

MSBA 7004

Operations Analytics

Tutorial 1: Process Flow Analysis

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Learning Objectives

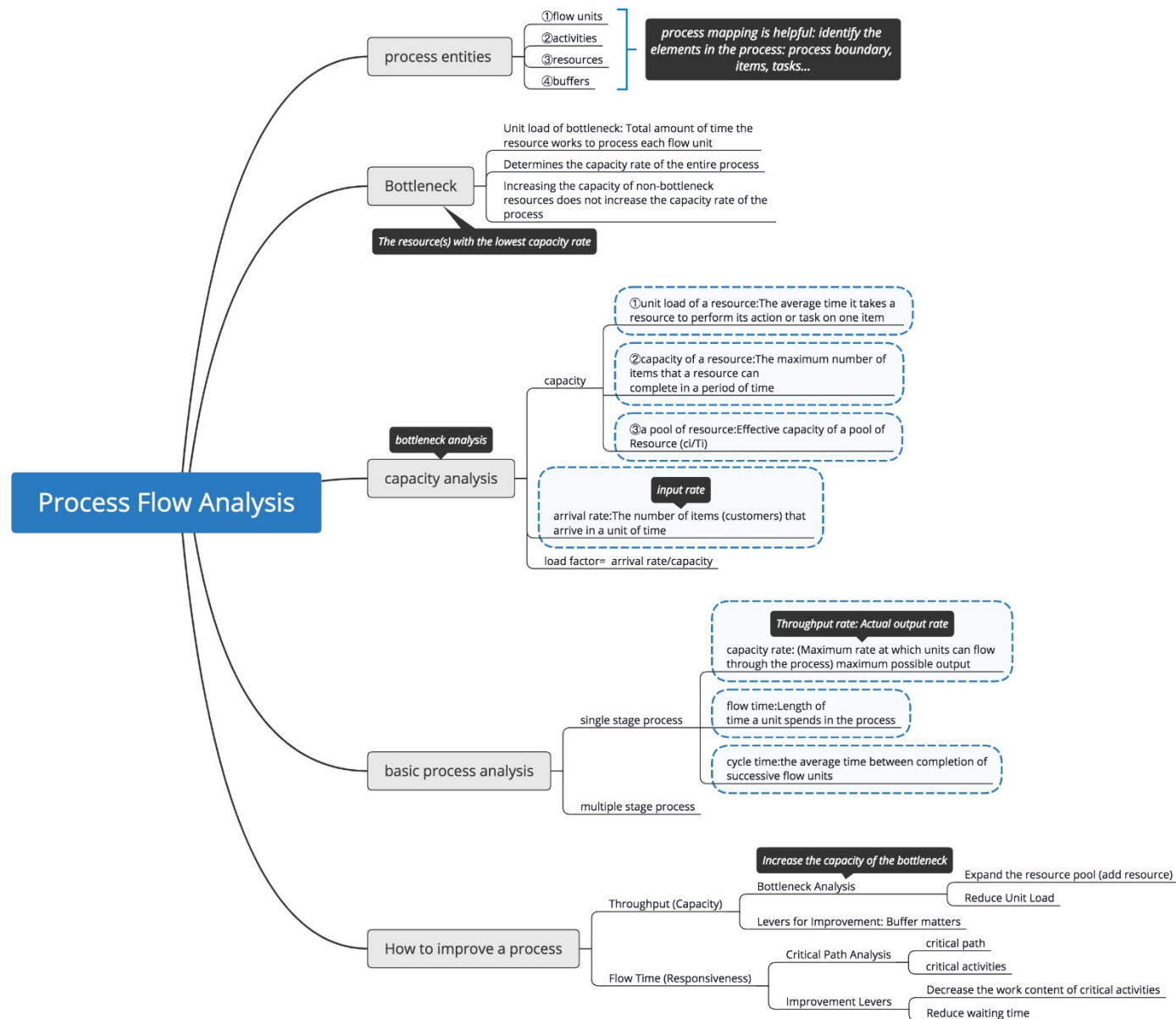
- Compare and clarify the concepts in class
- Review the process analysis
- Identify the key components in process analysis
- Learn to draw a process flow chart
- Identify how to improve a process

Warm-up True-or-False Question

(Some of the statements shown below maybe incorrect)

1. Flow units in a process could be homogeneous or heterogeneous.
2. If a process has two bottleneck resources, then they must have the same capacity rate.
3. In any process the non-bottleneck resource always gets idled for some time.
4. Buffers could have values added.
5. In any process, the flow time cannot be smaller than the cycle time.
6. The total duration of the process is the time spent on the bottleneck resource.
7. Increasing the capacity of the non-bottleneck resources does not increase the capacity rate of the process.

