Operations Management

Lecture 4:

Process Selection and Facility Layout

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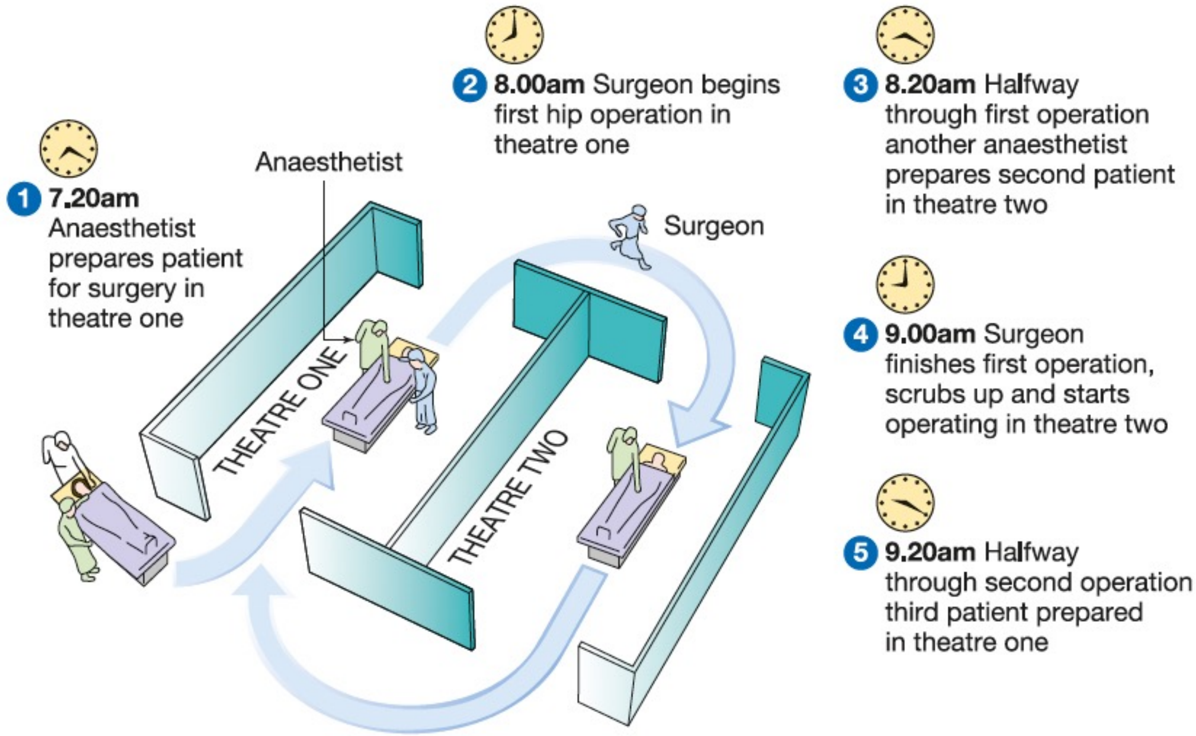
Process selection

- A **process strategy** is an organization's approach to transforming resources into goods and services.
- The objective is to create a process that can produce offerings that meet customer requirements within cost and other managerial constraints

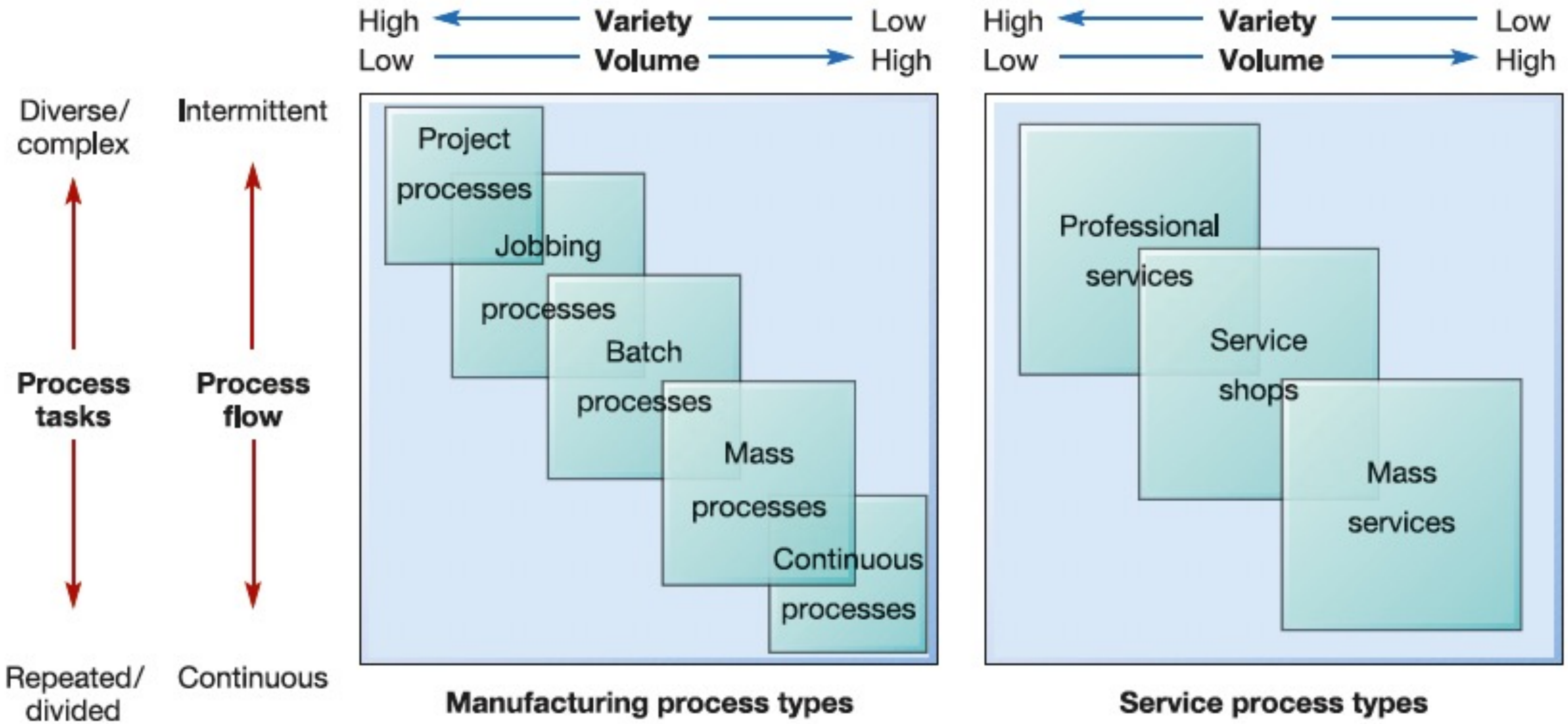


Process choice is demand driven. The two key questions in process selection are:

- How much variety will the process need to be able to handle?
- How much volume will the process need to be able to handle?

