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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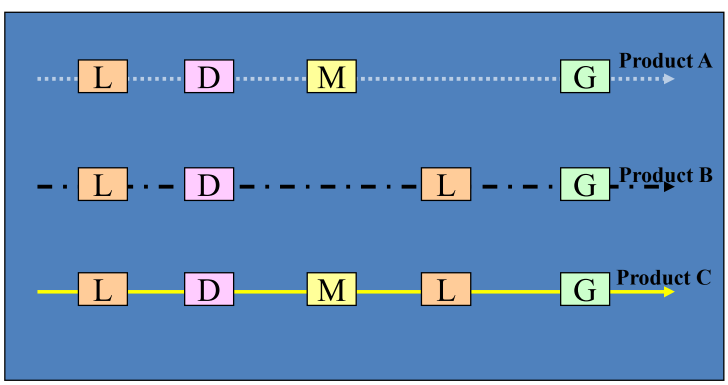
Product Layout



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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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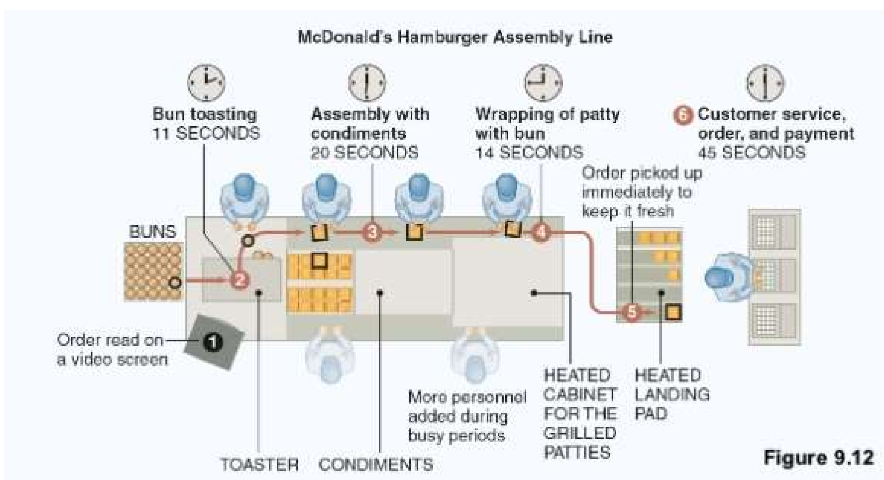

Figure 9.12

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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

$$Actual\ (Desired)\ Cycle\,Time = \frac{Available\,Time}{Actual\ (Desired)\ Production}$$

$$Minimum\ No.of\ work\,stations\ required = \frac{Sum\ of\ all\,task\ times}{Cycle\,Time}$$

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

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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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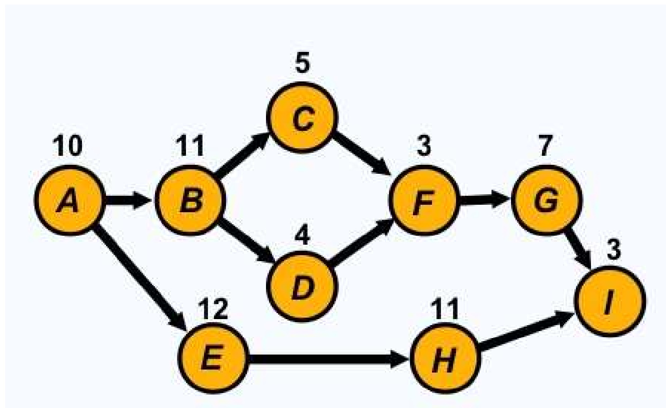
Precedence Diagram



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Line Balancing

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

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

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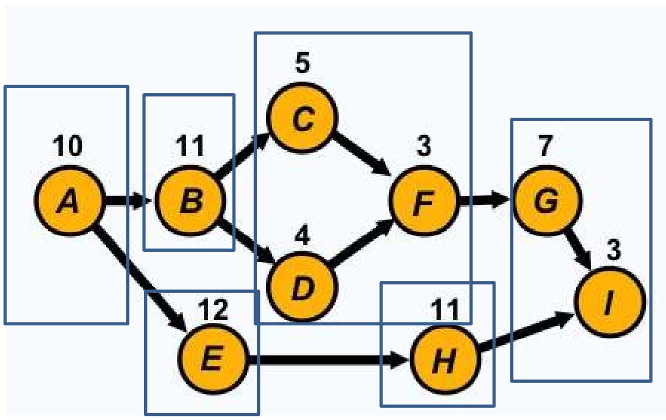
Allocating tasks to stations



