CHAPTER-IV
FACILITY PLANNING

To produce products or services business systems utilize various facilities like plant and machineries, ware houses etc.

Facilities can be broadly defined as buildings where people, material, and machines come together for a stated purpose – typically to make a tangible product or provide a service.

The facility must be properly managed to achieve its stated purpose while satisfying several objectives. Such objectives include producing a product or producing a service

- at lower cost,
- at higher quality,
- or using the least amount of resources.

4.1 Definition of Facilities Planning

Importance of Facilities Planning & Design Manufacturing and Service companies spend a significant amount of time and money to design or redesign their facilities. This is an extremely important issue and must be addressed before products are produced or services are rendered.

A poor facility design can be costly and may result in:

- poor quality products,
- low employee morale,
- customer dissatisfaction.

4.2 Disciplines involved in Facilities Planning (FP)

Facilities Planning (FP) has been very popular. It is a complex and a broad subject. Within the engineering profession:

- civil engineers,
- electrical engineers,
- industrial engineers,
- mechanical engineers are involved in FP.

Additionally,

- architects,
- consultants,
- general contractors,
- managers,
- real estate brokers, and
- urban planners are involved in FP.

4.3 Applications of Facilities Planning (FP)

Facilities Planning (FP) can be applied to planning of:

- a new hospital,
- an assembly department,

• an existing warehouse,
• the baggage department in an airport,
• department building of IE in EMU,
• a production plant, • a retail store,
• a dormitory,
• a bank,
• an office,
• a cinema,
• a parking lot,
• or any portion of these activities etc.

4.4 Factors affecting Facility Layout

Facility layout designing and implementation is influenced by various factors. These factors vary from industry to industry but influence facility layout. These factors are as follows:

- The design of the facility layout should consider overall objectives set by the organization.
- Optimum space needs to be allocated for process and technology.
- A proper safety measure as to avoid mishaps.
- Overall management policies and future direction of the organization.

4.5.1 Break-Even Analysis

The objective is to maximize profit. On economic basis only revenues and cost need to be considered for comparing various locations.

The steps for locational break-even analysis are :

- Determine all relevant costs for each location.
- Classify the location for each location in to annual fixed cost and variable cost per unit.
- Plot the total costs associated with each location on a single chart of annual cost versus annual volume.
- Selwct the location with the lowest total annual cost(TC) at the expected production volume.

Question:

Potential locations A,B and C have the cost structures shown below for manufacturing a product expected to sell for Rs 2700 per unit. Find the most economical location for an expected volume of 2000 units per year.

Site	Fixed Cost/year	Variable Cost/Unit
A	6,000,000	1500
B	7,000,000	500
C	5,000,000	4000

Solution:

For each plant find the total cost using the formula

TC=Fixed cost+ Variable cost/unit (volume)

= FC+VC(v)

Site	Total Cost
A	6,000,000+1500*2000=9,000,000
B	7,000,000+500*2000=8,000,000
C	5,000,000+4000*2000+13,000,000

From the above table, the cost of for the location B, is minimum. Hence it is to be selected for locating the plant.

Production Volume	Site A	Site B	Site C
500	6750000	7250000	7000000
1000	7500000	7500000	9000000
1500	8250000	7750000	11000000
2000	9000000	8000000	13000000
2500	9750000	8250000	15000000
3000	10500 000	8500000	17000000

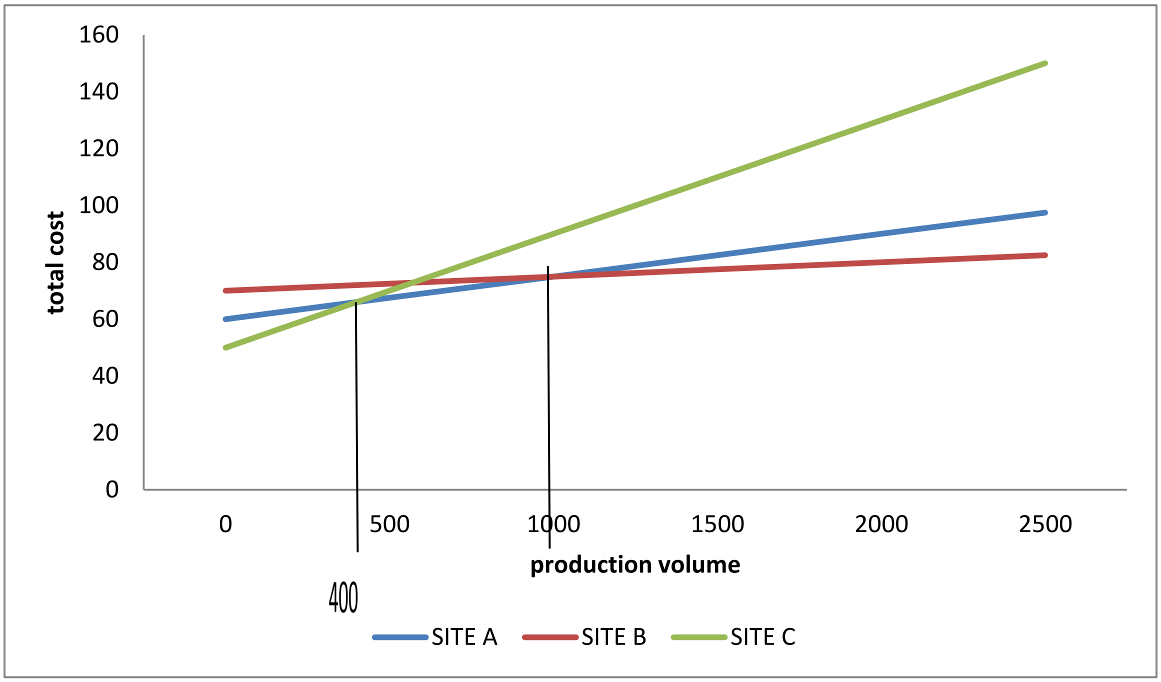


Fig 3.1 Break even analysis

From the graph, the different ranges of production volumes over which the best location to be selected are summarized.

