Flow Rate & Capacity Analysis
Review

• $I = R \times T$ for complex flows
• Process flow graphs and charts
• Flow unit dimensions & conversion factors
• Scaling in $I = R \times T$
• Capacity req’t estimation
• Flow time efficiency and improvement
Process Flow Graph

- Documents operations
- Where do you draw the boundary?
- Nodes <=> operations
- Arcs <=> precedence
Process Flow Charts

We will refer to this as a process flow graph rather than a process flow chart, because this shows only the structure of the flows, and not the detailed operation information.
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<thead>
<tr>
<th>Operation</th>
<th>Details of Operation Present Proposed</th>
<th>Operation</th>
<th>Transport</th>
<th>Inspection</th>
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Today

• Modeling details
• Issues in estimating process capacity requirements and maximizing process efficiency
• Fundamental problem of terminology
• Process utilization and improvement
What if only one punch?

FIGURE 4.1 Process Flow Chart for MBPF, Inc.
Gantt Chart

Punch base first

inspect
assemble
subassemble
form roof
form base
punch
separate

base
roof
garage

base waits

FIGURE 4.1 Process Flow Chart for MBPP, Inc.
Gantt Chart

Punch roof first

roof waits

base

garage

inspect
assemble
subassemble
form roof
form base
punch
separate

10 32 44 62 68 81 91 127

FIGURE 4.1 Process Flow Chart for MBPP, Inc.
Example 4.4

• $I = RT$ is based on a “system boundary” and $I$ is all the units in the boundary

• If you draw the boundary so it includes only the buffer, you get $I_b = RT_b$

• That’s why theoretical flow time is added to the “buffer” time
Circular Definitions

- System
- Process
- Operation
- Flow Unit/Material
- Process Chart
- Product
- Process loop
- product loop
Terminology

• Flow units: get moved between operations; note that while conservation of material holds at an operation, conservation of “flow unit” may not hold. E.g., raw material enters the process on a pallet, is converted into blanks, and leaves in totes
Terminology

- **Flow unit conversion**: when the units of measure for the flow units leaving an operation are not the same as the units of measure for the flow units entering the operation (NIB*)

- **Flow unit conversion factor**: output flow units/input flow unit (dimensionless) (NIB)

* NIB = “not in book”
Information Requirements

$R_{in} \rightarrow \text{Process} \rightarrow R_{out}$

- Resource Requirements
- Conversion factor
- Process Capacity
Defining Process Capacity

• *Different from text!*
• Not all flow units entering a process are the same
• Capacity should *not* be expressed in terms of maximum rate at which flow units can enter the process, because the mix may vary over time
Example

• Two products, A & B, requiring 1 hour and 2 hours, respectively of machine time.

• Product mix today is 4 A and 2 B, or a rate of 6 “flow units”, requiring 8 hours.

• Can I achieve 6 flow units tomorrow, if all I make is B?
Resolution

• **Process capacity:** the amount of process time available per unit of scheduled time, hrs/hr, e.g.

• **Operation process requirement:** the amount of *process* time required per *flow unit* entering the process, hrs/unit, e.g.
Unit Loads

• I don’t like the authors’ use of this term
• “Unit load” has a conventional definition, in material handling
• Their “unit load” is simply the operation time, or the sum of operation times assigned to a resource
Theoretical Capacity

• I see no benefit to thinking of a process as having a different “theoretical capacity” for every product/flow unit (process view).

• The book’s “theoretical capacity” is really the product (flow unit) “run rate” for that process (product view).
Capacity Required

• It is straightforward to compute, for a given process, the total amount of capacity required for a given set of products with given rates

• ReqCap = \text{Sum} (\text{ProdRate} \times \text{OpProcReqt})
Capacity Utilization

• Utilization = \( \frac{\text{CapReq}}{\text{TheoreticalCap}} \)

• E.g., supposed the plan rate for a product is 10 units/hr, and each unit requires 5 minutes of process time. Utilization is \( \frac{(10 \times 5)}{60} = 0.83 \)
Factors Affecting Process Capacity

- “Uncontrollable” factors (in the short run)
  - breakdowns, preventive maintenance
- “Controllable” factors
  - setup/changeover, starvation (no waiting job), blocking, no operator

for a given R, increasing lot sizes reduces utilization, because of setups.
Process Availability

- Different from text!
- Availability = scheduled time - uncontrollable losses
- Product mix has no effect on availability, unless it impacts maintenance requirements
Effective Capacity

• Is simply theoretical capacity $\times$ availability

• E.g., if there is one machine, and its availability is 90%*, then the effective capacity is 54 minutes/hour

*e.g., 10% is the historical average time lost to breakdowns and maintenance
Improving Theoretical Capacity

- Section 5.6 is misleading--capacity is determined by resources, not by operation “recipes”
- Increasing capacity requires adding resources, or using the resources for longer periods of time (overtime, two shifts, e.g.)
Improving Flow Rates

• Increase theoretical capacity
• Reduce availability losses
• Reduce operation process requirements at bottleneck processes, e.g., by reducing setup times, increasing yields, or improving run rates
• Reduce schedule or material related idle time on bottleneck processes
Summary

- Circular definitions
- Flow unit conversion
- Process capacity, availability, and utilization
- Improving capacity vs improving throughput
At this point, you should be able to

• Use terminology correctly
• Use $I = RT$
• Develop a process flow graph for a simple process
• Develop a process flow chart for a simple scenario
• Calculate flow time efficiency
• Determine process capacity, availability, & utilization
• Identify opportunities for improving flowtime and flow rates for simple scenarios