Assembly-Line Balancing

Assembly-Line Balancing

- Objective is to minimize the imbalance between machines or personnel while meeting required output
- Starts with the precedence relationships
  - Determine cycle time
  - Calculate theoretical minimum number of workstations
  - Balance the line by assigning specific tasks to workstations

Assembly Line Balancing

1. Precedence diagram: circles=tasks, arrows show the required sequence.
2. Determine cycle time:

$$C = \frac{P}{D} = \frac{\text{production /time\_unit}}{\text{demand(out put)/time\_ unit}}$$

3. Determine required workstations (theoretical minimum)

$$N_t = \frac{T}{C} = \frac{\sum \text{task\_times}}{\text{cycle\_time}}$$

4. Set rules for assigning tasks (number of following tasks, longest task time)

Assembly Line Balancing

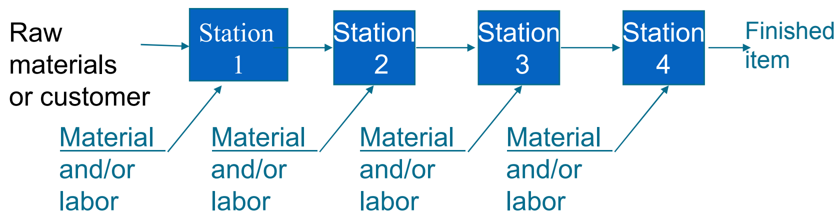
5. Assign tasks to first workstation, using rules and staying within cycle time. Repeat for following workstations until all tasks are assigned.
6. Evaluate line efficiency:

$$E = \frac{T}{N_a C}; N_a - \text{actual\_workstations}$$

7. Rebalance if efficiency is not satisfactory.

A Flow Line for Production or Service

Flow Shop or Assembly Line Work Flow



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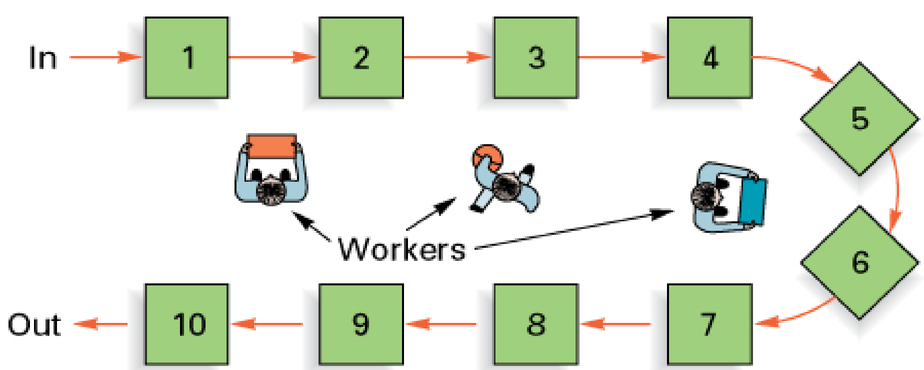
A U-Shaped Production Line



Advantage: more compact, increased communication facilitating team work, minimize the material handling

6

Wing Component Example

TABLE 9.2	Precedence Data for Wing Component		
TASK	ASSEMBLY TIME (MINUTES)	TASK MUST FOLLOW TASK LISTED BELOW	
A	10	–	This means that tasks B and E cannot be done until task A has been completed
B	11	A	
C	5	B	
D	4	B	
E	11	A	
F	3	C, D	
G	7	F	
H	11	E	
I	3	G, H	
	Total time 65		

Wing Component Example

TABLE 9.2	Precedence Data for Wing Component	
TASK	ASSEMBLY TIME (MINUTES)	TASK MUST FOLLOW
A	10	
B	11	
C	5	
D	4	
E	11	
F	3	
G	7	
H	11	
I	3	
	Total time 65	

480 available mins per day

40 units required

9.12

$$\text{Cycle time} = \frac{\text{Production time available per day}}{\text{Units required per day}}$$

$= 480 / 40$

$= 12$ minutes per unit

$$\text{Minimum number of workstations} = \frac{\sum_{i=1}^{n} \text{Time for task } i}{\text{Cycle time}}$$