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Determining efficiency

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

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

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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
	195		

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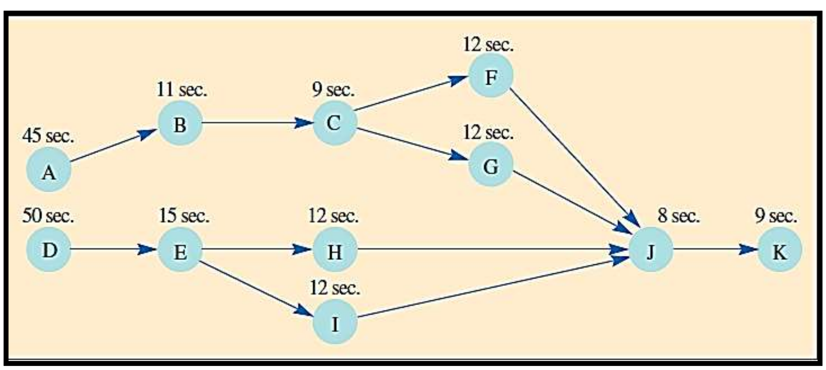
Example: Precedence Graph



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Example: C and N_t

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

$$= 57.6$$

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

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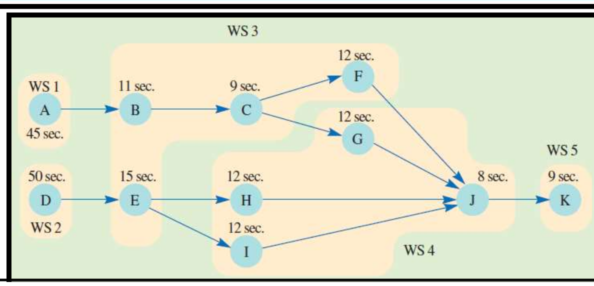
Example: Assignment

	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

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

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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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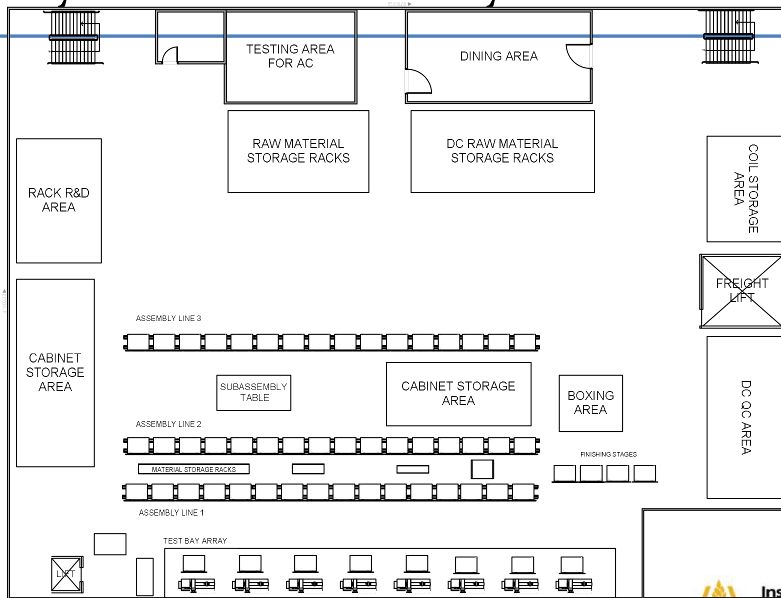
DC Power Systems – The Current Layout



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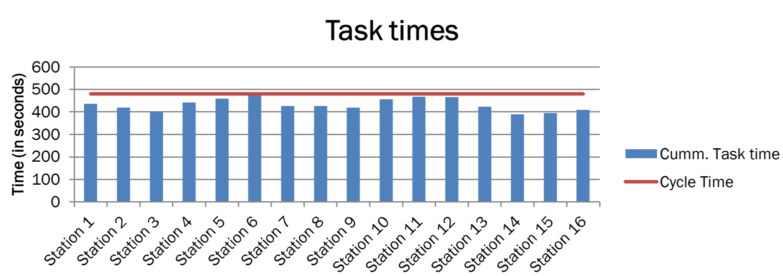
DC Power Systems – Task distribution



