Project Control : Project controls are activities designed to measure the status of component activities of a project, transmit data to a control centre, where it is compared with the performance standard and initiate corrective action when required.

Figure 19.2 shows the project planning and control flow chart.

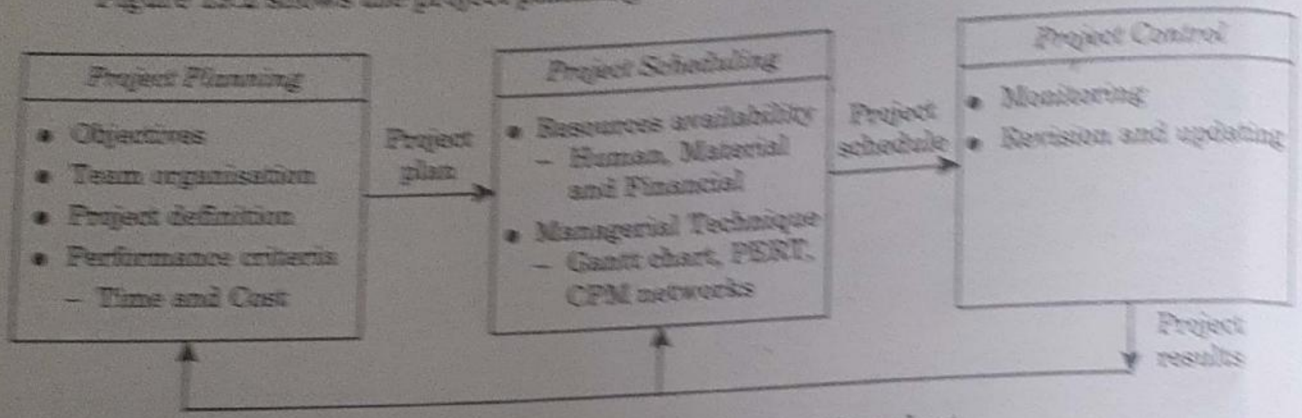


Fig.19.2 Project planning and control flow chart

(*Source: Joseph G. Monks, Operations Management*, 3rd Edition, McGraw Hill International, p.551)

Network Fundamentals

A network diagram is a model that uses small circles (nodes) connected by lines or branches (arcs) to represent precedence relationships. Networks are frequently used to show the precedence relationships among the activities.

The critical path method (CPM) and program evaluation and review technique (PERT) are network techniques for analysing a system in term of activities and events that must be completed in a specified sequence in order to achieve a goal. Some activities can be done concurrently, whereas others have precedence requirements.

Figure 19.3 shows a network diagram for power plant construction.

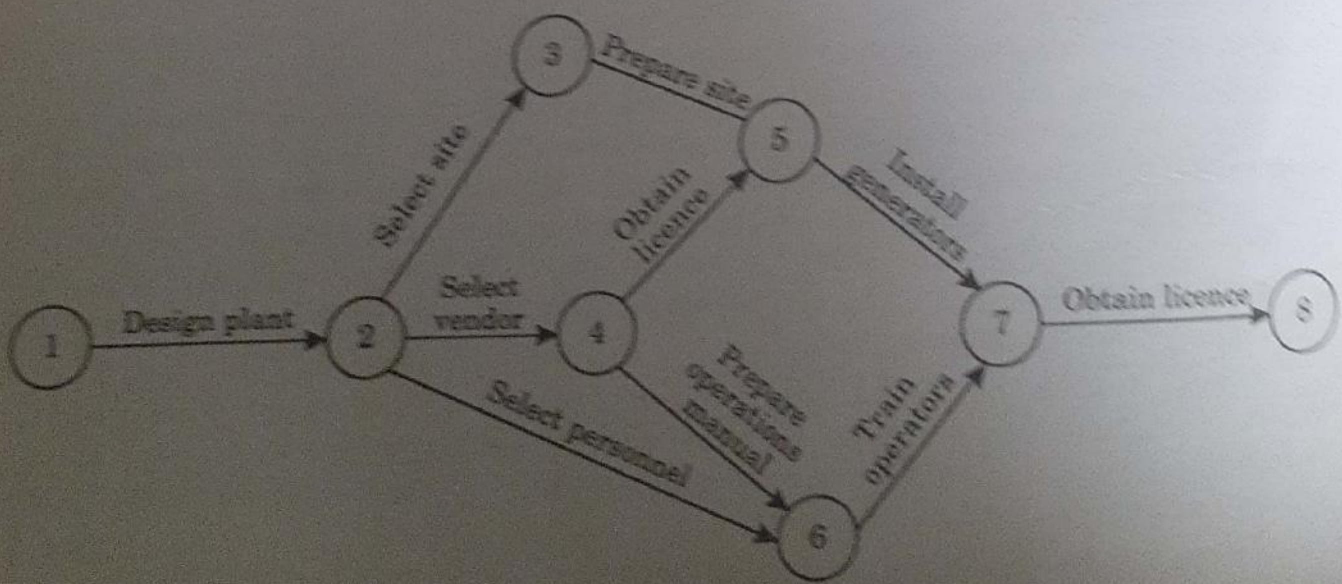
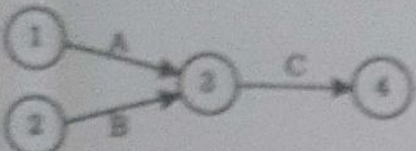
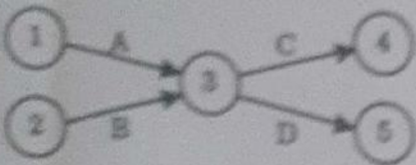
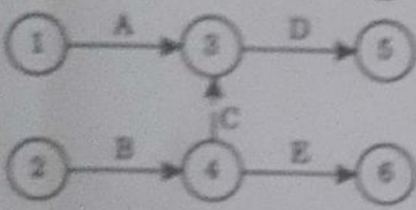


Fig.19.3 Network diagram for power plant construction

(*Source : Joseph G. Monks, Operations Management*, 3rd Edn., McGraw Hill International Edition, p. 553)

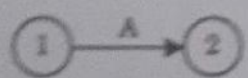
Commonly used Network Symbols

Figure 19.4 shows some of the commonly used network symbols.

Symbol	Meaning
——→	Activity
– – →	Dummy Activity
○	Event
	Activity A must be completed before activity B can begin.
	Activities A and B can occur concurrently, but both must be completed before activity C can begin.
	Activities A and B must be completed before activities C and D can begin, but C can begin independently of D and vice versa.
	Activities A and B can occur concurrently, but both must be completed before activity D can begin Activity E can occur only after activity B is completed. Activity C (dotted line with arrow head) is a dummy activity which shows a precedence relationship but has a zero time duration.

Terms used in Network Based Scheduling Techniques

1. ***Activity*** : An effort that is required to complete a part of a project. (——→)
2. ***Event*** : A beginning, completion point or milestone accomplishment within the project. An activity begins and ends with an event. (○)

   Eg. 

   1 & 2 – Events ; A - Activity
3. ***Prdecessor activity*** : An activity that must occur before another activity.