Range of production volume	Best plant selected
0≤Q≤400 400≤Q≤1000 1000≤Q	A B C

The same details can be worked out using a graph

From the graph one can visualize that the site c is desirable for lower volume of production. For higher volume production site B is desirable For moderate volumes of production site nA is desirable. In the increasing order of production volume the switch over from one site to another takes place as per the order below

Site C to site A to site B

Let Q be the volume at which we switch the site C to site A

Total cost of site C ≥ Total cost site A

$$5000000+4000Q \geq 6000000+1500*Q$$

$$2500Q \geq 1000000$$

$$Q \geq 400 \text{ Units}$$

Similarly the switch from site A to site B

Total cost of site A ≥ total cost of site B

$$6000000+1500Q \geq 7000000+500Q$$

$$1000Q \geq 1000000$$

$$Q \geq 1000 \text{ Units}$$

The cutoff production volume for different ranges of production may be obtained by using similar procedure.

4.5.2 GRAVITY LOCATION PROBLEM

Objective- The objective of the gravity location problem, the total material handling cost based on the squared Euclidian distance is minimized

Assumption:- If the same type of material handling equipment / vehicle is used for all the movements, then it is equivalent to minimize the total weighted squared Euclidian distance, since the cost per unit distance is minimized

a_i = x-co-ordinate of the existing facilities i

b_i = y- co-ordinate of the existing facilities i

x = x-co-ordinate of the new facilities

y= y-co-ordinate of the new facilities

w_i= weight associated with the existing facilities i. This is the quantum of materials moved between the new facility and existing facilities I per unit period

m= total no of existing facilities

the formula for the sum of the weighted squared Euclidian distance is given as:

$$f(x,y) = \sum_{i=1}^{m} w\,i[(x - ai)^2 + (y - bi)^2]$$

The objective is to minimize f(x,y)

This is quadratic in nature the optimal values for the x and y may be obtained by equating partial derivatives to zero

$$\frac{\delta f(x,y)}{\delta x} = o \ , \ \frac{\delta f(x,y)}{\delta y} = 0$$

$$x *= \frac{\sum_{i=1}^{m} wiai}{\sum_{i=1}^{m} wi} \quad ,y *= \frac{\sum_{i=1}^{m} wibi}{\sum_{i=1}^{m} wi}$$

Optimal location (x*,y*)=($\frac{\sum_{i=1}^{m} wiai}{\sum_{i=1}^{m} wi}$, $\frac{\sum_{i=1}^{m} wibi}{\sum_{i=1}^{m} wi}$)

These are weighted averages of the x-coordinate and y-co ordinates of the existing facilities.

Problem

There are five Existing facilities which are to be served by single new facilities are shown below in the table

Existing facility (i)	1	2	3	4	5
Co-ordinates (ai,bi)	(5,10) (15,20)	(20,5) (30,35)	(15,20) (25,40)	(30,25) (28,30)	(25,5) (32,40)
No of trips of loads/years (wi)	100 200	300 300	200 400	300 500	100 600

Find the optimal location of the new facilities based on giving location concept

SOLUTION

$$X^* = \frac{\sum_{i=1}^{5} wiai}{\sum_{i=1}^{5} wi} = \frac{(100*5+300*20+200*15+300*30+100*25)}{(100+300+200+300+100)} = 21$$

$$Y^* = \frac{\sum_{i=1}^{5} wibi}{\sum_{i=1}^{5} wi} = \frac{(100*10+300*5+200*20+300*25+100*5)}{(100+300+200+300+100)} = 14.5$$

4.5.3 SINGLE FACILITY LOCATION PROBLEM

Objective – To determine the optimal location for the new facility by using the given set of existing facilities co-ordinates on X-Y plane and movement of materials from a new facility to all existing facilities.

Generally we follow rectilinear distance for such decision. The rectilinear distance between any two points whose co-ordinates are (X1,Y1)and(X2,Y2) is given by the following formula

$d_{12} = |X1 - X2| + |Y1 - Y2|$

some properties of an optimum solution to the rectilinear distance location problems are as follows:

1. The X-coordinate of the new facility will be same as the X-co-ordinate of some existing facility. Similarly the Y co-ordinate of the new facility will coincide with the Y coordinate of some existing facility. It is not necessary that both coordinates of the new facility
2. The optimum X or Y-co-ordinate location for new facility is a median location. A median location is defined to be a location such that no more than one half the item movement is to the left/below of the new facility location and no more than one half the item movement is to the right /above of the new facility location.

EXAMPLE

Consider the location of a new plant which will supply raw materials to a set of existing plants in a group of companies, let there are 5 existing plants which have a materials movement relationship with the new plant. Let the existing plants have locations of (400,200),(800,500),(1100,800),(200,900)and(1300,300). Furthermore suppose that the number of tons of materials transported per year from the new plant to various existing plants are 450,1200,300,800 and 1500, respectively the objective is to determine optimum location for the new plant such that the distance moved(cost)is minimized

SOLUTION

Let (X,Y) be the coordinate of the new plant

The optimum X-coordinate for the new plant is determined as follows

Existing plant	X coordinate	weight	Cumulative Weight
4	200	800	800
1	400	450	1250
2	800	1200	2450
3	1100	300	2750
5	1300	1500	4250
		Total	4250 tons

Thus the median location corresponds to a cumulative weight of 4250/2=2125 from above the table, the corresponding X-coordinate value is 800, since the cumulative weight first exceeds 2125 at X=800

Similarly, the determination of Y coordinate is shown below

Existing plant	Y coordinate	weight	Cumulative Weight
1	200	450	450
5	300	1500	1950
2	500	1200	3150
3	800	300	3450
4	900	800	4250
		Total	4250 tons

Thus the median location corresponds to a cumulative weight of 4250/2=2125 from above the table, the corresponding Y-coordinate value is 500, since the cumulative weight first exceeds 2125 at X=500

The optimal (X*,Y*)=(800,500)

4.5.4 MINIMAX LOCATION PROBLEM

Objective- To locate the new emergency facility (X,Y) such that the maximum distance from the new emergency facility to any of the existing facilities is minimized

Fi(X,Y)= Distance between the new facilities and the existing facilities

Fi(X,Y)=|X-ai|+|Y-bi|

Fmax (X,Y)=maximum of the distance between the new facility and various existing facilities

Fmax(X,Y)= $\underbrace{max}_{1\le i\le m}$ {|X-a_i|+|Y-b_i|}

The distance between new facility and existing facility may be rectilinear or Euclidean

m=different shops in an industry

in the event of fire in any one of these shops a costly firefighting equipment showed reach the spot as soon as possible from its base location. Movements within any industry are rectilinear in nature. Our objective is to locate the new fire fighting equipment within the industry such that maximum distance it has to travel from its base location to any of the existing shops is minimized.