- Cycle time (TAKT time) – 480 Secs
- Output Per day – about 150 (ideal)
- Output Per day – not more than 100 mostly

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Issues with the Current System

- High number of stations:
  - Sixteen stations - sixteen operators work on one work piece.
  - Cumulative statistical fluctuation
- Operator fatigue due to excessive movement:
  - Back and forth to the inventory racks
- Lack of station discipline:
  - Just fill the gaps
- Absenteeism:
  - One operator effects 1/3rd of the production
- Lack of flexibility in the line:
  - No Place to add more stations
- Lack of teamwork and coordination:
  - 16 is a crowd

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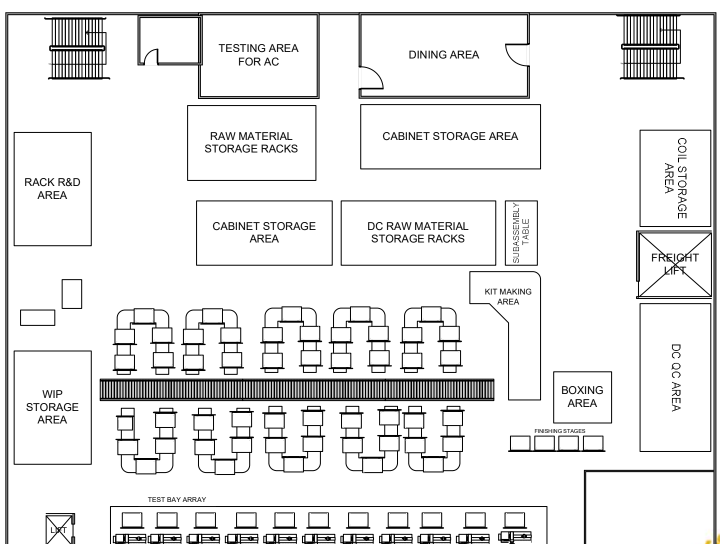
The Proposed layout



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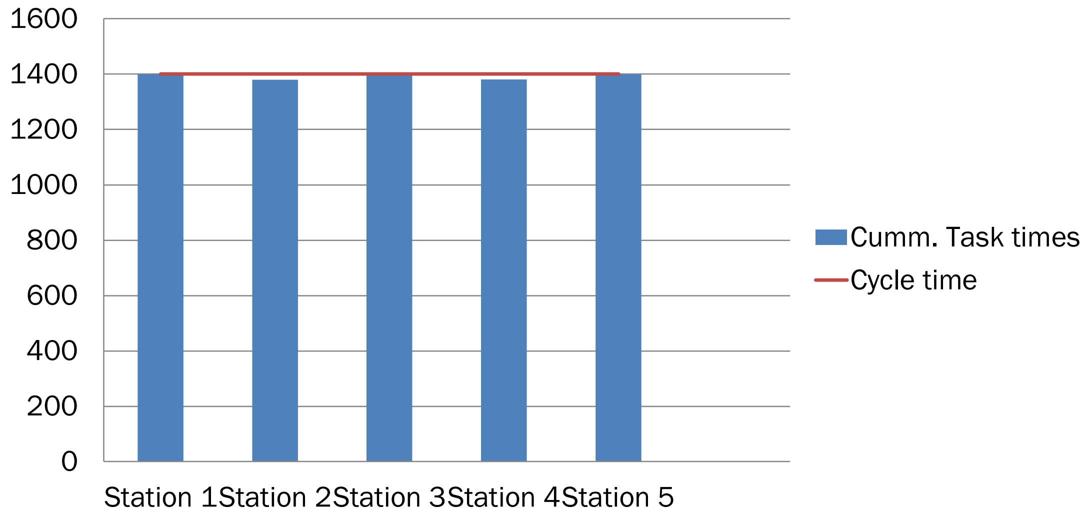
Alternative System



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Comparing the two systems

Attribute	Old Layout	New Layout
Capacity (ideal)	150	180
Variability	High	Low
Flexibility to change in process configuration	No	3 stations could be added
Manpower	54	54
Material handling	High	Low
Flexibility to change in demand	Low	High
Teamwork and coordination	16 member teams	5 member teams
Operator movement	High	Low
Effect of absenteeism	High	Low
Shop floor Inventory	50 units inventory	Zero
No. of Testing Bays required	8	11