Different process types imply different volume-variety characteristics

- Different process structures provide different capabilities.
- Process structure determines how inputs, activities, flows, and outputs of a process are organized.



Product-process matrix Categorizes processes into structures based on output volume and variety.

Comparison of Process Types

Process Type	Output Characteristics	Example	Process Characteristics
Project	Unique One of a kind	Custom home Designing a video game	Unique sequencing High complexity Employees and equipment must be flexible Activities are often outsourced to specialists
Job shop	Customized, low volume	Auto repair Beauty salon Copy shop	High variety of inputs and process flows Job sequencing is challenging High work-in-process inventory Highly skilled, flexible workers General-purpose equipment
Batch	Moderate volume and variety	Bakery Automotive parts Cinema	Dominant flow patterns Some common inputs Setup time can be high Moderately flexible employees and equipment
Repetitive process	Standard products with a range of options	Appliances Automobiles Buffet restaurant	All products follow the same sequence Standard methods and materials are used Low-skilled workers specialize in completing a limited number of activities
Continuous process	Commodities with high volume, little variety	Aluminum cans Laundry detergent Gasoline	Products follow sequence Operations often run 24/7 Line stoppages are very costly Highly specialized equipment Low-skilled operators

Source: Shutterstock.com: Ant Clausen

Project

Job shop

Don Tremain/Getty Images

Batch process

Repetitive process

vichie81/123RF

Continuous process

Volume and variety influence process choice

	High variety	Moderate variety	Low variety	Very low variety
Low or very low volume	**Job Shop** repair shop emergency room			
Moderate volume		**Batch** commercial bakery classroom lecture		
High volume			**Repetitive** assembly line automatic car wash	
Very high volume				**Continuous Flow** petroleum refining water treatment

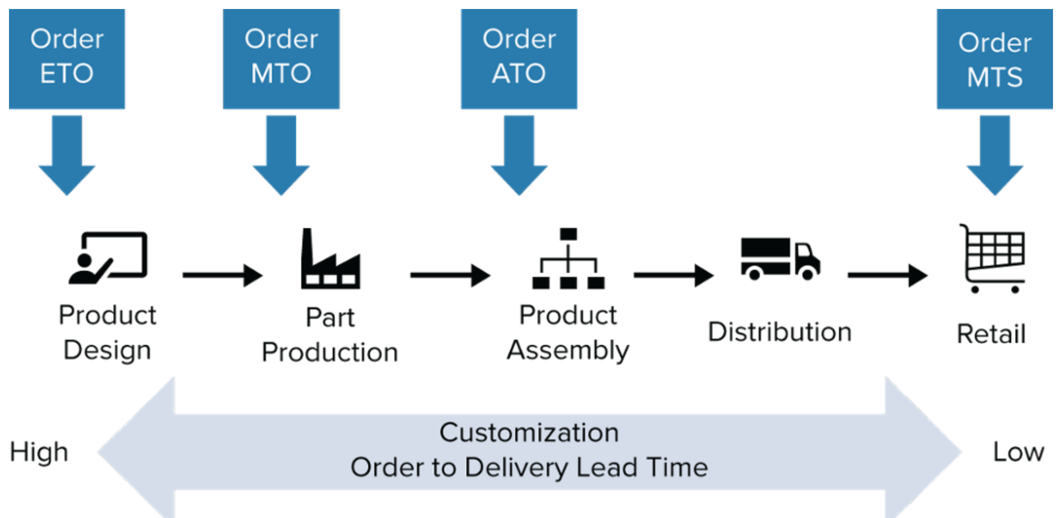
	Job Shop	Batch	Repetitive/ Assembly	Continuous
Description	Customized goods or services	Semi-standardized goods or services	Standardized goods or services	Highly standardized goods or services
Advantages	Able to handle a wide variety of work	Flexibility; easy to add or change products or services	Low unit cost, high volume, efficient	Very efficient, very high volume
Disadvantages	Slow, high cost per unit, complex planning and scheduling	Moderate cost per unit, moderate scheduling complexity	Low flexibility, high cost of downtime	Very rigid, lack of variety, costly to change, very high cost of downtime

Activity/ Function	Job Shop	Batch	Repetitive	Continuous	Projects
Cost estimation	Difficult	Somewhat routine	Routine	Routine	Simple to complex
Cost per unit	High	Moderate	Low	Low	Very high
Equipment used	General purpose	General purpose	Special purpose	Special purpose	Varied
Fixed costs	Low	Moderate	High	Very high	Varied
Variable costs	High	Moderate	Low	Very low	High
Labor skills	High	Moderate	Low	Low to high	Low to high
Marketing	Promote capabilities	Promote capabilities; semi-standardized goods and services	Promote standardized goods/services	Promote standardized goods/services	Promote capabilities
Scheduling	Complex	Moderately complex	Routine	Routine	Complex, subject to change
Work-in-process inventory	High	High	Low	Low	Varied

Aligning Process Structure and Market Orientation

There are four different marketing orientations; each delivers a different level of service in terms of lead time and customization.

Engineer to Order (ETO)	Unique, customized products that generally have long lead times.
Make to Order (MTO)	Products that have similar designs but are customized during production.
Assemble to Order (ATO)	Products that are produced from standard components and modules.
Make to Stock (MTS)	Finished goods that are held in inventory in advance of customer orders.



