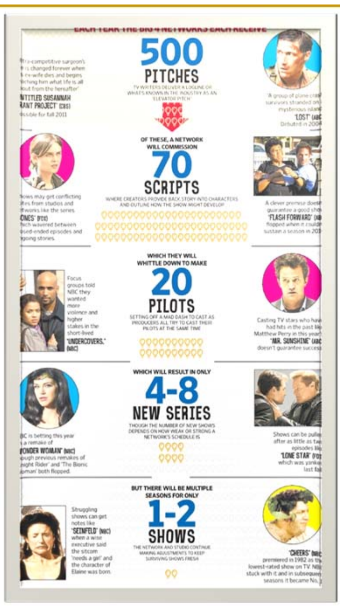
Chapter 3
Evaluating Process Capacity

- Process Flow Diagram
- Bottleneck and Capacity
- Utilization
- Multiple Types of Flow Units



Each pitch requires 2 days to review.

A writer needs 10 days to develop a script.

A team needs 30 days to complete a pilot.

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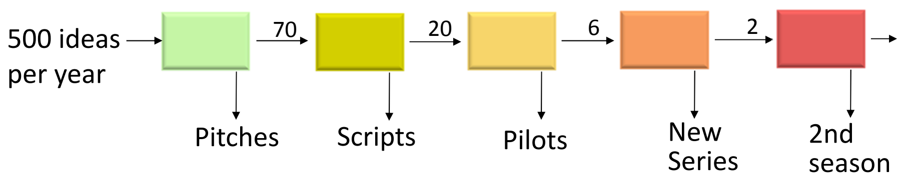
Processes with Attrition Loss



Processing time	2 days	10 days	30 days	70 days	200 days
Resources 250 days per year	5 judges	3 script writers	2 pilot teams	2 series crews	1 main crew

Where is the Bottleneck?

Basic Process Vocabulary

For each step of the process

- **Activity times**: how long does an operation (step) take?
- **Capacity**: number of flow units processed per unit of time.

For the entire process

- **Bottleneck**: operation (step) with the lowest capacity
- **Process capacity**: capacity of the bottleneck
- **Flow rate**: rate at which flow units flow through the process
- **Utilization** =Flow Rate / Capacity
- **Flow Time**: amount of time it takes to go through the process

3.1 The Circored Plant

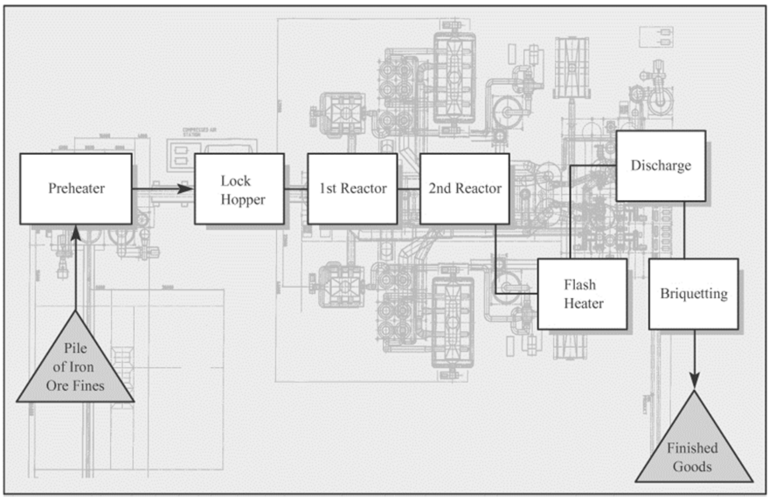
converts iron ores into iron briquettes to supply steel plants

How to Draw a Process Flow Diagram

- Focus on one or two types of flow units.
- Define the process boundaries and choose an appropriate level of detail.
- Include only those steps that are likely to affect the process flow or the economics of the process.
- Sizes and exact locations of arrows, boxes, and triangles do not carry any special meaning.
- Use different colors for different routes.
- Stay closer to the physical layout.

Complete Process Flow Diagram

FIGURE 3.7 Completed Process Flow Diagram for the Circored Process



3.2 Resource and Process Capacity

How much a resource can serve in a given unit of time?

- Design Capacity
  maximum amount of output w/o constraints
- Effective Capacity
  maximum amount of output under maintenance, quality, and human constraints
- Best Operating Level
  level of capacity at which average unit cost is minimized.