Step 1

Find c_1, c_2, c_3, c_4 and c_5,using following formula

$c_1 = \underbrace{min}_{1\le i\le m} (a_i + b_i)$ $c_2 = \underbrace{max}_{1\le i\le m} (a_i + b_i)$ $c_3 = \underbrace{min}_{1\le i\le m} (-a_i + b_i)$ $c_4 = \underbrace{max}_{1\le i\le m} (-a_i + b_i)$
$c_5 = \underbrace{max}_{1\le i\le m} (c_2 - c_1, c_4 - c_3)$

Step 2

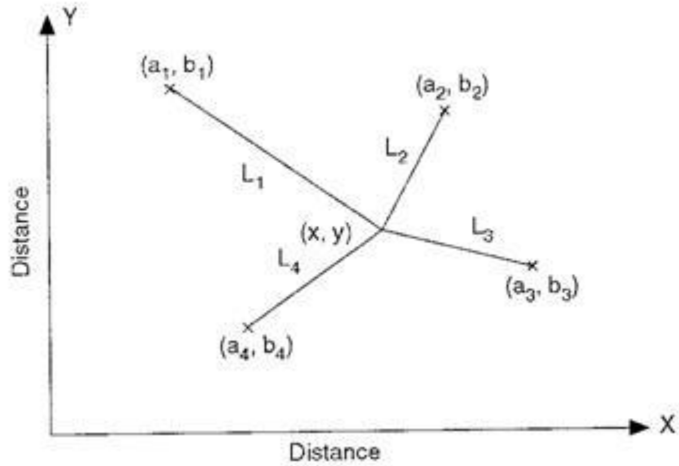
Find the points P_1 and P2 using the following formula

P1=[1/2$(c_1 - c_3)$, ½$(c_1 + c_3 + c_5)$]

P2=[1/2$(c_2 - c_4)$, ½$(c_2 + c_4 - c_5)$]

Step 3

Any pt(X*,Y*) on the line segment joining points P1 and P2 is a minimax location that minimize fmax(X,Y)



GRAPH OF MINIMAX LOCATION PROBLEM

EXAMPLE

In a foundry there are seven shops whose coordinates are summarized in the following table. The company is interested in locating a new costly fire fighting equipment in the foundry determine the minimax location of the new equipment

SL NO	EXISTING FACILITIES	CO-ORDINATE OF CENTROID
1	Sand plant	10,20
2	Molding shop	30,40
3	Pattern shop	10,120
4	Melting shop	10,60
5	Felting shop	30,100
6	Fabrication shop	30,140
7	Annealing shop	20,190

SOLUTION

The movement of new equipment is constrained within in the foundry the assumption of rectilinear distance more appropriate

The co ordinate of the centroid of the existing shops are

(a1,b1)=(10,20) (a2,b2)=(30,40) (a3,b3)=(10,120) (a4,b4)=(10,60) (a5,b5)=(30,100) (a6,b6)=(30,140) (a7,b7)=(20,140)

Step 1

$c_1 = \underbrace{min}_{1 \le i \le m} (a_i + b_i)$ = min [(10+20),(30+40),(10+120),(10+60),(30+100),(30+140),(20+190)]

=min[30,70,130,70,130,170,210]=30

$c_2 = \underbrace{max}_{1 \le i \le m} (a_i + b_i)$ = max[30,70,130,70,130,170,210]=210

$c_3 = \underbrace{min}_{1 \le i \le m} (-a_i + b_i)$=min[(-10+20),(-30+40),(-10+120),(-10+60),(-30+100),(-30+140),

(-20+190)]=min[10,10,110,50,70,110,170]=10

$c_4 = \underbrace{max}_{1 \le i \le m} (-a_i + b_i)$ =max[10,10,110,50,70,110,170]=170

$c_5 = \underbrace{max}_{1 \le i \le m} (c_2 - c_1, c_4 - c_3)$=max[(210-30),(170-10)]=max[180,160]=180

P1=[1/2$(c_1 - c_3)$, ½$(c_1 + c_3 + c_5)$]=[1/2(30-10),1/2(30+10+180)]=(10,110)

P2=[1/2$(c_2 - c_4)$, ½$(c_2 + c_4 - c_5)$]= [1/2(210-170),1/2(210+170-180)]=(20,100)

Any point X*,Y* on the line segment joining pts (10,110),(20,100) is a minimax location for the firefighting equipment.

4.6 Layout Design Procedure

Layout design procedures can be classified into manual methods and computerized methods.

Manual methods. Under this category, there are some conventional methods like travel chart and Systematic Layout Planning (SLP).

Computerized methods

Under this method, again the layout design procedures can be classified in to constructive type algorithm and improvement type algorithms.

Construction type algorithms

Automated Layout Design program (ALDEP)

Computerized Relationship Layout Planning (CORELAP)

Improvement type Algorithm

Computerized Relative Allocation of Facilities Technique (CRAFT)

4.6.1 Computerized Relative Allocation of Facilities Technique (CRAFT)

CRAFT algorithm was originally developed by Armour and Buffa. CRAFT is more widely used than ALDEP and CORELAP. It is an improvement algorithim.It starts with an initial layout and improves the layout by interchanging the departments pairwise so that transportation cost is minimized.