   Eg. 

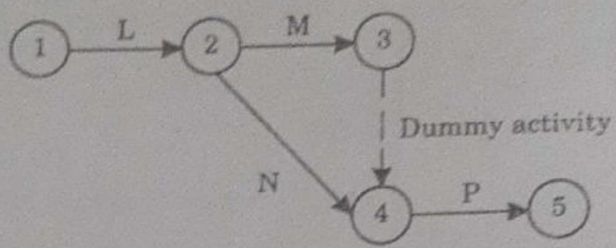
   Activity 'A' is a predecessor activity for activity B.
4. ***Successor activity*** : An activity that must occur after another activity.

   Eg. 

   Activity 'D' is a successor activity to activity 'C'.
5. ***Dummy activity*** - An activity that consumes no time (zero time duration) but shows precedence between events.

   Eg. 

The above network diagram shows that both activities M and N begin with event number 2 and end with event number 3. As a rule, no two activities can be represented by the same set of event numbers. This problem is solved by inserting a dummy activity as shown below:



6. ***Activity duration*** : In CPM, this means the best estimate of the time to complete an activity. In PERT, the expected time or average time to complete an activity.
7. ***Optimistic time*** (t_o) : The time for completing an activity if all goes well, used in PERT.
8. ***Pessimistic Time*** (t_p) : The time for completing an activity, if every thing goes wrong, used in PERT.
9. ***Most likely time*** (t_m) : The time for completing an activity, that is the consensus best estimate, used in PERT.
10. ***Expected time*** (t_e) : The average time for completing an activity.
11. ***Earliest start*** **(ES)** : The earliest that an activity can start, from the beginning of the project.
12. ***Earliest finish*** **(EF)** : The earliest that an activity can finish, from the beginning of the project.
13. ***Latest start*** **(LS)** : The latest that an activity can start, from the beginning of the project, without causing a delay in the completion of the project.
14. ***Latest finish (LF)*** : The latest that an activity can finish, from the beginning of the project, without causing a delay in the completion of the project.
15. ***Slack*** : The amount of time that an activity or group of activities can slip without causing a delay in the completion of the project. It is also known as '***float***'.
16. ***Critical activity*** : An activity that has no room for schedule slippage, if it slips the entire project completion will slip. An activity with zero slack.
17. ***Critical path*** : The chain of critical activities for the project and is the longest path through the network.

Networking Conventions

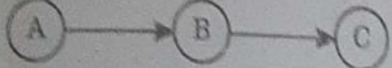
A network uses circles and arrows to represent the planned relationships among the activities required to complete a project. Either of two conventions can be used to develop a network. One convention uses circles to represent the project activities, with arrows linking them together to show the sequence in which they are performed. This is called *activity-on-node* (AON) diagram or convention.

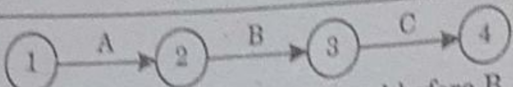
Another convention shows the activities as arrows and use circles to connect predecessor and successor activities. This method is called the *activity-on-arrow* (AOA) diagram or convention.

Figure 19.5 shows the AON and AOA methods of indicating activity relationships on network diagrams.

Activity-on-node (AON) convention (Precedence notation)	*Activity-on-arrow (AOA) convention (i-j notation)*

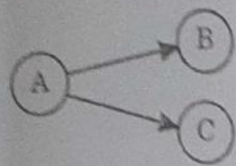
(a)

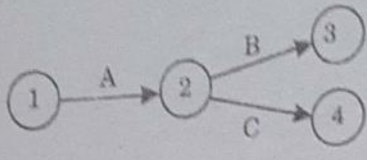




A, B and C are activities and 1, 2, 3 and 4 are events. A must be performed before B, which must be performed before C.

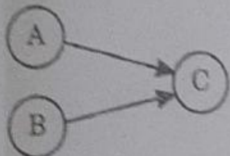
(b)

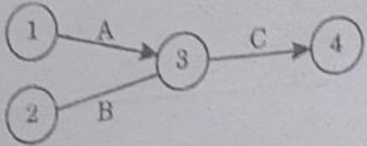




A must be completed before either B or C can begin.

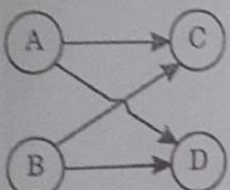
(c)

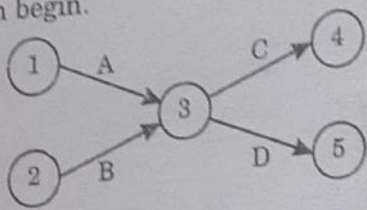




Both A and B must be completed before C can begin.

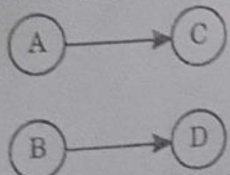
(d)

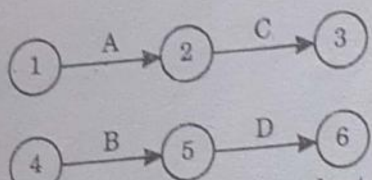




Both A and B must precede both C and D.

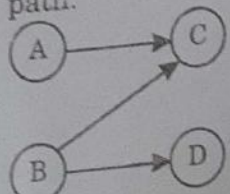
(e)

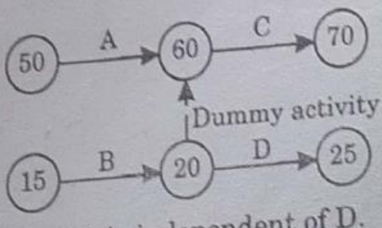




A must precede C and B must precede D, but the A - C path is independent of the B - D path.

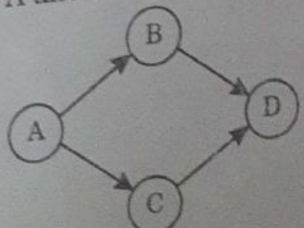
(f)

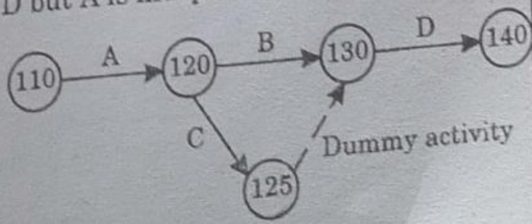




A and B must precede C and B must precede D but A is independent of D.

(g)





A must precede both B and C. Both B and C must precede D.

Fig. 19.5 AON and AOA methods of indicating activity relationships on network diagrams

(*Source* : James B. Dilworth. P.O.M. 4th Edition. McGraw Hill Publishing Company. p.461)

Fig. 10.9 shows the restructured layout with certain departments moving closer to others. For example, Department 5 has been shifted closer to Department 8, and Departments 8, 9 and 3 have been shifted to form a rectangular shape.

Thus, operations sequence analysis helps determine locations of operating departments relative to one another.

