MANUFACTURING PROCESSES

Chapter Six

Outline

- What is manufacturing process?
- Production process terms
- Little’s law (inventory measures)
- Organization of production processes
- Assembly line design
- Break-evan analysis

Production Processes

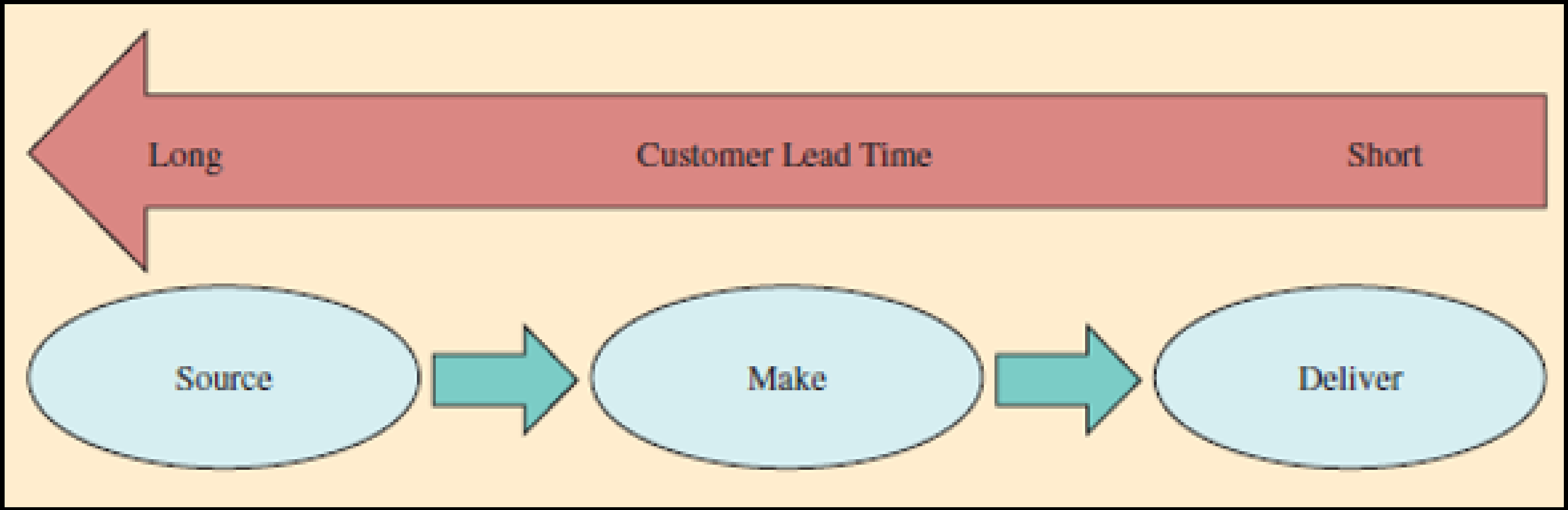
- Production processes are used to make any manufactured item.
  - Step 1 – Source the parts needed
  - Step 2 – Make the product
  - Step 3 – Deliver the product