$= 65 / 12$

$= 5.42$, or 6 stations

3

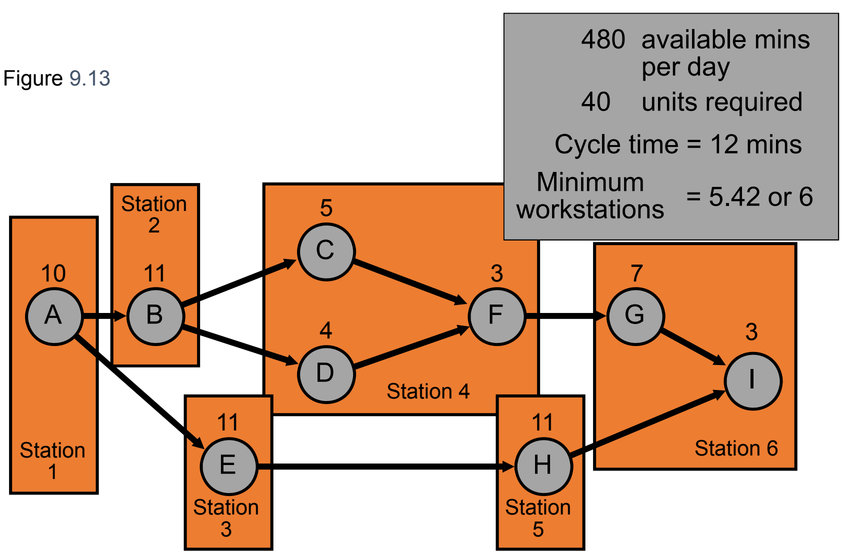
I

Wing Component Example

TABLE 9.3	Layout Heuristics That May Be Used to Assign Tasks to Workstations in Assembly-Line Balancing
1. Longest task time	From the available tasks, choose the task with the largest (longest) task time
2. Most following tasks	From the available tasks, choose the task with the largest number of following tasks
3. Ranked positional weight	From the available tasks, choose the task for which the sum of following task times is the longest
4. Shortest task time	From the available tasks, choose the task with the shortest task time
5. Least number of following tasks	From the available tasks, choose the task with the least number of subsequent tasks

Wing Component Example

Figure 9.13



Wing Component Example

TABLE 9.2	Precedence Data for Wing Component	
TASK	**ASSEMBLY TIME (MINUTES)**	**TASK MUST FOLLOW TASK LISTED BELOW**
A	10	–
B	11	A
C	5	B
D	4	B

480 available mins per day

40 units required

Cycle time = 12 mins

Minimum workstations = 5.42 or 6

Figure 9.12

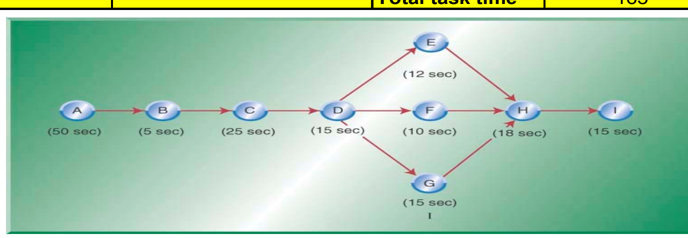
$$\text{Efficiency} = \frac{\sum \text{Task times}}{(\textit{Actual} \text{ number of workstations}) \times (\text{Largest cycle time})}$$

= 65 minutes / ((6 stations) x (12 minutes))

= 90.3%

Step 1: Identify Tasks & Immediate Predecessors

Example 10.4 Vicki's Pizzeria and the Precedence Diagram			
Work Element	Task Description	Immediate Predecessor	Task Time (seconds
A	Roll dough	None	50
B	Place on cardboard backing	A	5
C	Sprinkle cheese	B	25
D	Spread Sauce	C	15
E	Add pepperoni	D	12
F	Add sausage	D	10
G	Add mushrooms	D	15
H	Shrinkwrap pizza	E,F,G	18
I	Pack in box	H	15
		Total task time	165



Calculations

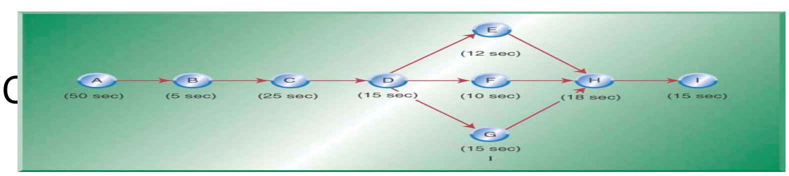
- **Step 2: Determine output rate**
  - **Vicki needs to produce 60 pizzas per hour**
- **Step 3: Determine cycle time**
  - The amount of time each workstation is allowed to complete its tasks

$$\text{Cycle time (sec./unit)} = \frac{\text{available time (sec./day)}}{\text{desired output (units/hr)}} = \frac{\text{60 min/hr x 60 sec/min}}{\text{60 units/hr}} = \text{60 sec./unit}$$