Summary of the concepts in lecture

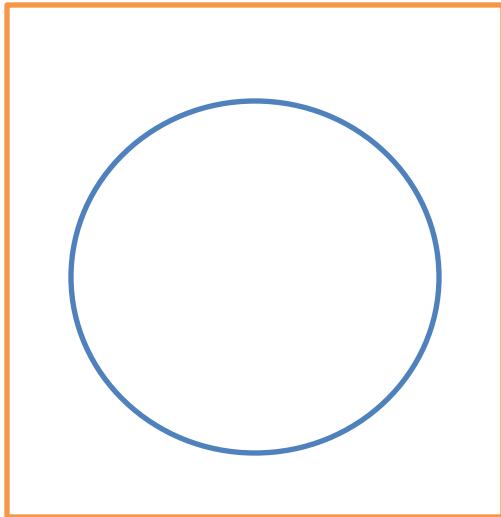


Process Flow Analysis

- **Key concepts:**
 - Flow Time T , Capacity Rate, Bottleneck
- **Process Flow Diagram:**
 - Elements: activities, buffers, decision points, flow of materials
 - Types: Standard, Linear, Swim-Lane, Gantt chart
- **Improving a process**
 - Throughput (Capacity)
 - Flow time (Responsiveness)

The Process: Drawing Faces

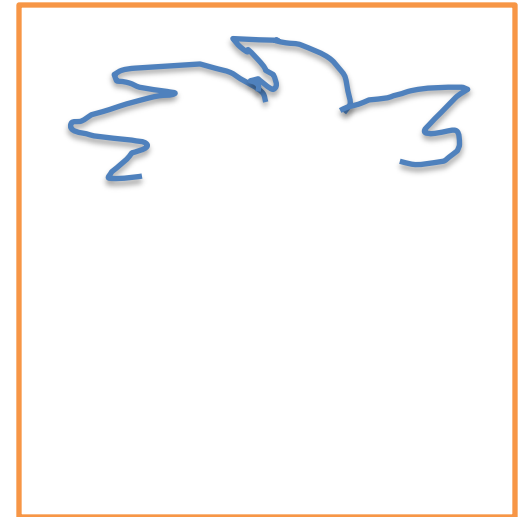
Step 1:
draw circle



Step 2:
draw features



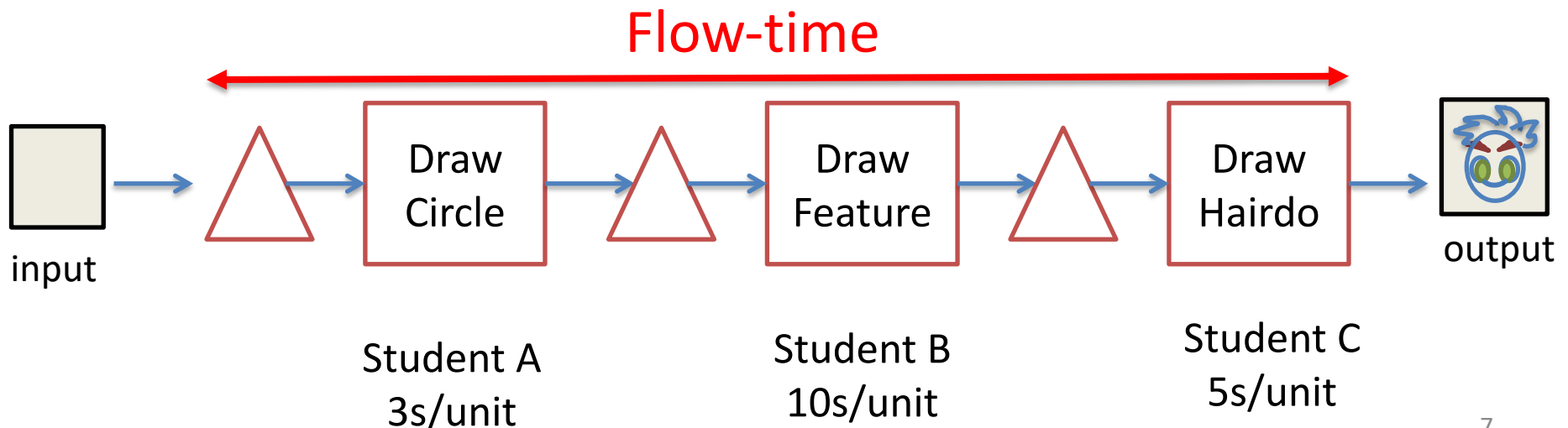
Step 3:
draw hairs



A Face!!

Definition: Flow-time

- **Flow-time (Raw process time):** The total time spent by a flow unit within process boundaries
 - Also known as “time in system”
 - Average flow-time: T
 - Units: hours, minutes, seconds



Definition: Theoretical flow time

- **Theoretical flow time:** The minimum amount of time required for a flow unit to go through the process without any waiting or interruptions.
- **Flow time**
 - = $\sum \text{Activity time} + \text{Waiting(buffer) time}$
 - = Theoretical flow time + Waiting time

Process Flow Diagram

How to Build a flow chart

- Determine objectives
- Define process boundaries
- Define flow units
- Observe process and collect data
- Map out process
- Validate chart

- Identify:

Items (flow units)

Tasks (steps)

Resources (people or machine)

Flows (movement or information exchange)

