

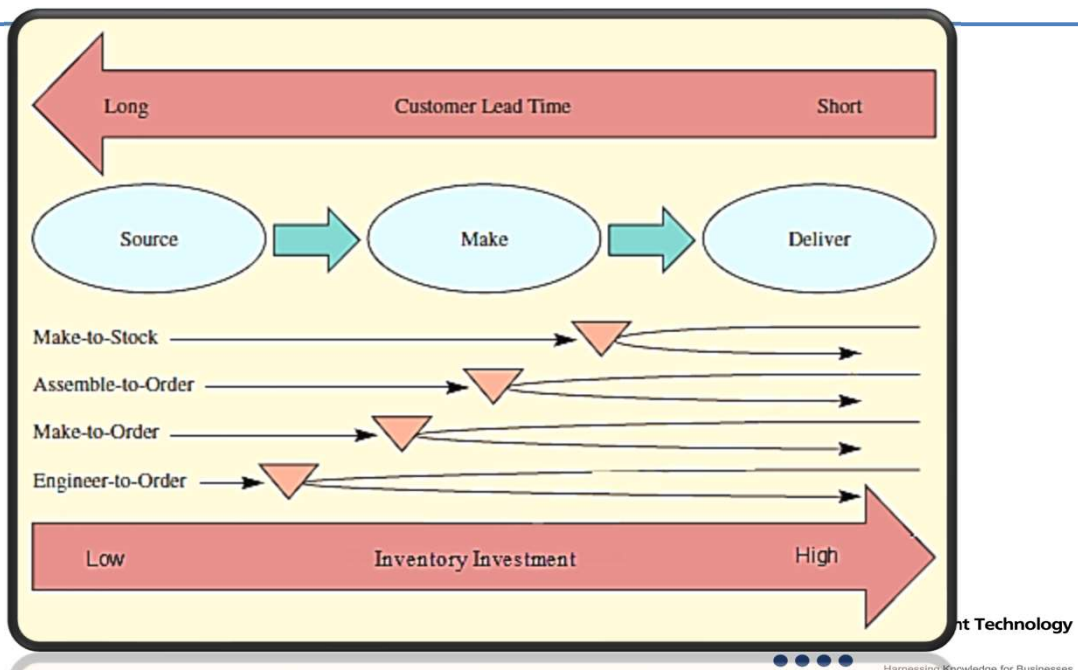
Process selection and Facility Design

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Friday, September 1, 2023

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Production Processes



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Make-to-Stock



- Key challenge: balance the level of inventory against the level of customer service.
 - Easy with unlimited inventory, but inventory costs money
 - Trade-off between the costs of inventory and level of customer service must be made.

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Assemble-to-Order



- Key challenge: Define a customer's order in terms of alternative components because these are carried in inventory.
- Needs a process design that enables as much flexibility as possible in combining components.

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Make-to-Order/Engineer-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.

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Types of Goods and Services

Custom or make-to-order

- Produced and delivered as one of a kind or in small quantities
- Designed to meet specific customers' specifications

