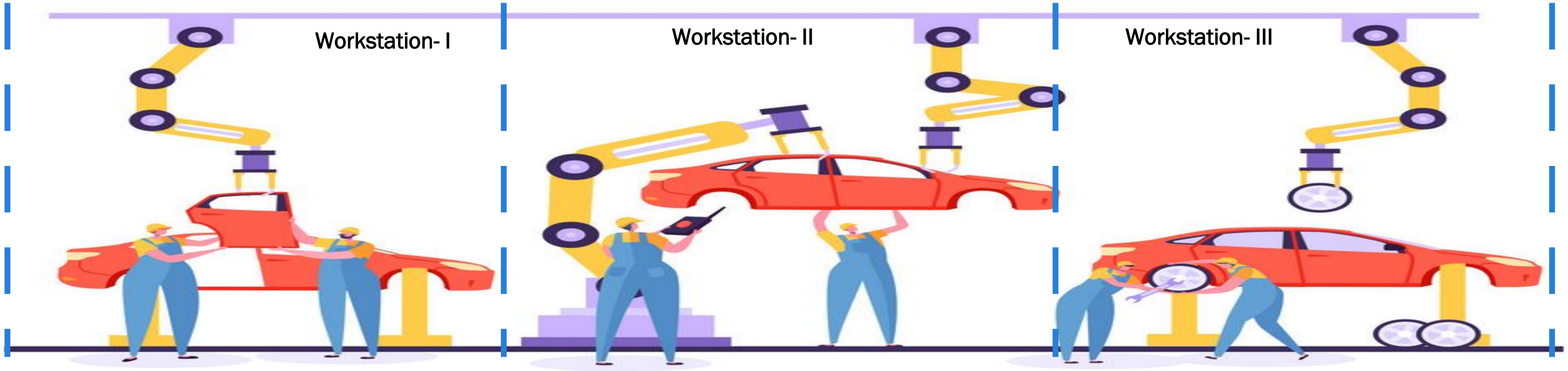
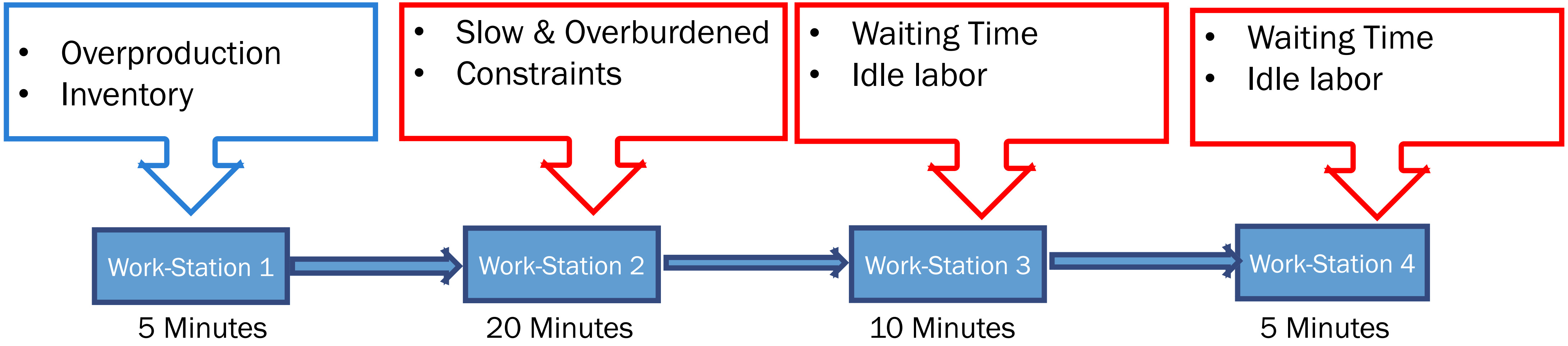
ASSEMBLY LINES & LINE BALANCING

