## *Line Balancing..*

Lecture 40

**Purpose is to minimize the number of people and/or machines on an assembly line that is required to produce a given number of units**

# Line Balancing Example

**EXAMPLE-1**

**Green Grass's plant manager just received marketing's latest forecasts of fertilizer spreader sales for the next year. She wants its production line to be designed to make 2,400 spreaders per week. The plant will operate 40 hours per week.**

**a. What should be the line's cycle time or throughput rate per hour be?**

**Throughput rate/hr = 2400 / 40 = 60 spreaders/hr**

**Cycle Time = 1/Throughput rate= 1/60 = 1 minute = 60 seconds**

# Line balancing Example continued:

**Assume that in order to produce the new fertilizer spreader on the assembly line requires doing the following steps in the order specified:**

| Work Element | Description | Time (sec) | Immediate Predecessor(s) |
|---|---|---|---|
| A | Bolt leg frame to hopper | 40 | None |
| B | Insert impeller shaft | 30 | A |
| C | Attach axle | 50 | A |
| D | Attach agitator | 40 | B |
| E | Attach drive wheel | 6 | B |
| F | Attach free wheel | 25 | C |
| G | Mount lower post | 15 | C |
| H | Attach controls | 20 | D, E |
| I | Mount nameplate | 18 | F, G |
| | | Total 244 | |

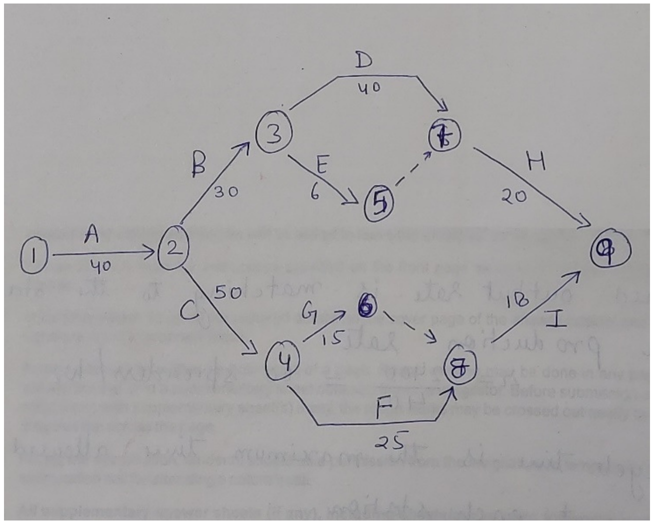
**b.** **What is the total number of stations or machines required?**

TM (total machines) = total production time / cycle time = 244/60 = 4.067 or 5

# Draw a Precedence Diagram

**SOLUTION**

**The figure shows the complete diagram. We begin with work element A, which has no immediate predecessors. Next, we add elements B and C, for which element A is the only immediate predecessor. After entering time standards and arrows showing precedence, we add elements D and E, and so on. The diagram simplifies interpretation. Work element F, for example, can be done anywhere on the line after element C is completed. However, element I must await completion of elements F and G.**