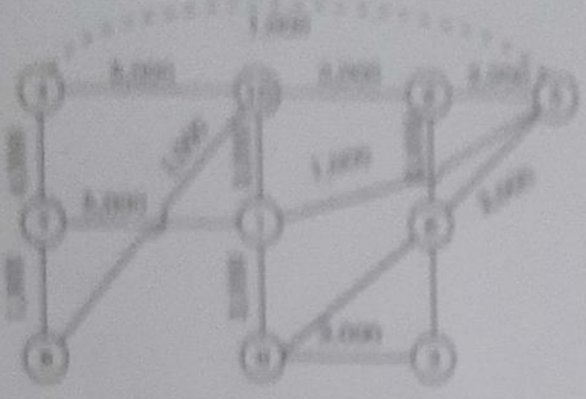


Fig. 10.9 Restructured layout

(Source : Norman Gaither, P.O.M., p.241)

Line Balancing : Line balancing is the phase of assembly line study that nearly equally divides the work to be done among the workers so that the total number of employees required on the assembly line is minimised. Line balancing is not simple; in fact, there are usually many alternative ways that the work can be divided among the workers. Operation researchers have used linear programming, dynamic programming and other optimal methods to study line balancing problems. Explanation of all these is beyond the scope of this text.

Analysing Layouts with Computers

As in other fields, computers have entered the field of layout engineering in a big way. Various techniques have been developed and used in layout planning. For example, in designing process layout, the analyses used are : ALDEP (automated layout design programs), CORELAP (computerised relationship layout planning) and CRAFT (computerised relative allocation of facilities technique).

These and other computer programmes can save time and effort in large and complex layout problems, but the plans they offer are only the beginning of a final layout. The layouts given by computers must be fine-tuned by hand and checked for logic, and machines and other elements of the layout must usually be hand-fitted with templates.

Layout or Building?

Which comes first, the chicken or the egg? This ancient puzzle can be used to illustrate the relationship between the layout and the industrial building. Should the building be built first and the layout planned to fit it? Or should the layout be planned first and the building built around it?[2]

The ideal procedure would be to plan the layout first and construct the building around it. But the ideal situation is not always available because of certain reasons. In the case of going concerns, some, if not all, the buildings may be in existence. To demolish the existing building to plan the layout would be very difficult and expensive. Moreover, the site selected may impose restrictions and make it difficult for one to plan the layout first and construct the building around it. In such circumstances, the building comes first, and then the lay[illegible] layout will be generally a compromise between the ideal or functional layout and the limitations of a plant site and building.

Whichever comes first, care should be taken to make the building and the layout as ideal as possible within the available facilities, for both are vital to the success of any industrial establishment. If the building is compared to the skin and bones of a human body, the layout is naturally the arrangement of heart, liver, muscles, etc., inside the skin and bones; the difference between the two is that, in the case of a factory, one comes after the other; but the human body emerges from the womb ready-made.

Criteria for Selection and Design of Layouts

Facility layouts must integrate work centre location, office, computer facilities, tool room, storage space and washrooms etc. Two of the major criteria for selecting and designing and layout are:-

1. Material handling cost and
2. Worker effectiveness.

Materials handling costs are minimized by using mechanised material handling equipments such as belts, cranes and conveyors to automate product flows and keeping the flow distances as short as possible by locating the work centres for sequential processing activities in adjacent areas.

Worker effectiveness is another important criteria in the layout of facilities. Good layout provides workers with a 'satisfying' job and permit them to work effectively at the highest skill level for which they are being paid. Good communication systems and well-placed supporting activity locations are critical to the success of any facility.

The various methods used for selecting the best layout among several alternative layouts are illustrated below with example:

1. *Travel Chart Method*

The travel chart which is also known as *from-to-chart* is helpful in analysing the overall flow of material. It shows the *number of moves* made between departments and identifies the most active departments. A typical travel chart is shown in Fig. 10.10.

1	2	3
4	5	6

(a) Facility outline chart

From	Number of moves to					
	A	B	C	D	E	F
A	—	7	—	—	—	5
B	—	—	—	4	10	—
C	—	7	—	—	2	—
D	—	—	8	—	—	—
E	4	—	—	—	—	3
F	—	6	—	—	10	—

Fig. 10.10 Facility outline chart and travel chart for a typical facility

(*Source:* Joseph G. Marks *Operations Management.* 3rd Edition McGraw-Hill International Edition. p.130)

The solution is obtained by the trial and error method which attempts to minimise non-adjacent flows by centrally locating the *active departments* (ie., departments which have the maximum number of links with other departments). The work centres are shown as circles and the connecting lines represent the loads transported during a given time. Departments next to each other or diagonally across from each other are regarded as adjacent departments.

Procedure

Step No.1 : Determine which departments have the most frequent links with other departments. This can be done by totalling the number of entries in each row and column. The number of links between the departments are as below

Department	A	B	C	D	E	F
Number of links	3	5	3	2	5	4

Step No.2 : Try to locate the most active departments in the central positions in the facility outline.

In this example, departments B and E which have the maximum number of links with other departments are located at locations 2 and 5 of the facility outline.

Step No. 3 : By trial and error method, locate the other departments so that the non-adjacent flows are minimised. Fig. 10.11 shows one such arrangement made by the trial and error method. Next, the number of moves and the link between departments are indicated on the schematic diagram as per travel chart.

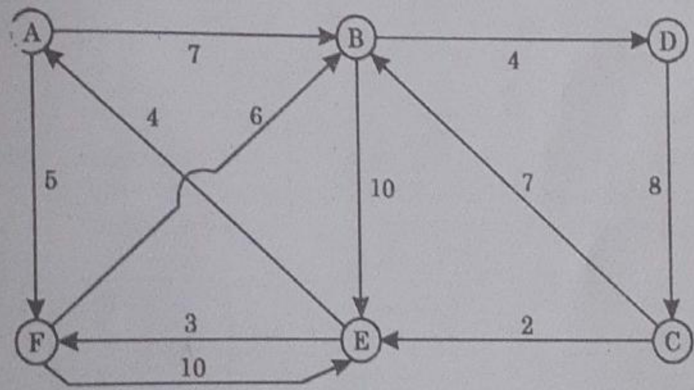


Fig. 10.11 Schem.atic diagram for facility layout

Step No.4 : If all the non-adjacent moves are eliminated, the solution is complete. If non-adjacent flows still exist, try to minimise the number of units flowing to non-adjacent areas as weighted by the distances between non-adjacent departments. In this example, the trial and error solution indicated by the schematic diagram in Fig. 10.11 results in complete elimination of non-adjacent flows and hence gives the complete solution.

2. Load-distance Analysis Method

Load-distance analysis is useful in comparing alternative layouts to identify the one with the least product or material travel time per period. This method helps to minimise transportation costs by evaluating alternate layouts on the basis of the total of the product of actual distance moved and the load (the units moved) for each layout alternative. Alternatively, *Step No. 2* : Compute the total [illegible] each layout [illegible] overall materials handling plan

Product	Products per month (load/units)	Distance per unit		
		Layout A	[illegible]	[illegible]
a	1000	70	[illegible]	[illegible]
b	2000	90	[illegible]	[illegible]
c	3000	30	[illegible]	[illegible]
d	1000	50	[illegible]	[illegible]
e	2000	30	[illegible]	[illegible]
f	4000	30	[illegible]	[illegible]
			Total	[illegible]

Step No. 3 : Determine the layout alternative to be chosen [illegible] x distance) per month. Layout B results in the [illegible] per month and hence the choice.

