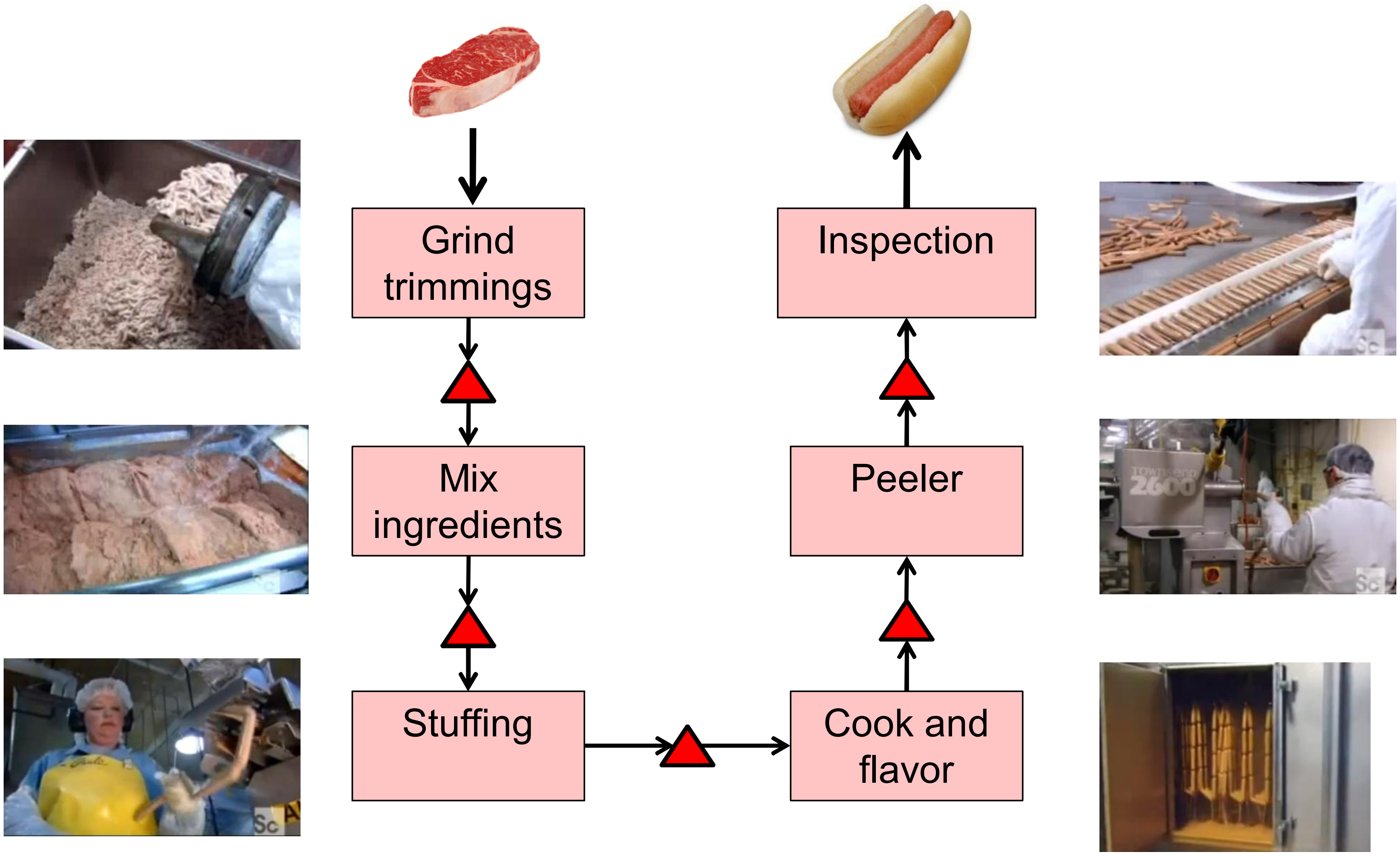
Chapter 3. Understanding the Supply Process: Evaluating Process Capacity