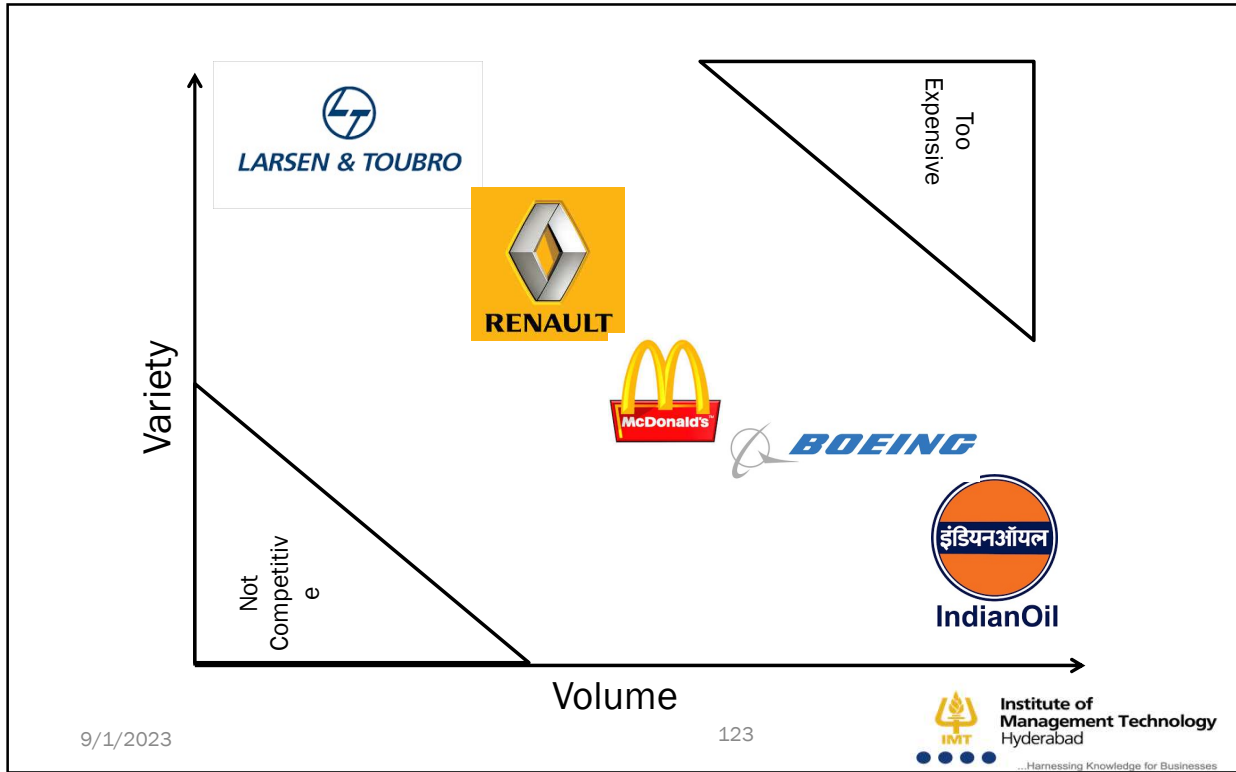
Option or assemble-to-order

- Configurations of standard parts, subassemblies, or services that can be selected by customers from a limited set