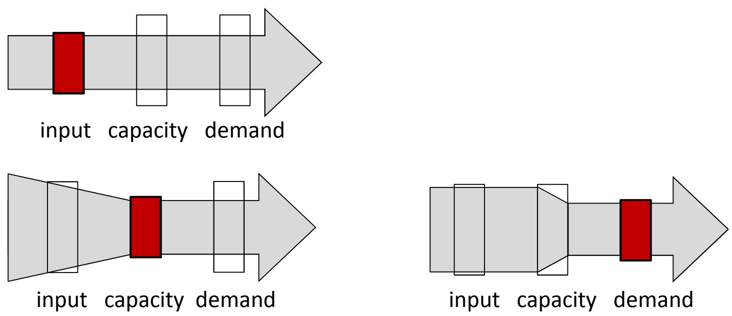
Multiple Resources/Servers

- Activity time = T time units
- Capacity of a single server = $\frac{1}{T}$ units per time unit

- If a step has m identical servers in parallel
- Capacity = $\frac{m}{T}$ units per time unit
- Output 1 unit every $\frac{T}{m}$ time units

Bottleneck and Process Capacity

- Process capacity is determined by the resource with the smallest capacity.
- Flow rate = min{ available input, process capacity, demand }

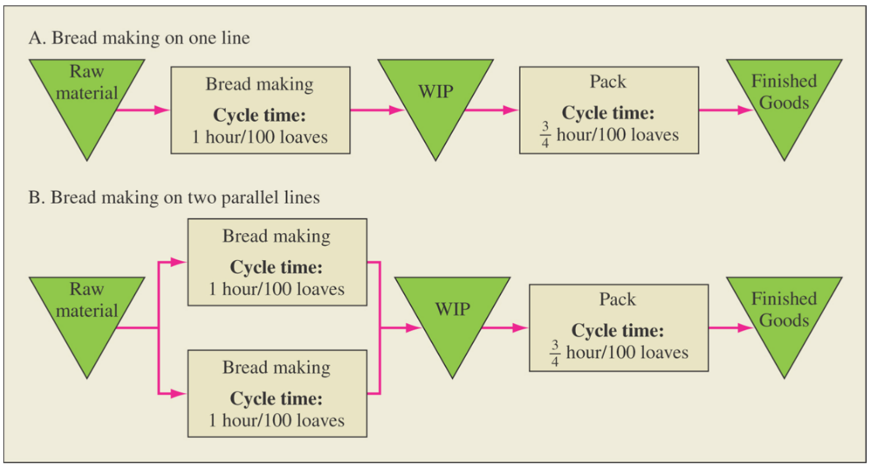


Finding the Bottleneck in a Process

Process Step	Calculations	Capacity
Preheater		120 tons per hour
Lock hoppers		110 tons per hour
CFB	Little's Law: Flow rate = 28 tons/0.25 hour	112 tons per hour
Stationary reactor	Little's Law: Flow rate = 400 tons/4 hours	100 tons per hour
Flash heater		135 tons per hour
Pressure let-down system		118 tons per hour
Briquetting machine	Consists of three machines: 3 × 55 tons per hour	165 tons per hour
Total process	Based on bottleneck, which is the stationary reactor	**100 tons per hour**

Stationary reactor $\text{capacity} = \frac{\text{WIP}}{\text{flow time}} = \frac{400\text{ tons}}{4\text{ hours}} = 100\text{ tons/hour}$

Example: Bread Making and Packing



3.3 Time to Process a Certain Amount of Supply

- Assuming the process is already producing output

$$\text{Time to serve } \mathbf{X} \text{ units} = \frac{X}{\text{flow rate}}$$

- If the process starts empty

$$\text{Time to serve } \mathbf{X} \text{ units} = \text{total processing time} + \frac{X-1}{\text{flow rate}}$$

- Improving the bottleneck $\Rightarrow$ Reducing time to serve X units

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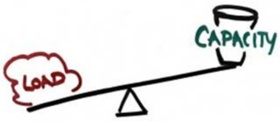
3.4 Process Utilization and Capacity Utilization

$$\text{Process Utilization} = \frac{\text{flow rate}}{\text{process capacity}}$$



$$\text{Resource Utilization} = \frac{\text{flow rate}}{\text{resource capacity}}$$

- The objective of most businesses is to increase profit, not to increase utilization.

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Utilization with limited demand

- Assume the demand is only 657,000 tons.

Process Step	Calculations	Utilization
Preheater	657,000 tons/year/[120 tons/hour × 8,760 hours/year]	62.5%
Lock hoppers	657,000 tons/year/[110 tons/hour × 8,760 hours/year]	68.2%
CFB	657,000 tons/year/[112 tons/hour × 8,760 hours/year]	66.9%
Stationary reactor	657,000 tons/year/[100 tons/hour × 8,760 hours/year]	75%
Flash heater	657,000 tons/year/[135 tons/hour × 8,760 hours/year]	55.6%
Discharger	657,000 tons/year/[118 tons/hour × 8,760 hours/year]	63.6%
Briquetting	657,000 tons/year/[165 tons/hour × 8,760 hours/year]	45.5%
Total process	657,000 tons/year/[100 tons/hour × 8,760 hours/year]	**75%**

- The bottleneck is the resource with the highest utilization.