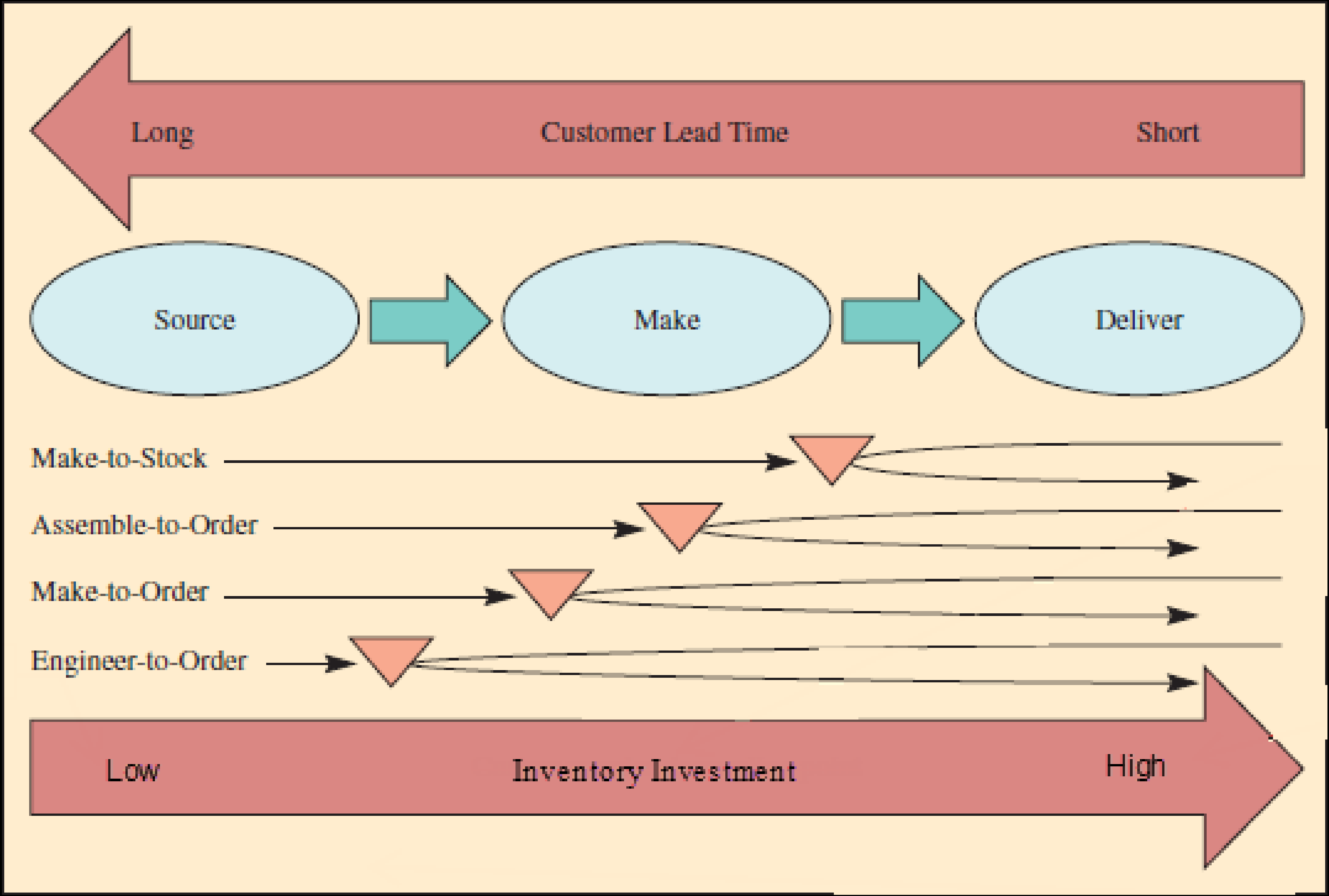
Production Process Terms

- **Lead time** – the time needed to respond to a customer order
- **Customer order decoupling point** – where inventory is positioned to allow entities in the supply chain to operate independently
- **Lean manufacturing** – a means of achieving high levels of customer service with minimal inventory investment

Customer Order Decoupling Point

- 顧客需求切入點
- Inventory is positioned in the supply chain




Long
Customer Lead Time
Short
Source
Make
Deliver
Make-to-Stock
Assemble-to-Order
Make-to-Order
Engineer-to-Order
Low
Inventory Investment
High

Types of Firms

Make-to-Stock

- Serve customers from finished goods inventory

Assemble-to-Order

- Combine a number of preassembled modules to meet a customer’s specifications

Make-to-Order

- Make the customer’s product from raw materials, parts, and components

Engineer-to-Order

- Work with the customer to design and then make the product

Make-to-Stock

- Examples of products include the following:
  - Televisions
  - Clothing
  - Packaged food products

Make-to-Stock (cont'd)

- Essential issue in satisfying customers is to balance the level of inventory against the level of customer service.
- Use lean manufacturing to achieve higher service levels for a given inventory investment.