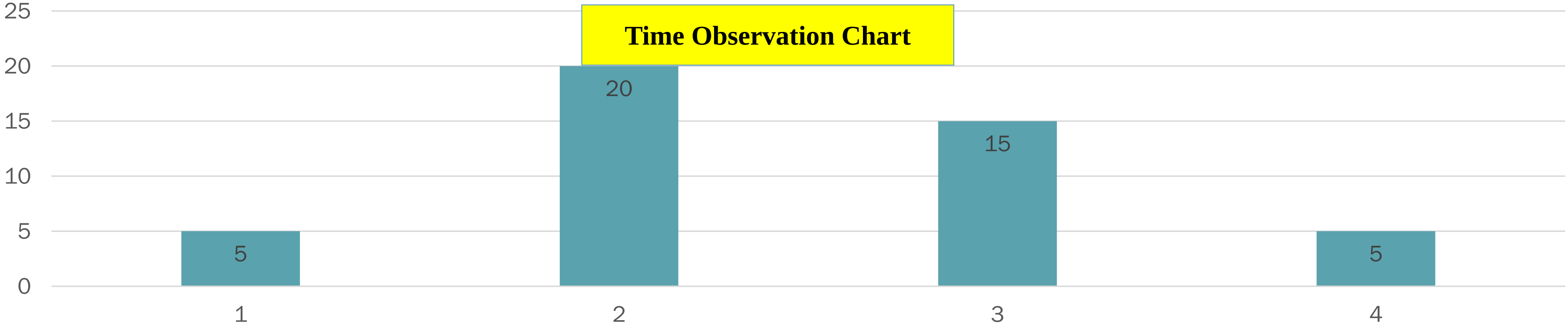
Assembly Lines



- Assembly line requires work into a series of elemental tasks
- Durations of these elemental tasks typically range from a few seconds to 15 minutes or more
- Tasks are usually grouped into manageable bundles and assigned to workstations staffed by one or two operators.
- Workers/equipment are arranged in a sequence of processes required
- The length of Assembly lines may range from a few meters to several miles,

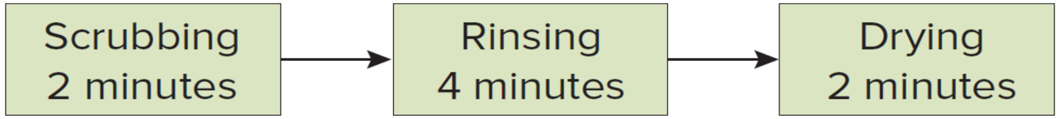
Line Balancing





Line Balancing

- The process of deciding how to assign tasks to workstations is referred to as **line balancing.**
  - *Obtain appropriate task groupings that represent approximately equal time requirements.*
  - *Minimizes the idle time along the line to ensure high utilization of labour and equipment.*
- Difficulties
  - *It may not be feasible to combine certain activities into the same bundle (Bundling constraint), because differences in equipment requirements, or incompatible activities*
  - *Differences among elemental task lengths cannot always be overcome by grouping tasks*
  - *Precedence constraints, i.e., a component can be assembled only after other components*



Automatic Car-Wash

Scrubbing and Drying can’t be combined

Cycle Time

- Maximum time allowed at each workstation to complete the set of assigned tasks on one unit before the work moves on.

Fabrication: Consisting 5 elemental tasks

1.0 min.
0.2 min.
0.5 min.
0.7 min.
0.1 min.

Single Workstation

→ 0.1 min. → 0.7 min. → 1.0 min. → 0.5 min. → 0.2 min. →

Five Workstations

Cycle Time = 2.5 Minutes

Maximum cycle time

Potential range of an output line is a function of Cycle Time

Minimum cycle time

Cycle Time = 1.0 Minute

Output Rate

- Output Rate = Operating Time per Day/Cycle Time
- Example:
  - *An assembly line operates for eight hours per day. With a cycle time of 1.0 minute, Output Rate ?*
  - *Answer: 8*60/1 = 480 units per day*
  - *If the cycle time is 2.5 minutes, the output rate will be 8*60/2.5 = 192 units per day*

- Cycle time is determined by the desired output rate.
  - *Cycle Time= Operating Time per Day/ Output Rate*
  - *If the desired output rate doesn't fall between the minimum & maximum bounds of cycle time. The desired output rate must be revised*

Number of Workstations

If the desired rate of output is the maximum of 480 units per day, N_{min} = ?