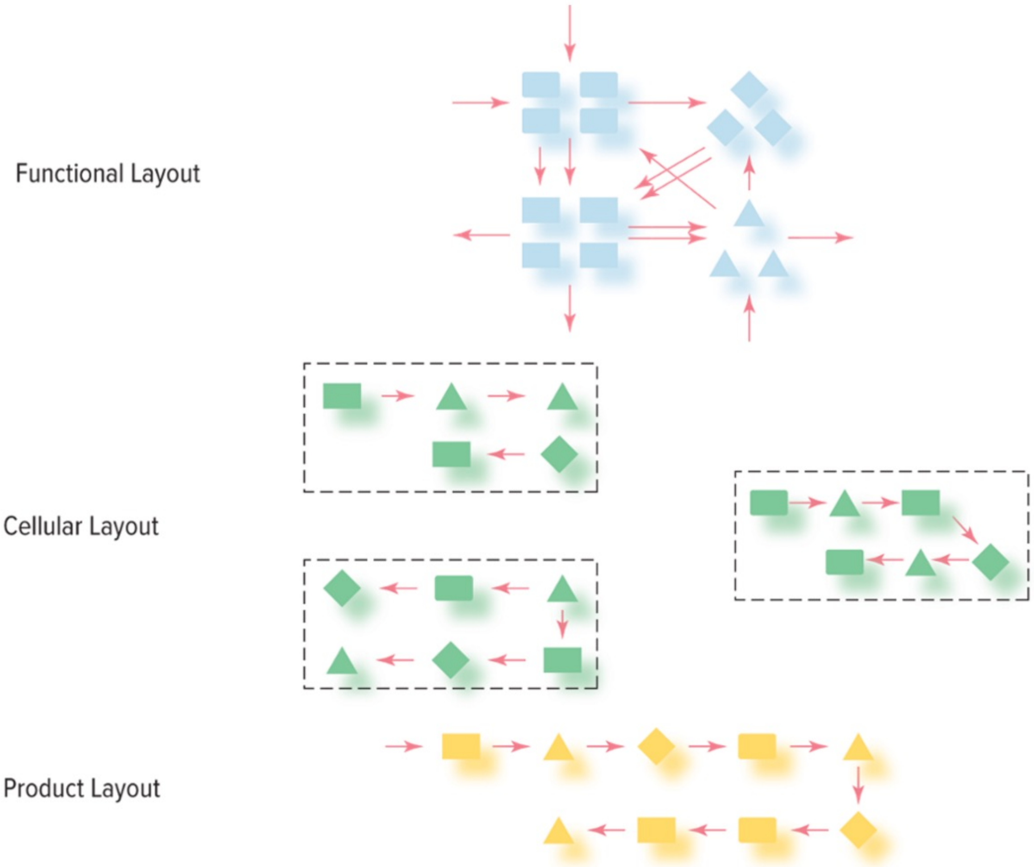
Facility Layout

Layout refers to the configuration of departments, work centers, and equipment, with particular emphasis on movement of work (customers or materials) through the system.

The basic objective of layout design is to facilitate a smooth flow of work, material, and information through the system.

General objectives of playout planning:

- To facilitate attainment of product or service quality.
- To use workers and space efficiently.
- To avoid bottlenecks.
- To minimize material handling costs.
- To eliminate unnecessary movements of workers or materials.
- To minimize production time or customer service time.
- To design for safety.



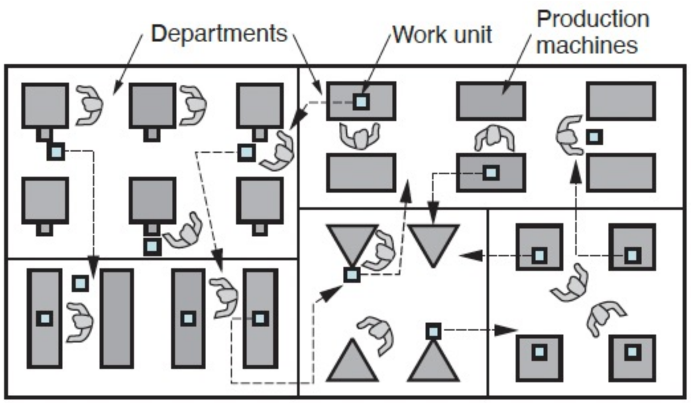
Facility Layout: Functional Layout

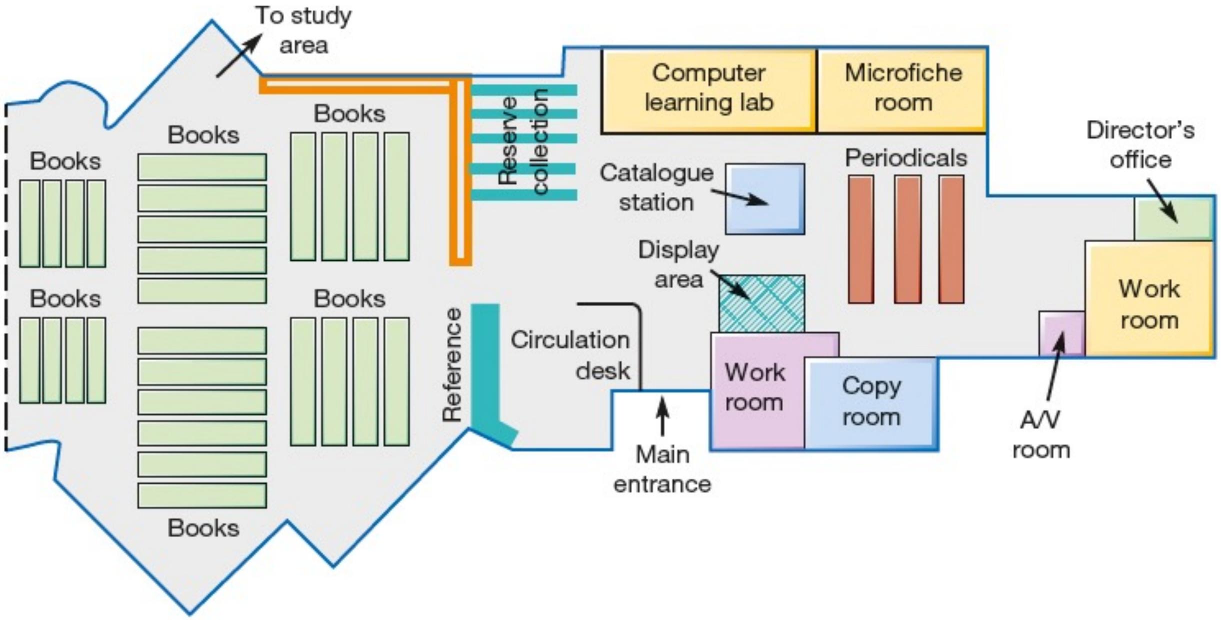
A layout that groups together similar resources

Sometimes called a departmental layout

Some examples are: fitness centers, copy shops, libraries

In manufacturing, Job shops and batch processes often use a functional layout where work centers using the same types of equipment are grouped together.





Facility Layout: Cell Layout

Workstations arranged into small assembly lines to make families of products with similar processing needs.

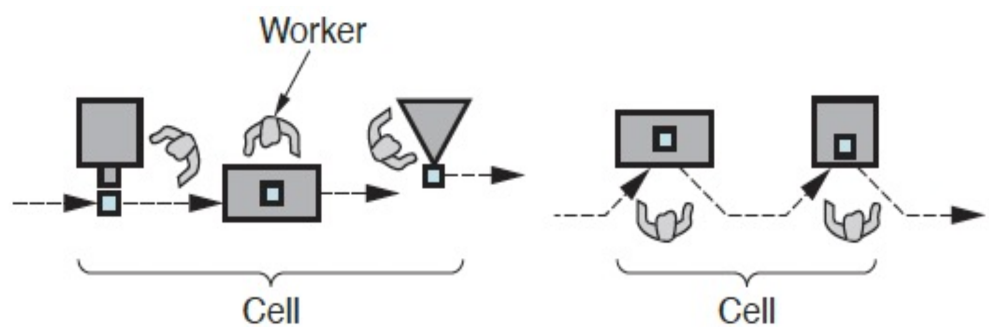
Layout in which workstations are grouped into a cell that can process items that have similar processing requirements

Groupings are determined by the operations needed to perform the work for a set of similar items, ***part or product families***, that require similar processing

The cells become, in effect, miniature versions of product layouts

Enables companies to produce a variety of products with very little waste

Cells can make job shops or batch processes more efficient, or increase the flexibility of repetitive processes.