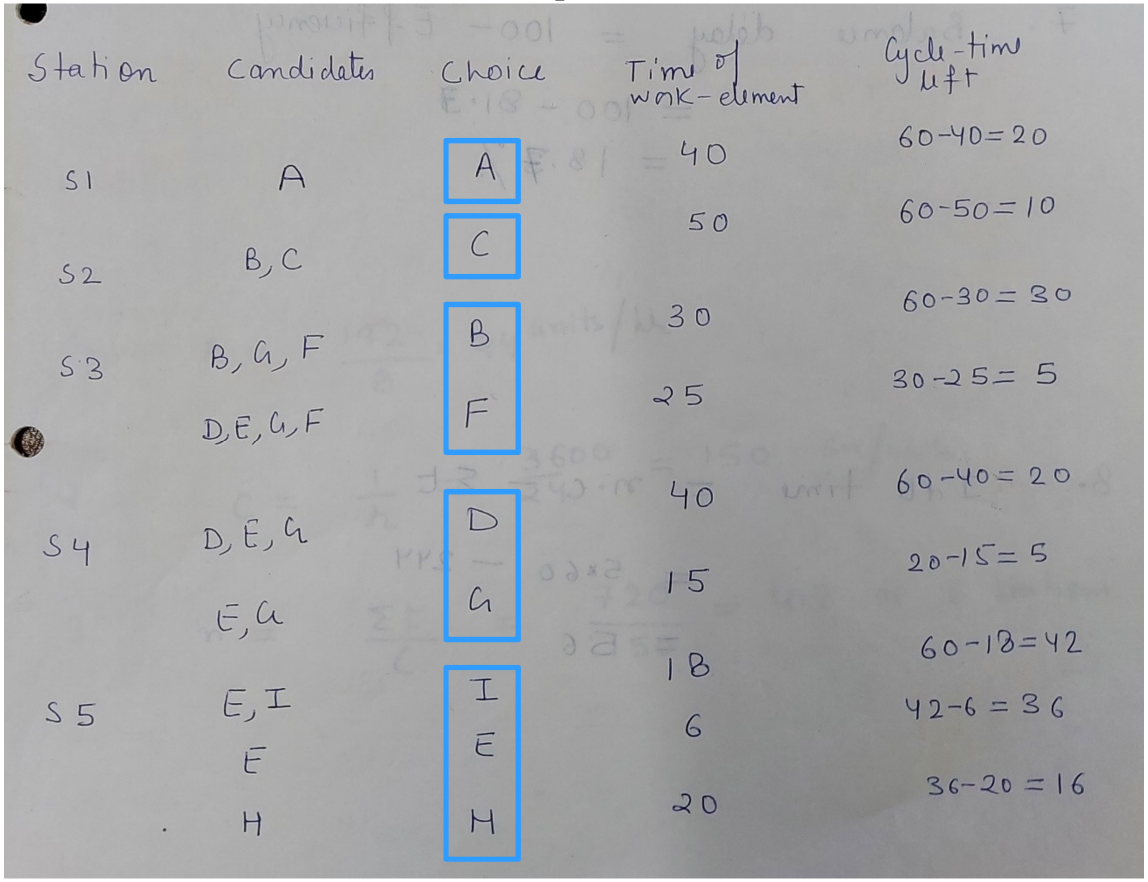

Precedence Diagram for
Assembling the Big Broadcaster

# *Allocating work or activities to stations or machines*

- **The goal is to cluster the work elements into workstations so that**
  1. **The number of workstations required is minimized**
  2. **The precedence and cycle-time requirements are not violated**
- **The work content for each station is equal (or nearly so, but less than) the cycle time for the line**
- **Trial-and-error can be used but commercial software packages are also available**

# Finding a Solution

- **The minimum number of workstations is 5 and the cycle time is 60 seconds, so Figure 5 represents an optimal solution to the problem**



| Station | Candidates | Choice | Time of work-element | Cycle-time left |
|---|---|---|---|---|
| S1 | A | A | 40 | 60-40=20 |
| S2 | B, C | C | 50 | 60-50=10 |
| S3 | B, G, F | B | 30 | 60-30=30 |
| | D, E, G, F | F | 25 | 30-25=5 |
| S4 | D, E, G | D | 40 | 60-40=20 |
| | E, G | G | 15 | 20-15=5 |
| S5 | E, I | I | 18 | 60-18=42 |
| | E | E | 6 | 42-6=36 |
| | H | H | 20 | 36-20=16 |

# Calculating Line Efficiency

c. Now calculate the efficiency measures of a five-station solution:

$$\text{Efficiency} = \frac{\Sigma t}{nc}(100) = \frac{244}{5(60)} = 81.3\%$$

Balance delay (%) = 100 – Efficiency = 100% - 81.3% = 18.7%

Idle time = $nc - \Sigma t = 5(60) - 244 = 56$ seconds

# A Line Process

- The desired output rate is matched to the staffing or production plan
- Line Cycle Time is the maximum time allowed for work at each station is

$$c = \frac{1}{r}$$

where

$c$ = cycle time in hours

$r$ = desired output rate

# A Line Process

- The theoretical minimum number of stations is

$$TM = \frac{\Sigma t}{c}$$

where

$\Sigma t$ = total time required to assemble each unit

# A Line Process

- **Idle time, efficiency, and balance delay**

$$\text{Idle time} = nc - \Sigma t$$

where

$n$ = number of stations

$$\text{Efficiency (\%)} = \frac{\Sigma t}{nc}(100)$$

$$\text{Balance delay (\%)} = 100 - \text{Efficiency}$$

# Solved Problem 2

A company is setting up an assembly line to produce 192 units per 8-hour shift. The following table identifies the work elements, times, and immediate predecessors:

| Work Element | Time (sec) | Immediate Predecessor(s) |
|---|---|---|
| A | 40 | None |
| B | 80 | A |
| C | 30 | D, E, F |
| D | 25 | B |
| E | 20 | B |
| F | 15 | B |
| G | 120 | A |
| H | 145 | G |
| I | 130 | H |
| J | 115 | C, I |
| | Total 720 | |

# Solved Problem 2

a. What is the desired cycle time (in seconds)?

b. What is the theoretical minimum number of stations?

c. Use trial and error to work out a solution, and show your solution on a precedence diagram.

d. What are the efficiency and balance delay of the solution found?