3. Systematic Layout planning

Systematic layout planning (SLP) method is used in some production [illegible] systems, where the amount of material that flows between departments [illegible] for developing a good facility layout. This method develops a chart known as [illegible] chart" or Richard Muther's half-matrix, which rates the relative importance [illegible] department close to another department. The importance ratings are indicated [illegible] a, e, i, o, u, x is known as *'nearness codes'*, which indicate the following degree of [illegible]

Nearness code	*Degree of importance*
a	absolutely necessary
e	very important or essential
i	important
o	ok, ordinary importance
u	unimportant
x	undesirable

In addition to the nearness code, a reason code indicated by a number (say 1, 2 or 3) based on a variety of reasons for locating any two departments adjacent to each other, is used.

The examples of reason codes are:

Reason code	*Reason*
1	use of common personnel
2	noise isolation
3	safety purposes
4	ease of supervision
5	common equipment
6	type of customer

Fig. 10.12 illustrates the half-matrix developed for a job-shop layout for producing a made-to-order product.

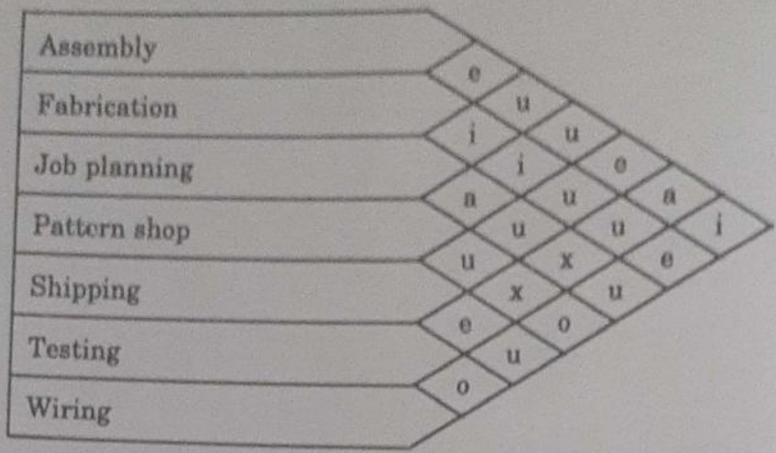


Fig. 10.12 Richard Muther's half-matrix for a job shop layout (or process layout)
(*Source :* Joseph G. Monks, Operations Management, 3rd Edition, McGraw-Hill International Edition, p.132)

Based on the nearness code, the above seven departments can be arranged in the job-shop layout as shown in Fig. 10.13 below.

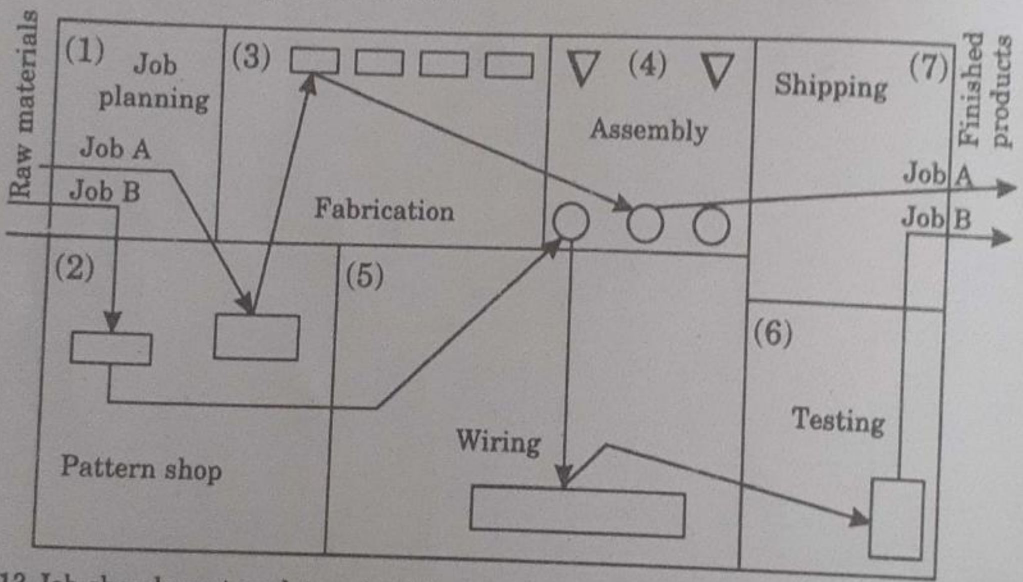


Fig. 10.13 Job shop layout as determined by systematic layout planning method using Richard Muther's half-matrix indicating nearness codes.

Layout Design Procedure

Designing the layout of a plant is a specialised activity and should be carried out systematically. The various steps to be followed in the layout design are:

1. Statement of specific objectives, scope and factors to be considered.
2. Collection of basic data on sales forecasts, production volumes, production schedules, part lists, operations to be performed and their sequences, work measurement, existing layouts, building drawings.
3. Preparation of various kinds of charts such as flow process charts, flow diagram, string diagram, templates etc.

have separate production facilities for each product and to vary the production rate in response to the demand pattern. But this would require a high investment in various facilities that would seldom be fully utilized.

(b) To run one large facility on a product for a while and then change to another product for a while. In this case, the rescheduling and co-ordinating problems could be significant.

(c) To stabilize the product-mix and the production rate for an extended period so that, many of the advantages of just - in-time production can be achieved.

Estimating the time required to perform jobs, which are standardized, can be simpler as compared to that in job shops. When a sizeable volume of a standard product is produced, the direct labour hours required to produce a unit may decrease considerably as more and more units are produced. This reduction in labour hours is significant enough, so that, it should be taken into account in scheduling delivery rates and in planning capacity utilization. This phenomenon is called *learning curve*, or an improvement curve or a progress curve or a manufacturing progress function.

Controlling Continuous Production

The major problem in flow shop production control (flow control) is to attain the desired production rate with maximum possible efficiency (i.e. max possible utilization of resources) For this, it is necessary to determine the technological process steps (sequence of operations), the required capacity of assembly lines, the number of personnel and the amount of work per person working on the assembly line. This is done by dividing the total work content of the job into elementary or basic operations and group these operations at work stations without violating their pre-determined sequence. The jobs move successively from one work station to another work station till completion. The speed of the assembly line is controlled by the required output rate, the distance between successive work station and the operation time required at each work station. By controlling the speed of the conveyor in the assembly line, the cycle time (i.e. the time for which the job is available at each work station for completion of the operation) is controlled and also the output rate on the production line is controlled.

The technique used in such a production situation where it is necessary to nearly equally divide the work to be done among the workers, so that, the total number of employees required on the assembly line is minimized, is known as *line balancing technique* or *assembly line balancing*.