Basic Process Vocabulary

- **Inventory**: The number of flow units in the system
- **Activity times**: how long does the worker spend on the task?
- **Capacity**=1/activity time: how many units can the worker make per unit of time
  If there are *m* workers at the activity: Capacity=*m*/activity time
- **Bottleneck**: process step with the lowest capacity
- **Process capacity**: capacity of the bottleneck
- **Flow rate** =Minimum{Demand rate, Process Capacity)
- **Utilization** =Flow Rate / Capacity
  (a measure of how much the process actually produces relative to
  how much it could produce if it were running at full speed)
- **Flow Time:** The amount of time it takes a flow unit to go through the process

Making hot dogs (http://www.youtube.com/watch?v=moM1s3cltTc)

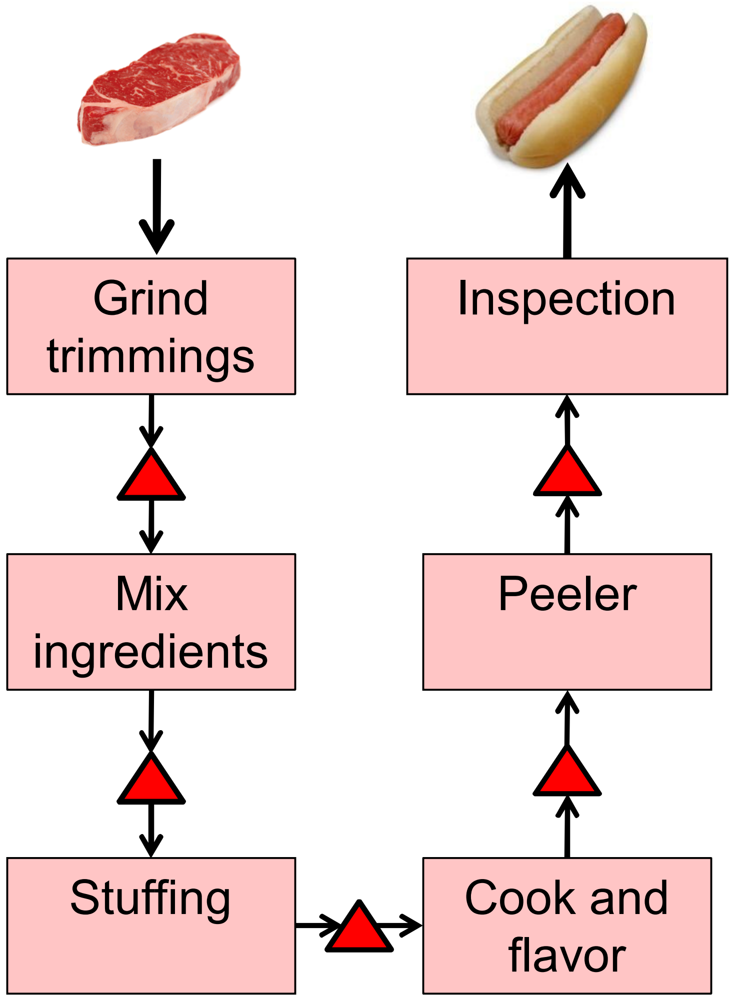


Process data

- 2 grinders
- 22,000 dogs per batch
- 5 minutes to load and grind

- 6 mixers
- 22,000 dogs per batch
- 1/3 hour to mix

- 3 machines
- 2,300 dogs per minute per machine



- 17 inspection stations
- Each inspector requires only 1/6th of a second to inspect each dog

- 8 peelers
- 700 dogs per minute per peeler

- 5 ovens
- Each oven holds 15,000 dogs
- Each dog spends 15 minutes in process

Capacity calculations – grind, mix, stuff

- Find the *capacity* of each process step, which is the maximum flow rate (*R*) through that process step.

- Express each process step's capacity in the same units
  - You can choose any time length you want (e.g., dogs / min, dogs / day, lbs / second), but you must be consistent.
  - We'll choose dogs / min.