Assemble-to-Order

- A primary task is to define a customer's order in terms of alternative components because these are carried in inventory.
  - An example is the way Dell Computer makes their desktop computers.
- One capability required is a design that enables as much flexibility as possible in combining components.
- There are significant advantages from moving the customer order decoupling point from finished goods to components.

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Make-to-Order

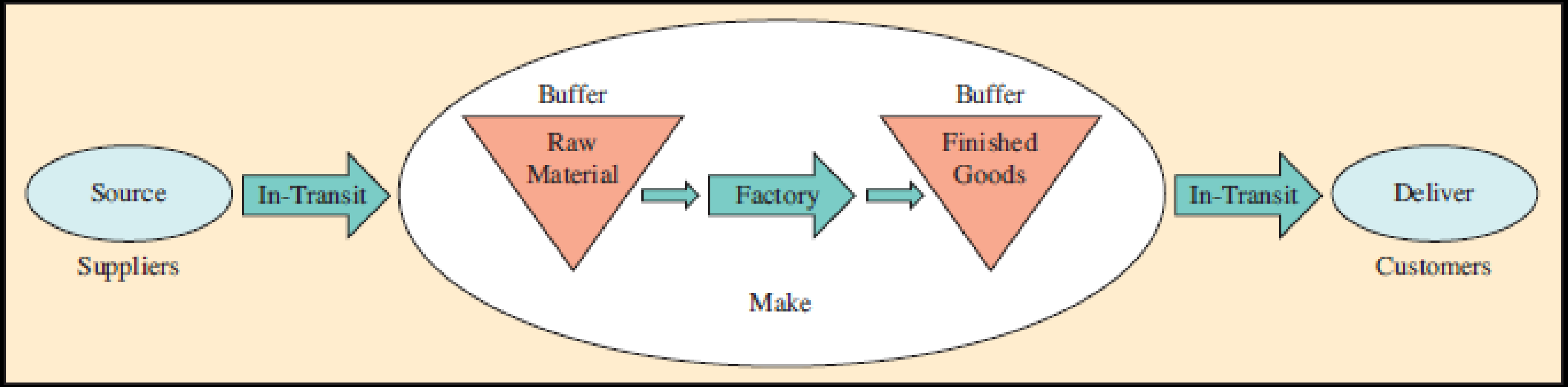
- Customer order decoupling point could be in either raw materials at the manufacturing site or the supplier inventory.
- Depending on how similar the products are, it might not even be possible to preorder parts.
- For example,

Engineer-to-Order

- The firm works with the customer to design the product, which is then made from purchased material, parts, and components.
- For example, 室內設計師

Production Process Mapping

- Develop a high-level map of a supply chain process
- Useful to understand how material flows and where inventory is held
- First step in analyzing the flow of material through a production process



Little's Law

- The flow of items through a production process can be described using Little's Law
- $Inventory = Throughput\ rate\ \mathrm{X}\ Flow\ time$
  - Throughput –average rate that items flow through a process (e.g., units/day) 產出率
  - Flow time – time for a single unit to traverse the entire process
  - Inventory – materials held by the firm for future use

Inventory Measures

- Total average value of inventory - the sum of the value (at cost) of the raw material, work-in process, and finished goods inventory
  - Commonly tracked in accounting systems and reported in financial statements
- Inventory turn - the cost of goods sold divided by the average inventory value(存貨周轉率)
- Days of supply - the inverse of inventory turns scaled to days(可供應存貨天數)

Example 6.1: Car Batteries

- An automobile company purchases batteries from a vendor in China
- The average cost of each battery is $45
- 12 hours to make a car in the plant
- 200 cars are assembled per 8-hour shift in one day
- 8000 batteries are hold in the company in raw material inventory at the plant as a buffer

Example 6.1: Car Batteries

- Please find the total number of batteries in the plant (raw material inventory + work-in-process inventory)

Raw material

Work-in-process

8,000

WIP inventory = throughput X Flow time
= (200/8) X 12 = 300 (batteries/per hr)

Example 6.1: Car Batteries (p.174)

- How much are these batteries worth?