Line Balancing

Line balancing is, arranging a production line so that, there is an even flow of production from one work station to the next, i.e., so that there are no delays at any work station that will leave the next work station with idle time.

Line balancing is also defined as '*the apportionment of sequential work activities into work stations in order to gain a high utilization of labour and equipment and therefore minimize idle time.*' Balancing may be achieved by rearrangement of the work stations or by adding machines and / or workers at some of the stations so that, all operations take about the same amount of time.

Line Balancing Procedure in Assembly Layouts

Step No.1 : Determine what tasks must be performed to complete one unit of a finished product and the sequence in which the tasks must be performed. Draw the precedence diagram.

Step No.2 : Estimate the task time (amount of time it takes a worker to perform each task).

Step No.3 : Determine the cycle time (the amount of time that would elapse between products coming off the end of the assembly line, if the desired hourly production were being produced.)

Step No.4 : Assign each task to a worker and balance the assembly line. This process results in determining the scope of each worker's job or which tasks that he or she will perform.

Steps Involved in Combining of the Tasks into Worker's Jobs

1. Starting at the beginning of the precedence diagram, combine tasks into a work station in the order of the sequence of tasks, so that the combined task times approach, but do not exceed the cycle time or multiples of the cycle time.
2. When tasks are combined into a workstation, the number of multiples of the cycle time is the number of workers required at the work station, all performing the same job.

Analysis of Line Balancing Problems

The procedure involves the following steps

1. Determine the number of work stations and time available at each work station.
2. Group the individual tasks into approximately equal amounts of work at each work station.
3. Evaluate the efficiency of grouping.

When the available work time at any station exceeds that, which can be done by one worker, additional workers must be added at that work station.

The key to efficient line balancing is to group activities or tasks in such a way that, the work times at the work station are at or slightly less than the cycle time or a multiple of cycle time, if more than one worker is required in any workstation.

Determination of cycle time (CT) : When the amount of output units required per period (period may be hour, shift, day or week etc.) is specified and the available time per period is given (i.e. the number of working hours per shift, number of shifts per day, number of working days per week etc.) then,

$$\text{Cycle time (CT)} = \frac{\text{Available time per period}}{\text{Output units required per period}}$$

Cycle time is the time interval at which, completed products leave the production line/ assembly line.

Determination of the Ideal or Theoretical Minimum Number of Workers Required in the Line.

$$\left.\begin{array}{r}\text{Ideal or theoritical}\\ \text{minimum no. of workers}\\ \text{required in the assy.}\\ \text{line / production line}\end{array}\right\} = \frac{\left(\begin{array}{c}\text{Total operation}\\ \text{or task time}\end{array}\right)\times\left(\begin{array}{c}\text{Output units}\\ \text{required per period}\end{array}\right)}{\text{Available time per period per worker}}$$

$$N = \sum t \times \left(\frac{1}{CT}\right) = \frac{\Sigma t}{CT}$$

Balancing Efficiency : An efficient line balancing will minimize the amount of idle time.

(g) Real estate.
(h) Hotel & Restaurant.
(i) Medical services.
(j) Educational services.
(k) Consultancy services.

The characteristics of services are:

1. services are intangible outputs,
2. services cannot be inventoried,
3. services need extensive customer contact,
4. services have short lead times,
5. services are labour intensive,
6. service quality is difficult to determine.

Relationship between Employee's Work and Customers

(a) *Services :*

Employee's work activities ⟶ Customer's needs

(b) *Manufacturing :*

Employee's work activities → Product → Customer's needs

Service Operations

Also known as non-manufacturing operations, service operations are those operations which do not produce tangible products. Service operations can be classified as (a) standard services and (b) customer services. This classification is according to the degree of standardization of the outputs and the process performed by the service systems.

Service systems do not hold finished goods inventories and the demand for their output is highly variable from time to time (e.g., hour to hour, day to day and week to week). Their operations are labour intensive. The principal means of performing the services is through personnel. Hence, personnel scheduling becomes quite complex because the demand for services is highly variable and services are consumed as they are produced.

Service systems providing standard services are more like product-focused manufacturing systems. Services are standard for most customers and the processes once begiun, are carried through to completion without significant delays. The only difference as compared to product -focused manufacturing is that services are produced according to customers order, rather than for finished goods inventory.

Example of service systems providing standard services are transport companies, fast-food restaurants, postal services, airlines etc. Sophisticated scheduling such as on-line computer based scheduling systems, are used in the airlines.

Service systems providing customer services are like job shops in their characteristics and hence, their scheduling systems are much like that of job shops. In small services such as doctor's clinics, small retailers and local transport companies, no formal scheduling systems are employed. Simple scheduling devices such as appointment schedules, take-a-number system (i.e., token system) or first-cum-first-served rules are used to assign priorities to the customers. Part-time workers and stand-by equipments are frequently employed during high demand periods.

Service systems such as hospitals use more sophisticated scheduling systems than that, found in job shop manufacturing. These systems are also produce-to-order systems and as finished goods inventories cannot be maintained, capacities must be variable to meet wide

(b) Idle time at operation centre A = (N x C.T.) − Opn.time
= 2 x 6 − 12 = Nil
Idle time at operation centre B = 3 x 6 − 16 = 2 minutes
Idle time at operation Centre C = 1 x 6 − 3 = 3 minutes
Total idle time = 2 + 3 = 5 minutes
Total cycle time = N x C.T. = 6 x 6 = 36 minutes

$$\text{Percentage of idle time} = \frac{5}{36} \times 100 = 14\%$$

(c) Balance efficiency

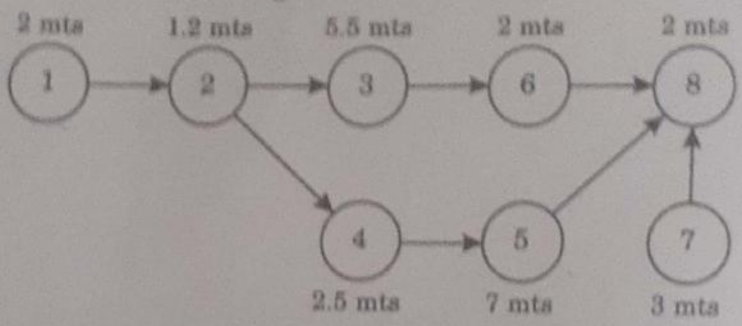
$$= \frac{\text{Total operation time}}{\text{No. of operators} \times \text{cycle time}}$$

$$= \frac{\Sigma t}{N \times C.T.} = \frac{31}{6 \times 6} = \frac{31}{36} \times 100 = 86\%$$

$$\text{or Balance efficiency} = \frac{\text{Theoretical number of operators}}{\text{Actual number of operators}}$$

$$= \frac{5.2}{6} \times 100 = 86\ \%$$

3. Balance the line for the following



Only 4 work stations are available. Find the idle time and efficiency of balancing.