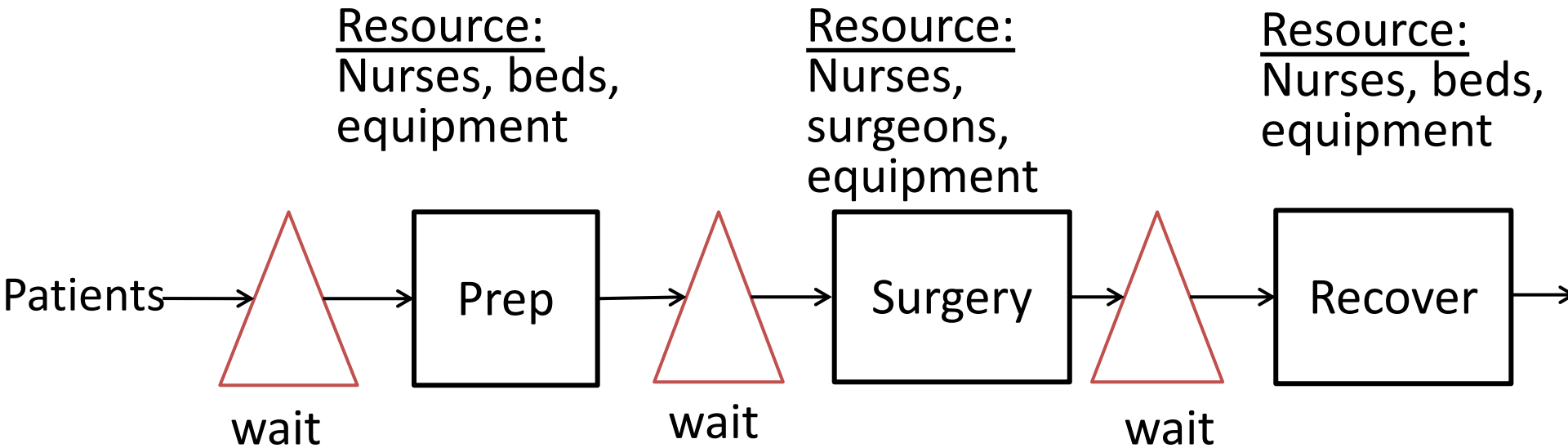
Storages (waiting, inventory)



Example: Surgical Center

Flow units (items)	Patients
Start and end of system	From patient entering to leaving
Flow rate / Throughput (items/hr)	patients left/hour
Flow-time (hours)	from patient arrival to release
Inventory (items)	patients, in prep, in surgery, in recovery, waiting, etc.
Tasks	prep, surgery, recovery time, etc.

Surgical Center: Flow Chart



Items

Tasks

Resources

Flows

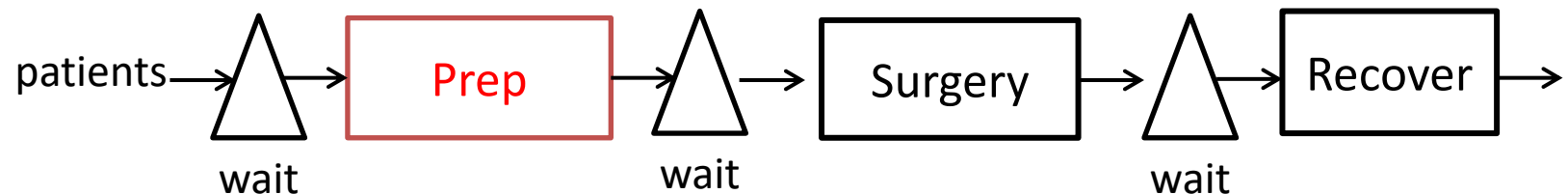
Storages/inventory

Capacity Analysis (Bottleneck Analysis)

- **Capacity of a Resource:**
 - Unit load (T_i), Resource Capacity ($1 / T_i$), Resource pool(n / T_i)
- **Bottleneck :** The resource with lowest capacity rate, can be multiple in a process
- **Capacity of a Process:**
 - =The capacity rate of the bottleneck resource
- Definitions needs to distinguish:
 - Arrival rate (input rate):
 - The number of flow units that arrive in a unit of time
 - Capacity rate:
 - Maximum rate at which flow units can flow through the process
 - Throughput rate (output rate):
 - $\text{Min \{Arrival rate, Capacity rate\}}$
 - Implied utilization (Load factor):
 - = Arrival rate/capacity
 - Utilization:
 - = Throughput rate/capacity ≤ 1
 - Cycle time
 - = $1 / \text{capacity rate of the process}$

Capacity Planning Example: Surgical Center Again

- A nurse can prepare a patient for surgery in 10 minutes. Can the nurse handle the load of 5 patients per hour?
- Question: Can the nurse handle the load?
- Flow-units: (items) patients
- Steps or tasks or actions prep for surgery
- Resources nurses, beds, equipment.
- Process flow diagram

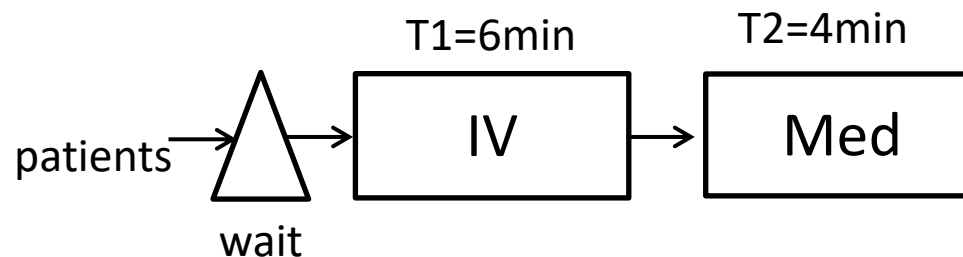


- Arrival rate: R_i
- Capacity: R_p

Series of Tasks (One Resource)

A nurse needs to do two tasks to prepare a patient: Put in an IV(infusion) which takes 6 minutes and give the patient medications which takes 4 minutes. Can the nurse handle a demand of 7 patients per hour?