- Grind:
  - Each grinder = 22,000 dogs / 5 min = 4,400 dogs / min
  - 2 grinders x 4,400 dogs / min = 8,800 dogs / min

- Mix:
  - Each mixer = 22,000 dogs/ (1/3 hour x 60 min / hour) = 1,100 dogs / min
  - 6 mixers x 1,100 dogs / min = 6,600 dogs / min

Capacity calculations – stuff, cook, peel, inspect

- Stuff:
  - 3 stuffers x 2,300 dogs / min = 6,900 dogs / min

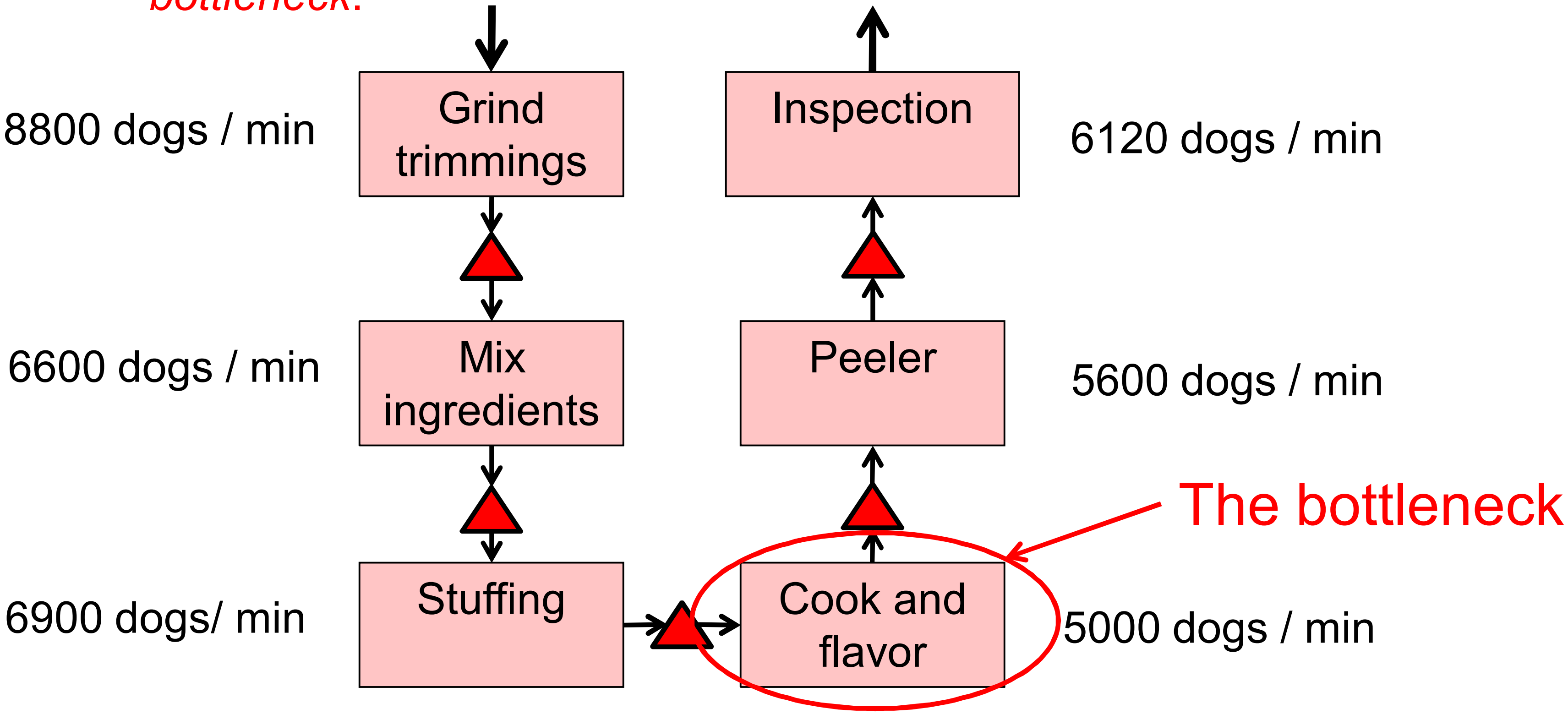
- Cook and flavor:
  - To find *R*, use Little's Law, *R* = *I* / *T*
  - *I* = 15,000 dogs, *T* = 15 min
  - *R* = 15,000 dogs / 15 min = 1,000 dogs / min
  - 5 ovens x 1,000 dogs / min = 5,000 dogs / min

- Peeler
  - 8 peelers x 700 dogs / min = 5,600 dogs / min

- Inspection
  - 1/6 sec / dog = 6 dogs / sec
  - 17 stations x 6 dogs / sec x 60 sec / min = 6,120 dogs / min