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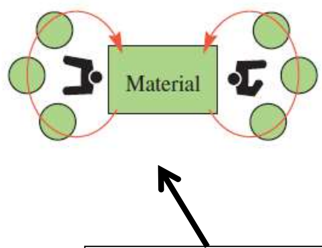
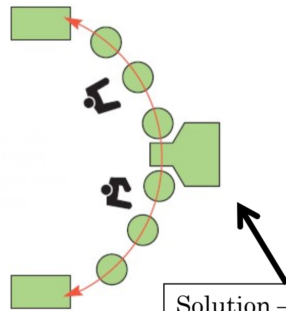
Improving layouts by moving to Workcell concept



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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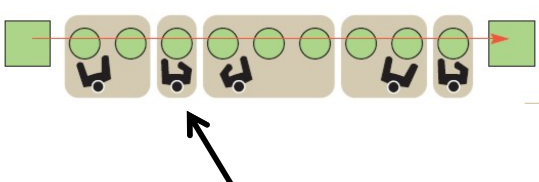
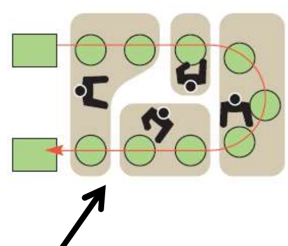
Improving layouts by moving to Workcell concept



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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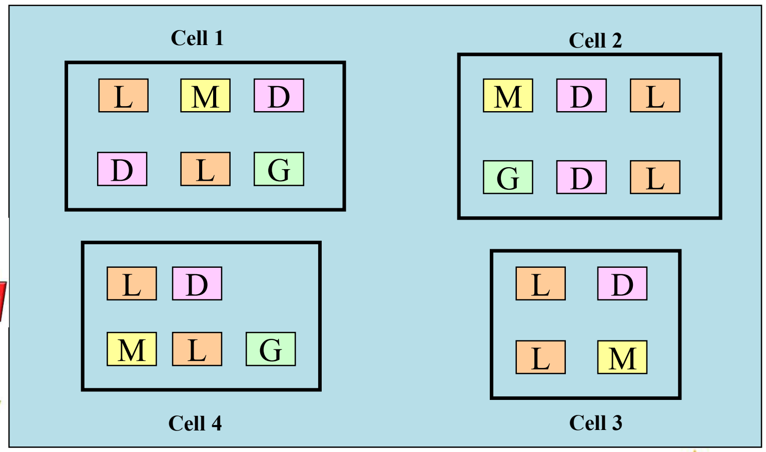
Group Technology Layout



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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

Machines

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
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

Machines

	2	3	5	8	1	4	7	20	18	17	15	14	13	6	9	11	12	16	19
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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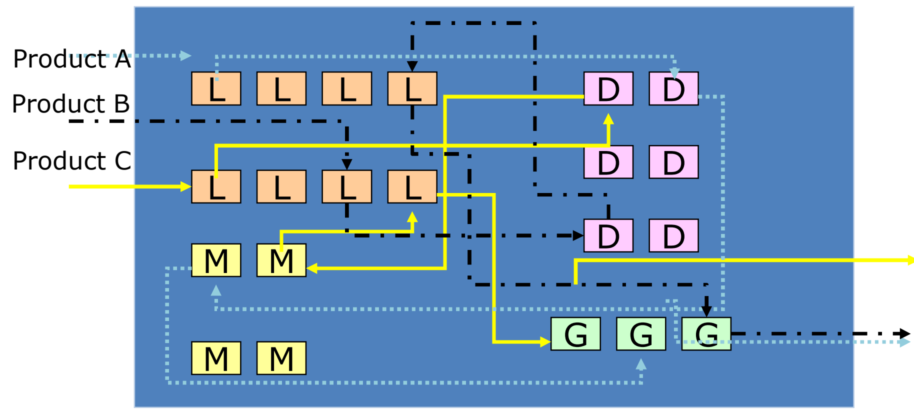
Process Layout