  - Limited by the bottleneck task (the longest task in a process):

$$\text{Maximum output} = \frac{\text{available time}}{\text{bottleneck task time}} = \frac{\text{3600 sec./hr.}}{\text{50 sec./unit}} = \text{72 units/hr, or pizzas per hour}$$

Layo



- **Step 5: Assign tasks to workstations**
  - Start at the first station & choose the **longest eligible task** following precedence relationships
  - **Continue adding the longest eligible task that fits without going over the desired cycle time**
  - When no additional tasks can be added within the desired cycle time, begin assigning tasks to the next workstation until finished

Workstation	Eligible task	Task Selected	Task time	Idle time
1	A	A	50	10
	B	B	5	5
2	C	C	25	35
	D	D	15	20
	E, F, G	G	15	5
3	E, F	E	12	48
	F	F	10	38
	H	H	18	20
	I	I	15	5

Calculation

- Step 6: Compute efficiency and balance delay
  - **Efficiency (%) is the ratio of total productive time divided by total time**

$$\text{Efficiency } (\%) = \frac{\sum t}{NC} = \frac{165\text{ sec.}}{3 \text{ stations x } 60 \text{ sec.}}(100) = 91.7\%$$

  - **Balance delay (%) is the amount by which the line falls short of 100%**

$$\text{Balance delay } = 100\% - 91.7\% = 8.3\%$$

Sample Problem

Task	Imm. predecessor	Task time (sec)
A	None	55
B	A	30
C	A	22
D	B	35
E	B, C	50
F	C	15
G	F	5
H	G	10
	TOTAL	222

- Draw precedence diagram
- Determine cycle time—demand = 50 units/hr
- Theoretical minimum no. of work stations
- Assign tasks to workstations using cycle time
- Efficiency and balance delay of line?
- Bottleneck?
- Maximum output?

Example 5 Golf Club mfg/assy firm

- Customer demand requires production volume of 24 finished clubs in an 8 hour shift

task	task description	operation time (min)	must follow
A	inspection	5	-
B	trim the shaft to length	4	A
C	weight the head	13	A
D	finish the shaft	9	B
E	gel coat the head	7	C
F	assemble the head to the shaft	6	D, E
	total work content	44	

- How often does a club need to come off the line in order to meet the customer demand required?
  - Exclude initial start-up
  - Cycle time = (480 min/shift)/(24 clubs/shift) = 20 min/club
  - Takt time (for this example, same as cycle time as defined above)
    - Takt time = available work time/customer demand
    - Aligns output of a process with customer demand (or the pull of the customer)
    - “Takt” is a German word referring to the rhythm or beat of music
  - Theoretical minimum number of workstations for this operation
    - Total work content/cycle time
    - 44 min/20 min per workstation = 2.2 workstations → 3 workstations

stations	1	2	3
tasks	A, C	E, B, D	F
time per club	18 min	20 min	6 min
time available per unit	20 min	20 min	20 min
idle time	2 min	0 min	14 min

- Efficiency of the line
  = (total work content)/(# of workstations x cycle time)
  = (44 min)/(3 workstations x 20 min/workstation) = 0.733 (73.3%)
- Where is the bottleneck?
  - Capacity fully utilized
  - Work-in-process inventory builds up in front of workstation 2

Example 6
Balancing manufacturing line

- For a manufacturing line, the data below on the task precedence relationships exist (assume the tasks cannot be split)

task	performance time (min)	must follow
A	3	-
B	6	A
C	7	A
D	2	A
E	2	A
F	4	C, B
G	5	C
H	5	D, E, F, G

Example 6 continue

- Construct the precedence diagram for the tasks.
- What is the theoretical minimum cycle time?
- To balance the line to the cycle time determined above, what is the minimum number of work stations?
- Use the "longest-operation-time" rule to balance the line to the theoretical minimum cycle time determined above.
- Calculate the efficiency of the balanced line.