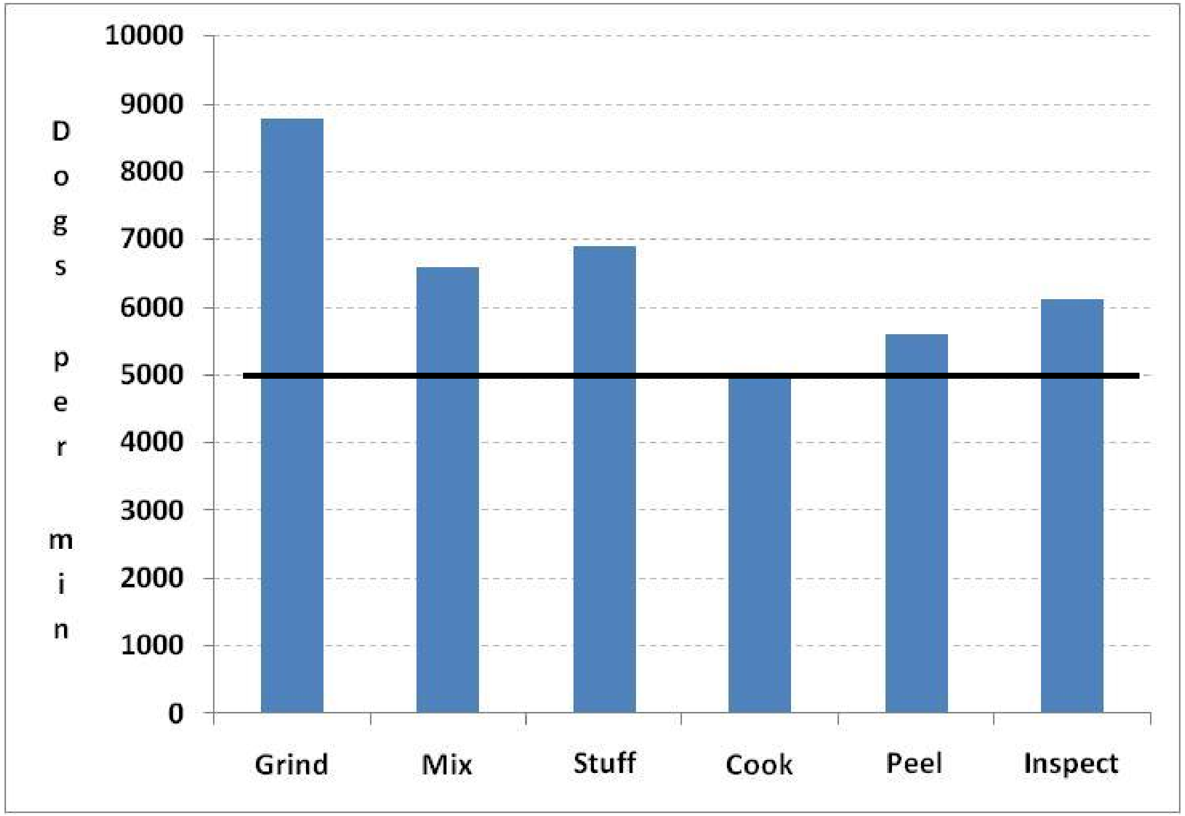
Capacity of the entire process

- The capacity of a process is the minimum capacity of the sub processes:
  - This process cannot produce any more than 5,000 dogs / min on a consistent basis.
  - The sub process that constrains the entire process is called the *bottleneck*.



Capacity of the entire process – cont.

- For this process, the flow rate, *R*, is 5,000 dogs / min
- This process can also produce 5,000 dogs / min x 60 min / hour = 300,000 dogs/ hour



Utilization vs. Implied Utilization

- Utilization=Flow Rate/Capacity ($\leq$ 100%)

- Implied Utilization=Demand Rate (or Work Load) /Capacity

  ($\leq$100% or > 100%)

$\rightarrow$ Captures the mismatch between what could flow through and what the resource can provide.

Utilization vs. Implied Utilization

- Table 3.3 (sufficient market demand) vs
  Table 3.4 (125 tons/hour)
  (Remark) Are there several bottlenecks in Table 3.4?