CRAFT requirements

1. Initial layout
2. Flow data
3. Cost per unit distance
4. Total number of departments
5. Fixed departments
   Number of such departments
   Location of those departments
6. Area of departments

4.7 Algorithms and models for Group Technology

In this section Rank Order Clustering (ROC) and Bond Energy Algorithms are the methods can be applied to Group Technology (GT).

4.7.1 Rank Order Clustering Algorithm (ROC)

This algorithm was developed by J.R King(1980).This algorithm considers the following data**.**

- Number of Components
- Component Sequence

Based on the component sequences, a machine-component incidence matrix is developed. The rows of the machine-component incidence matrix represent the machines which are required to processes the components. The columns of the matrix represent the component numbers.

STEPS IN ROC LOGARITHM

Step 0 : Input : Total no of components and component sequences

Step 1. From the machine component incidence matrix using the component sequences

Step 2. Compute binary equivalent of each row.

Step 3. Re arrange the rows of the matrix in rank wise (high to low from top to bottom)

Step 4. Compute binary equivalent of each column and check whether the column of the matrix are arranged in rank wise (high to low from left to right)? If not go to step 5 otherwise go to step 7

step 5. Rearrange the columns of the matrix rank wise and compute the binary equivalent of each row

Step 6. Check whether the rows of the matrix are arranged rank wise? If not go to step 3; Otherwise, go to step 7

Step 7. Print the final machine component incidence matrix.

By following this steps the problems can be solved.

Chapter 6: Production Planning and Control

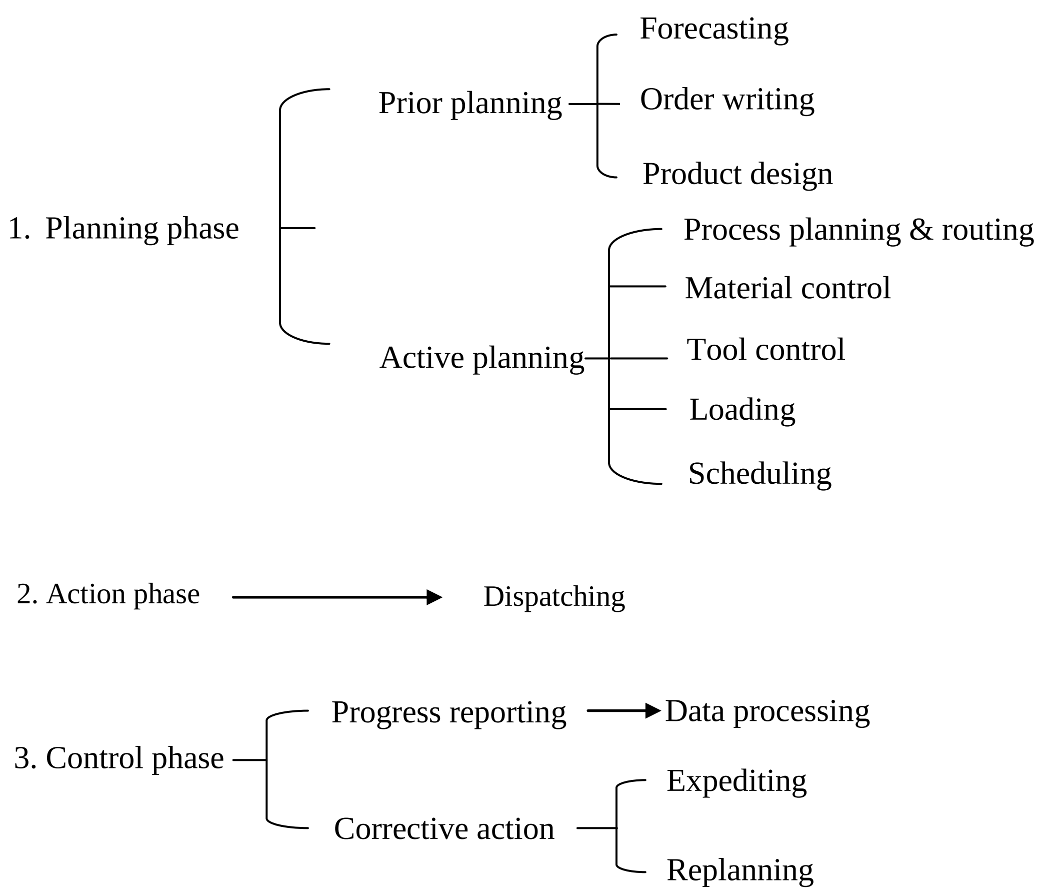
6.1 Production:

It is an organized activity of converting raw materials into useful products. But before starting the actual production, production planning is done to anticipate possible difficulties and to decide in advance as to how the production process should be carried out in a best and economical way to satisfy customers. Since only planning of production is not sufficient, hence management takes all possible steps to see that plans chalked out by planning department are properly adhered to and the standard set are attained. In order to achieve it, control over production is exercised. The ultimate aim of production planning and control (PPC) is to produce the products of right quality in right quantity at the right time by using the best and least expensive methods.

Production planning and control can thus be defined as:

- The process of planning the production in advance.
- Setting the exact route of each item.
- Fixing the starting and finishing date for each item.
- To give production orders to different shops.
- To see the progress of products according to order.

The various functions of PPC department can also be systematically written as:



Explanation on each term

1. Forecasting: Estimation of type, quantity and quality of future work.

2. Order writing: Giving authority to one or more persons to undertake a particular job.

3. Product design: Collection of information regarding specification, bill of materials, drawing, etc.

4. Process planning and routing: Finding the most economical process of doing work and then deciding how and where the work will be done.

5. Material control: It involves determining the material requirement and control of materials.

6. Tool control: It involves determining the requirement and control of tools used.

7. Loading: Assignment of work to man power and machining etc.

8. Scheduling: It determines when and in what sequence the work will be carried out. It fixes the starting and finishing time for the job.

9. Dispatching: It is the transition from planning to action phase. In this phase the worker is ordered to start the actual work.

10. Progress reporting: Data regarding the job progress is collected. It is interpreted by comparison with the preset level of performance.