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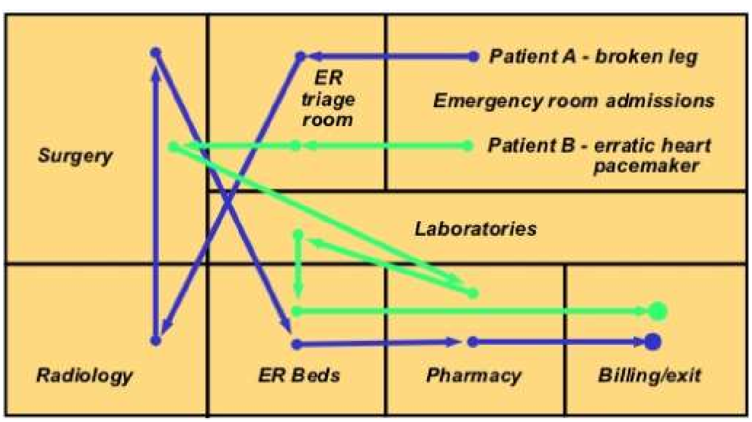
Process layout



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Process layout example

- Arrange six departments in a factory to minimize the material handling costs. Each department is 20 X 20 feet and the building is 60 feet long and 40 feet wide
- Transportation costs are $1 to move a load between adjacent work centers and $1 extra for each work center in between.
  1. Construct a "from-to matrix"
  2. Determine the space requirements
  3. Develop an initial schematic diagram
  4. Determine the cost of this layout
  5. Prepare a detailed plan

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Process Layout example

Number of loads per week

Department	Assembly (1)	Painting (2)	Machine Shop (3)	Receiving (4)	Shipping (5)	Testing (6)
Assembly (1)		50	100	0	0	20
Painting (2)			30	50	10	0
Machine Shop (3)				20	0	100
Receiving (4)					50	0
Shipping (5)						0
Testing (6)						

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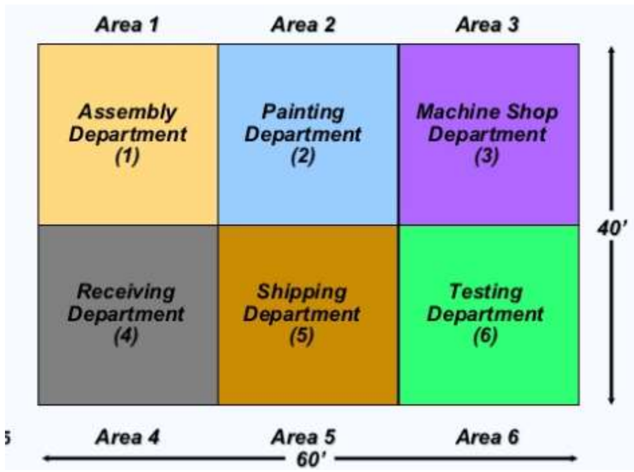
Process layout example



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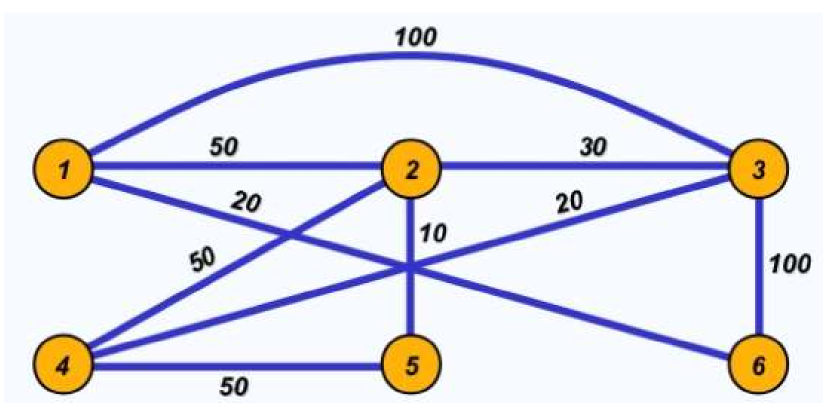
Process Layout example



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Process Layout example

$$Cost = \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij} C_{ij}$$

$$\begin{aligned} Cost = \; & \underset{(1 \text{ and } 2)}{\$50} + \underset{(1 \text{ and } 3)}{\$200} + \underset{(1 \text{ and } 6)}{\$40} \\ & + \underset{(2 \text{ and } 3)}{\$30} + \underset{(2 \text{ and } 4)}{\$50} + \underset{(2 \text{ and } 5)}{\$10} \\ & + \underset{(3 \text{ and } 4)}{\$40} + \underset{(3 \text{ and } 6)}{\$100} + \underset{(4 \text{ and } 5)}{\$50} \\ = \; & \$570 \end{aligned}$$