Solution

Total operation time (Σt) = 2+1.2+5.5+2.5+7+2+3+2 = 25.2 mts
No. of workstations available (N) = 4

$$\text{Theoretical cycle time (CT)} = \frac{\Sigma t}{N} = \frac{25.2}{4} = 6.3 \text{ mts}$$

Practical cycle time = 7 mts
Allocation of activities to 4 work stations is done as below
Work station No.1 = opn. 1 + opn 2 + opn 4
Total operation. time at work station 1 = 2 + 1.2 + 2.5 = 5.7 mts
Work station No.2 = opn no.3 (5.5 mts)
Work station No.3 = opn no.5 (7 mts)
Work station No.4 = opn 6 + opn 7 + opn 8

Operation time taken in WS No.4 = $2+3+2 = 7$ mts

Idle time in WS No.1 = $7 - 5.7 = 1.3$ mts

Idle time in WS No.2 = $7 - 5.5 = 1.5$mts

Idle time in WS No.3 = $7 - 7 =$ Nil

Idle time in WS No.4 = $7 - 7 =$ Nil

Total idle time = $1.3 + 1.5 = 2.8$ mts

Total operation time (Σt) = 25.2 mts

Total cycle time = $N \times C.T. = 4 \times 7 = 28$ mts

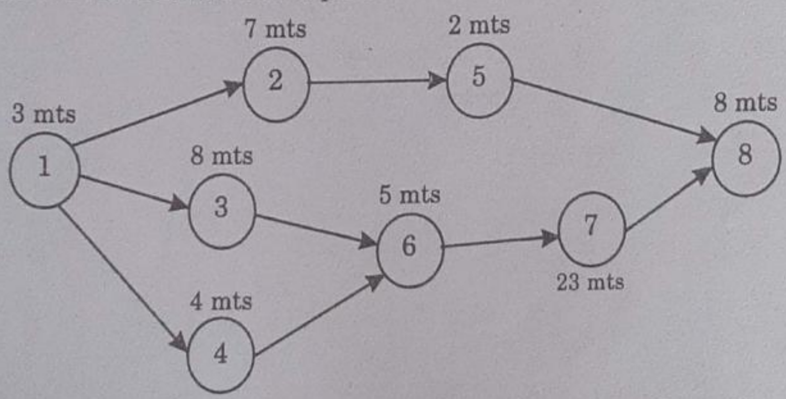
$$\text{Idle time (\%)} = \frac{2.8}{28} \times 100 = 10\%$$

$$\text{Balance Efficiency (\%)} = \frac{\Sigma t}{N \times C.T.} = \frac{25.2}{4 \times 7} \times 100 = \frac{25.2 \times 100}{28} = 90\%$$

$$\text{Also Balance Efficiency} = \frac{\text{Theoretical cycle time}}{\text{Practical cycle time}} \times 100$$

$$= \frac{6.3}{7} \times 100 = 90\%$$

4. The sequence of manufacture for a product is as given below:



(a) What is the most efficient number of work stations to produce this product at the rate of 40 units per day. How many workers are required ?

(b) What is the most efficient and best balanced operation assignment for 10 workers. What is the rate of production ?

(c) What is the total direct labour cost per unit for a & b? Assume the labour hour rate for direct labour as Rs 40 per hour. What is the idle time cost per unit ? Assume 8 hours work per day

Solution

(a) Total operation time = $\Sigma t = 3+7+8+4+2+5+23+8 = 60$ mts.

Output required per day of 8 hours working = 40 units

$$\text{Cycle time} = \frac{\text{Available work time per day}}{\text{Output required per day}}$$

$$= \frac{8 \times 60}{40} = \frac{480}{40} = 12 \text{ mts.}$$

production operation and lays down the precise path or route through which the product will flow during the conversion process.

Route sheets contain the following information :

(a) The operations required and their desired sequence.

(b) Machine or equipment to be used for each operation.

(c) Estimated set up time and operation time per piece (standard time).

(d) Tools, jigs and fixtures required for the operation.

(e) Detailed drawings of parts, sub-assemblies and final assemblies.

(f) Specification, dimensions, tolerances, surface finishes and quality standards to be achieved.

(g) Specification of raw materials to be used .

(h) Cutting speed, feed, depth of cut, etc., to be used on machine tools for the operations to be carried on.

(i) Inspection procedure and metrology tools required for inspection.

(j) Packing and handling instructions during the movement of parts and sub assemblies through the operation stages.

3. Scheduling

Involves fixing priorities for each job and determining the starting time and finishing time for each operation, the starting dates and finishing dates for each part, sub-assembly and final assembly. Scheduling lays down a time table for production, indicating the total time required for the manufacture of a product and also the time required for carrying out the operation for each part on each machine or equipment.

Objectives of scheduling are:

(a) To prevent unbalanced use of time among work centres and departments and

(b) To utilise labour such that the output is produced within established lead time or cycle time so as to deliver the products in time and complete production at minimum total cost.

4. Loading

Facility loading means loading of facility or work centre and deciding, which jobs to be assigned to which work centre or machine. Loading is the process of converting operation schedules into practice. Machine loading is the process of assigning specific jobs to machines, men or work centres based on relative priorities and capacity utilization.

A machine loading chart (Gantt chart) is prepared showing the planned utilisation of men and machines by allocating the jobs to machines or workers as per priority sequencing established at the time of scheduling.

Loading ensures maximum possible utilisation of productive facilities and avoids bottlenecks in production. It is important to avoid either over loading or under loading the facilities, work centres or machines to ensure maximum utilization of resources.

Production Control Functions

The control functions are:

1. Dispatching

Dispatching may be defined as setting production activities in motion through the release of orders (work order, shop order) and instructions in accordance with the previously planned time schedules and routings.

and production machine capacities may more than offset the savings in inventory carrying costs.

The factors which would be important in deciding between the two plans viz, 'level capacity plan' and 'varying capacity to match aggregate demand' are

(a) The total costs for each alternative plan
(b) Maintaining positive relations between management and trade unions. (attitude of workers towards working overtime)
(c) Fatigue, reduced morale and increased costs could result from working too much overtime on a continual basis.
(d) Product quality might be better with overtime plan rather than sub-contracting plan because all production would be in-house and under the direct control of the firm.
(e) The flexibility of increasing or decreasing production levels either by hiring or laying-off, by over time or idle time or by subcontracting.

Aggregate Plans for Services

In some of the service systems that supply standardized services to customers, *aggregate planning* may be even simpler than in systems that produce products. Examples of these situations in service systems are fast food corners, trucking firms and banks.

Some service systems that supply customized services to customers have the same difficulty as job shops in specifying the nature and extent of services to be performed for each customer. Examples of these systems are hospitals, computer service centres and auto repair shops.

Another problem with planning capacity levels for service systems is the absence of finished goods inventories as a buffer between system capacity and customer demand. In such cases, the service systems must develop capacity plans that nearly match the expected aggregate demand.

In custom-designed services, a two-step approach is suggested. The steps involved are:

(a) Developing aggregate demand forecasts in some homogeneous units of measure such as labour-hours, machine capacity or sales in rupee value.
(b) Trying to find out common denominator units of capacity that are useful in transforming aggregate demand into production resource requirements.