Cell Layout: Group Technology

The grouping into part families of items with similar design or manufacturing characteristics

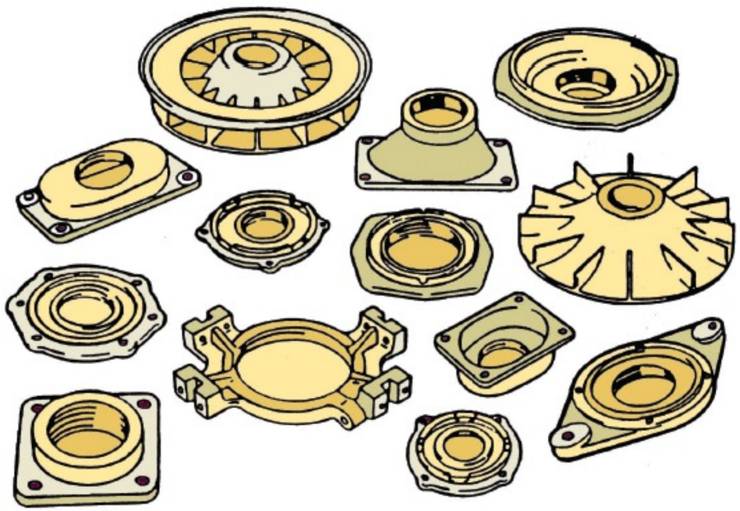
Design characteristics:

- Size
- Shape
- Function

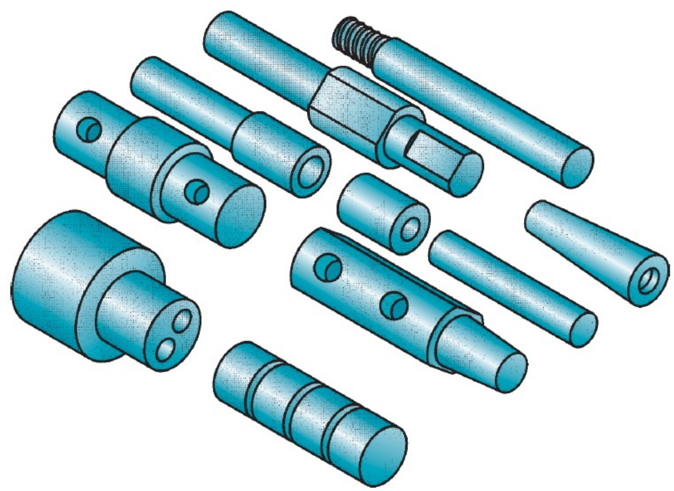
Manufacturing or processing characteristics:

- Type of operations required
- Sequence of operations required

Requires a systematic analysis of parts to identify the part families



A group of parts with similar manufacturing process requirements but different design attributes



Ten parts that are different in size and shape, but quite similar in terms of manufacturing. All parts are machined from cylindrical stock by turning; some parts require drilling and/or milling.

Cell Layout: Balancing Work Cells

Takt time

- The maximum allowable cycle time at each workstation.
- Is the cycle time needed in a production system to match the pace of production to the demand rate.
- (similar to cycle time) the time between items emerging from a process, usually applied to 'paced' processes

How to balance a work cell?

1. Determine the takt time
   a. Determine the net time available per shift by subtracting any nonproductive time from total shift time.
   b. If there is more than one shift per day, multiply the net time per shift by the number of shifts to obtain the net available time per day.
   c. Compute takt time by dividing the net available time by demand.

2. Determine the number of operators required

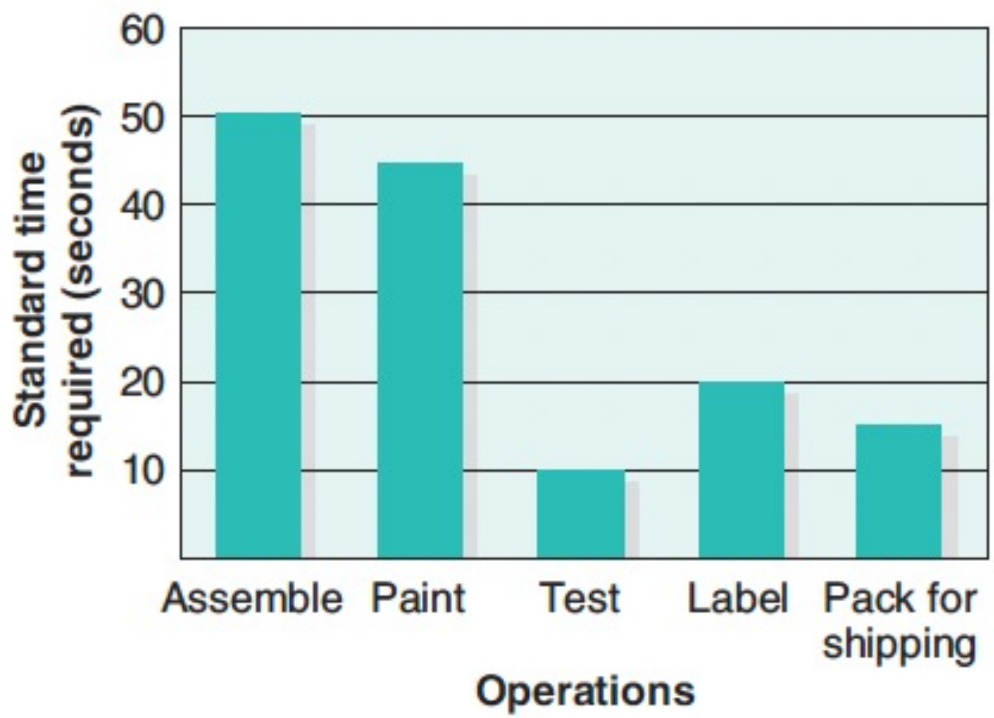
Formulas

$$Takt\ Time = \frac{Total\ work\ time\ available\ (available\ production\ time\ per\ day)}{Units\ required\ to\ satisfy\ customer\ demand\ (output\ needed\ per\ day)}$$

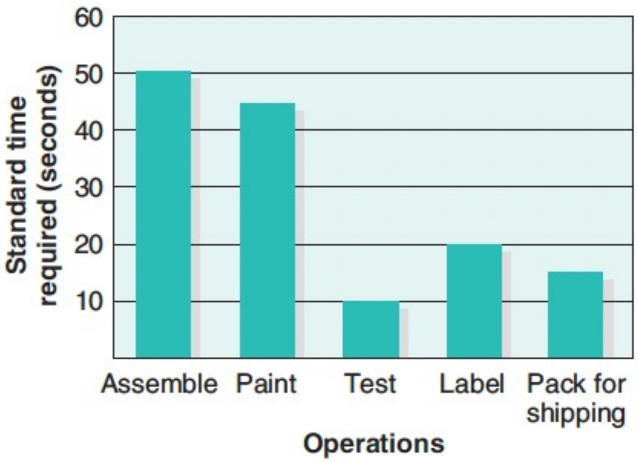
$$Workers\ required = \frac{Total\ operation\ time\ required}{Takt\ time}$$

Example 1: Balancing Work Cells

Company X makes auto mirrors. The major customer is the Honda plant nearby. Honda expects 600 mirrors delivered daily, and the work cell producing the mirrors is scheduled for 8 hours. Company X develops a work balance chart and wants to determine the takt time and the number of workers required.