**SOLUTION**

a. Substituting in the cycle-time formula, we get

$$c = \frac{1}{r} = \frac{8 \text{ hours}}{192 \text{ units}} (3{,}600 \text{ sec/hr}) = 150 \text{ sec/unit}$$

# *Solved Problem 2*

b. The sum of the work-element times is 720 seconds, so

$$TM = \frac{\Sigma t}{c} = \frac{720 \text{ sec/unit}}{150 \text{ sec/unit-station}} = 4.8 \quad \text{or 5 stations}$$

which may not be achievable.

# Solved Problem 2

c. The precedence diagram is shown in Figure 7.6. Each row in the following table shows work elements assigned to each of the five workstations in the proposed solution.

| Work Element | Immediate Predecessor(s) |
|---|---|
| A | None |
| B | A |
| C | D, E, F |
| D | B |
| E | B |
| F | B |
| G | A |
| H | G |
| I | H |
| J | C, I |

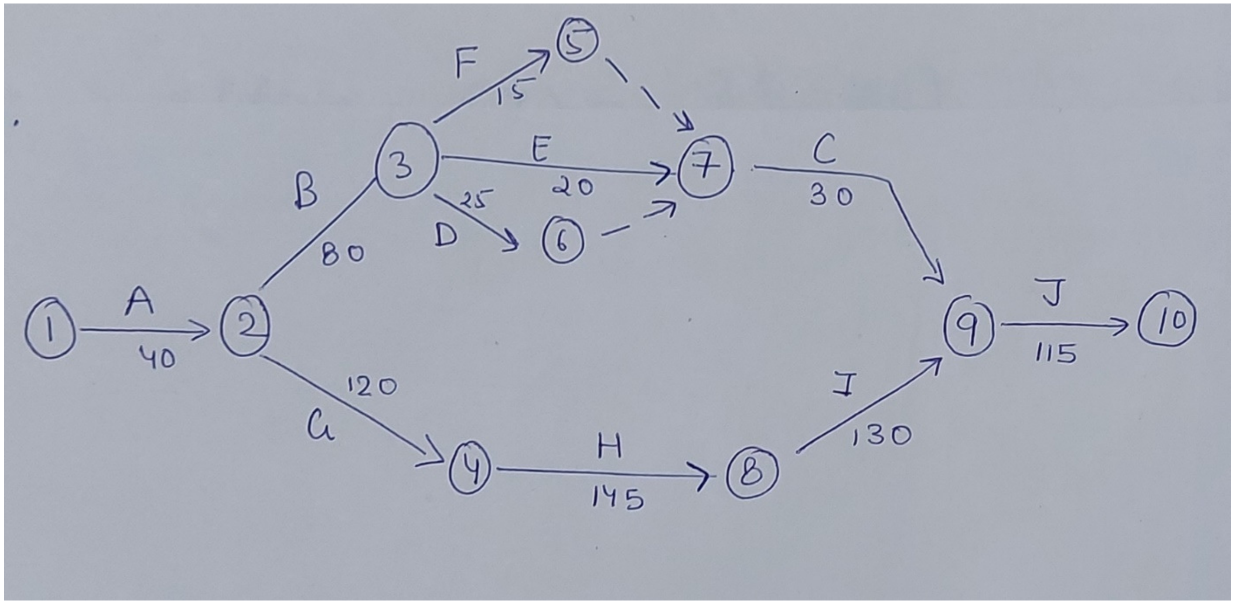



Figure 7.6 – Precedence Diagram

# Solved Problem 2

| Station | Candidate(s) | Choice | Work-Element Time (sec) | Cumulative Time (sec) | Idle Time (c= 150 sec) |
|---|---|---|---|---|---|
| S1 | | | | | |
| S2 | | | | | |
| S3 | | | | | |
| S4 | | | | | |
| S5 | | | | | |

# Solved Problem 2

| Station | Candidate(s) | Choice | Work-Element Time (sec) | Cumulative Time (sec) | Idle Time (c= 150 sec) |
|---|---|---|---|---|---|
| S1 | A | A | 40 | 40 | 110 |
| | B | B | 80 | 120 | 30 |
| | D, E, F | D | 25 | 145 | 5 |
| S2 | E, F, G | G | 120 | 120 | 30 |
| | E, F | E | 20 | 140 | 10 |
| S3 | F, H | H | 145 | 145 | 5 |
| S4 | F, I | I | 130 | 130 | 20 |
| | F | F | 15 | 145 | 5 |
| S5 | C | C | 30 | 30 | 120 |
| | J | J | 115 | 145 | 5 |

# *Solved Problem 2*

d. Calculating the efficiency, we get

$$\text{Efficiency (\%)} = \frac{\Sigma t}{nc}(100) = \frac{720 \text{ sec/unit}}{5(150 \text{ sec/unit})}$$

$$= 96\%$$

Thus, the balance delay is only 4 percent (100–96).