> Total inventory X cost per battery →
>
> 8300 X $45 = $373,500

- How many days of supply are held in raw material inventory on average?

> The day of supply in raw material = flow time →
>
> 8000 (inventory) / 200 (throughput) = 40 (days)

Organization of Production Processes

Project – the product remains in a fixed location, equipment is moved to the product

Workcenter (job shop) - similar equipment or functions are grouped together

Manufacturing cell - a dedicated area where products that are similar in processing requirements are produced

Assembly line - work processes are arranged according to the progressive steps by which the product is made

Continuous process - assembly line only the flow is continuous such as with liquids

How Production Processes Are Organized

- **Project:** the product remains in a fixed location
  - Manufacturing equipment is moved to the product (e.g., construction sites)
  - Arranging materials according to their assembly priority

How Production Processes Are Organized

- **Workcenter (job shop)**: similar equipment or functions are grouped together
  - A part is worked on travels, according to the established sequence of operations
  - Optimizing the movement of material, and focused on a particular type of operation

How Production Processes Are Organized

- **Manufacturing cell**: a dedicated area where products that are similar and formed by allocating dissimilar machines to cells
  - Typically at lower volume levels and scheduled to produce “as needed” in response to current customer demand
  - For example, metal fabricating, computer chip manufacture

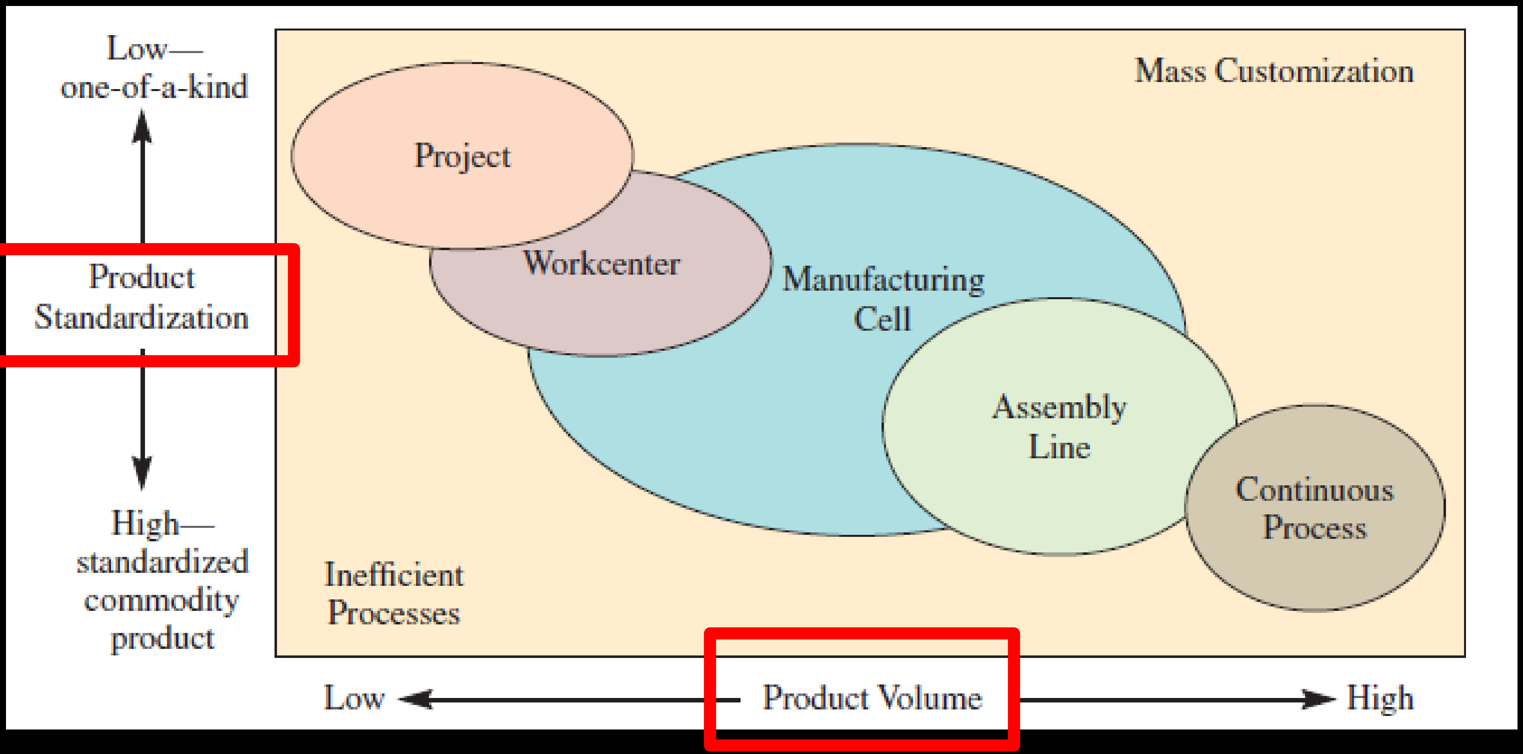
How Production Processes Are Organized

