Production Planning Solution Techniques Part 1 MRP, MRP-II

Mads Kehlet Jepsen
Overview
Overview

- Material Requirement Planning (MRP)
Overview

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- MRP Procedure
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- MRP Procedure
- Issues with MRP
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- Manufacturing Resource Planning (MRP II)
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Material Requirement Planning (MRP)

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- Reorder point is suited for independent demand.
- But not for dependent demand.
- MRP works backwards from independent demand to derive a schedule.
- MRP is called a push system since it pushes items in the production chain.
Overview of MRP
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External orders is called Purchase orders.
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- Time is divided into buckets.
- The bill of material (BOM) describes relationship.
- The routing describes the work processes.
Schematic of MRP

- Item master (BOM)
- On-hand inventory
- Scheduled receipts
- Master production schedule

MRP:
- Netting
- Lot sizing
- Offsetting
- BOM exploding

- Planned order releases
- Change notices
- Exception notices
MRP Inputs and Outputs
MRP Inputs and Outputs

- Master Production Schedule:
MRP Inputs and Outputs

- Master Production Schedule: Item, Quantity and due dates.
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- MRP outputs: Planned order release, Change notices and Exception reports.
MRP Procedure
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- $D_t$ gross requirements (demand) for period $t$
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- $N_t$ net requirements for period $t$
MRP Procedure: Netting
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1. Compute $I_t = I_{t-1} - D_t \quad \forall t$
MRP Procedure: Netting

1. Compute \( I_t = I_{t-1} - D_t \quad \forall t \)
2. Find \( t_m = \{\min_{1 \leq t \leq T} : I_t < 0\} \)
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1. Compute $I_t = I_{t-1} - D_t \quad \forall t$

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4. Adjust projected on-hand inventory to $I_t = I_t + S_t$
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4. Adjust projected on-hand inventory to \( I_t = I_t + S_t \)
5. Find \( t^* = \{ t | I_t < 0 \} \)

Net requirement follows as:

\[
N_t = \begin{cases} 
0 & t < t^* \\
-I_t & t = t^* \\
D_t & t > t^*
\end{cases}
\]
### Netting example

<table>
<thead>
<tr>
<th></th>
<th>15</th>
<th>20</th>
<th>50</th>
<th>50</th>
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I_3 = I_2 - D_3 = -45
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N_3 = -I_3 = 45
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\[
N_4 = D_4 = 50
\]
MRP Procedure continued
Lot sizing:
MRP Procedure continued

Lot sizing:

Wagner Whitin
MRP Procedure continued

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MRP Procedure continued

- Lot sizing:
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MRP Procedure continued

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Time fasing. All lead times are considered for items, not for status on floor
MRP Procedure continued

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Time fasing. All lead times are considered for items, not for status on floor

Bom Explosion. Netting and lot sizing is done for each sub item.
Part Period Balancing

- Number of items \( n \)
- Number of Periods \( p \) the item is carried in the inventory.
- Part Period cost is \( n \times p \)
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Production Planning Solution Techniques Part 1 MRP, MRP-II – p.11/31
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<td>10</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Quantity 1</td>
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<td>Part-Periods</td>
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</tr>
<tr>
<td>10</td>
<td>30</td>
<td>0</td>
<td>0</td>
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<tr>
<td>25</td>
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</tr>
<tr>
<td>35</td>
<td>30</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>
Part Period Balancing

- Number of items $n$
- Number of Periods $p$ the item is carried in the inventory.
- Part Period cost is $n \times p$

Example:

<table>
<thead>
<tr>
<th>Period</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
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- System Nervousness. Plans that are feasible can become infeasible.
Questians or comments to MRP

Are there any questians or comments ?
Address deficiencies in MRP
Manufacturing Resource Planning

- Address deficiencies in MRP
- Brings in new functionalities including:
Manufacturing Resource Planning

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Long-Range Planning

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- Resource Planning. Determines long time capacity need. Is used to decide is knew facilities must be build or old facilities must be expanded.
- Aggregate Planning. Determines how inventory is build. Do we use overtime or do we carry inventory over a long period.
Intermediate Planning