Example 1: Balancing Work Cells



$$Takt\ Time = \frac{available\ production\ time\ per\ day}{output\ needed\ per\ day}$$

$$Takt\ Time = \frac{(8\ hours \times 60\ minutes)}{600\ units}$$

$$Takt\ Time = 0.8\ minute \ \rightarrow 48\ seconds$$

$$Workers\ required = \frac{Total\ operation\ time\ required}{Takt\ time}$$

$$Workers\ required = \frac{50 + 45 + 10 + 20 + 15}{48}$$

$$Workers\ required = 2.92 \ \rightarrow 3$$

To produce one unit every 48 seconds will require 2.92 people.
With three operators this work cell will be producing one unit each 46.67 seconds (140 seconds/3 employees = 46.67) and 617 units per day (480 minutes available X 60 seconds/46.67 seconds for each unit = 617).

Example 2: **Balancing Work Cells**

Given the following information, compute the takt time: Total time per shift is 480 minutes per day, and there are two shifts per day. There are two 20-minute rest breaks and a 30 minute excel lunch break per shift. Daily demand is 80 units.

1. Compute net time available per shift:

Total time	480 minutes
Rest breaks	- 40 minutes
Lunch	- 30 minutes
	410 minutes per shift

2. Compute the net time available per day

410 minutes per shift X 2 shifts/day = 820 minutes per day

3. Compute the takt time

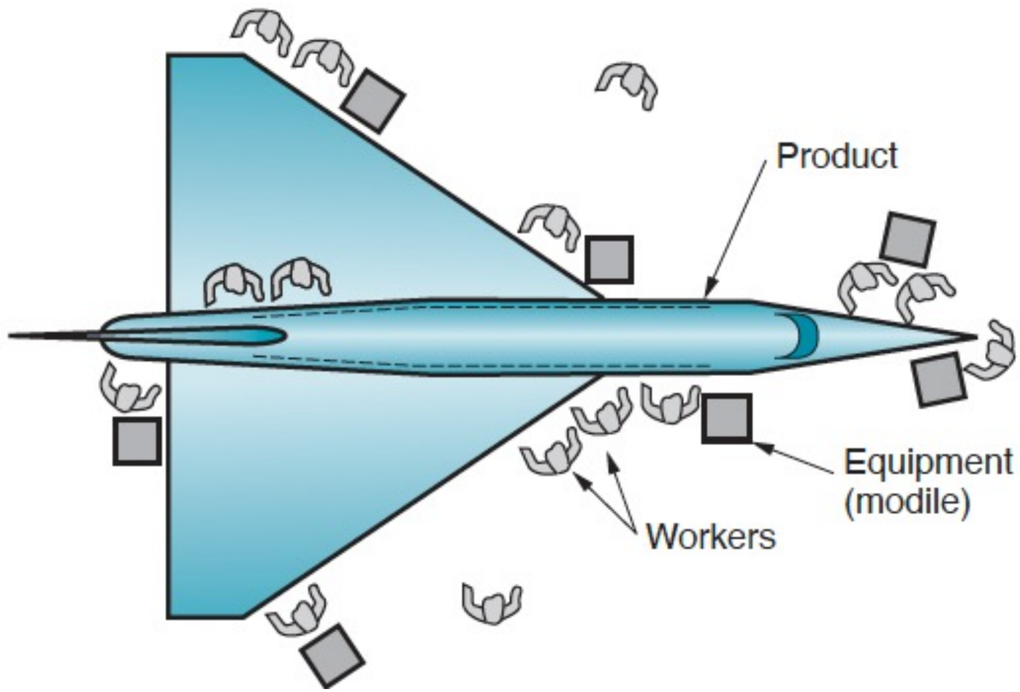
$$Takt\ Time = \frac{Net\ available\ time\ per\ day}{Daily\ demand} = \frac{820\ minutes\ per\ day}{80\ units\ per\ day} = 10.25\ minutes\ per\ cycle$$

Facility Layout: Fixed – Position Layout

The layout used when the product cannot be moved during production

Fixed-position layouts are typically used for projects involving large products such as homes, buildings, bridges, large ships, airplanes, and spacecraft.

Low – quantity production (1 – 100 units/year)



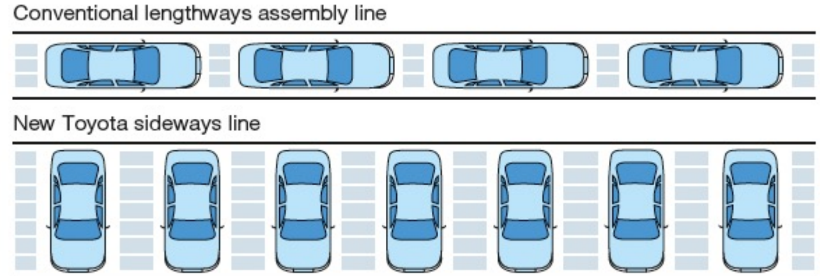
Facility Layout: Product (line) Layout

Layout that uses standardized processing operations to achieve smooth, rapid, high-volume flow

A layout where resources are arranged according to a regularly occurring sequence of activities.

The flow of products or customers is visible and easy to trace.

Some examples: automobile assembly, self service cafeteria, mass-immunization programme.