- **Assembly line**: discrete products are made by moving from workstation to workstation at a controlled rate, following the sequence needed to build the project
  - For example, assembly of toys, appliances, and automobiles

How Production Processes Are Organized

- **Continuous process**: assembly line only the flow is continuous such as with liquids
  - Highly automated and operating 24 hours a day to avoid expensive shutdowns and start-ups

Product–Process Matrix: Framework Describing Layout Strategies



以汽車產業為例

Assembly Line Design

- <u>Workstation cycle time</u> - a uniform time interval in which a moving conveyor passes a series of workstations
  - Also the time between successive units coming off the line
- <u>Assembly-line balancing</u> - assigning tasks to a series of workstations so that the required cycle time is met and idle time is minimized
- <u>Precedence relationship</u> - the order in which tasks must be performed in an assembly process

Assembly-Line Balancing

1. Specify the sequential relationships among tasks using a precedence diagram.
2. Determine the required workstation cycle time (C).

$$C = \frac{Production\ time\ per\ day}{Required\ output\ per\ \ day\ (in\ units)}$$

3. Determine the theoretical minimum number of workstations (N_t).

$$N_t = \frac{Sum\ of\ task\ times\ (T)}{Cycle\ time\ (C)}$$

4. Select a primary rule to assign tasks to workstations and a secondary rule to break ties.
5. Assign tasks (on at a time) to the first workstation until no more tasks can be added (due to cycle time or sequencing constraints). Repeat for all subsequent workstations until all tasks are assigned.
6. Evaluate the efficiency of the balance