If the first suggestion is infeasible, alternative innovations are developed for expanding the flexibility of production resource capacities. Examples of these innovations are -

(a) Stand-by workers who are on call for peak demand periods
(b) Machines and buildings that can be activated during peak demand periods.
(c) Sub-contractors who respond quickly.
(d) Retired supervisors who wish to work only part time and can be recalled for short periods.

The above stand-by resources provide a new-level capacity aggregate plan with the extra capacity needed to respond to the surges in demand.

Master Production Scheduling

The *master schedule* (or master production schedule or MPS) sets the quantity of each end item (finished product) to be completed in each time period (week or month or quarter) of the short-range planning horizon.

Master production schedules (MPS) are developed by reviewing market forecasts, customer orders, inventory levels, facility loading and capacity information regularly.

The MPS is a plan for future production of end items over a short-range planning horizon that usually spans from a few weeks to several months. It is an important link between marketing and production.

Objectives of Master Production Scheduling

1. To schedule end items to be completed promptly and when promised to customers.
2. To avoid overloading or underloading the production facility, so that, production capacity is efficiently utilized and low production costs result.

Functions of Master Production Schedule

The MPS formalizes the production plan and converts it into specific material and capacity requirements. This leads to the assessment of labour, material and equipment needs for each job. Then the MPS derives the entire production and inventory system by setting production targets and responding to feed back from all downstream operations. It is the beginning of all short-range production planning. From the MPS, material requirement planning (MRP) develops short range schedules for producing parts that go into the end items in every work centre of the production system. The MRP develops short-range plans for purchasing the raw materials and components that are required to produce the products.

Some key functions of MPS are:

(a) Translating aggregate plans into specific end items;
(b) Evaluating alternative schedules;
(c) Generating material requirements;
(d) Generating capacity requirements;
(e) Facilitating information processing;
(f) Maintaining valid priorities;
(g) Utilizing capacity effectively.

(a) Translating aggregate plans : The aggregate plan sets the level of operations that roughly balances market demands with the material, labour and equipment capabilities of the firm. The aggregate is translated into specific number of end products to be produced in specific time periods. Products are grouped into economical lot sizes that can realistically load the firm's facilities. The MPS represents a manufacturing plan of what the firm intends to produce and not the forecast of what the firm hopes to sell.

(b) Evaluating alternative master schedules : Master scheduling is done on a trial and error basis. Trial-fitting of alternative MPS can be done by simulation using computers. Detailed material and capacity required are then derived from the firm's MPS.

(c) Generating material requirements : The MPS is the prime input to the MRP-1 system. The MRP-1 system provides for purchasing or manufacturing the necessary items in sufficient time to meet the final assembly dates specified, based on the MPS for end products.

(d) Generating capacity requirements : Capacity needs, arise for manufacturing the components in the required time schedule to meet the requirements of end products as per the MPS. Capacity requirement planning is based on the MPS which should reflect an economic usage of labour and equipment capacities. Master schedules will have to be revised when capacity requirements are inadequate.

(e) Facilitating information processing : By controlling the work load on work centres, the MPS determines the delivery schedules for end products both for make-to-stock and make-to-order items. It co-ordinates other management information such as marketing capabilities, financial resources (for carrying inventory) and personnel policies (for supplying labour)

(f) Maintaining valid priorities : The absolute or relative priorities for various jobs to be completed should reflect the true needs. This means that, the due date and the ranking of jobs should correspond with the time the order is actually needed. When customers change their orders or materials get scrapped sometimes, either the components are not actually needed or the end items cannot be produced because of shortage of some materials and then it is necessary that the MPS should be modified to reflect this change.

(g) Effectively utilizing the capacity : By specifying the end item requirements over a time period, the MPS establishes the load and utilization parameters for labour and equipment (i.e., shifts worked or overtime or idle time)

Time Interval and Planning Horizon for MPS

The time interval used (for example, weekly, monthly, or quarterly) depends upon the type, volume and component lead times of the products being produced.

The time horizon covered by the MPS also depends upon product characteristics and lead times. The time horizon may vary from a few weeks to an year or more and should encompass the lead times for all purchased and assembled components.

Time Fences in Master Production Schedules

MPS can be divided into four sections, each section separated by a point of time called a *'time fence'*. The first section includes the first few weeks of the schedule and is referred to as *'frozen'*, the second section of a few weeks is referred to as *'firm'*, the third section is referred to as *'full'* and the last section of a few weeks is referred to as *'open'*.

(i) 'Frozen' means that this early part of the MPS cannot be changed except under extraordinary circumstances and only with authorization from the highest levels in the organization. It is not desirable to change this section of MPS because it would be costly to reverse the plans to purchase materials and produce the parts that go into the products belonging to this section of MPS.

(ii) 'Firm' means that changes can occur in this section of MPS but only in exceptional situations.

(iii) 'Full' means that all the available production capacity has been allocated to orders. Changes in this section of the schedule can be made and production costs will be only slightly affected but the effect on customer satisfaction is uncertain.

(iv) 'Open' means that, not all of the production capacity has been allocated and in this section of MPS, new orders are ordinarily slotted.

Procedure for developing MPS

Fig. 16.9 describes the process for developing MPS and Fig. 16.10 describes the flow chart for its development.

The total demand for the end items (produced) from all sources is estimated, orders are assigned to production slots, delivery promises are made to customers before detailed calculations are made of the workload on work centres for a MPS.

III unit 1) Assembly line balancing
2) scheduling

CHAPTER 3

Forecasting - Starting Point for Production Function

One of the steps, nay the very first one, in the process of management is planning. Planning is understood as *the process of setting goals and choosing the means to achieve these goals.* Planning is essential for, without it, managers cannot organise people and resources effectively.

Meaning and Definition

Forecasting is fundamental to planning. Forecasts are statements about future, specifying the volume of sales to be achieved and equipment, materials and other inputs needed to realise the expected sales. A popular definition of forecasting is that, it is *estimating the future demand for products and services and the resources necessary to produce these outputs.* Starting point in forecasting is sales or demand forecasting. Sales forecasts trigger all other forecasts in production function.

Need for Sales Forecasting[1]

Following are some of the reasons, why operations managers must develop forecasts :

1. *New Facility Planning*

Strategic activities such as designing and building a new factory or designing and implementing a new production process, might take a long time, say five years. This requires long range forecasts of demand for existing and new products, so that, operations managers can have the necessary lead time to build the processes to produce the products and services when needed.

2. *Production Planning*

The rate of production must vary to meet the fluctuating demand from time to time (usually month to month). A time period of several months may be necessary to change the capacities of production processes. Intermediate range demand forecast, helps operations managers get the lead time necessary to provide the capacity to produce the products to meet the variable monthly demands.

3. *Work Force Scheduling*

Where the demand for products and services varies from week to week, it is necessary to vary the work force levels to meet the varying demands by using overtime, lay-offs or hiring. For this, operations managers need short-range demand forecasts to enable them to have the lead time necessary to provide work force the changes to produce products or services to meet the weekly demands.