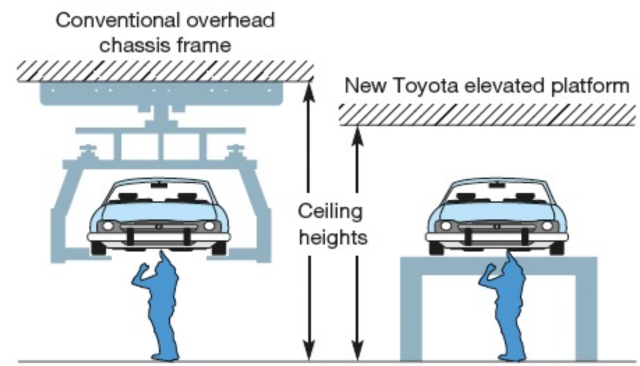
Advantages	Disadvantages

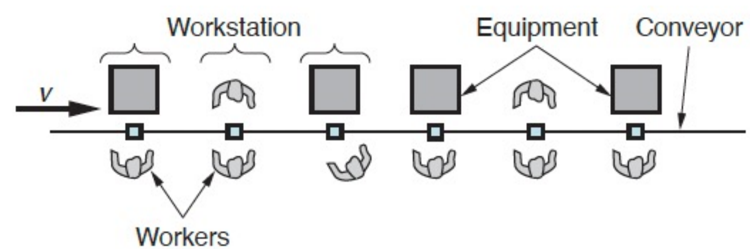
Advantages

- High rate of output
- Low unit cost
- Labor specialization
- Low material handling cost per unit
- High utilization of labor and equipment
- Established routing and scheduling
- Routine accounting, purchasing, and inventory control

Disadvantages

- Creates dull, repetitive jobs
- Poorly skilled workers may not maintain equipment or quality of output
- Fairly inflexible to changes in volume or product or process design
- Highly susceptible to shutdowns
- Preventive maintenance, capacity for quick repair, and spare-parts inventories are necessary expenses
- Individual incentive plans are impractical





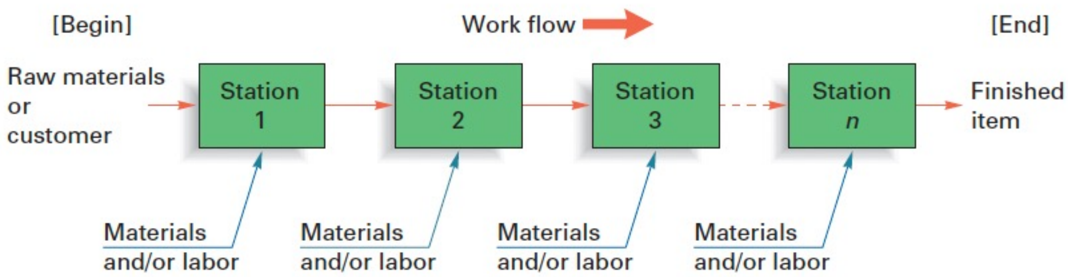
Facility Layout: Product (line) Layout

Product layouts are used to achieve a smooth and rapid flow of large volumes of goods or customers through a system. This is made possible by highly standardized goods or services that allow highly standardized, repetitive processing. The work is divided into a series of standardized tasks, permitting specialization of equipment and division of labor.

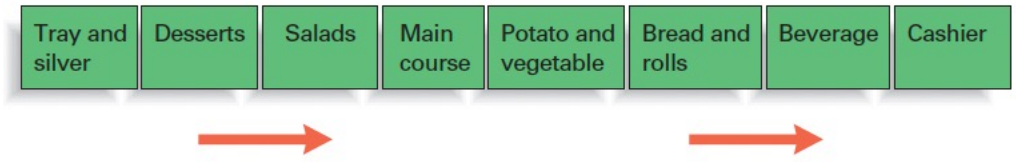
Production line Standardized layout arranged according to a fixed sequence of production tasks.

Assembly line Standardized layout arranged according to a fixed sequence of assembly tasks.

A flow line for production or service



Cafeteria line



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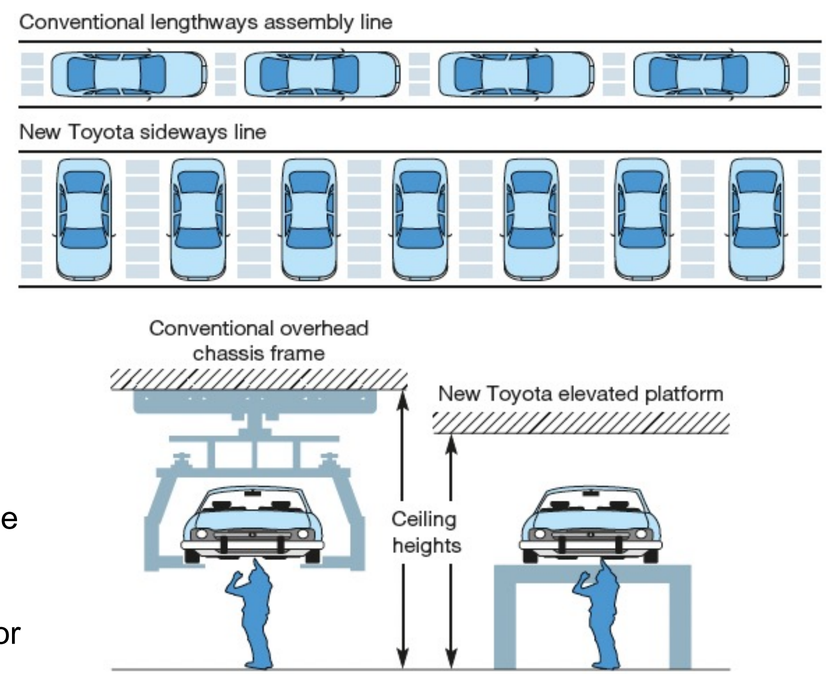

Advantages	Disadvantages
▪ High rate of output ▪ Low unit cost ▪ Labor specialization ▪ Low material handling cost per unit ▪ High utilization of labor and equipment ▪ Established routing and scheduling ▪ Routine accounting, purchasing, and inventory control	▪ Creates dull, repetitive jobs ▪ Poorly skilled workers may not maintain equipment or quality of output ▪ Fairly inflexible to changes in volume or product or process design ▪ Highly susceptible to shutdowns ▪ Preventive maintenance, capacity for quick repair, and spare-parts inventories are necessary expenses ▪ Individual incentive plans are impractical

Facility layout comparison

<table>
<tr><th>Manufacturing Process Type</th><th colspan="2">Potential Layout Types</th><th>Service Process Type</th></tr>
<tr><td rowspan="2">Project</td><td rowspan="2">Fixed-position layout
Functional layout</td><td rowspan="3">Fixed-position layout
Functional layout
Cell layout</td><td rowspan="3">Professional Service</td></tr>
<tr></tr>
<tr><td rowspan="2">Jobbing</td><td rowspan="2">Functional layout
Cell layout</td></tr>
<tr><td rowspan="4">Functional layout
Cell layout</td><td rowspan="4">Service Shop</td></tr>
<tr><td rowspan="2">Batch</td><td rowspan="2">Functional layout
Cell layout</td></tr>
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<tr><td rowspan="2">Mass</td><td rowspan="2">Cell layout
Product layout</td></tr>
<tr><td rowspan="3">Cell layout
Product layout</td><td rowspan="3">Mass Service</td></tr>
<tr><td rowspan="2">Continuous</td><td rowspan="2">Product layout</td></tr>
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Assembly Line Balancing

The goal of a product layout is to arrange workers or machines in the sequence that operations need to be performed

Line balancing: the process of assigning tasks to workstations in such a way that the workstations have approximately equal time requirements

Goal:

Obtain task grouping that represents approximately equal time requirements, since this minimizes idle time along the line and results in a high utilization of equipment and labor

Why is line balancing important?