11. Corrective action: (i) Expediting means taking action if the progress reporting indicates a deviation of the plan from the original set target. (ii) Replanning of the whole affair becomes essential, in case expediting fails to bring the deviation plan to its right path.

Objectives of PPC

1. To determine the sequence of operations to continue production.
2. To issue co-ordinated work schedule of production to the supervisor/foreman of various shops.
3. To plan out the plant capacity to provide sufficient facilities for future production programme.
4. To maintain sufficient raw materials for continuous production.
5. To follow up production schedule to ensure delivery promises.
6. To evaluate the performance of various shops and individuals.
7. To give authority to right person to do right job.

PPC and related functions

The Fig. 6.1 shows the relation of PPC with other functional departments.

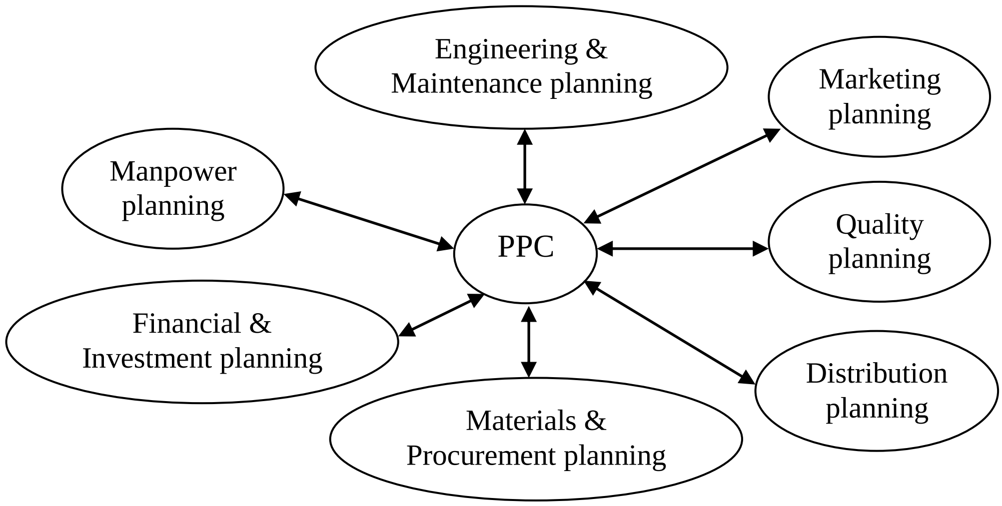
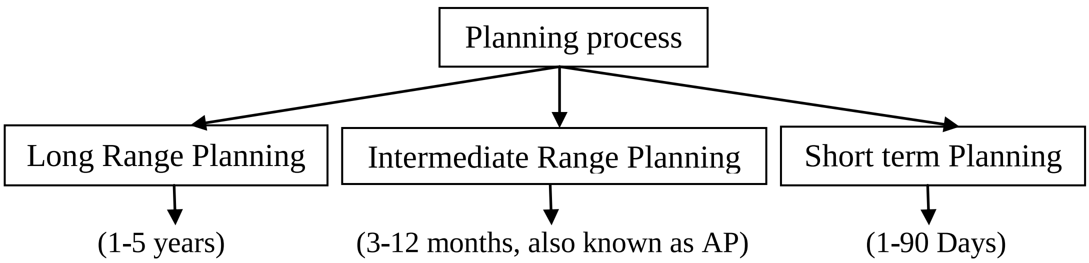
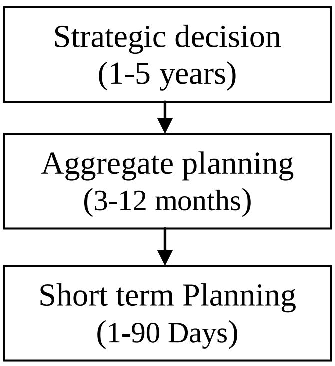


Fig. 6.1 Relation of PPC with other functional departments

6.2 Aggregate planning (AP)



Planning hierarchy



AP: Production planning in the intermediate range of time is termed as Aggregate planning.

Explanation of AP

The aggregate planning concentrates on scheduling production, personnel and inventory levels during intermediate term planning horizon such as 3-12 months. Aggregate plans act as an interface between strategic decision (which fixes the operating environment) and short term scheduling and control decision which guides firm's day-to-day operations. Aggregate planning typically focuses on manipulating several aspects of operations-aggregate production, inventory and personnel levels to minimize costs over some planning horizon while satisfying demand and policy requirements. In brief the objectives of AP are to develop plans that are feasible and optimal.

Aggregate planning

Aggregate Production Planning | Aggregate Capacity Planning

Aggregate Production Planning indicates the level of output.
Aggregate Capacity Planning keep capacity utilization at desired level and test the feasibility of planned output.

6.3 Decision options in Aggregate Planning

Decision options are basically of 2 types:

(i) Modification of demand for a product.
(ii) Modification of supply of a product.

(i) Modification of demand

Demand can be modified in several ways:

(a) Differential pricing: It is often used to reduce the peak demand or to increase the off period demand. Some examples are: reducing off season fan/woollen item rate, reducing the hotel rate in off season.
(b) Advertising and promotion: These methods are used to stimulate/smooth out demand. Advertising is generally so timed as to increase demand during off period and to shift demand from peak period to he off period.
(c) Backlogs: Through the creation of backlogs, the manufacturers ask customers to wait for the delivery of products, thereby shifting the demand from peak period to off period.
(d) Development of complementary products: Producer, who produces products which are highly seasonal in nature, applies this technique. Ex: Refrigerator company produce room heater, TV Company produces DVD, etc.

(ii) Modification of supply

There are various methods of modification of supply.

(a) Hiring and lay off employees: The policy varies from company to company. The man power/work force varies from peak period to slack/off period. Accordingly, firing/lay off employee is followed without affecting employee morale.
(b) Overtime and undertime: Overtime and undertime are common options used in cases of temporary change of demand.
(c) Use of part time or temporary labour: This method is attractive as the payment of part time/temporary labour is less.
(d) Subcontracting: The subcontractor may supply the entire product/some of the components needed for the product.
(e) Carrying inventories: It is used by manufacturers who produces items in a particular season and sell them throughout the year.