- Question: Can the nurse handle the load?
- Flow-units: (items) patients
- Steps or tasks or actions **Put an IV and then give medications**
- Resources Nurse
- Process flow diagram

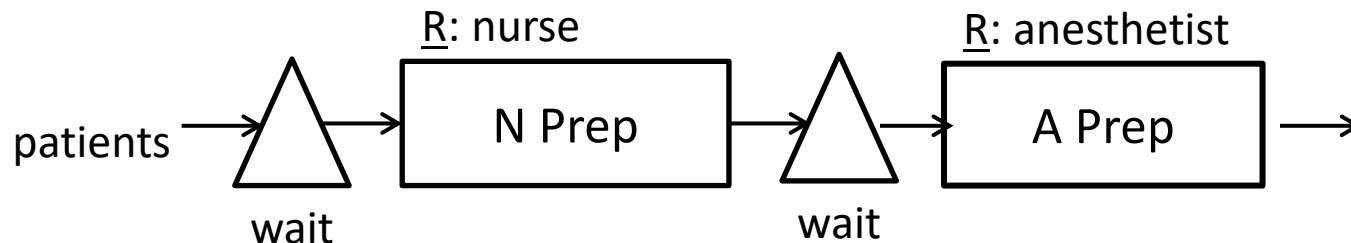


- Arrival rate: R_i
- Capacity: R_p

Series of Tasks (Multiple Resources)

A nurse can prepare a patient in 10 minutes for surgery and an anesthetist can prepare a patient in 15 minutes. Can these two handle a demand of 5 patients per hour?

- Question: Can **they** handle the demand?
- Flow-units: (items) Patients
- Steps or tasks or actions Nurse prep and anesthetist prep
- Resources Nurse and anesthesiologist
- Process flow diagram

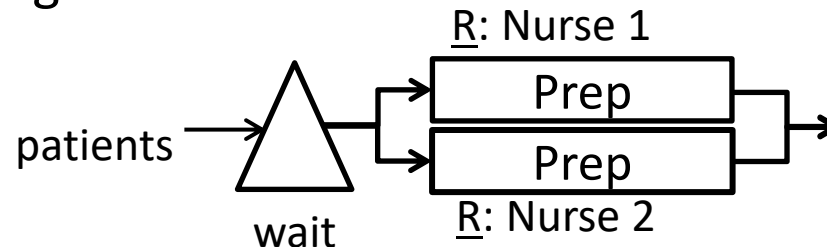


- Arrival rate: R_i
- Capacity: R_p

Multiple (Parallel) Resources

There are two nurses and each can prepare a patient in 10 minutes for surgery. Can these two nurses handle a demand of 10 patients per hour?

- Question: Can the **two nurses** handle?
- Flow-units: (items) Patients
- Steps or tasks or actions Prep
- Resources Nurse 1 and Nurse 2
- Process flow diagram

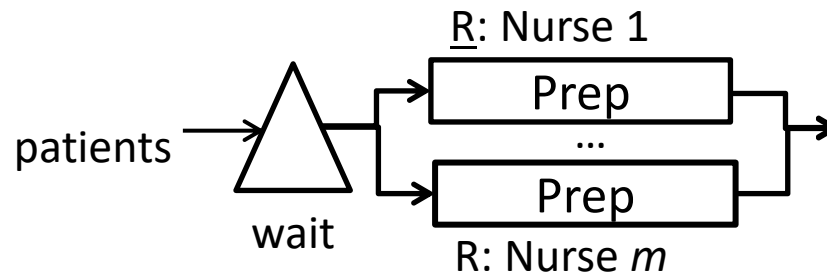


- Arrival rate: R_i
- Capacity: R_p

Capacity Planning

Each nurse can prepare a patient for surgery in 10 minutes. The ASU(Ambulatory surgical unit) expects a demand of 25 patients per hour. How many nurses does the ASU need to meet demand?

- Question: How many nurses do we need?
- Flow-units: (items) Patients
- Steps or tasks or actions Prep
- Resources Nurses
- Process flow diagram



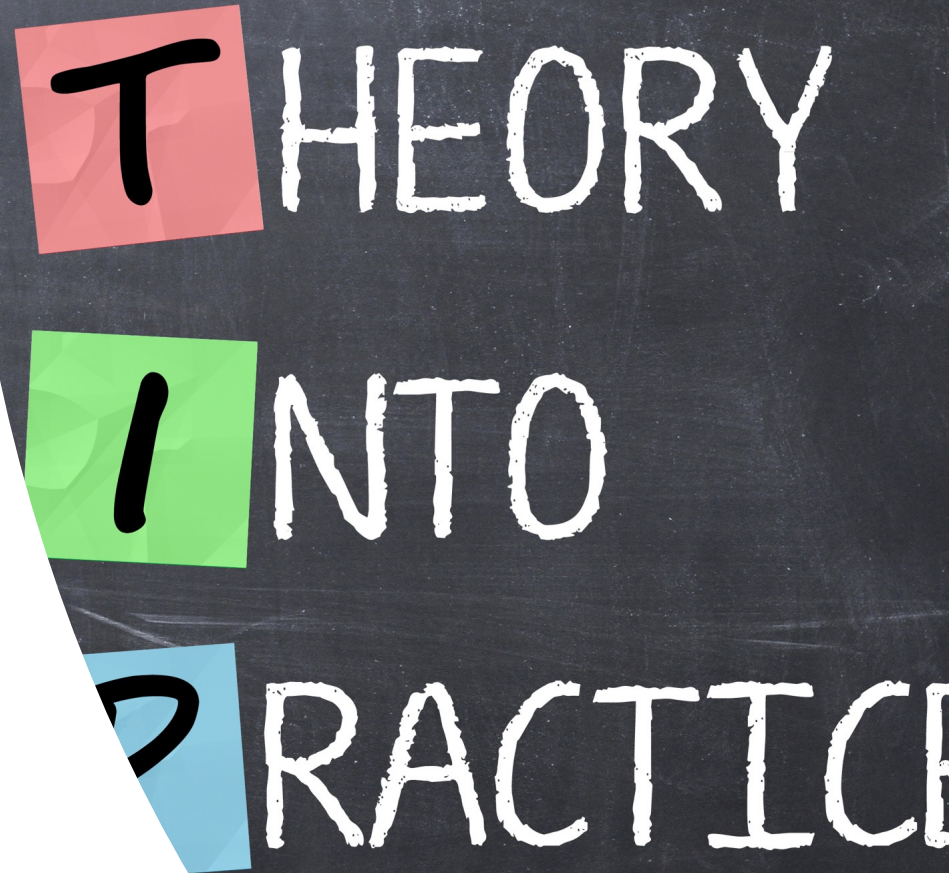
- Arrival rate: R_i 25 patients
- Capacity: R_p $R_p = m \times 6 \geq R_i ; m \geq 25/6$
- and hence $m=5$