Process Step	Calculations	Implied Utilization	Utilization
Preheater	125/120	104.2%	83.3%
Lock hoppers	125/110	113.6%	90.9%
First reactor	125/112	111.6%	89.3%
Second reactor	125/100	125% *	100.0%
Flash heater	125/135	92.6%	74.1%
Discharger	125/118	105.9%	84.7%
Briquetting machine	125/165	75.8%	60.6%
Total process	**125/100**	**125%**	**100%**

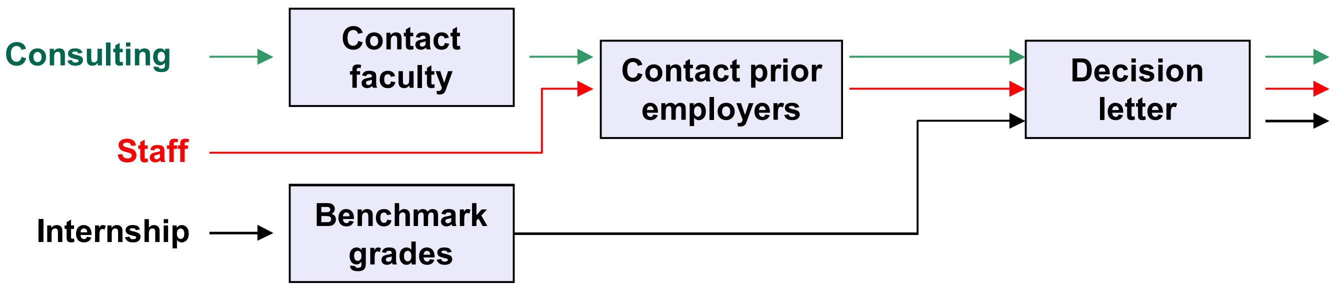
Steps for Basic Process Analysis with Multiple Types of Flow Units

1. For each resource, compute the number of minutes that the resource can produce
2. Create a process flow diagram, indicating how the flow units go through the process
3. Create a table indicating how much workload each flow unit is consuming at each resource
4. Add up the workload of each resource across all flow units.
5. Compute the implied utilization of each resource as

$$\text{Implied Utilization} = \frac{Result\ of\ Step\ 4}{Result\ of\ Step\ 1}$$

The resource with the highest implied utilization is the bottleneck.

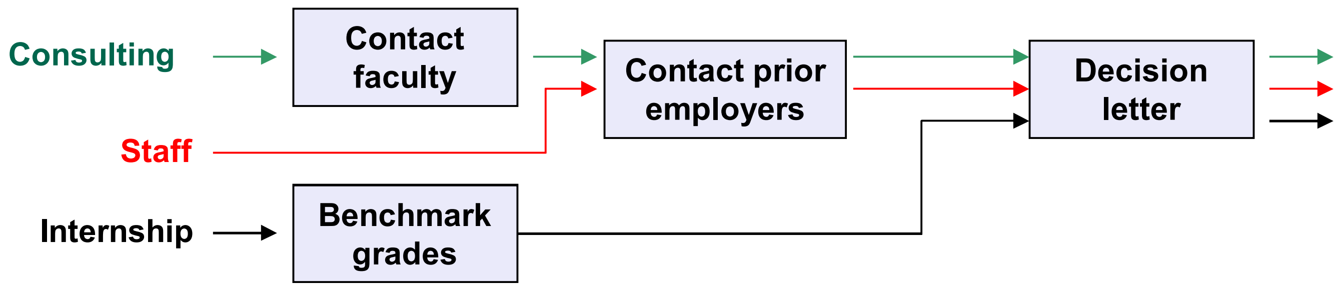
Process analysis with different types of flow units



Employment Verification Agency

- Three types of job applications need to be processed: “Consulting”, “Staff” and “Internship”
- There are inventory buffers in front of each resource/task (not shown)
- Each type of application has its own path through the process and does not necessarily visit all tasks.

Defining the common flow unit



- Define the **common flow unit** so that:
  - (1) The capacity of each task can be expressed in terms of the “flow unit” per unit of time.
  - (2) Demand can be expressed in terms of the “flow unit”.

