A moving average with $N = 4$

For each of these methods, compute $F_{13}$.
Once $D_{13}$ is known, how do you update your values for each of these methods ?

3. At the beginning of period 13, PICASSO starts to export its products to other european countries. Consequently, observed demand in period 13 is 92 ($D_{13} = 92$).
- Is it relevant to keep these methods unchanged ?
- Which one will best react (i.e. will have the smallest errors for the next forecasts)
- Would you draw other conclusions if the increase of demand was due to a special order of 40 units ?
- What will be the impact on the MAD, TSE and IC ?
- If MAD\textsubscript{12} = 1.9, TSE\textsubscript{12} = 1.067 (assuming we came up with the same figures for each method), what will be the values of MAD\textsubscript{13} and TSE\textsubscript{13} for the two first method? Compute a confidence interval of 95% for F\textsubscript{13}.

4. Optional questions

- Forecasting is very important in production. Could you give in which parts of this course forecasting methods are used? For each of them, what is the impact of a bad forecast, i.e. a large MAD or a large TSE (+/-)?

- Does it make sense to approximate a seasonal demand with
  - a linear regression?
  - an exponential smoothing?
  - Which is worst?

- What is the necessary condition regarding the distribution of errors to build a confidence interval?

- In the exponential smoothing (moving average) method, how should $\alpha$ (N) be tuned with increased unstability of demand?