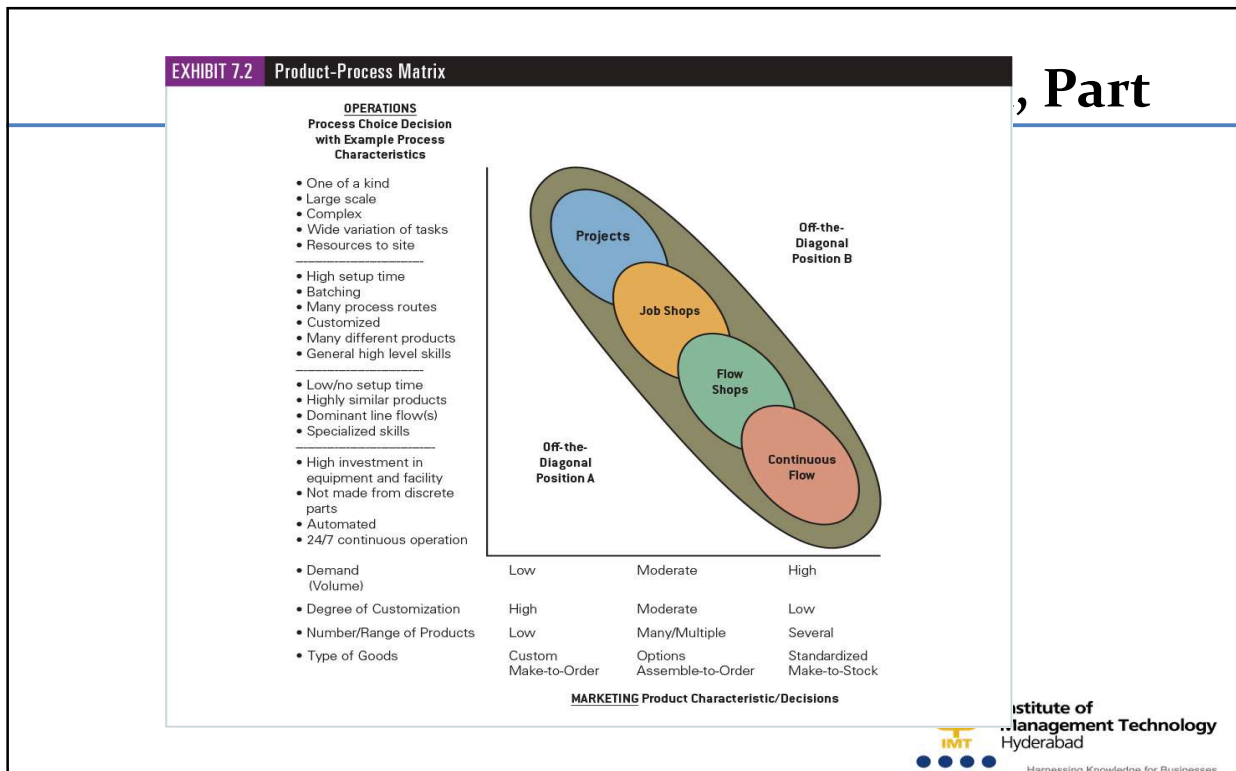
Standard or make-to-stock

- Made according to a fixed design that leaves the customers with no options to choose from

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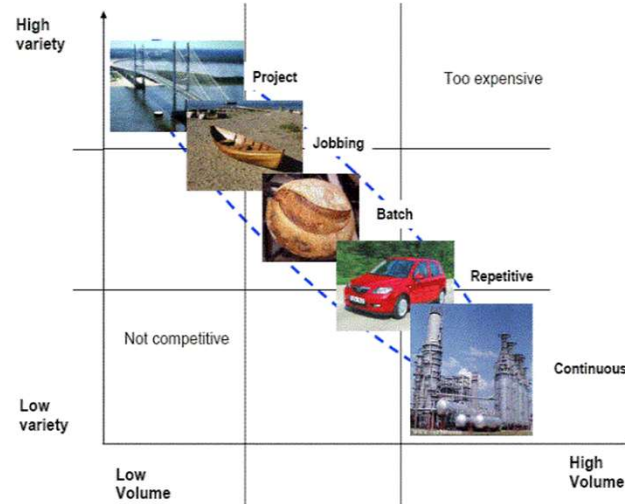


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Product Process Matrix



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Types of Goods and Services Producing Processes, Part 1

Projects

- Large-scale, customized initiatives that consist of smaller tasks and activities that must be coordinated and completed to finish on time and within budget

Job shop processes

- Organized around particular types of general-purpose equipment that are flexible and capable of customizing work for individual customers

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Types of Goods and Services Producing Processes, Part 2

Flow shop processes

- Organized around a fixed sequence of activities and process steps to produce a limited variety of similar goods or services
- Observed in assembly lines

Continuous flow processes

- Create highly standardized goods or services continuously in very high volumes

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Continuous flow

- Highly standardized goods and services
- Very efficient, very high volume
- Very rigid, lack of variety, costly to change, very high cost of downtime
- Usually continuous flow
- Equipment has very less flexibility



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Repetitive/Assembly

- Standardized goods or services
- Low per unit cost
- High volume, efficient
- Flexibility?
- Flow?



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Batch Process

- Semi-standardized goods and services
- Flexibility
 - easy to add or change products or services
- Moderate cost per unit, moderate scheduling complexity



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Project

- Customized Goods and Services
- Able to handle a wide variety of work
- Slow, high cost per unit, complex planning and scheduling
- Flexibility?
- Flow?



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Service-Positioning Matrix (SPM)

- Roughly analogous to the product-process matrix for manufacturing
- Helps management design a service system that best meets the technical and behavioral needs of customers
 - Superior performance results by staying along the diagonal of the matrix

