Production Scheduling

MRP, TOC & Lean

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Microsoft Corporation
Outline

- Product & production classification
- MRP, CRP and job dispatching
- TOC scheduling
- Lean scheduling
- Is production scheduling dead?
Product classifications

• Discrete products
  – Make-to-order
    • Projects scheduling
    • Job shop
  – Make-to stock/make-to-order parts
    • Production scheduling
    • Flow shop
    • Independent products
    • Dependant parts
    • Bill of material relates independent demand to dependent demand

• Continuous products
Production classifications

- **Job shop production**
  - Single jobs
  - Make to order

- **Batch & queue production**
  - Departmental
  - Traditional layout

- **Flow shop production**
  - Cellular manufacturing
  - Group technology
<table>
<thead>
<tr>
<th>Part A</th>
<th>Period (Time bucket)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Gross requirements</strong></td>
<td></td>
</tr>
<tr>
<td>At beginning of period</td>
<td>10</td>
</tr>
<tr>
<td><strong>Schedules receipts</strong></td>
<td></td>
</tr>
<tr>
<td>At beginning of period</td>
<td>50</td>
</tr>
<tr>
<td><strong>Projected available balance</strong></td>
<td></td>
</tr>
<tr>
<td>At end of period</td>
<td>4</td>
</tr>
<tr>
<td><strong>Planned order releases</strong></td>
<td></td>
</tr>
<tr>
<td>At beginning of period</td>
<td></td>
</tr>
<tr>
<td><strong>Lead time = period</strong></td>
<td></td>
</tr>
<tr>
<td>Lot size = 50</td>
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<tr>
<td>Planning horizon = 5 periods</td>
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</tr>
</tbody>
</table>

Lead time = period
Lot size = 50
Planning horizon = 5 periods
MRP – BOM Explosion

**Precedence relationship**

- **Independent demand**
  - A
  - A'

- **Dependant demand**
  - B
  - B'
  - C
  - D

<table>
<thead>
<tr>
<th>Part</th>
<th>Inventory</th>
<th>Scheduled Receipts</th>
<th>Gross Requirements</th>
<th>Net Requirements</th>
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<tbody>
<tr>
<td>A</td>
<td>70</td>
<td>--</td>
<td>60</td>
<td>10</td>
</tr>
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<td>B</td>
<td>--</td>
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<td>70</td>
<td>10</td>
</tr>
<tr>
<td>B'</td>
<td>10</td>
<td>--</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>C</td>
<td>--</td>
<td>--</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>D</td>
<td>--</td>
<td>30</td>
<td>20</td>
<td>15</td>
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</table>
MRP – Back scheduling

Also known as backward loading
MRP - enhancements

- Calculation frequency
  - Gross calculation
  - Net change calculation
- Bucketless system
- Lot sizing
  - Lot-for-lot most common
  - Setup vs inventory carry cost trade-off
- Safety stock and safety lead times
  - Made bigger when there is more uncertainty
- Pegging
  - Tie sales orders to production, transfer and purchase orders
- Firmed planned orders
  - Prevent changes to planned orders
### CRP– Capacity Requirements

<table>
<thead>
<tr>
<th>Part</th>
<th>Lot Size</th>
<th>Operation</th>
<th>Work center</th>
<th>Setup hours</th>
<th>Setup hours/unit</th>
<th>Run time hours/unit</th>
<th>Total hours/unit</th>
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</thead>
<tbody>
<tr>
<td>A'</td>
<td>50</td>
<td>1of1</td>
<td>100</td>
<td>1.0</td>
<td>.02</td>
<td>.025</td>
<td>.045</td>
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### Part A

<table>
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<th>Period (Time bucket)</th>
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<td>50</td>
</tr>
<tr>
<td><strong>Projected available balance</strong></td>
<td>4</td>
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<tr>
<td>At end of period</td>
<td>54</td>
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<td>4</td>
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</tr>
<tr>
<td><strong>Planned order releases</strong></td>
<td>50</td>
</tr>
<tr>
<td>At beginning of period</td>
<td></td>
</tr>
<tr>
<td><strong>Hours of capacity Required on work center 100</strong></td>
<td></td>
</tr>
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</table>