Improve a process

- Throughput (Capacity)
 - Bottleneck Analysis(Capacity analysis)
 - Increase the capacity rate of a bottleneck
 - Increase resource pool for bottleneck
 - Reduce the unit load at the bottleneck
- Flow time (Responsiveness)
 - Critical Path Analysis
 - Reduce activity time on the critical path
 - Work faster
 - Move work content off the critical path
 - Reduce waiting (buffer) time

Practice Questions for today

- Quotable manufactures
- Bottlenecks
- Capacity for Cleaning and Sterilizing in a Surgical Suite(optional)
- Process Analysis with Different Types of Flow Units (optional)



THEORY
INTO
PRACTICE

Practice 1: Quotable manufactures

Quotable manufactures a removable disk for PC's. There are four major stages in its manufacture.

- The first stage is coating of disks. Coating is done by an automated machine that can run 24 hours/day. It produces 100 disks/hour.
- The second stage is assembly of the disk into the case. Assembly takes the average worker 2 minutes/disk. There are 10 workers at this stage.
- The third stage is testing, which catches defects from the coating operation. Each testing machine takes 5 minutes to test a disk. There are 30 machines and enough operators to keep these machines busy if necessary.
- The fourth stage is labeling the disk. Each worker here can do 2 disks/minute. There are 3 workers who do this task.

Assume the workforce completes 8 full hours of work each day, and stages 2 through 4 run 8 hours/day. Demand is 2100 a day.

Assume all rates and times are deterministic (no variability in demand or production). Testing finds no defects.

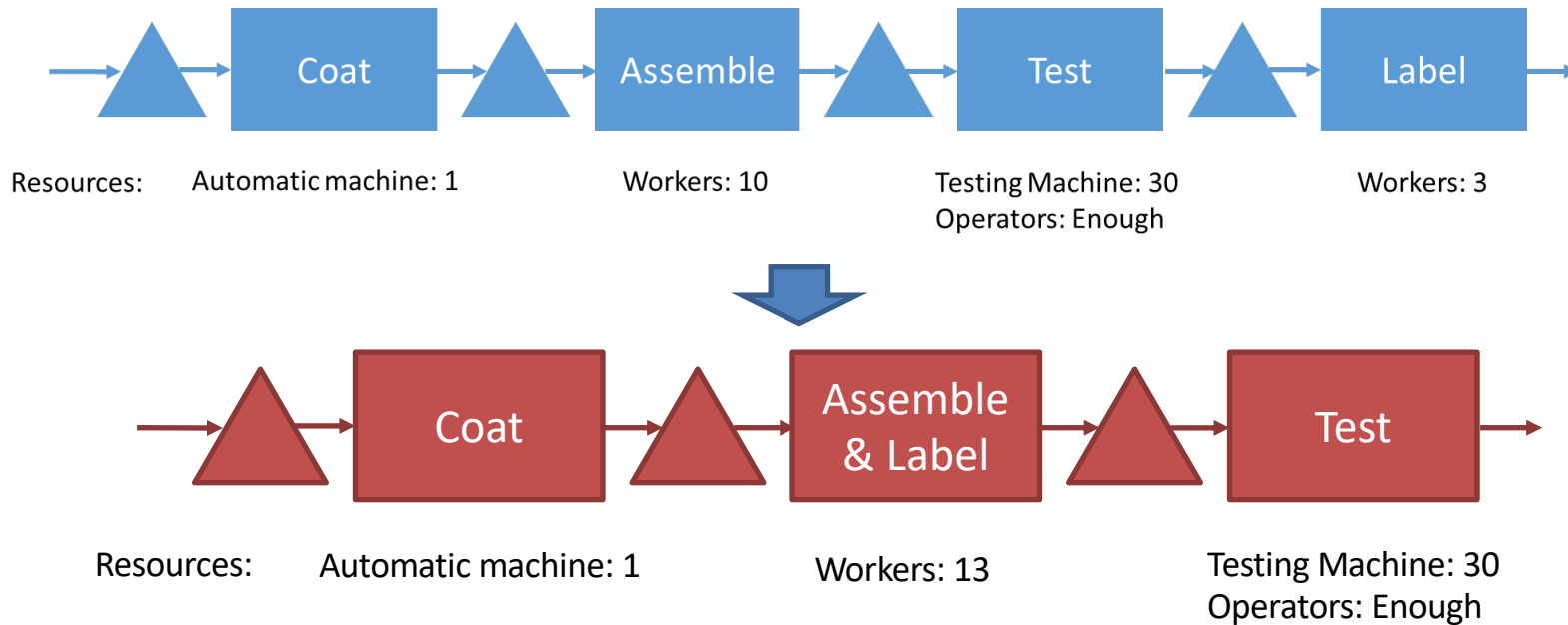
(a) Draw the flow chart.

