TU-E2020

Capacity Planning and Management, and Production Activity Control
ISA-95: Manufacturing IT System - positioning

Level 4: Business Planning & Logistics
- Establishing the basic plant schedule - production, material use, delivery, and shipping. Determining inventory levels.
  - Time Frame: Months, weeks, days

Level 3: Manufacturing Operations Management
- Work flow / recipe control to produce the desired end products. Maintaining records and optimizing the production process.
  - Time Frame: Days, Shifts, hours, minutes, seconds

Level 2: Batch Control, Continuous Control, Discrete Control
- Monitoring, supervisory control and automated control of the production process
  - Time Frame: Hours, minutes, seconds, subseconds

Level 1: Control
- Sensing the production process, manipulating the production process

Level 0: The actual production process

Kuva. ANSI/ISA—95.00.03 Multi-level functional hierarchy of activities
ISA-95 Standard on Production Planning

ANSI/ISA-95.00.03-2005

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**Business plan** *(APICS terminology)*
(Per Product Line, Per Time – Very Long Time Horizon)

- Demand plan* *(APICS terminology)*
(Per Product, Per Time – Long Time Horizon)
  - 1.1 Production Forecasting Activity *(ISA-95.01)*

- Production plan* *(APICS terminology)*
(Per Product, Per Time – Long Time Horizon)
  - 2.4 Production scheduling activity *(ISA-95.01)*

- Production schedule – *(Master production schedule – APICS terminology)*
(Per Site/Area, Per Product, Per Time – Medium Time Horizon)
  - Detailed production scheduling activity *(ISA-95.03)*

- Detailed production schedule
(Per Workcenter, Per Product/Intermediate, Per Time – Short Time Horizon)
  - Production dispatching activity *(ISA-95.03)*

- Production Dispatch list
(Per Workcenter or Workcenter element, Per produced Item, Per Time – Very Short Time Horizon)

Figure 32 - Sample hierarchy of schedules and scheduling activities.

APICS (the Association for Operations Management)
Different capacity planning options

Capacity to match maximum demand

Capacity to match average demand

Capacity is adjusted to demand

Outsourcing of peaks OR

Outsourcing the base load

Complimentary products
APS (web-client): Finite Capacity Scheduling

- Order sequence
- Highlight: Progress, Qty, Late, Material shortage
- Resource Work queue
- Resources
- Maintenance/breakdown
- Time line
- Production status ON-LINE:
  - Grey = Done
  - Green = In progress
  - Yellow = To be done

Worker capacity / resource work load
Two main managerial problems related to capacity planning and management

1. Matching capacity with the plans
   - Either to provide sufficient capacity to execute the plans…
   - …or to adjust plans to match capacity constraints

2. Trade-off between time and capacity utilization
   - Fast throughput typically requires underutilization of some capacity in the system
   - High priority scheduling results in fast throughput for the high priority jobs…but with the expense of longer throughput times for lower priority jobs and underutilization of some capacity
Role of capacity planning in PPC

- The primary objective of capacity planning techniques is to estimate capacity requirements early enough to be able to meet those requirements.
- Flawless execution of the capacity plan allows the firm to avoid unpleasant surprises:
  - Insufficient capacity leads to deteriorating delivery performance.
  - Excess capacity may be a needless expense.
### Links to the other PPC system modules

**Resource planning**
- Linked to sales and operations planning (SOP)
- Converts SOP data to aggregate resource units

**Rough-cut planning**
- Linked to Master Production Schedule (MPS)
- Estimates capacity requirements of MPS

**Capacity Requirements Planning**
- Linked to material requirements planning (MRP)
- Prepares detailed capacity plan based on time-phased material plans

**Finite loading**
- Linked to material planning and shop floor control
- Considers adjustment of plans due to capacity utilization

**Input/output analysis**
- Linked to shop floor control
- Monitors actual consumption of capacity during execution of detailed material planning
Infinite and finite capacity planning

• Providing sufficient capacity to execute plans represents infinite approaches to capacity planning

• Adjusting manufacturing plans to match capacity constraints represents finite approaches to capacity planning
Capacity increase and reduction

• Increase capacity by more
  – overtime & hiring
  – more tools & machines

• Reduce capacity requirements by
  – more subcontracting
  – alternate routings
  – revised customer delivery dates
Infinite capacity planning

- Periodic
- No capacity constraints
- Does not consider any adjustment to plans because of planned capacity utilization
Finite scheduling/loading

- Schedules work through work centers only to the extent that there is capacity available to do so
- Capacity constraints will define order completion times
Capacity planning and control techniques

- Capacity planning using overall factors (CPOF)
- Capacity bills
- Resource profiles
- Capacity requirements planning (CRP)
Capacity planning using overall factors (CPOF)