Aggregate planning strategies

Pure strategy | Mixed strategy

Pure strategy:

If the demand and supply is regulated by any one of the following strategy, i.e.

(a) Utilizing inventory through constant work force.
(b) Varying the size of workforce.
(c) Subcontracting.
(d) Making changes in demand pattern.

Mixed strategy:

If the demand and supply is regulated by mixture of the strategies as mentioned, it is called mixed strategy.

6.4 Sequencing

The order in which jobs pass through the machines or work stations is called sequencing. The relative priorities are based on certain rules as discussed in the following:

1. First Come, First Served (FCFS) rule: This is a fair approach particularly applicable to people. In case of inventory management, it is First In First Out (FIFO). That means the 1^{st} piece of inventory at a storage area is the 1^{st} one to be used.
2. The shortest processing time (SPT) rule: SPT rule sequences jobs in increasing order of their processing times (including set up).
3. The Earliest Due Date (EDD) rule: Sequences jobs in order of their due dates, earliest first.
4. The critical ratio (CR) rule: Sequences jobs in increasing order of their critical ratio.

   $$CR = \frac{\text{Due date- Today's date}}{\text{Remaining processing time}}$$

   If CR>1 The job is ahead of schedule.
   If CR<1 The job is behind schedule.
   If CR=1 The job is exactly on schedule.
5. The Slack Time Remaining (STR) rule: It employs that the next job processed is the one that has the least amount of slack time.
   Slack = (Due date – Today's date) – Remaining processing time

6.5 Sequencing of n jobs through 2 machines (Johnson's rule)

Considering 2 machines and 'n' jobs as shown in Table 6.1.

Table 6.1 Job sequencing for n jobs

1	t_{11}	t_{12}
2	t_{21}	t_{22}
3	t_{31}	t_{32}
4	t_{11}	t_{42}
.	.	.
.	.	.
i	t_{i1}	t_{i2}
.	.	.
n	t_{n1}	t_{n2}

Step 1: Find the minimum among t_{i1} and t_{i2}.

Step 2(a): If the minimum processing time requires m/c-1, place the associated job in the 1st available position in sequence.

Step 2(b): If the minimum processing time requires machine-2, place the associated job in the last available position in sequence.

Step 3: Remove the assigned job from the table and return to Step 1 until all positions in sequence are filled. (Ties may be considered randomly)

The above algorithm is illustrated with the following example.

Ex.1 Consider two machines and six jobs flow shop scheduling problem. Using Johnson's algorithm, obtain the optimal sequence which will minimize the makespan.

Job	Time taken by machines	
	1	2
1	5	4
2	2	3
3	13	14
4	10	1
5	8	9
6	12	11
Sum	50	42

Solution: The working of the algorithm is summarized in the form of a table which is shown below.

Stage	Unscheduled job	Min	Assignment	Partial sequence/ Full sequence
1	1 2 3 4 5 6	t_{42}	Job 4-[6]	× × × × × 4
2	1 2 3 5 6	t_{21}	Job 2-[1]	2 × × × × 4
3	1 3 5 6	t_{12}	Job 1-[5]	2 × × × 1 4
4	3 5 6	t_{51}	Job 5-[2]	2 5 × × 1 4
5	3 6	t_{62}	Job 6-[4]	2 5 × 6 1 4
6	3	t_{31}	Job 3-[3]	2 5 3 6 1 4

Now the optimal sequence is 2-5-3-6-1-4.

The makespan is determined as shown below.

Job	M/C-1		M/C-1		Idle time on m/c-2
	Time in	Time out	Time in	Time out	
2	0	2	2	5	2
5	2	10	10	19	5
3	10	23	23	37	4
6	23	35	37	48	0
1	35	40	48	52	0
4	40	50	52	53	0

The makespan for this schedule is 53.

6.6 Line balancing

Plants having continuous flow process and producing large volume of standardized components prefer conveyor assembly line. Here the work centres are sequenced in such a way that at each stage a certain amount of total work is carried out so that at the end of conveyor line, the final product comes out. This requires careful preplanning to balance the timing between each work centres so that idle/waiting time is minimized. This process of internal balancing is called Assembly line balancing.

Line balancing is defined as the procedure for creating work stations and assigning tasks to them according to a predetermined technological sequence such that the idle time at each work station is minimized.

In perfect line balancing, each work centre completes its assigned work within a fixed time duration so that output from all operations are equal on the line. Such a perfect balancing is difficult to achieve. Certain work station/centre take more operation time causing subsequent work centre to become idle.

Balancing may be achieved by

- Rearrangement of work stations
- Adding m/c and or workers at some work stations.

So that all work centres take about the same amount of time.

Some terminologies used in line balancing:

1. Work station: It is a location on the assembly line where specified work is performed.
2. Cycle time: It is the amount of average time a product spends at one work station

$$\text{Cycle time (CT)} = \frac{\text{Available time period}}{\text{Total no. of products/output}}$$

3. Task : The smallest grouping of work that can be assigned to a work station.
4. Task time: Standard time to perform task.
5. Station time: Total standard time at a particular work station.

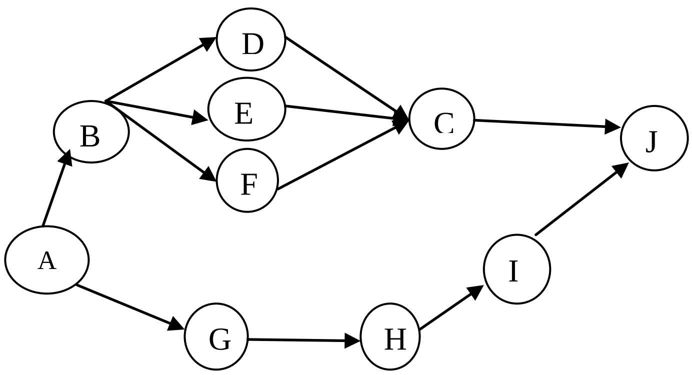
A typical example will clarify the procedure of line balancing.