(b) Fill in the table below.

Stage	Resource	Time (T_p) (minutes/disk)	Rate for one resource ($1/T_p$) (disks/hour)	Number of resources	Rate for all resources at this stage (disks/day)
1	Coating machine				
2	Assembly workers				
3	Testing machines and operators				
4	Labeling people				

(c) Assume the demand is 2100 disks/day, explain why there is sufficient capacity to meet the demand.

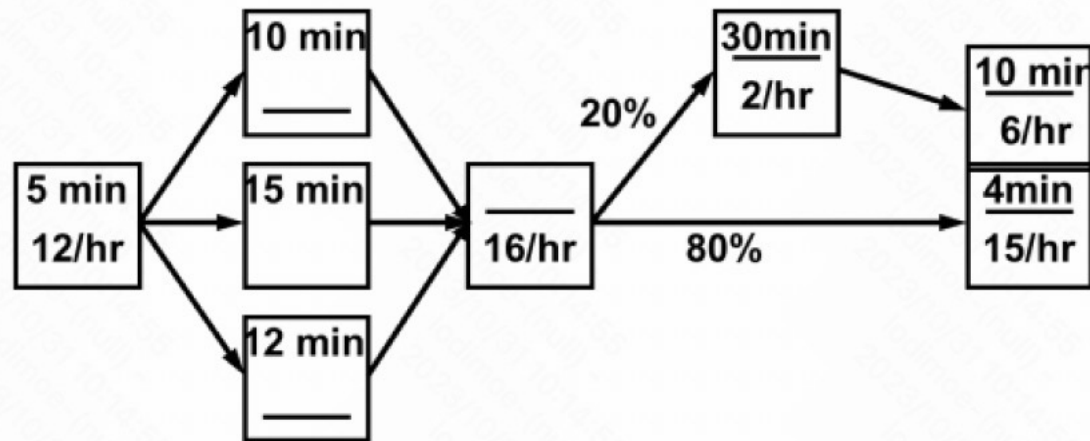
(d) If assembly and labeling are combined into a single step, can the process handle the demand? The raw processing time for one disk when assembly and labeling are combined into a single step equals to the sum of the original times. That is 2.5 minutes for one disk. Assume testing is done after this new combined step.



(e) How many people do we need in the combined stage in order to satisfy the demand?

Practice 2: Bottlenecks

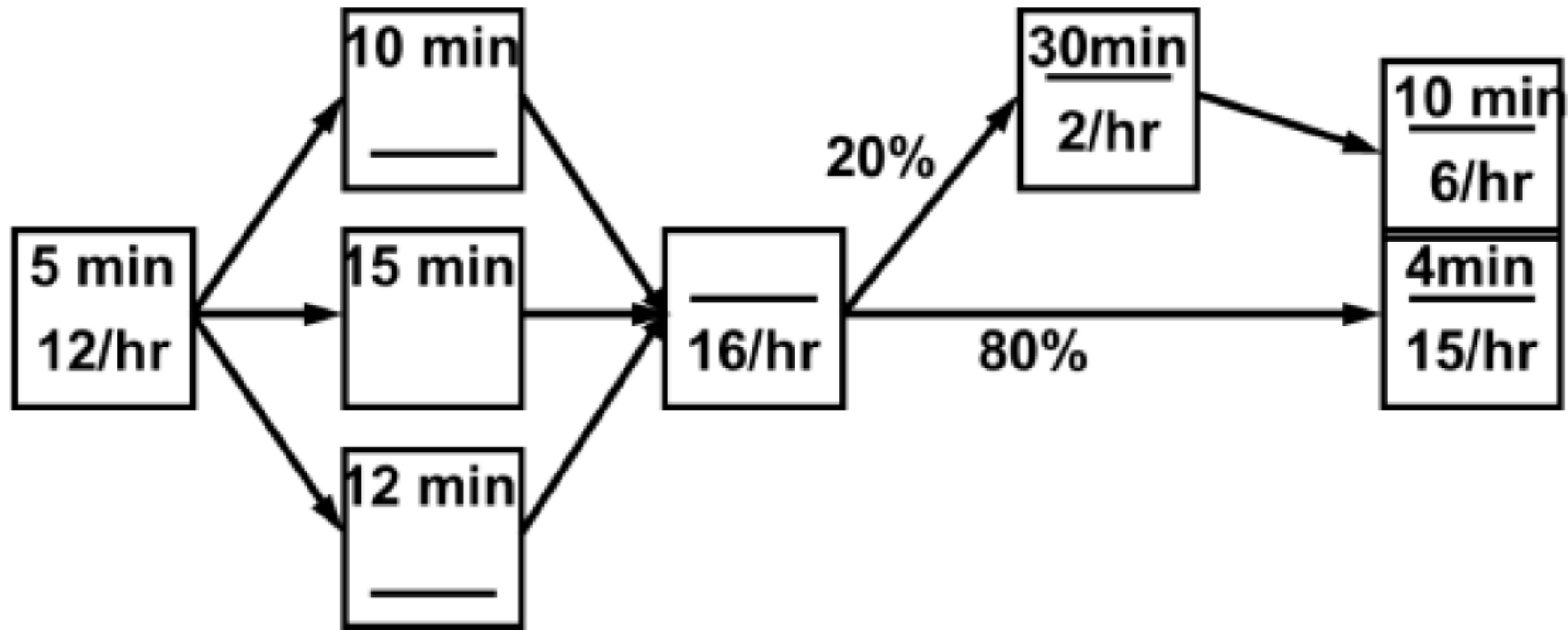
- For this problem assume all times and rates are deterministic and there is a reasonable amount of buffer between stages.
- Stage 1 has a single resource.
- Stage 2 has 3 servers. The job needs to visit only one of them, so these three work in parallel. The times the individual resources require are given.
- Stage 3 has a single resource
- Stage 4 is only required of 20% of the units.
- Stage 5 is a single resource that handles both the 20% of the units that go through stage 4 at the rate of 6/hr and the 80% of the units that don't use stage 4 at a rate of 15/hour.