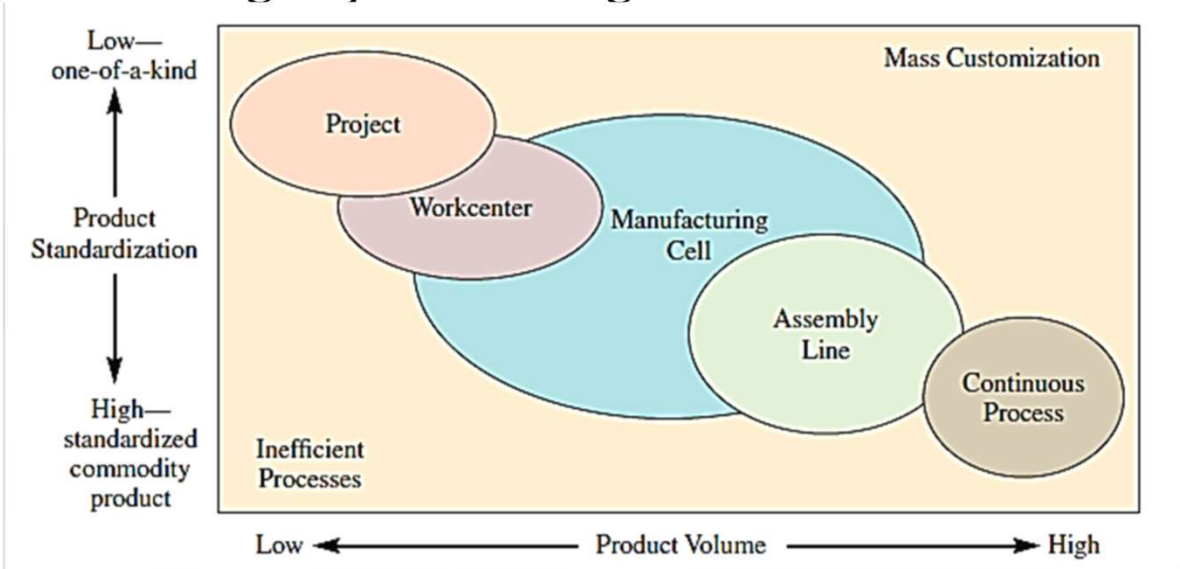
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Layout Planning

- Layout planning in manufacturing & service organizations
 - deals with physical arrangement of various resources that are available in the system
 - with an objective to improve the performance of the operating system
- Benefits of good layout design
 - Jobs in a manufacturing system travel lesser distance
 - Customers spend less time in service systems
 - Costs & Lead time come down
 - Improved quality

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Product-Process Matrix: Framework Describing Layout Strategies



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Production System Design

Project Layout/Fixed position layout

- The product remains in a fixed location.
- A high degree of task ordering is common.
- materials arranged according to their assembly priority.

Workcenter/Process Layout/functional layout

- Arrange work centers in a way that optimizes the movement of material.
- work centers with large interdepartmental traffic placed adjacent to each other.
- Referred to as a department and is focused on a particular type of operation.

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Production System Design

Manufacturing Cell/Group Technology Layout

- Formed by allocating dissimilar machines to cells that are designed to work on similar products (shape, processing, etc.)

Assembly Line/Product Layout and Continuous Layout

- Designed for the special purpose of building a product by going through a series of progressive steps

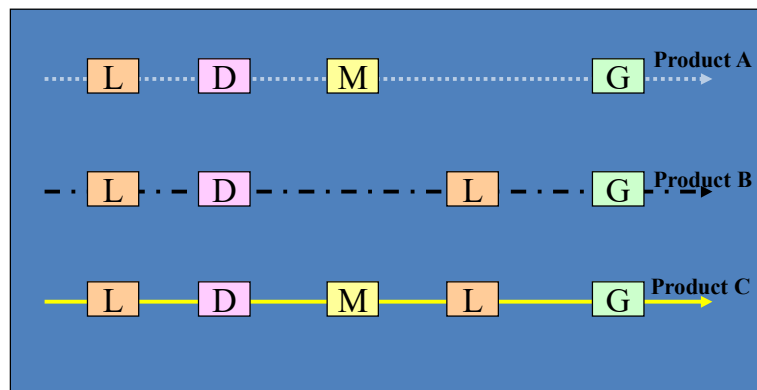
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Types of Layout

- **Product Layout (Assembly line)**
 - order in which the resources are placed follow exactly the visitation sequence dictated by a product
- **Process Layout (Workcenter layout)**
 - arrangement of resources on the basis of the process characteristics of the resources available
- **Group Technology (GT) Layout (Manufacturing cell)**
 - seeks to exploit commonality in manufacturing and uses this as the basis for grouping components and resources
- **Fixed Position Layout (Project layout)**
 - emphasis is not so much on optimum position of resources required for the process, since the product itself largely dictates this; the focus is on gaining better control of material flow and reducing delays