What is the minimum number of workstations required for a given cycle time T ?

What are the minimum number of workstations so that maximum time required to complete the task at any of the workstations is <= T) ?

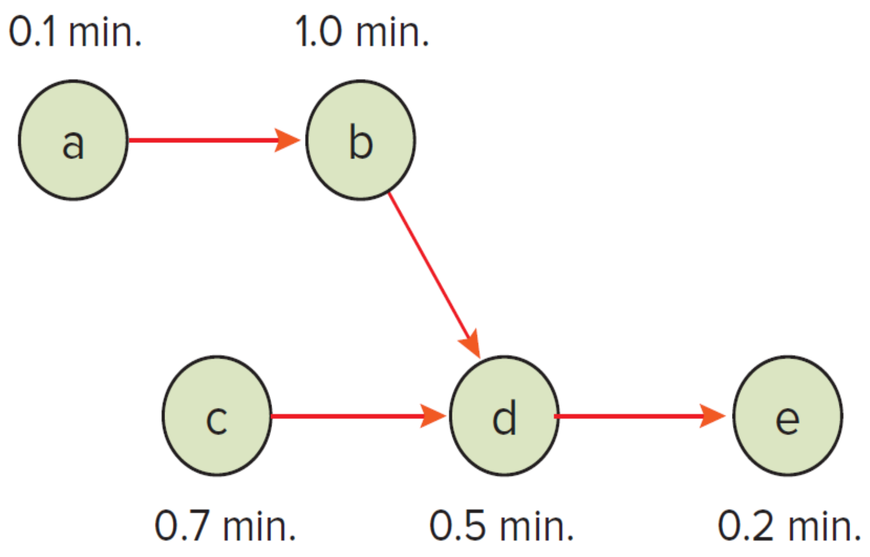
$$N_{\min} = \frac{\sum t}{\text{Cycle time}}$$

where

$N_{\min}$ = Theoretical minimum number of stations
Σt = Sum of task times

Precedence Diagram

- Portrays the technological constraints,
  - *i.e., to begin task d, tasks b and c must both be finished (precedence relationship)*
- Incompatible groupings due to space constraints etc.