3.5 Workload and Implied Utilization

- Utilization only carries information about excess capacity.
- Implied utilization captures the mismatch when the demand exceeds the capacity.

Process Step	Calculations	Implied Utilization	Utilization
Preheater	125/120	104.2%	83.3%
Lock hoppers	125/110	113.6%	90.9%
CFB	125/112	111.6%	89.3%
Stationary reactor	125/100	125%	100%
Flash heater	125/135	92.6%	74.1%
Pressure let-down system	125/118	105.9%	84.7%
Briquetting machine	125/165	75.8%	60.6%
Total process	**125/100**	**125%**	**100%**

Service Example: Driver's License Office

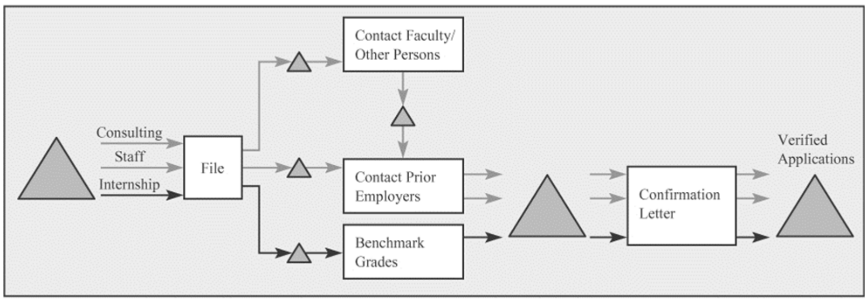
1	2	3	4	5	6
Check application	Process payment	Check for violations	Conduct eye test	Photograph applicant	Issue new license
15 sec.	30 sec.	60 sec.	40 sec.	20 sec.	30 sec.

- The office has 6 clerks, one for each step. The current capacity is 60 applicants per hour.
- It is under pressure to increase its productivity to process 120 applicants per hour with the addition of only one clerk.
- Can rearrange steps 2-4 in any order.

3.6 Multiple Types of Flow Units

- The flow may break up into multiple flows.
- Different types of flow units move through the process.

FIGURE 3.10 Process Flow Diagram with Multiple Product Types



Bottleneck in the Multiproduct Process

- The product mix affects the process capacity.
- Not all activities are required by all product type.

TABLE 3.5 Finding the Bottleneck in the Multiproduct Case

	Activity Time	Number of Workers	Available Capacity	Requested Capacity [Applications/Hour] Workload				Implied Utilization
				Consulting	Staff	Interns	Total	
File	**3** [min./appl.]	**1**	1/3 [appl./min.] = *20* [appl./hour]	3	11	4	18	18/20 = 90%
Contact persons	**20** [min./appl.]	**2**	2/20 [appl./min.] = *6* [appl./hour]	3	0	0	3	3/6 = 50%
Contact employers	**15** [min./appl.]	**3**	3/15 [appl./min.] = *12* [appl./hour]	3	11	0	14	14/12 = 117%
Grade/school analysis	**8** [min./appl.]	**2**	2/8 [appl./min.] = *15* [appl./hour]	0	0	4	4	4/15 = 27%
Confirmation letter	**2** [min./appl.]	**1**	1/2 [appl./min.] = *30* [appl./hour]	3	11	4	18	18/30 = 60%

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Economy of Scale

As the plant gets larger and production volume increases, the plant can fully utilize dedicated resources and thus reduce unit cost and selling price.

Larger Plant → Lower Cost → Lower Price → More Market Share

- Economy of Scale will backfire and incur huge loss if demand cannot match capacity.
- The size of a plant may become too large and management, material handling, or maintenance become a serious problem.

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Economy of Scale for Service Industry

- Chain stores lead to buying power.
- Travel agencies buy airline tickets and hotel rooms in bulks to get deeper discount.
- Small business can form an alliance to increase the bargaining power against big suppliers.

- Competing retail stores or restaurants located in the same area may attract more consumers. 瑞豐night market

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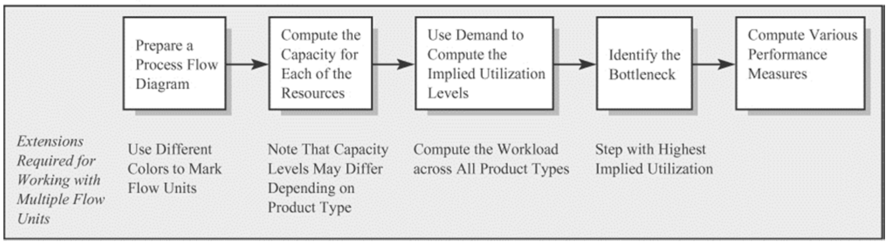
Summary



- World class enterprises excel at the speedy and flexible integration of the business processes.
- **Finding the bottleneck** is the key to improve a variety of performance measures.

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