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Product Layout

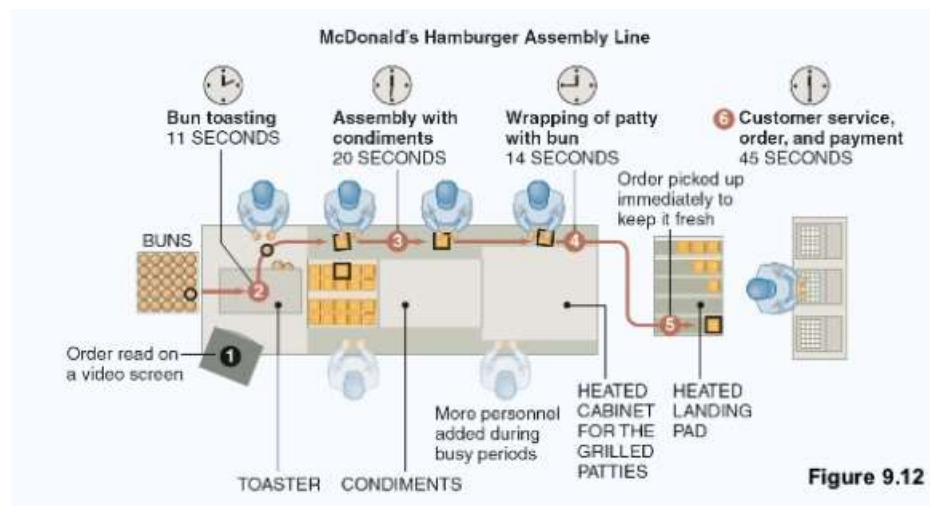


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Product layout

- Adequate volume, stable demand with enough supply of raw materials of uniform quality
- Fabrication or assembly
- Need for balance

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Design of Product Layout

- Mass Production Systems are ubiquitous
 - Each sub-assemblies need to be configured to match the production rate
 - Need resources at each station to meet the targeted demand
- A product layout design
 - seeks to identify the minimum number of resources required to meet a targeted production rate and the order in which these resources are to be arranged
 - Technique employed for designing of product layout is known as [line balancing](#)

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Line Balancing – Decisions and Tradeoffs

- [Line balancing](#)
 - A method by which the tasks are optimally combined without violating precedence constraints and a certain number of workstations designed to complete the tasks
 - Key decision variables are production rate, cycle time and the number of workstations, which are inter-related
 - Solving the “line balancing” problem calls for striking the right trade-off between increased production and better utilization of resources
- [Cycle time](#) is the ratio of the available time to the actual (desired) production rate

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Line Balancing

$$\text{Actual (Desired) CycleTime} = \frac{\text{AvailableTime}}{\text{Actual (Desired) Production}}$$

$$\text{Minimum No.of work stations required} = \frac{\text{Sum of all task times}}{\text{CycleTime}}$$

$$\text{Average resource utilisation} = \frac{\text{Sum of all task times}}{\text{Number of workstations} * \text{Cycle time}}$$

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Wing component example

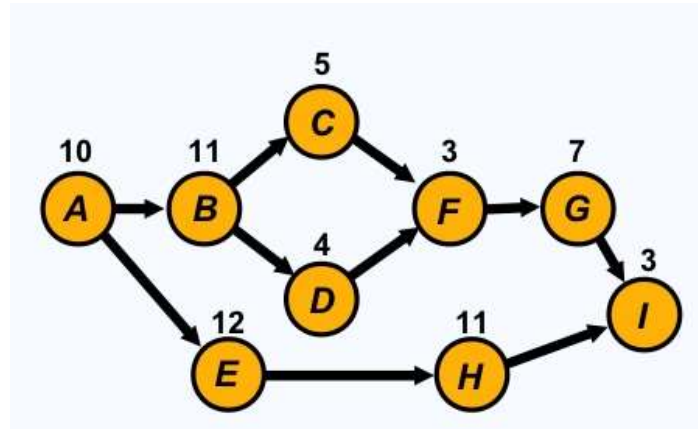
Task	Performance Time (minutes)	Task Must Follow Task Listed Below
A	10	—
B	11	A
C	5	B
D	4	B
E	12	A
F	3	C, D
G	7	F
H	11	E
I	3	G, H
Total time 66		

This means that tasks B and E cannot be done until task A has been completed

Requirement is 40 units per day

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Precedence Diagram



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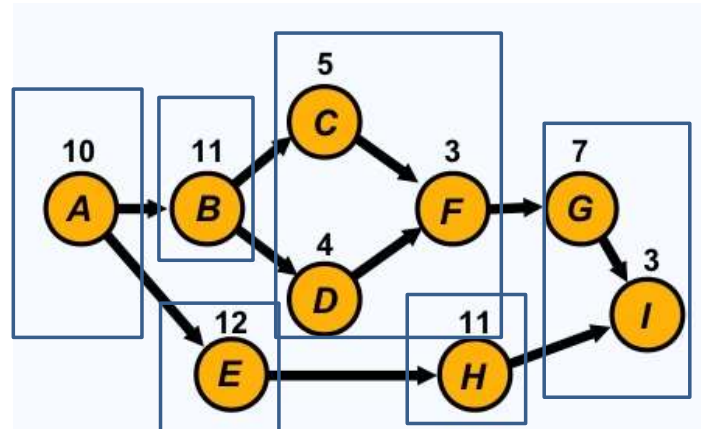
Line Balancing