• Simplest rough-cut capacity planning approach
• Data inputs from Master Production Schedule
• Based on planning factors from historical data (work center utilization, production standards)
• Overall labor- or machine-hour capacity requirements are estimated from MPS data
  – Estimate is allocated to work centers based on historical workloads
• Inaccuracies may limit usefulness
Bill of Capacity

- Rough-cut capacity planning method that provides more direct link to individual end products
- Bill of capacity indicates total standard time to produce one unit of an end product by work center
- MPS data is then used to estimate capacity requirements for each work center
- Requires more data than CPOF procedure
**Bill of Capacity**

### Product Structure Data

- **A**
  - **C**
  - **D**
- **B**
  - **D**
    - **E** (2 required)
    - **F** (2 required)

**Routing and Standard Time Data**

<table>
<thead>
<tr>
<th>Lot Sizes</th>
<th>Operation</th>
<th>Work Center</th>
<th>Standard Setup Hours</th>
<th>Standard Setup Hours per Unit</th>
<th>Standard Run Time Hours per Unit</th>
<th>Total Hours per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>End Products</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>40</td>
<td>1 of 1</td>
<td>100</td>
<td>1.0</td>
<td>0.025*</td>
<td>0.025</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>1 of 1</td>
<td>100</td>
<td>1.0</td>
<td>0.050</td>
<td>1.250</td>
</tr>
<tr>
<td><strong>Components</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>40</td>
<td>1 of 2</td>
<td>200</td>
<td>1.0</td>
<td>0.025</td>
<td>0.575</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 of 2</td>
<td>300</td>
<td>1.0</td>
<td>0.025</td>
<td>0.175</td>
</tr>
<tr>
<td>D</td>
<td>60</td>
<td>1 of 1</td>
<td>200</td>
<td>2.0</td>
<td>0.033</td>
<td>0.067</td>
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<tr>
<td>E</td>
<td>100</td>
<td>1 of 1</td>
<td>200</td>
<td>2.0</td>
<td>0.020</td>
<td>0.080</td>
</tr>
<tr>
<td>F</td>
<td>100</td>
<td>1 of 1</td>
<td>200</td>
<td>2.0</td>
<td>0.020</td>
<td>0.0425</td>
</tr>
</tbody>
</table>

*Std. Setup hours are spread over the standard lot size*

†Total hours include both std. run time and std. setup time
Resource profiles

- Rough-cut capacity planning technique that includes production lead time information
- Provides time-phased projections of capacity requirements for individual work centers
- More sophisticated approach but requires tracking of relatively short lead time periods compared to the planning horizon
Production of one unit of product A in period 5 requires production activity in periods 3, 4, and 5 and in work centers 100, 200, and 300.
Resource profile example

Requirements (by work center and period) for one unit of end product are multiplied by the MPS plan to determine capacity requirements. These requirements are then summed over all periods to finalize the process.

<table>
<thead>
<tr>
<th>End product A</th>
<th>Time Period</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work center 100</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0.05</td>
</tr>
<tr>
<td>Work center 200</td>
<td></td>
<td>0.60</td>
<td>0.10</td>
<td>0</td>
</tr>
<tr>
<td>Work center 300</td>
<td></td>
<td>0</td>
<td>0.20</td>
<td>0</td>
</tr>
<tr>
<td>End product B</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1.30</td>
</tr>
<tr>
<td>Work center 100</td>
<td></td>
<td>0.25</td>
<td>0.30</td>
<td>0</td>
</tr>
</tbody>
</table>

**Time-phased capacity requirements generated from MPS for 40 As and 13 Bs in time period 5:**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 As</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work center 100</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Work center 200</td>
<td>24</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Work center 300</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>13 Bs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work center 100</td>
<td>0</td>
<td>0</td>
<td>16.9</td>
</tr>
<tr>
<td>Work center 200</td>
<td>3.25</td>
<td>3.9</td>
<td>0</td>
</tr>
<tr>
<td>Work center 300</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total from period 5 MPS</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Work center 100</td>
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<td>0</td>
<td>18.9</td>
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<tr>
<td>Work center 200</td>
<td>27.25</td>
<td>7.9</td>
<td>0</td>
</tr>
<tr>
<td>Work center 300</td>
<td>0</td>
<td>8.0</td>
<td>0</td>
</tr>
</tbody>
</table>
Capacity requirements planning (CRP)

• Capacity requirements planning differs from the rough-cut planning procedures
  – Utilizes time-phased material plan from MRP
  – Takes into account materials in inventory
  – Accounts for the current status of work-in-process
  – Accounts for service parts and other demands not accounted for in the MPS

• Requires more inputs and more computational resources
Capacity requirements planning example