Capacity rate: S₁ _____ S₂ _____ S₃ _____ S₄ _____ S₅ _____

(a) Compute the capacity of each stage

(b) Which stage is the bottleneck?



Stage 1

Stage 2

Stage 3

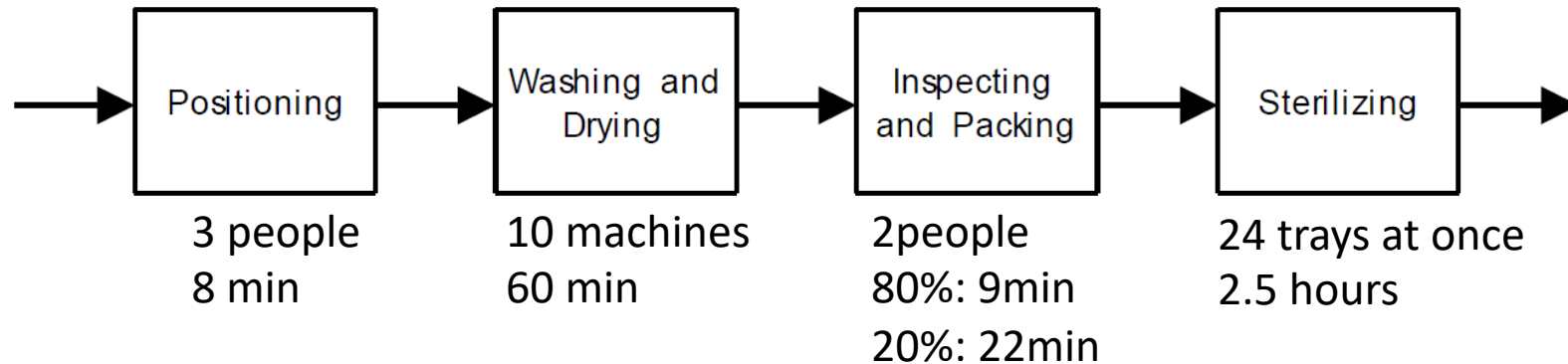
Stage 4

Stage 5

(c) The maximum production rate of the system ?

Practice 3: Capacity for Cleaning and Sterilizing in a Surgical Suite (optional)

Surgical instruments, when they are not in use, are stored in “trays” that are wrapped and kept sterile until they are needed. Once a tray of instruments has been used in surgery and returned to the supplies area the instruments must be 1) positioned for washing, 2) washed and dried, 3) inspected for damage and packed back in the tray, and 4) sterilized. The four-step process is shown below



Positioning is done by three people and a person can do one tray in 8 minutes.

The washing and drying is done by 10 automated machines. Each machine washes and dries a tray of instruments in 60 minutes. No labor is required except to place the instruments in the machine and take them out, which we will ignore for this problem.

Inspecting and packing can be broken into two cases. Everything is fine (80% of the trays) and some instrument is damaged (20% of the trays). When everything is fine it takes 9 minutes for one person to do. If any instrument is damaged, the average time to (1) repair or find a replacement and (2) inspect and pack is 22 minutes. Two people work at this stage, and both people do both steps.

The sterilizing step is like a baking or kiln operation that cannot be interrupted to add more trays. The sterilizing step takes 2.5 hours and the one “oven” can handle up to 24 trays at once.

(a) Use the table below and compute the capacity of each resource pool.