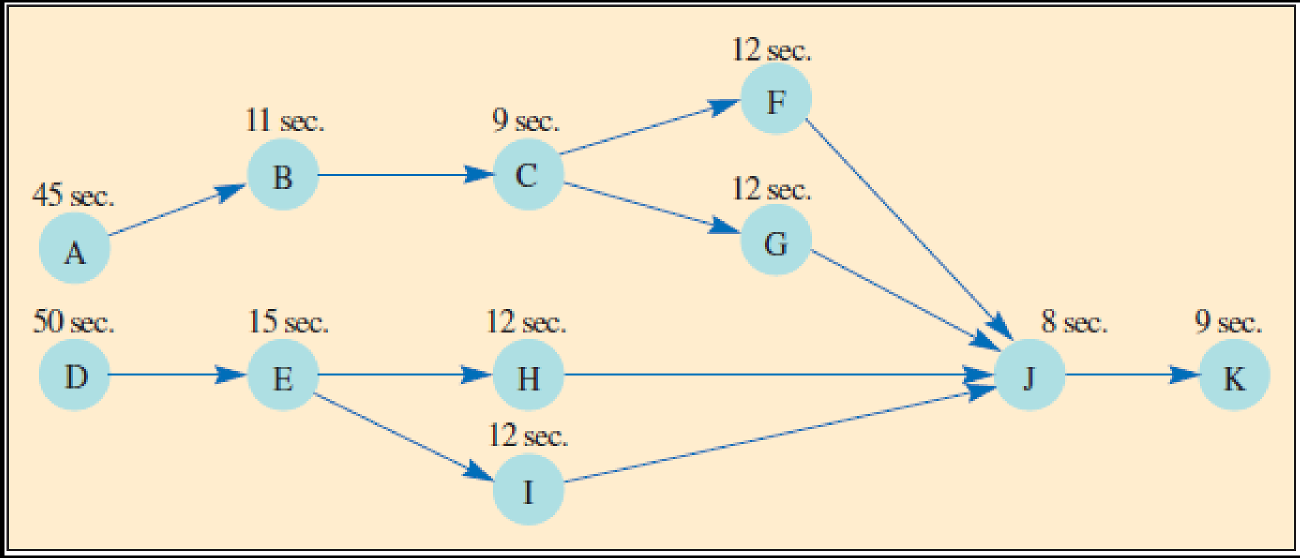
$$Efficiency = \frac{Sum\ of\ task\ times\ (T)}{Actual\ number\ of\ workstations\ (N_a) \times Workstation\ cycle\ time\ (C)}$$

7. If efficiency is unsatisfactory, rebalance using a different rule.

Example 6.2 – Assembly-Line Balancing

Task	Task Time (in Seconds)	Description	Tasks That Must Precede
A	45	Position rear axle support and hand fasten four screws to nuts.	—
B	11	Insert rear axle.	A
C	9	Tighten rear axle support screws to nuts.	B
D	50	Position front axle assembly and hand fasten with four screws to nuts.	—
E	15	Tighten front axle assembly screws.	D
F	12	Position rear wheel #1 and fasten hubcap.	C
G	12	Position rear wheel #2 and fasten hubcap.	C
H	12	Position front wheel #1 and fasten hubcap.	E
I	12	Position front wheel #2 and fasten hubcap.	E
J	8	Position wagon handle shaft on front axle assembly and hand fasten bolt and nut.	F, G, H, I
K	9	Tighten bolt and nut.	J
	195		

Example 6.2 – Precedence Diagram



$$C = \frac{\text{Production Time per Day}}{\text{Output per Day}} = \frac{60\ {}^{\text{sec}}/_{\text{min}} \times 420\ \text{min.}}{500\ \text{wagons}} = \frac{25{,}200\ \text{sec}}{500\ \text{wagons}} = 50.4\ {}^{\text{sec}}/_{\text{wagon}}$$

$$N_t = \frac{T}{C} = \frac{195\ \text{seconds}}{50.4\ \text{seconds}} = 3.87 \Longrightarrow 4$$