$$\text{Actual (Targeted) Cycle Time} = \frac{480}{40} = 12 \text{ min/unit}$$

$$\text{Minimum No. of work stations required} = \frac{66}{12} = 5.5 \sim 6 \text{ stations}$$

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Allocating tasks to stations



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Determining efficiency

$$\text{Average resource utilisation} = \frac{\text{Sum of all task times}}{\text{Number of workstations} * \text{Cycle time}}$$

$$\text{Average resource utilisation} = \frac{66}{6 * 12} = 91.6\%$$

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Assembly Steps and Times

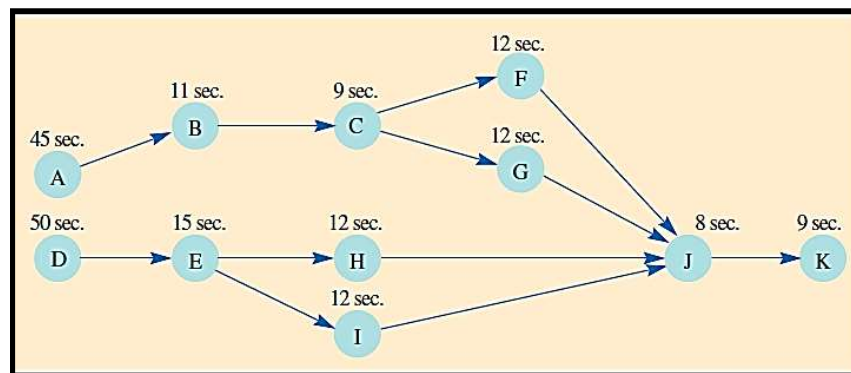
TASK	TASK TIME (IN SECONDS)	DESCRIPTION	TASKS THAT MUST PRECEDE
A	45	Position rear axle support and hand fasten four screws to nuts.	—
B	11	Insert rear axle.	A
C	9	Tighten rear axle support screws to nuts.	B
D	50	Position front axle assembly and hand fasten with four screws to nuts.	—
E	15	Tighten front 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
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Example: Precedence Graph



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Example: C and N_t

$$C = \frac{\text{Production time per day}}{\text{Output per day}} = \frac{60 \text{ sec.} \times 480 \text{ min}}{500 \text{ wagons}}$$

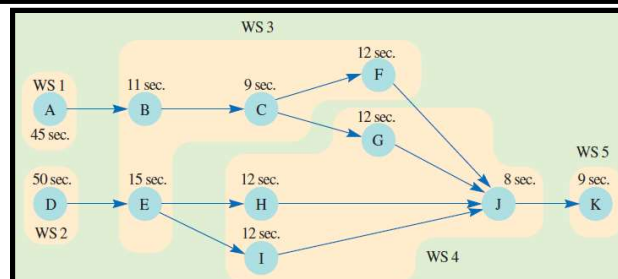
$$= 57.6$$

$$N_t = \frac{T}{C} = \frac{195 \text{ seconds}}{57.6 \text{ seconds}} = 3.38 \Rightarrow 4$$

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Example: Assignment

	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		



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Example: Efficiency

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

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Line balancing methodology

- Identify the master list of tasks
- Eliminate tasks already assigned to stations
- Eliminate tasks whose precedence not satisfied
- Eliminate tasks for which inadequate time is available
- Use one of the following heuristics

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Line balancing heuristics

- Longest task operation time
- Most following tasks
- Ranked position weight
 - Sum of times for each following task is longest
- Shortest task time
- Least number of following tasks

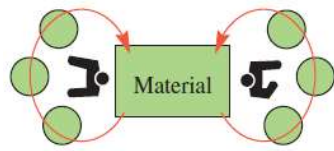
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Task Splitting

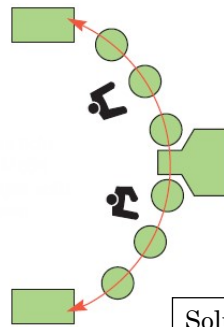
- Split the task
- Share the task
- Use parallel workstations
- Use a more skilled worker
- Work overtime
- Redesign