<table>
<thead>
<tr>
<th>Period</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>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
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</thead>
<tbody>
<tr>
<td>Product A MPS</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>40</td>
<td>40</td>
<td>40</td>
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<td>37</td>
<td>37</td>
<td>37</td>
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<tr>
<td>Component C</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Lot size = 40</td>
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<tr>
<td>Lead time = 2</td>
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<tr>
<td>Gross requirements</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>30</td>
<td>30</td>
<td>37</td>
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<tr>
<td>Projected available balance</td>
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<td>4</td>
<td>11</td>
<td>18</td>
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<td>Planned order releases</td>
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<td>40</td>
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</tr>
<tr>
<td>Work center 300 Capacity Requirements Using CRP</td>
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</tr>
<tr>
<td>Period</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Hours of capacity*</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
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<tr>
<td>Total = 88</td>
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</tr>
</tbody>
</table>

This process is repeated for each work center to complete the plan.
Finite capacity scheduling

• Simulates job order start and finish times in each work center
• Establishes a detailed schedule for each job in each work center
• When a work center’s capacity is not sufficient for all planned jobs, prioritization rules determine which jobs will be shifted to later times
Finite capacity scheduling

Product A does not consume all available capacity

Combination of all products consumes all available capacity in several periods

Planned orders are shifted to stay within capacity limitations
Finite capacity scheduling

• The FCS plan is a simulation
• Randomness leads to actual times that don’t match scheduled times
  – Should the work center wait for a job that isn’t available on time (idleness = lost capacity)
• Over time, the accuracy of the plan deteriorates
• Frequent rescheduling may be needed to maintain accuracy
• Rescheduling process is computationally expensive
Work center scheduling

- **Vertical loading**—each work center is scheduled job by job without consideration of other work centers
  - Increases capacity utilization but may result in more partial job completion
- **Horizontal loading**—jobs are scheduled through all work centers in order of priority
  - Lower capacity utilization but generally a higher proportion of jobs are completed in a shorter time span (higher customer service levels)
Capacity monitoring with input/output control

• Planned inputs are determined by the capacity planning process

• Planned outputs depend upon the nature of the work center
  – Capacity-constrained—planned output is determined by the processing rate of the work center
  – Non-capacity-constrained—planned outputs match planned inputs

• Differences between plan and actual must be addressed; management by exception
Choosing the measure of capacity

• Capacity can be measured in many ways
  – Labor hours, machine hours, physical units, monetary units, weight etc.

• The firm’s business needs and constraints should determine the capacity measure

• Trends
  – Shrinking portion of direct labor
  – Less clear distinctions between direct and indirect labor
  – Reduced ability to change labor capacity
  – Outsourcing
  – Flexible automation/cellular technologies
Choice of a specific planning technique

Rough-cut methods
- CPOF
- Capacity bills
- Resource profiles
- Most general
- Widely applicable
- Easier to implement
- but less powerful
- Useful in JIT situations

Capacity requirements planning
- Requires more data and computational effort
- Only applicable in conjunction with MRP

APS Systems
- Highest levels of effort
- High levels of accuracy possible
- with good data and flawless execution
Production environments and capacity planning techniques

- **Rate-based planning**
  - Recognizes product mix changes
  - Different capacity requirements for different products
  - **Capacity bills**

- **Time-phased planning**
  - Recognizes product mix changes
  - Different lead-times for different products
  - **Resource profiles**
  - **Capacity requirements planning (CRP)**

**Capacity planning using overall factors (CPOF)**
- Stable material flows
- Simple product structures
- Simple accounting systems

**Increasing:**
- requirements for input data volume and quality
- computational capability and capacity
- difficulties in making changes to the plans
PRODUCTION ACTIVITY CONTROL
Two main managerial problems related to Production Activity Control

• What job to produce next?
• How to simultaneously control capacity and material flow for maximum performance?
Production Activity Control (PAC)

- Concerns the execution of detailed material plans
- Describes planning and release of individual orders to both factory and outside vendors
- Ensures meeting the customer service goals
- A key element is feedback on shop-floor and supplier’s performance against plans -> loop-closing provides signals for revising plans when necessary
Summarizing principles of Capacity Planning

• Managerial problems related to capacity planning
  – Matching capacity with the material plans
  – Trade-off between time and capacity
• Five level hierarchy of capacity planning decisions
  – Resource planning
  – Rough-cut capacity planning
  – Capacity requirement planning
  – Finite loading
  – Input/output control
Summarizing principles of Capacity Planning

- Capacity plans must be developed concurrently with material plans if the material plans are to be realized.
- Capacity planning techniques must match the level of detail in particular product and production structures.
- Capacity planning techniques must be matched with the particular company circumstances.
- Capacity must be planned, but use of capacity must also be monitored and controlled.