**Forward load if capacity constraint**
Job Dispatching

- Conflict resolution strategies to decide on which job takes precedence at a work center
  - Minimum processing time
    - best in efficiency and flow rate measures
  - Minimum slack time per operation
    - Slack time = time till due date/processing time left
    - best in meeting due dates
  - Critical ratio
    - remaining time till due date/remaining processing time
  - First come first served
    - worse than random
  - Minimum planned start date
    - worse than random
  - Minimum due date
  - Random selection

- Results based on Hughes Aircraft study
Theory of Constraints

• Schedule mix on bottleneck work center first to optimize throughput profit calculation.
  – Job dispatch rule is to schedule jobs with highest throughput dollars/minute of bottleneck processing value first.
• Backward load scheduled jobs from bottleneck schedule.
• Forward load scheduled and unscheduled jobs from bottleneck schedule.
• Inflate lead times to account for variation.
• Place inventory buffers at constraints and at shipping.
• Continuously improve process by moving constraint to the market
Lean – Process design and analysis

• For each product
  – Create future value stream map for process
  – Measure material wait time and processing time
  – Measure operator work time
  – Create pacemaker cell
  – Identify constraints

• Design product families so that operator work content for each product in family is within 30% of each other – rule of thumb.

• Change factory layout – usually necessary
• Create schedule only for the pace maker cell (this is not the constraint)

• Calculate average takt time to determine demand rate. Takt time should be close to cycle time at pace maker.

\[
\text{Effective working time} = \text{Sum(demand during working time)}
\]

• Calculate pace maker capacity requirements

\[
\text{Sum(cycle time x demand)}
\]

\[
\text{Effective working time}
\]

• Calculate the product family interval to determine batch size (EPEI). Interval is total time to produce every product in product family.
  
  – E.g. if it takes a month to produce the products then the batch size is one months worth or products.
Lean – work design and analysis

**Operator Balance Chart**

- **120 Takt time**

- **Time**: 0, 20, 40, 60, 80, 100, 120, 140, 160, 180

- **Operators**
  - 1
  - 2
  - 3
  - 4

No good
Lean – work design and analysis

Use CPI to remove under utilized operator

Takt time
• Place a FIFO buffer between the pace maker cell and the constraint when product cycle time is greater than takt time.

• Buffer size:

$$\frac{(\text{Product Cycle Time} - \text{Takt time}) \times \text{volume}}{\text{Takt time}}$$
Lean – Balance flow

Option #1:
- Discrete Parts
- Low Demand Variation
- High Volume

Level mix, sequence orders based on work content and pull signals

Pacemaker
- 90–150 seconds
- Number of operators always constant
- Output varies based on work content

Test
- 90–200 seconds

Kanban path

Supermarket

Ship
Lean – Balance flow

Option #2:
- Discrete Parts
- Custom Parts
- Low Demand Variation

Customer demand

Production Control

Build ahead, leveled mix

ACBCBCABC

Pacemaker
- Number of operators always constant
- Output varies based on work content
- 50–150 seconds

Test
- 90–200 seconds

Ship
- 1–2 Days

FIFO

Microsoft Dynamics
Lean – Balance flow

Option #3:
- Discrete Parts
- Custom Parts
- High Demand Variation

Customer demand

Production Control

Kanban path

Supermarket of main products

Pacemaker
90–150 seconds

Test
90–200 seconds

Ship

Number of operators always constant

FIFO

Build to demand as much as possible

Output varies based on work content
Is production scheduling dead?

• Lean does not optimize throughput
  – Single piece continuous flow not optimum
  – Not necessary to control every resource
  – Simple rules of thumb to design process and schedule
  – No push/pull inventory boundary
  – Need to take what we have learnt from MRP, TOC and Lean and revisit system behavior fundamentals and build them into robust throughput optimization models
• Variance (1918): \( \sigma^2 = \frac{1}{N} \sum (x_i-\mu)^2 \)
• Queueing (1961): \( N = \lambda T \)
• Accounting (1980’s): \( T = P - TVC \)