1. It allows us to use labor and equipment more efficiently
2. To avoid fairness issues that arise when one workstation must work harder than another

Steps

1. Develop a precedence diagram for the assembly line
2. Calculate the Cycle Time
3. Calculate the theoretical minimum number of workstations
4. Balance the line using one of the line-balancing heuristics

Example 3: Assembly Line Balancing

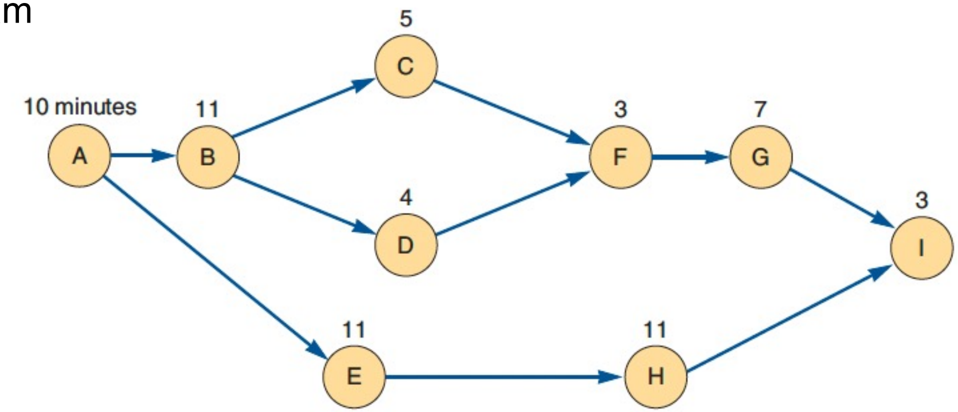
Boeing wants to develop a precedence diagram for an electrostatic wing component that requires a total assembly time of 65 minutes. On the basis of the precedence diagram and activity times , Boeing determines that there are 480 productive minutes of work available per day. Furthermore, the production schedule requires that 40 units of the wing component be completed as output from the assembly line each day. It now wants to group the tasks into workstations.

a) Develop a precedence diagram
b) Group the tasks into workstations

TASK	ASSEMBLY TIME (MIN)	TASK MUST FOLLOW TASK LISTED BELOW
A	10	–
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	

Example 3: Assembly Line Balancing

Develop a precedence diagram



Calculate the cycle time

$$Cycle\ Time = \frac{Production\ time\ available\ per\ day}{Units\ required\ per\ day} = \frac{480\ minutes}{40\ units} = 12\ {}^{minutes}/_{unit}$$

Calculate the minimum number of workstations

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

$$Minimum\ number\ of\ workstations = \frac{65\ minutes}{12\ minutes/unit} = 5.42 \rightarrow 6\ stations$$

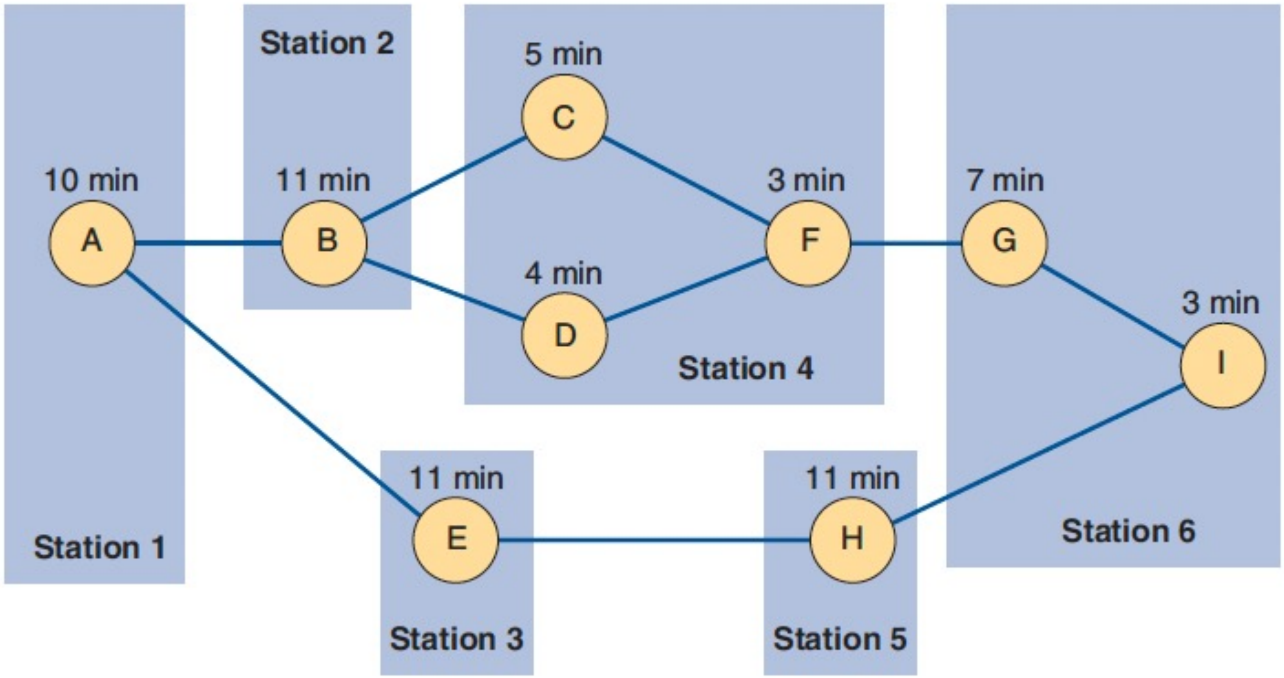
Example 3: Assembly Line Balancing

Balancing the line

a. Identify a master list of tasks.
b. Eliminate those tasks that have been assigned.
c. Eliminate those tasks whose precedence relationship has not been satisfied.
d. Eliminate those tasks for which inadequate time is available at the workstation.
e. Use one of the line-balancing “heuristics”

1. Longest task (operation) time	From the available tasks, choose the task with the largest (longest) 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 the times for each following task is longest
4. Shortest task (operations) 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.