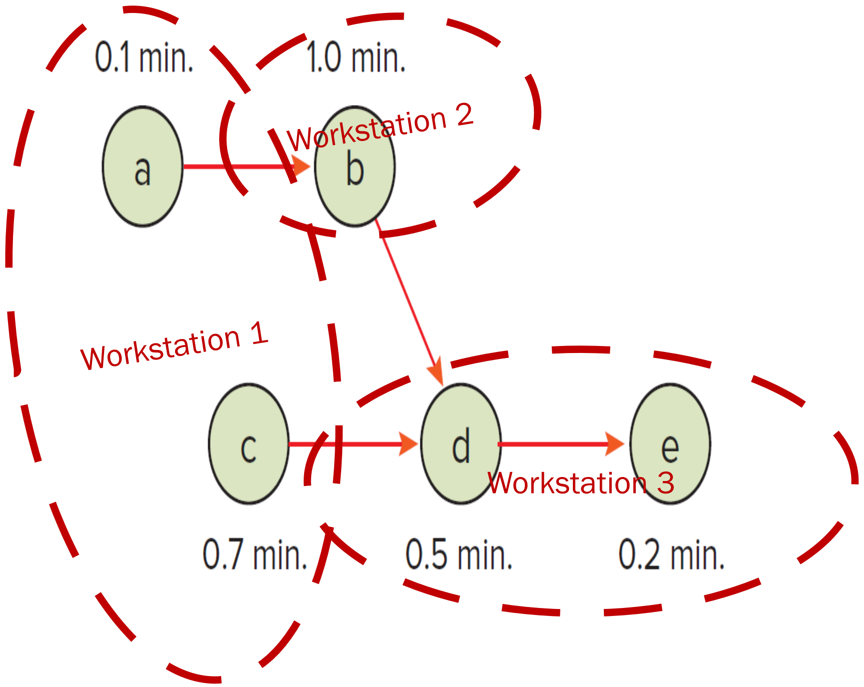


- Generally *heuristic (intuitive) rules are employed to* provide good and sometimes optimal sets of task groupings
- Two heuristics are generally used:
  - Assign tasks in order of most following tasks
  - Assign tasks in order of greatest positional weight

(Positional weight is the sum of each task's time and the times of all following tasks)

Assign tasks in order of most following tasks

Arrange the tasks shown in the following figure into three workstations using a cycle time of 1 minute.



Assign tasks in order of most following tasks

Workstation	Time Remaining	Eligible	Assign Task	Revised Time Remaining	Station Idle Time
1	1.0	a,c	a	0.9	
	0.9	b,c	c	0.2	
	0.2	None	--		0.2
2	1.0	b	b	0.0	0.0
3	1.0	d	d	0.5	
	0.5	e	e	0.3	0.3
Total station idle time					0.5

The minimum number of workstations needed is a function of the desired output rate and, therefore, the cycle time

Basic Guidelines

- Tasks are assigned one at a time to the line, starting at the first workstation.
- At each step, the unassigned tasks are checked to determine which are eligible for assignment.
- Next, the eligible tasks are checked against rules to see which of them will fit in the workstation being loaded:
  - *Primary rule by which tasks are assigned to workstations (e.g., maximum number of following tasks)*
  - *Secondary rule to break the ties (e.g., tasks with longer task times are preferred for assignment)*
- If a task can be assigned to a workstation without exceeding the cycle time, then the task will fit
- This process is repeated until there are no eligible tasks that will fit at that workstation.
- Then the next workstation can be loaded. This continues until all tasks are assigned.
- Key concerns:
  - *The desired output rate determines the cycle time*
  - *The sum of the task times assigned to any workstation must not exceed the cycle time.*
  - *The objective is to minimize the idle time for the line subject to technological and output constraints.*

Effectiveness Measure

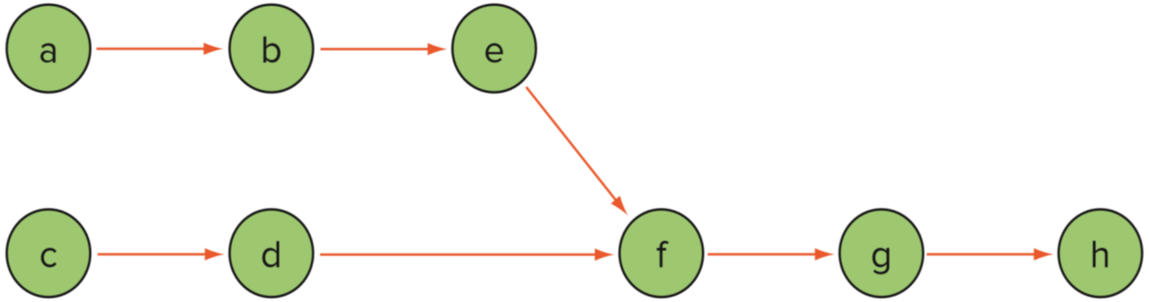
- Line Efficiency = [Sum of task times] / [N_{actual}*Cycle Time]

- Line Efficiency = 100 % − Percent idle time

- Percentage of Idle Time =
  - *[Idle time per cycle*100] / [N_{actual}*Cycle Time]*
    - Where N_{actual} = Actual Number of Work Stations
  - *In the previous example, Percentage of idle time is 0.5 *100 / 3 × 1.0 = 16.7%*