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- Master Production Schedule: Generates an anticipated production schedule.
- Rough-cut Planning: Provides a schedule where the capacity on critical resources is meet.
- Capacity Requirements Planning: Does not perform actual capacity check. CRP assumes infinite capacity on resources. Basically it just calculates finish dates based on fixed lead times.
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- Job release Converts jobs to scheduled receipts. Resolves conflicts if several high-level items uses same low-level item.
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  - Least slack per remaining operation Divide slack with number of operation remaining on routing.
Are there any questions or comments?
Rough-Cut Capacity Planning (RCCP)

- Considers aggregated work
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- $\frac{1}{p_j}$ is the maximum fraction of a job that can be completed in a week.
Precedence constraints

If job $J_i$ must finish before $J_j$, there is a precedence relation. For a period $\tau$ this can be modelled as:
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There will be $d_j - r_j$ constraints per precedence relation. Time windows can in some cases be tightened, due to precedence constraints.
Nonregular capacity

Let $Q_{kt}$ denote the nonregular capacity for resource $k$ in period $t$. Then for each resource and time period:
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The cost of using nonregular capacity for resource $k$ in time period $t$ is $c_{kt}$. It is assumed that there is no limit on the nonregular resources.
Mathematical Model

\[
\begin{align*}
\min & \quad \sum_{t=1}^{T} \sum_{k=1}^{K} c_{kt} U_{kt} \\
\text{subject to} \quad & \quad \sum_{t=r_j}^{d_j} x_{jt} = 1 \quad 1 \leq j \leq n \\
& \quad x_{jt} \leq \frac{1}{p_j} \quad 1 \leq j \leq n, 1 \leq t \leq T \\
& \quad \sum_{j=1}^{n} q_{jk} x_{jt} - U_{kt} \leq 0 \quad 1 \leq j \leq n, 1 \leq t \leq T \\
& \quad x_{jt}, U_{kt} \geq 0 \quad 1 \leq j \leq n, 1 \leq t \leq T
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Controlling feasibility

Allowed To Work window for job $J_j$ is defined as $[S_j, C_j]$. 
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2. $C_j - S_j \geq p_j - 1$
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1. Every ATW window is feasible
2. $S_j > C_j$ if $J_i \rightarrow J_j$
Mathematical Model ATW windows

\[ s_{jt} = \begin{cases} 
1 & S_j \leq t \leq C_j \\
0 & \text{otherwise} 
\end{cases} \]

\[(P_S) \min \sum_{t=1}^{T} \sum_{k=1}^{K} c_{kt} U_{kt} \]

subjectto

\[ \sum_{t=r_j}^{d_j} x_{jt} = 1 \quad 1 \leq j \leq n \]

\[ x_{jt} \leq \frac{s_j}{p_j} \quad 1 \leq j \leq n, 1 \leq t \leq T \]

\[ \sum_{j=1}^{n} q_{jk} x_{jt} - U_{kt} \leq 0 \quad 1 \leq j \leq n, 1 \leq t \leq T \]

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Constructive heuristics \( H_{BASIC} \)

- Construct a feasible set \( S \) of ATW windows.
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Have I forgotten an important assumption?
Constructive heuristics ($H_{CPM}$)

Define the slack of job $J_j$ as $L_j = C_j - (S_j + p_j)$
Constructive heuristics (HCPM)

- Define the slack of job \( J_j \) as \( L_j = C_j - (S_j + p_j) \)
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A critical path is a path where:

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\begin{align*}
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Production Planning Solution Techniques Part 1 MRP, MRP-II – p.27/31
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- $\{J_{i_l}, J_{i_1}, J_{i_2}, \ldots, J_{i_k}\}$ is critical
Initialize $S_j = r_j$ and $C_j = d_j$ for all $J_j$
$(H_{CPM})$ continued

- Initialize $S_j = r_j$ and $C_j = d_j$ for all $J_j$
- Compute the slack for all jobs
(H_{CPM}) continued

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(H<sub>CPM</sub>) continued

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- Set \( S_{j_i} = S_{j_1} + \sum_{k=1}^{i-1} p_{i_k} + |\bar{L} \sum_{k=1}^{i-1} p_{i_k} / \sum_{k=1}^{R} p_{i_k}| \)
Initialize $S_j = r_j$ and $C_j = d_j$ for all $J_j$