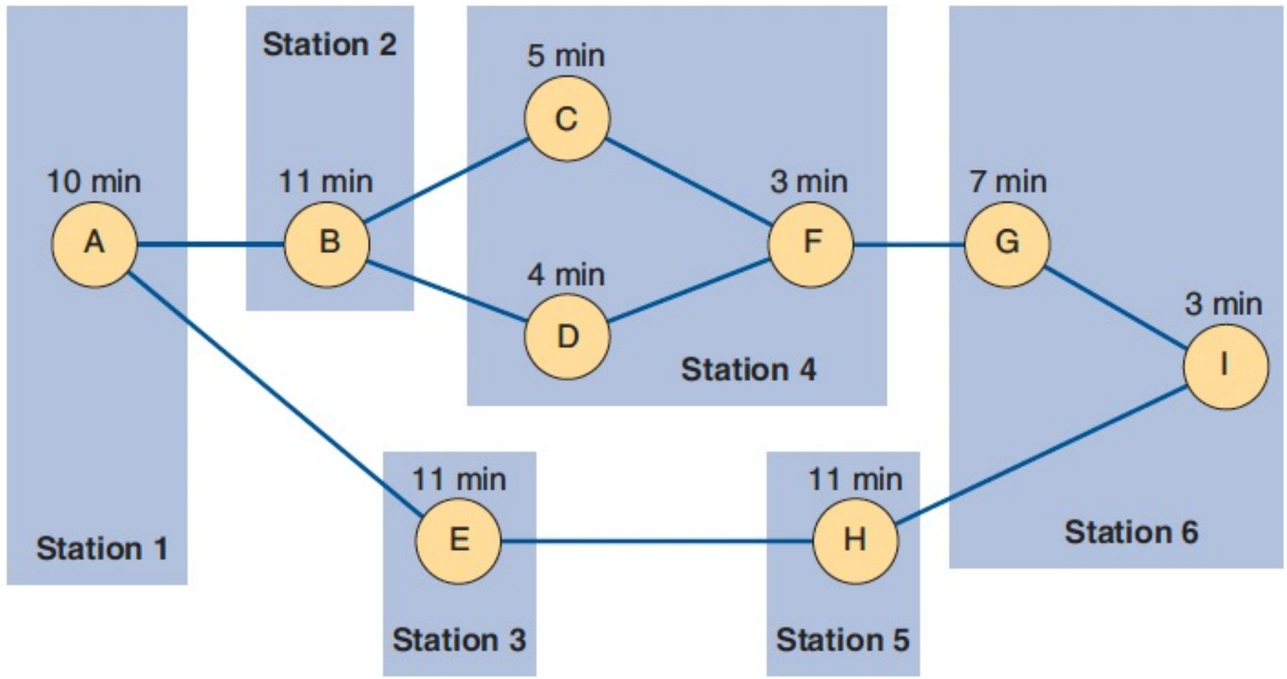
Example 3: Assembly Line Balancing



Activities with the most following tasks were moved into workstations to use as much of the available cycle time of 12 minutes as possible

- The second and third workstations use 11 minutes.
- The fourth workstation groups three small tasks and balances perfectly at 12 minutes.
- The fifth has 1 minute of idle time, and the sixth (consisting of tasks G and I) has 2 minutes of idle time per cycle.
- Total idle time for this solution is 7 minutes per cycle.

Example 3: Assembly Line Balancing



Determining Line efficiency

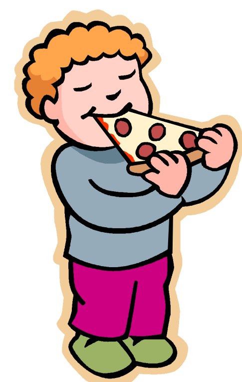
$$Efficiency - \frac{65\ minutes}{(6\ stations)(12\ minutes)} = 90.3\%$$

Example 4: Assembly Line Balancing

Given the following precedence relationships for sausage and pepperoni pizza assembly. The number of pizzas prepared per day are 200 and the Pizza place operates 8 hrs per day.

a. What is the takt time?
b. What is the theoretical number of workstations
c. Assign the tasks to the workstations to balance the line using the longest operating time rule
d. What is the efficiency of the line

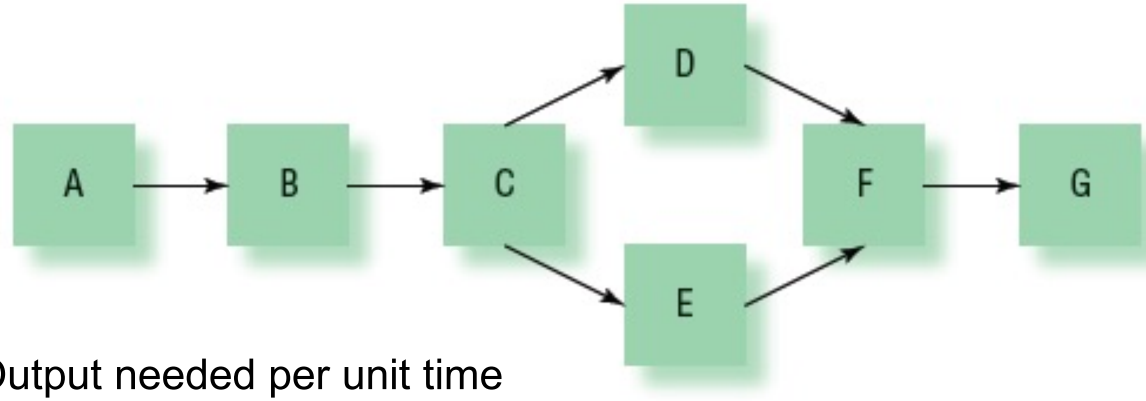
Task		Predecessors	Time (minutes)
A	Shape the dough to form the crust	None	2
B	Add the pizza sauce	A	1
C	Add the cheese	B	2
D	Add the sausage	C	0.75
E	Add the pepperoni	C	1
F	Package the pizza	D, E	1.5
G	Label the package	F	0.5
		Total Time	8.75



Example 4: Assembly Line Balancing

Number of Pizzas per Day: 200

Hours Operating per Day: 8



a. What is the takt time?

Takt time = Available service time/Output needed per unit time

Takt time = [Number of hours/day × 60 min/hour]/Pizza per day

Takt time = [8 hours/day × 60 min/hour]/200 Pizzas per day

Takt time = 0.04 hours

Takt time = 2.4 minutes per workstation

b. What is the theoretical number of workstations?

N = Total number of minutes required to process all tasks per pizza/Number of minutes per station

N = [2 min + 1 min + 2 min + 0.75 min + 1 min + 1.5 min + 0.5 min]/2.4 min per station

N = 8.75 min per pizza/2.4 min per station= 3.7, so round up to 4 workstations

Example 4: Assembly Line Balancing

c. **Assign the tasks to the workstations to balance the line using the longest operating time rule.**

Workstation	Tasks in Order	Workstation Time (minutes)	Idle Time (minutes)
1	A	2	0.4
2	B	1	1.4
3	C	2	0.4
4	E, D	1.75	0.65
5	F, G	2	0.4

d. What is the efficiency of the balanced line?

Efficiency = [Total time per pizza/(Number of workstations needed × Number of minutes per pizza)] × 100

Efficiency = [8.75 minutes needed per pizza/(5 workstations × 2.4 minutes per pizza)] × 100

Efficiency = 0.729 or 72.9 %

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