Example

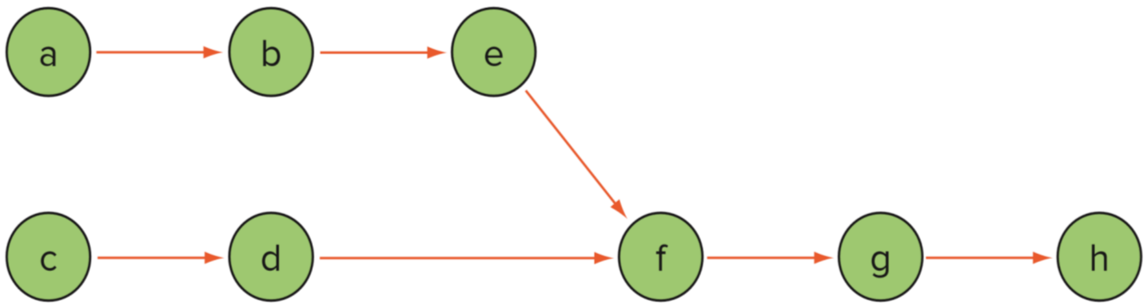
1. Draw a precedence diagram.



Task	Immediate Predecessor	Task Time (in minutes)
a	—	0.2
b	a	0.2
c	—	0.8
d	c	0.6
e	b	0.3
f	d, e	1.0
g	f	0.4
h	g	0.3
		$\Sigma t = 3.8$

Example

1. Assuming an eight-hour workday, compute the cycle time needed to obtain an output of 400 units per day.
2. Determine the minimum number of workstations required.



Task	Immediate Predecessor	Task Time (in minutes)
a	—	0.2
b	a	0.2
c	—	0.8
d	c	0.6
e	b	0.3
f	d, e	1.0
g	f	0.4
h	g	0.3
		$\Sigma t = 3.8$

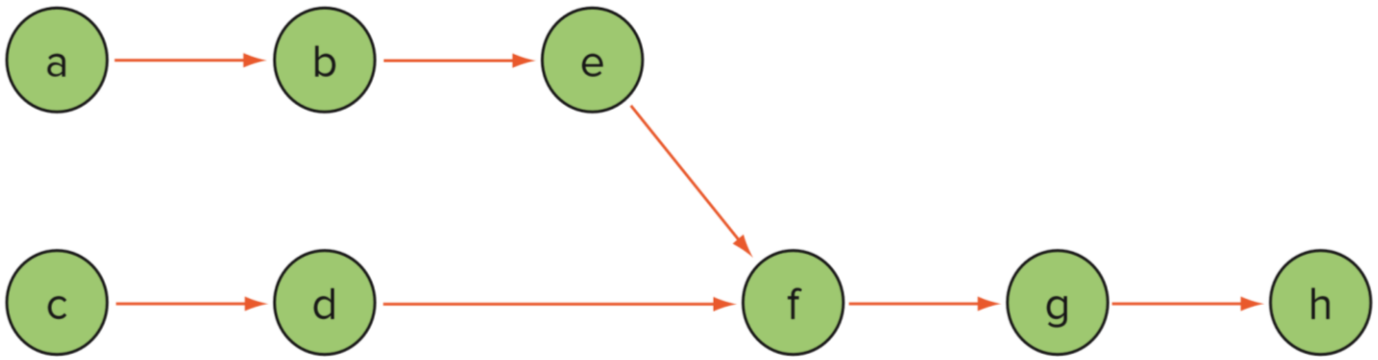
Cycle time = Operating Time/Expected Output Rate= 1.2 Minutes

N_{min} = Σt /Cycle Time= 3.8/1.2 =3.17 (rounded to 4)

Example

4. Assign tasks to workstations (using the rule of greatest number of following tasks; In case of a tie, use the tiebreaker of assigning the task with the longest processing time first.)