Compute the slack for all jobs

Find a maximal critical path $\{J_{i_1}, J_{i_2}, \ldots, J_{i_k}\}$

Compute the total slack $\bar{L} = C_{j_R} - (S_{j_1} + \sum_{i=1}^{R} p_{ji})$

Set $S'_{ji} = S_{j_1} + \sum_{k=1}^{i-1} p_{ik} + |\bar{L} \sum_{k=1}^{i-1} p_{ik} / \sum_{k=1}^{R} p_{ik}|$

Change to $C'_{i_k} = S'_{i_{k+1}} - 1$
$H_{CPM}$ example

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$\bar{L} = C_4 - (0 + 20) = 5$
$H_{CPM}$ example

\begin{center}
\begin{tabular}{|c|c|c|c|c|}
\hline
 & 1 & 2 & 3 & 4 \\
\hline
S & 0 & 5 & 15 & 20 \\
\hline
C & 10 & 15 & 25 & 30 \\
\hline
p & 5 & 5 & 10 & 5 \\
\hline
\end{tabular}
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$\bar{L} = C_4 - (0 + 20) = 5$

Recall $\hat{S}_{ji} = S_{ji} + \sum_{k=1}^{i-1} p_{jk} + |\bar{L} \sum_{k=1}^{i-1} / \sum_{k=1}^{R} p_{jk}|$
$H_{CPM}$ example

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$S_2 = 0 + 5 + \frac{5 \times 5}{25} = 6$
### HCPM Example

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\[
\bar{L} = C_4 - (0 + 20) = 5
\]

Recall \( \hat{S}_{j_i} = S_{j_i} + \sum_{k=1}^{i-1} p_{jk} + \left| \frac{\bar{L} \sum_{k=1}^{i-1} / \sum_{k=1}^{R} p_{jk}}{\sum_{k=1}^{R} p_{jk}} \right| \)

\( S_2 = 0 + 5 + \frac{5 \times 5}{25} = 6 \)

\( S_3 = 0 + 10 + \frac{10 \times 5}{25} = 12 \)
\[ H_{CPM} \] example

\[
\begin{array}{c|cccc}
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\end{array}
\]

\[ \bar{L} = C_4 - (0 + 20) = 5 \]

Recall \( \hat{S}_{ji} = S_{ji} + \sum_{k=1}^{i-1} p_{jk} + \left| \bar{L} \sum_{k=1}^{i-1} / \sum_{k=1}^{R} p_{jk} \right| \)

\[ S_2 = 0 + 5 + \frac{5*5}{25} = 6 \]

\[ S_3 = 0 + 10 + \frac{10*5}{25} = 12 \]

\[ S_4 = 0 + 20 + \frac{20*5}{25} = 24 \]
\[ H_{CPM} \text{ example} \]

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\[ \bar{L} = C_4 - (0 + 20) = 5 \]

\[
\hat{S}_{ji} = S_{ji} + \sum_{k=1}^{i-1} p_{jk} + \frac{\bar{L} \sum_{k=1}^{i-1} p_{jk}}{\sum_{k=1}^{R} p_{jk}}
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\[ S_2 = 0 + 5 + \frac{5 \times 5}{25} = 6 \]

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\[ S_4 = 0 + 20 + \frac{20 \times 5}{25} = 24 \]

\[ C_1 = S_2 - 1 = 5, \quad C_2 = 11, \quad C_3 = 23 \]
Neighbourhoods
Neighbourhoods

For job $J_j$ increase $S_j$ or decrease $C_j$.
Neighbourhoods

- For job $J_j$ increase $S_j$ or decrease $C_j$

- Decrease $S_j$ implies $S_j > r_j$, $C_k = S_j - 1$ for any preceding job $J_k$ and $C_k - S_k \geq p_k$
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- Decrease $S_j$ implies $S_j > r_j$, $C_k = S_j - 1$ for any preceding job $J_k$ and $C_k - S_k \geq p_k$
- Neighbourhood can be ordered after the greedy choice or the steepest edge rule.
Exercises

Ex 1 Suggest some improvements for 2-3 of the modules in the MRP II model. You should describe what additional data the system and need and what value it would add for the users.
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- Ex 2.3 Describe a heuristic for the resource driven RCCP. The heuristic should include a constructive heuristic and a improvement heuristic.