Example 6.2 - Assignment

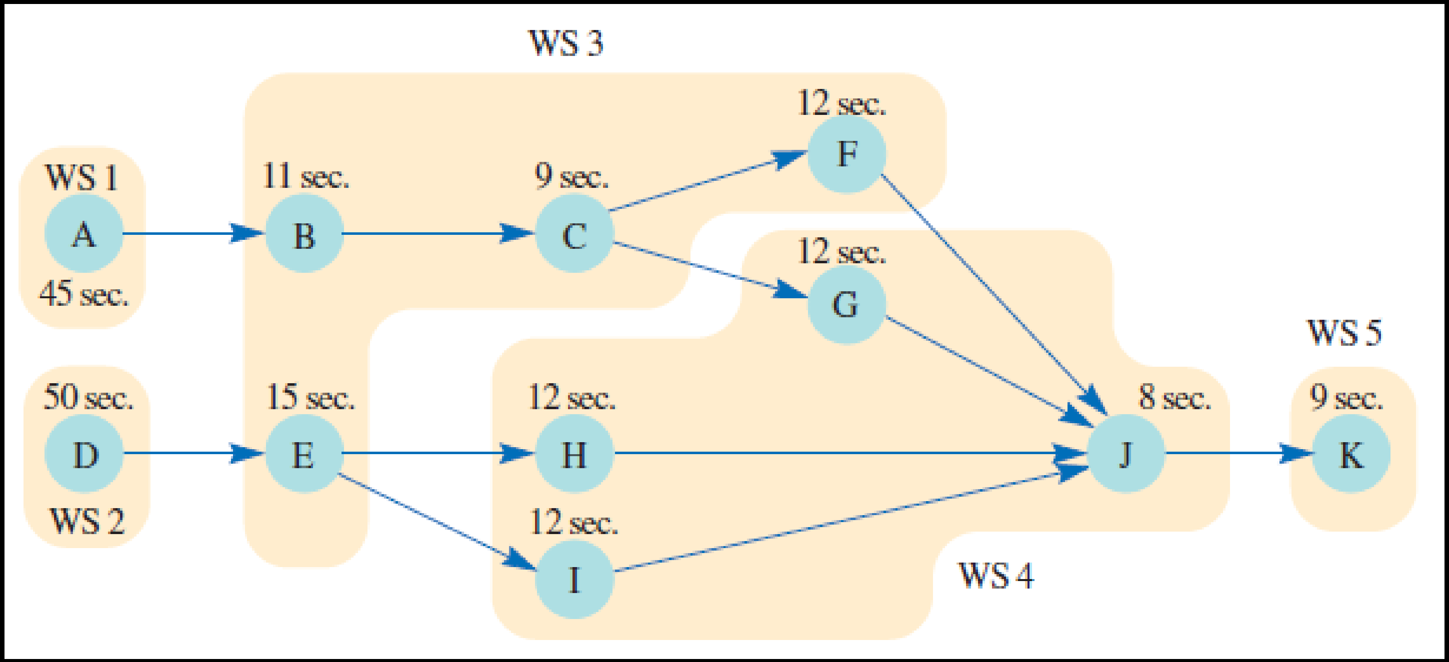
Task	Number of Following Tasks
A	6
B or D	5
C or E	4
F, G, H, or I	2
J	1
K	0

Prioritize based on the number of following tasks.

	Task	Task Time (in Seconds)	Remaining Unassigned Time (in Seconds)	Feasible Remaining Tasks	Task with Most Followers	Task with Longest Operation Time
Station 1	A	45	5.4 idle	None		
Station 2	D	50	0.4 idle	None		
Station 3	B	11	39.4	C, E	C, E	E
	E	15	24.4	C, H, I	C	
	C	9	15.4	F, G, H, I	F, G, H, I	F, G, H, I
	F*	12	3.4 idle	None		
Station 4	G	12	38.4	H, I	H, I	H, I
	H*	12	26.4	I		
	I	12	14.4	J		
	J	8	6.4 idle	None		
Station 5	K	9	41.4 idle	None		

*Denotes task arbitrarily selected where there is a tie between longest operation times.

Example 6.2 - Efficiency



$$\text{Efficiency} = \frac{T}{N_a C} = \frac{195 \text{ seconds}}{5(50.4 \text{ seconds})} = 0.77 = 77\%$$

Reducing Task Time Requirements

- Split the task
- Share the task
- Use parallel workstations
- Use a more skilled worker
- Work overtime
- Redesign