5. Calculate Line Efficiency



Task	Immediate Predecessor	Task Time (in minutes)
a	—	0.2
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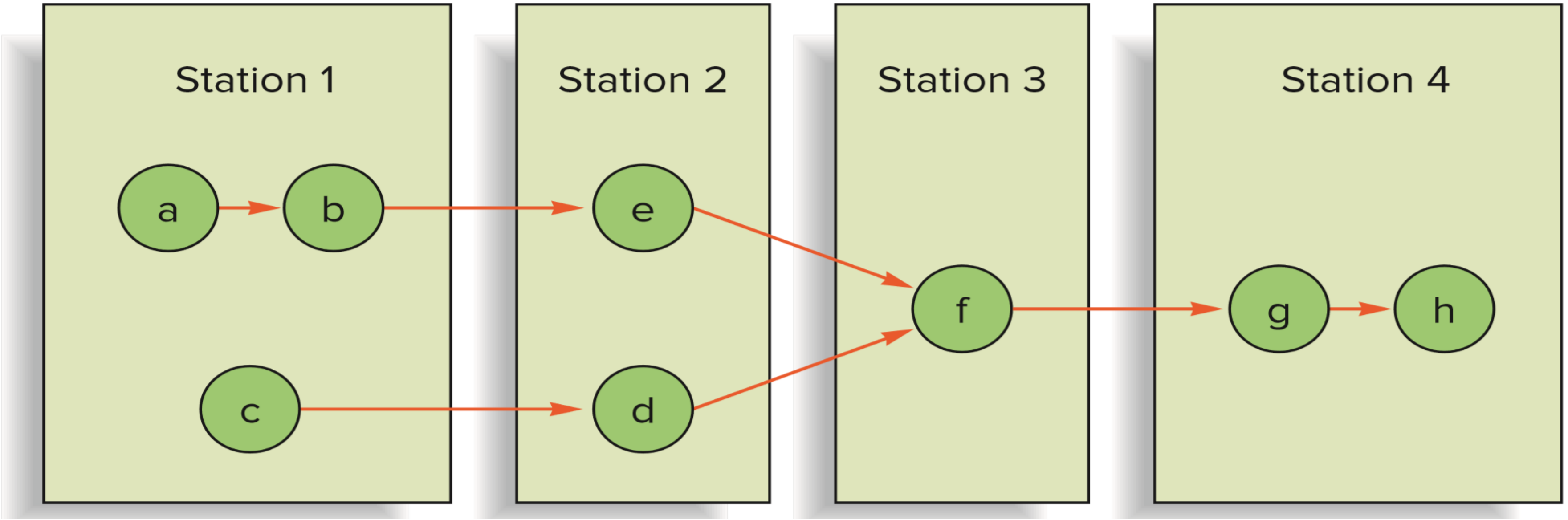
c	—	0.8
d	c	0.6
e	b	0.3
f	d, e	1.0
g	f	0.4
h	g	0.3
		$\Sigma t = 3.8$

Work-station	Time Remaining	Which task is eligible?	Which task will Fit ?	Assign Task	Revised Time Remaining	Station Idle Time
1	1.2	a,c	a,c	a (0.2)	1.0	
	1.0	c,b	c,b	c (0.8)	0.2	
	0.2	b,d	b	b (0.2)	0.0	
	0.0	d,e	None			0.0
2	1.2	d,e	d,e	d (0.6)	0.6	
	0.6	e	e	e(0.3)	0.3	
	0.3	f	None			0.3
3	1.2	f	f	f(1.0)	0.2	
	0.2	g	None			0.2
4	1.2	g	g	g(0.4)	0.8	
	0.8	h	h	h(0.3)	0.5	
	0.5					0.5
						1.0 min.



$$\text{Percent idle time} = \frac{1.0 \text{ min.}}{4 \times 1.2 \text{ min.}} \times 100 = 20.83\%$$

$$\text{Efficiency} = 100\,\% - 20.83\,\% = 79.17\%$$

Alternatively,

Efficiency = = Σt / N_a * Cycle Time = 3.8/1.2*4 = 79.17%