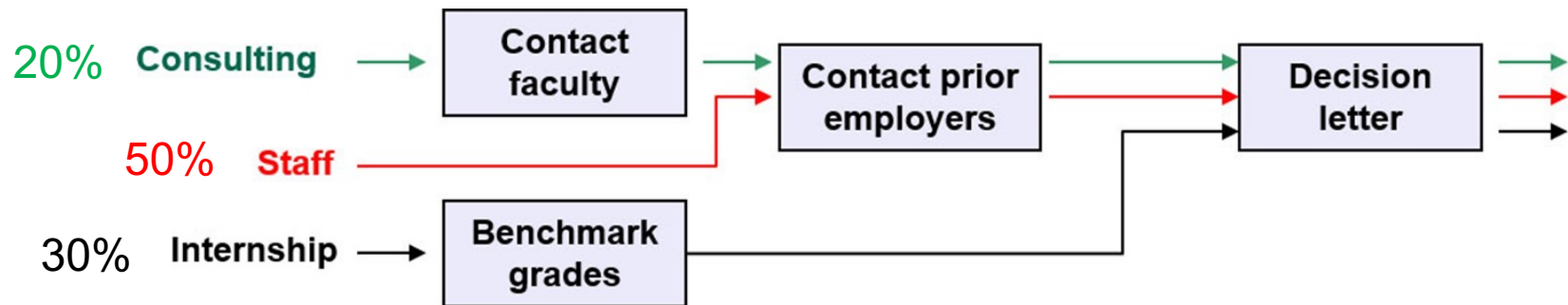
Resource Pool	Calculation step	Capacity of Resource pool (tray/hour)
Positioning people		
Washing and Drying machines		
Inspecting and Packing people		
Sterilizing “oven”		

(b) Capacity of this system?

(c) An expansion of the OR (operating room) will require that trays be handled at the rate of 12/hour. What changes / additions need to be made to meet this demand?

Practice 4: Process Analysis with Different Types of Flow Units (optional)

Three types of job applications need to be processed: “consulting,” “staff,” and “internship.” There are reasonable amount of 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. 20% of the arrived applications are consulting application, 50% are staff and 30% are internship. Unit load and numbers of workers for each task are given below:

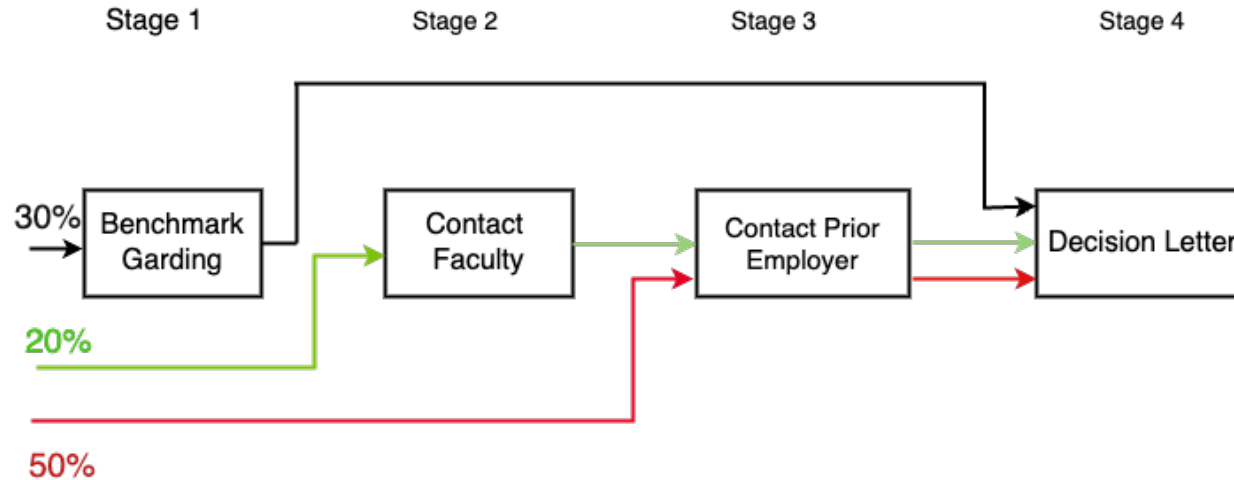


	Contact faculty	Contact employers	Benchmark grades	Decision letter
Data:				
Unit load(min/app)	20	15	8	2
Number of workers	2	3	3	1

Which step is the bottleneck?

Can this process handle an arrival rate of 20 applications per hour?

What is the capacity rate of this process?



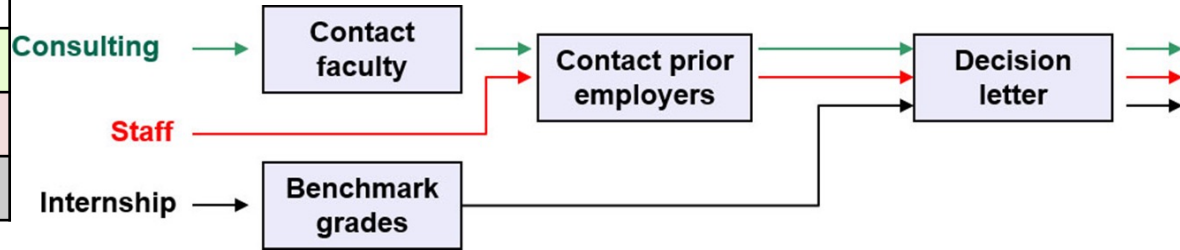
	Benchmark grades	Contact faculty	Contact employers	Decision letter
Unit load(min/app)	8	20	15	2
Number of workers	3	2	3	1

	Stage 1	Stage 2	Stage 3	Stage4
Average processing time				
Number of resource				
Capacity rate				

Another method: By calculating implied utilization.

Can this process handle an arrival rate of 20 applications per hour?

	Proportion	Arrival Rate
Consulting	20%	
Staff	50%	
Internship	30%	



	Contact faculty	Contact employers	Benchmark grades	Decision letter
Unit load(min/app)	20	15	8	2
Number of workers	2	3	3	1
Capacity rate (app/hour)				
Arrival rate (app/hour)				
Implied utilization				

Key take-aways

- Concepts clarification
- Key process characteristics
- Process Flow diagram
- Improving a process