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Improving layouts by moving to Workcell concept



Problem – operators “birdcaged” with no opportunity to share work or add third operator

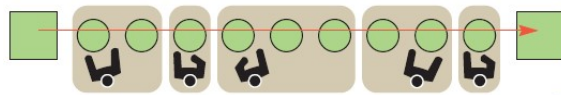


Solution – operators can help each other and third operator can be added if needed

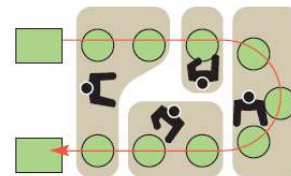
Source: R. W. Hall, *Attaining Manufacturing Excellence* (Homewood, IL: Dow Jones-Irwin, 1987), p. 125. Copyright © 1987 McGraw-Hill Companies Inc.

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Improving layouts by moving to Workcell concept



Problem – straight line is difficult to balance

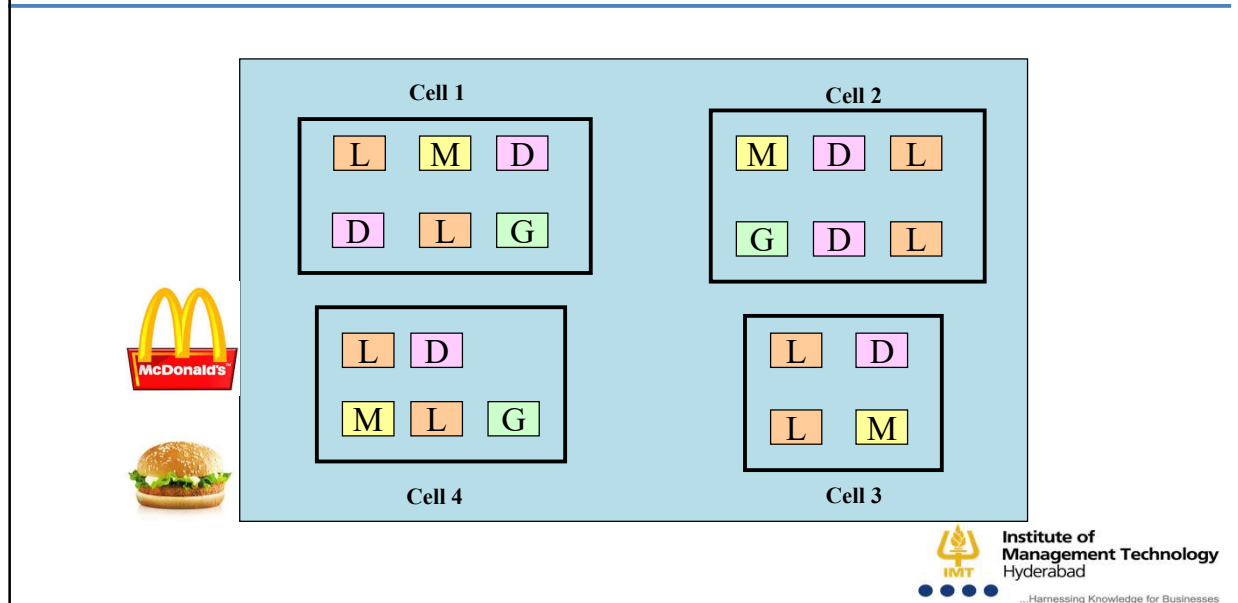


Solution – U-shaped line gives better operator access and may reduce need for operators

Source: R. W. Hall, *Attaining Manufacturing Excellence* (Homewood, IL: Dow Jones-Irwin, 1987), p. 125. Copyright © 1987 McGraw-Hill Companies Inc.