- An intuitive and natural flow unit for this process is an “**application**”:
  - Given that an “application” is the flow unit …
    - The capacity of each task should be defined in terms of “applications per unit time”.
    - Demand should be expressed in terms of “applications per unit time”

Demand and capacity

- Demand data (given to us):

	Applications per hour
Consulting	3
Staff	11
Internship	4

- Staffing and processing time data (given to us) and capacity calculations:

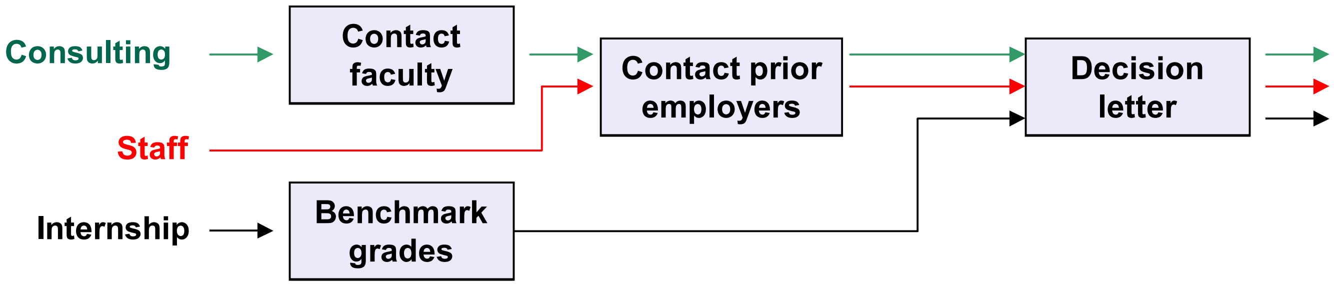
		Contact faculty	Contact employers	Benchmark grades	Decision letter
Data:					
Number of workers	(a)	2	3	2	1
Processing time (min/app)	(b)	20	15	8	2
Calculations:					
Capacity per worker (app/min)	(c = 1/b)	0.05	0.07	0.13	0.50
Task's capacity (app/min)	(d = a x c)	0.10	0.20	0.25	0.50
Task's capacity (app/hour)	(d x 60)	6	12	15	30

Evaluating implied utilization

		Contact faculty	Contact employers	Benchmark grades	Decision letter
Data:					
Consulting demand (app/hour)		3	3	0	3
Staff demand (app/hour)		0	11	0	11
Internship demand (app/hour)		0	0	4	4
Calculations					
Total Demand (app/hour)	(a)	3	14	4	18
Task's capacity (app/hour)	(b)	6	12	15	30
Implied Utilization	(a/b)	50%	117%	27%	60%

- Evaluate the total workload on each task:
  - For example, "Contact employers" receives 14 apps/hr.
- **Implied utilization** is the ratio of demand on a task to its capacity.
- The task with the highest implied utilization is the **bottleneck.**

Defining a different flow unit – one minute of work



- Define the flow unit to be "one minute of work":
  - Demands and capacity should then be expressed in terms of "minutes of work".
- Consider the "Contact employers" task:
  - Recall:
    - Demand on this task is 14 applications per hour.
    - Each application requires 15 minutes of work.
    - So demand on this task each hour is 14 x 15 = 210 minutes of work

Defining a different flow unit – one minute of work

		Contact faculty	Contact employers	Benchmark grades	Decision letter
Data:					
Total Demand (app/hour)	(a)	3	14	4	18
Processing time (min/app)	(b)	20	15	8	2
Number of workers	(c)	2	3	2	1
Calculations					
Total Demand (min/hour)	(d = a x b)	60	210	32	36
Task's capacity (min/hour)	(e = c x 60)	120	180	120	60
Implied Utilization	(d/e)	50%	117%	27%	60%

- Defining the flow unit as "one minute of work" **yields the same implied utilizations** as defining the flow unit as "one application".
- In other words, **the implied utilization does not depend on how the flow unit is defined** as long as all demands and capacities are defined with the same flow unit.

Summary

- In a process with a series of tasks:
  - The bottleneck's capacity determines the maximum flow rate through the process.
- Adding capacity to the bottleneck will increase the capacity of the total process, but may cause the bottleneck to move to another task/resource.
- Line balancing (i.e., reallocating tasks from the bottleneck to another resource) can improve the capacity of the total process without adding resources.
- Integrating work improves line balancing.
- Implied utilization of a resource can be evaluated even if there are different types of flow units.