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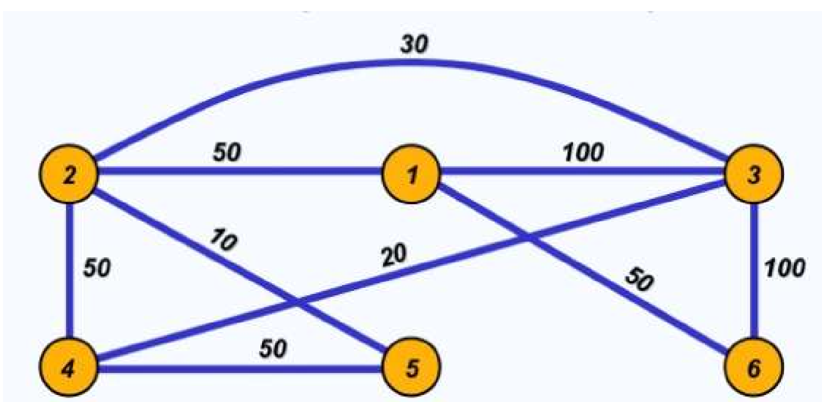
Process Layout example



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Process Layout example

$$Cost = \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij} C_{ij}$$

$$\begin{aligned} Cost = {} & \underset{(1\text{ and }2)}{\$50} + \underset{(1\text{ and }3)}{\$100} + \underset{(1\text{ and }6)}{\$20} \\ & + \underset{(2\text{ and }3)}{\$60} + \underset{(2\text{ and }4)}{\$50} + \underset{(2\text{ and }5)}{\$10} \\ & + \underset{(3\text{ and }4)}{\$40} + \underset{(3\text{ and }6)}{\$100} + \underset{(4\text{ and }5)}{\$50} \\ = {} & \$480 \end{aligned}$$

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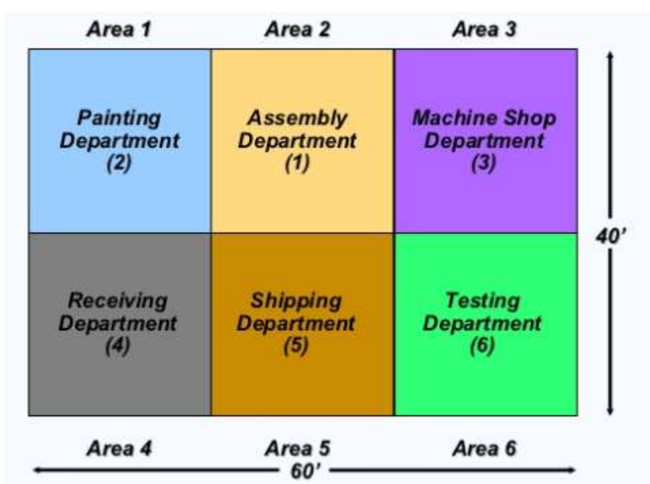
Process Layout example



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Design of Process Layout
Quantitative Method

- C_{ij} = Cost per unit of transporting a unit distance from department "*i*" to department "*j*"
- F_{ij} = *I*nter-departmental flow between department "*i*" and department "*j*"
- D_{ij} = Distance between department "*i*" and department "*j*"
- *n* = *N*umber of departments to be laid out
- The total cost of the plan is given by: $TC = \sum_{i=1}^{n} \sum_{j=1}^{n} F_{ij} D_{ij} C_{ij}$
- One can model the above as a mathematical programming problem with the objective function of minimising the total cost of the plan

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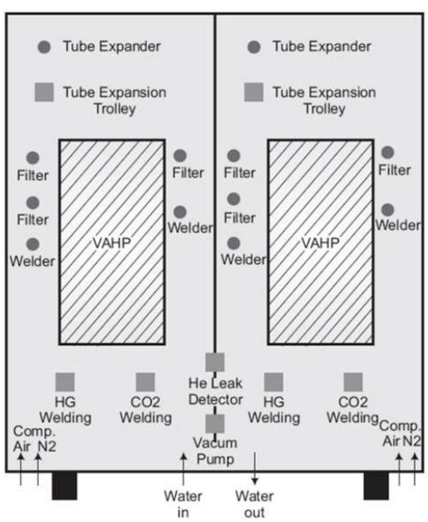
Fixed Position Layout



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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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