Ex: A company is setting an assembly line to produce 192 units per 8 hour shift. The information regarding work elements in terms of times and intermediate predecessors are given below:

Work element	Time (Sec)	Immediate predecessor
A	40	None
B	80	A
C	30	D,E,F
D	25	B
E	20	B
F	15	B
G	120	A
H	145	G
I	130	H
J	115	C,I
Total	720	

1. What is the desired cycle time?
2. What are the theoretical numbers of stations?
3. Use largest work element time rule to work out a solution on a precedence diagram.
4. What are efficiency and balance delay of the solution obtained?

Solution: The precedence diagram is represented as shown below:



(a) Cycle time: 8hours/192 units = 150 sec/unit.
(b) Sum of the time of all work elements = 720 secs
So, minimum number of work station = 720/150 = 4.8 = 5 stations.

(c) Assignment of work element to stations:

Station/ stations	Elements	Work element time (Sec)	Cumulative time (Sec)	Idle time for station (Sec)
S1	A	40	40	05
	B	80	120	
	D	25	145	
S2	G	120	120	10
	E	20	140	
S3	H	145	145	05
S4	I	130	130	05
	F	15	145	
S5	C	30	30	05
	J	115	145	

(d) Efficiency: $\sum t \times 100/n \times CT = 720 \times 100/5 \times 150 = 96\%$.
(e) Balance delay = 100-96 = 4%.

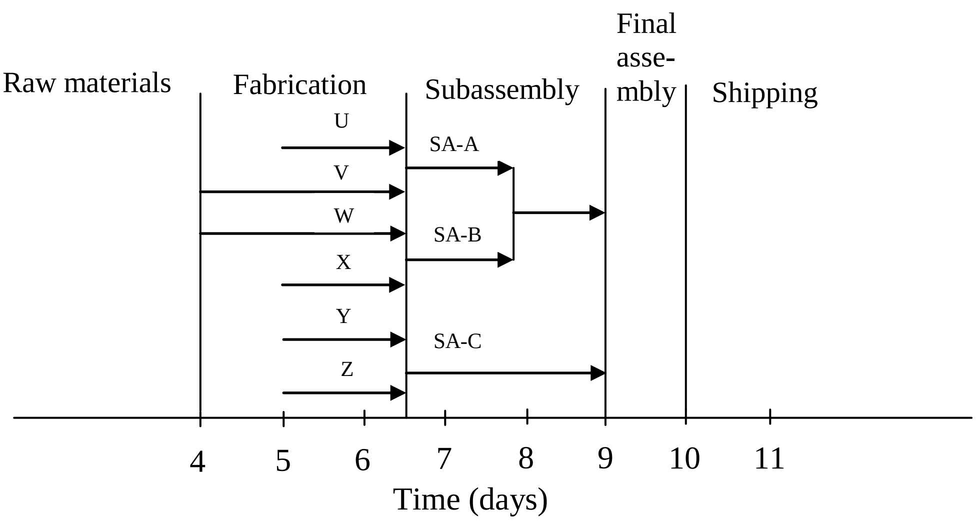
6.6 Flow control

Flow control applies to the control of continuous production as found in oil refineries, bottling works, cigarette making factories, paper making mills and other mass manufacturing plants.

The function of flow control is to match up the rates of flow of parts, subassemblies and final assemblies. Each part should be ready before the time of subassembling and each subassembly should be made available at the time and place of assembly in order to make the final product.

Flow control can be performed through the following:

(a) **Operation time**: It amounts the time required to manufacture each part, to make one subassembly and to execute one assembly. This information is available from the operation sheet.
(b) **Line balancing**: the assembly line should be balanced. Each work station should have the more or less same operating time and the various operations should be sequenced properly.
(c) **Routing and scheduling**: A combination route and schedule chart showing the fabrication of parts, subassemblies and final assembly is shown below.



The chart shows that part V & W started on 4th day and the other parts on 5th day such that all the components become ready for subassembly on 6.5th day and all the subassembly become ready on 9th day for final assembly. The assembly is over on 10th day.

(d) **Control of parts subassemblies and Assembly**: A supervisory function coupled with an appropriate information feedback system keeps a check whether the small parts arriving in lots and big parts coming continuously are available at right time, in proper quantities for making subassemblies as per scheduled plan.

(e) Dispatching: Dispatching is nothing but issuing orders and instructions to start a particular work which has already been planned under routing and scheduling.

Functions of Dispatching

(i) Assignment of work to individual man, m/c or work place.
(ii) Release necessary order and production firm.
(iii) Authorize for issue of materials, tools, jigs, fixtures, gauges, dies for various jobs.
(iv) Required materials are authorized to move from stores or from operation to operation.
(v) Issue m/c loading and schedule chart, route sheet, etc.
(vi) To fix up the responsibilities of guiding and controlling the materials and operation processes.
(vii) To issue inspection order.
(viii) Issue of time tickets, drawing, instruction cards.

Dispatch procedure

The product is broken into different components. For each component, operations are mentioned in order as shown in Figure aside.

Route sheet for component C
Material-
Operation 1-
Operation 2-

The various steps of dispatch procedure for each operation are listed below:

(a) Store issue order: Authorise store department to deliver required material.
(b) Tool order: Authorise tool store to release the necessary tools. The tools can be collected by the tool room attendant.
(c) Job order: Instruct the worker to proceed with operation.
(d) Time tickets: It records the beginning and ending time of the operation and forms the basis for workers pay.
(e) Inspection order: Notify the inspectors to carry out necessary inspections and report the quality of the component.
(f) Move order: Authorise the movement of materials and components for one facility to another for further operation.

In addition, there are certain dispatch aspects such as:
(1) All production information should be available beforehand.
(2) Various order cards and drawing with specification should be ready.
(3) Equipment should be ready for use.
(4) Progress of various orders should be recorded.
(5) All production records should be on Gantt chart.