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Group Technology Layout



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Design of GT Layout

- The objective is one of sub-dividing an universe of machines and components into sub-groups
 - Each sub-group of components form a part family and is endowed with a corresponding sub-group of machines known as machine groups
 - Each sub-group is referred to as a cell
- GT layout design is done with a systematic analysis of a machine-component incident matrix
- Number of methods available for identifying sub-groups
 - Production Flow Analysis (PFA)
 - Clustering techniques
 - Matrix manipulation methods
 - Graph theory
 - Mathematical programming methods

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Machine – Component Incident Matrix

		Components																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Machines	A	1			1			1														
	B			1		1			1													
	C		1	1		1			1													
	D	1			1				1													
	E													1	1	1			1	1		1
	F	1			1				1													
	G						1			1		1	1				1				1	
	H						1			1		1	1				1				1	
	I													1	1	1			1	1		1
	J						1			1		1	1					1			1	

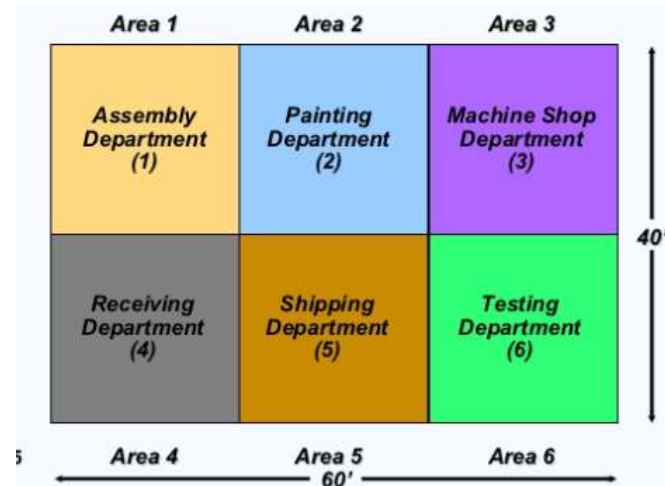
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Machine – Component Incident Matrix

		Components																			
		2	3	5	8	1	4	7	20	18	17	15	14	13	6	9	11	12	16	19	
Machines	B		1	1	1			1													
	C	1	1	1	1																
	D					1	1	1													
	A					1	1	1													
	F					1	1	1													
	E								1	1	1	1	1	1							
	I								1	1	1	1	1	1							
	G															1	1	1	1	1	1
	H															1	1	1	1	1	1
	J															1	1	1	1	1	1

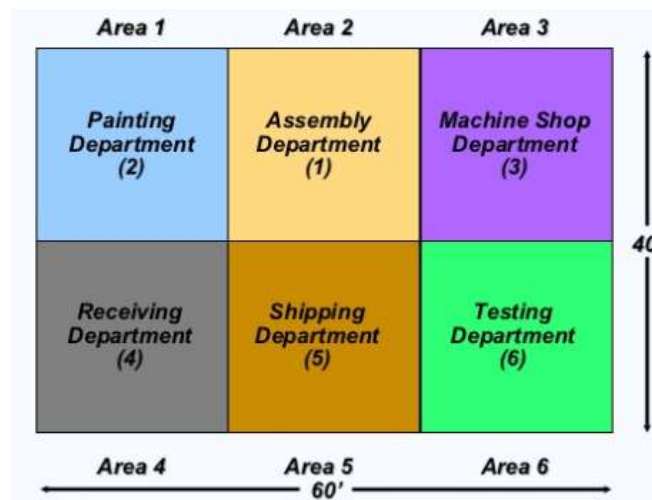
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Process layout example



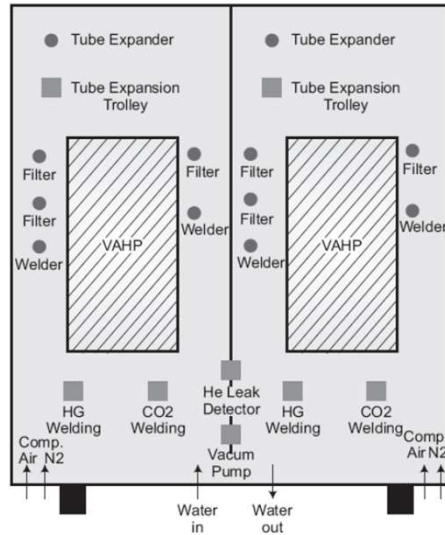
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Process Layout example



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Fixed Position Layout



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Layout Design - Performance Measures

Performance Measure	Basis for measurement
Distance travelled by jobs in the shop floor	Kg - Metres of job movement for each product
Space utilization index	Minimum space required to actual space utilised
Material Handling costs	Rupees per month
Lead time of the processes	Hours per average product
Investment in work-in-progress	Rupees per month
Inter-departmental moves	Number and quantum of inter-departmental moves
Utilisation of the resources	Percent to total capacity
Ease of production control	Number of job cards and control documents generated; Size of the progress chasing staff
Number of ownership changes	Number of times the responsibility for the job changes hands

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