Centralized and decentralized dispatching

(a) Centralized Dispatching:

In centralized dispatching system, a central dispatching department orders directly to the work stations. It maintains a full record of the characteristics and capacity of each equipment and work load against each m/c. The orders are given to the shop supervisor who runs his machine accordingly. In most of the cases, the supervisor can also give suggestions as regards to loading of m/cs under him. A centralized system has the following advantages:

1. A greater degree of overall control can be achieved.
2. Effective coordination between different facilities is possible.
3. It has greater flexibility.
4. Because of urgency of orders, changes in the schedule can be made easily without upsetting the whole system.
5. Progress of orders can be readily assessed at any time because all the information is available is available at a central place.
6. There is effective and better utilization of manpower and machines.

(b) Decentralized Dispatching:

In decentralized dispatching system, the shop supervisor performs the dispatch function. He/she decides the sequence of handling different orders. He/she dispatches the orders and materials to each equipment and worker, and is required to complete the work within the prescribed duration. In case he/she suspects delay, he/she informs the production control department. A centralized dispatching system has the following advantages:

(i) Much of red tape (excessive adherence to official rules) is minimized.
(ii) Shop supervisor knows the best about his shop.
(iii) Communication gap is reduced.
(iv) It is easy to solve day to day problem.

Levels of Dispatch office: At plant manager’s level.
At shop superintendent level.
At shop supervisor’s level.
At specialist level.

6.7 Expediting

Expediting and dispatching are frequently performed under the same agency, particularly in special project control. An expeditor follows the development of an order from the raw material stage to the finished product. He/she is often given the authority and facilities to move materials or semi-finished products to relieve congestion in production flow.

6.8 Gantt chart

HL Gantt has developed a simplified graph which represents/displays the planned starting and finishing time of each task on a time scale. But it does not show the interrelationship among the tasks. On the left of the chart is a list of the activities and along the top is a suitable time scale. Each activity is represented by a bar; the position and length of the bar reflects the start date, duration and end date of the activity. This allows you to see at a glance:

- What the various activities are
- When each activity begins and ends
- How long each activity is scheduled to last
- Where activities overlap with other activities, and by how much
- The start and end date of the whole project

6.8 Line of balance (LOB)

LOB is a graphical technique used to find out the state of completion of various processes at a given time for a product. This technique is economical when the production volume is limited and applied to the production of aircrafts, missiles, heavy machines, etc.

For drawing the LOB, the following information are required:

- Contracted schedule of delivery
- Key operations in making the product.
- The sequence of key events.
- The expected/observed lead time w.r.t. delivery of final product.

Based on above information, a diagram is drawn which compares pictorically the planned verses actual progress. This is called line of balance (LOB).

6.9 Learning curve

From our everyday experience, we know that the first time we perform a skilled job, it takes much longer time than an experienced worker. But the next time if we perform the same job, we can perform it not only at faster rate but also with higher quality. Each additional time we do the same job, we become faster and better in performing. This improvement in productivity and quality of work as a job is repeated is called quality of work, as a job is repeated is called learning effect.

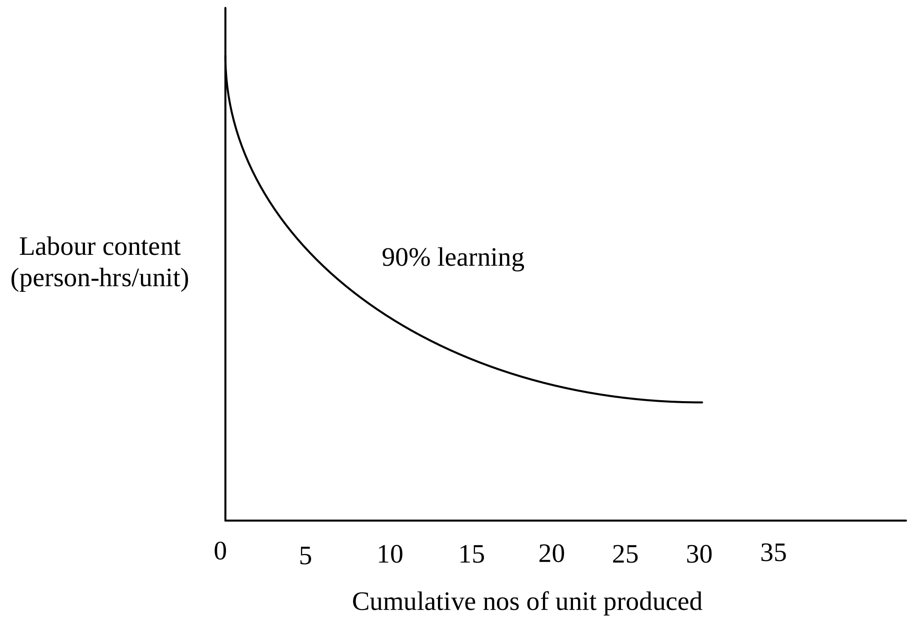
Similarly, when the number of units produced increases, the direct labour hours required per unit decreases for a variety of reasons such as:

(i) Workers become more and more skilled for a particular set of task.
(ii) Improvement in production methods and tooling takes place.
(iii) Improvement in layout and flow takes place and many other reasons.

While designing jobs, estimating work standards, scheduling production and planning capacity, it is important to know at what rate workers productivity will increase through learning. For example, if it takes a worker 10 hours to make the first 50 units of product, we don't want to plan on it taking 10 hours for every additional 50 units. Otherwise we will underestimate our production capacity and overstaff our operations. The role of worker learning in production, its effect on production costs and ways to measure it were popularized long ago.

The rate of learning and learning curve

The labour content (in person-hrs per unit) requires to make a product, expressed as a function of the cumulative number of units made is called Learning Curve. A typical learning curve is shown below.



We normally express the rate of leraning in terms of how quickly the labour requirement decrease as we double the cumulative amount of output. We say that an activity exhibits an x% learning rate or has an x% learning curve, if the amounts of labour required to make the 2nth units of the product is x% of that required to make the nth unit. More generally, the amount of time required to make the nth unit of the product will be

$T_n = T_1 \times n^a$

where T_n = Time to make the nth unit.
T_1 = Time to make 1st unit.
a = (ln x/ln 2)
x = learning rate (expressed as decimal)

This learning data can also be represented in tabular form.