4. Financial Planning

Sales forecasts are the driving force in budgeting. Budgeting is used by many operations managers to plan and control the financial performance of their production department.

Types of Forecasts

There are *long-term* forecasts as well as *short-term* forecasts. Operations managers need long-range forecasts to make strategic decisions about products, processes and facilities. They also need short-term forecasts to assist them in making decisions about production issues that span, only the next few weeks. Since forecasting forms an integral part of planning and decision-making, production managers must be clear about the horizon of forecasts - month or year, for example. Additionally, they must also be clear about the method of forecasting and unit of forecasting (gross rupee sales, individual product demand, etc). Table 3.1 cites some examples of the things that are commonly forecast in production management.

Table 3.1 : Examples of Things that are Forecast in Production Management

Forecast horizon	*Time span*	*Example of things that are forecast*	*Typical units of forecast*
Long-range	Years	New product lines	Rupees
		Old product lines	Rupees
		Factory capacities	Gallons, hours, kgs, units or customers per time period
		Capital funds	Rupees
		Facility needs	Space, volume
		Product groups	Units
Intermediate-range	Months	Departmental capacities	Hours, strokes, kg, gallons units, or customers per time period.
		Workforce	Workers, hours
		Purchased materials	Units, kgs, gallons
		Inventories	Units, Rupees
Short-range	Weeks	Labour-skill classes	Workers, hours
		Machine capacities	Units, hours, gallons strokes, kgs or customers per time period
		Cash	Rupees
		Inventories	Units, Kgs, Rupees
		Specific products	Units

(*Source :* Adapted from *Production and Operations Management* by Norman Gaither, p.75)

Application of Long-range and Short-range Demand Forecasts

(a) Long-range Forecast

Long range forecasts provide, operations managers, with information to make important decisions such as the following :

1. Selecting a product design. The final design is dependent on expected sales volume. If the demand is high, the design should be such that the product can be mass-produced to ensure low-cost manufacture.
2. Selecting a production processing scheme (i.e., process design) for a new product.
3. Selecting a plan for the long range supply of scarce materials.
4. Selecting a long range production capacity plan.
5. Selecting a long range financial plan for acquiring funds for capital investment.
6. To build new buildings and to purchase new machines.
7. To develop new sources of materials and new sources of capital funds (finance).

(b) Short-range Forecast

Short range sales forecasts provide operations managers, with information to make important decisions such as the following :

1. How much inventory of a particular product (i.e., finished goods) should be carried next month?
2. How much of each product should be scheduled for production next week? (given the quantity in the sales forecast and the quantity in inventory)
3. How much of each raw material should be ordered for delivery next week? (given the quantity of products in the production schedule and the quantity in inventory)
4. How many workers should be scheduled to work on regular time basis and on overtime basis next week? (given the production schedule and the number of workers available)
5. How many maintenance workers should be scheduled to work next week end? (given the production schedule and the past experience regarding break downs).

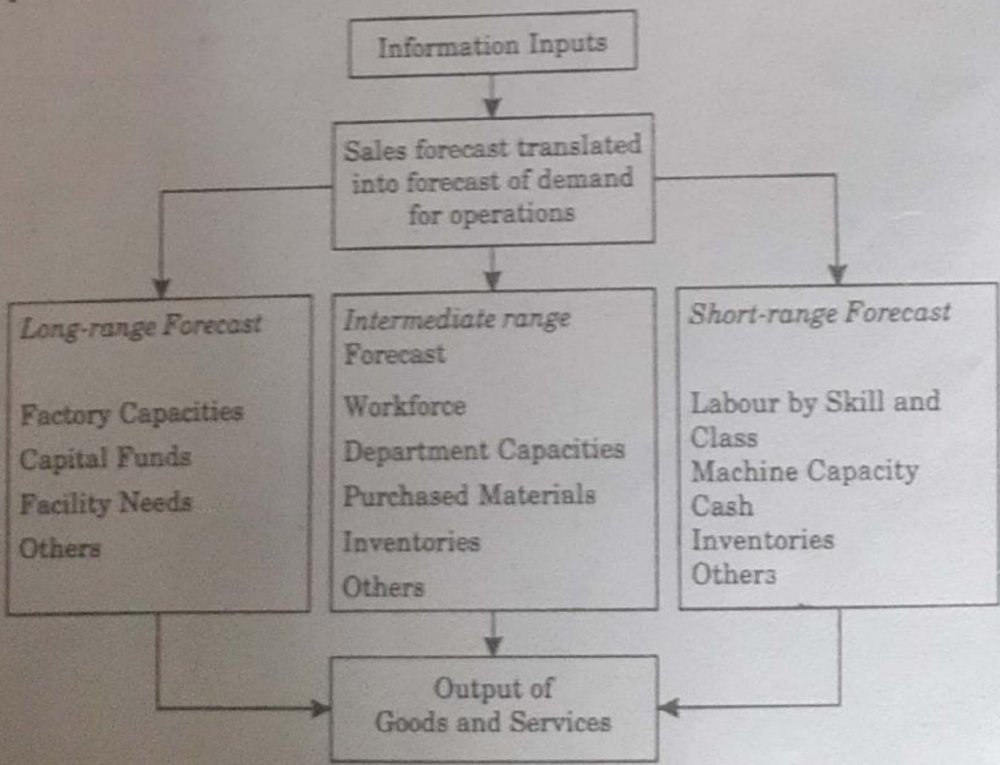


Fig. 3.1 Forecasting Model

A Forecasting Model

Forecasting is more than a technique – it is a system. Most successful organisations, view it as a system (see Fig. 3.1 for a typical model of forecasting).

As seen in Fig. 3.1, forecasting model begins with information inputs. Forecasts are possible, only when a history of past data exists. An established TV manufacturer, for example, can use past data to forecast the number of picture screens required for next week's TV assembly schedule. Past data are available for products, which are already being produced. Suppose, the TV manufacturer decides to offer a totally new model. Because, past data are not available, forecasting needs to be based on the manager's skill, experience, judgement and established techniques.

Data are used to forecast sales in terms of quantity and value of sales. Sales forecast is translated into demand for factory capacities, funds, facilities and others (long-term forecasting); for workforce, materials, department requirements, inventories and others (intermediate-range forecasting) and short-term forecasting involving forecasting for specific labour skill required, machine hours, cash and inventories.

When the long-range, intermediate-range and short-range forecasts are operationalised, the consequence is production of goods and services.

Forecasting Methods

Forecasting methods can be broadly divided into two main categories:

- Quantitative methods
- Qualitative or judgemental methods

In some situations, a combination of methods may be used. In quantitative methods, also called *time series* methods, past data are used in making a forecast for the future. This process looks like driving a car by looking through the rear mirror. However, where forecast is made for short-periods, quantitative methods are more appropriate.

Qualitative or judgemental methods rely on an expert's opinion in making a prediction for the future. These methods are useful for intermediate to long-range forecasting tasks. The use of judgement in forecasting sounds unscientific and adhoc. But, where new products are sought to be introduced, there are few alternatives other than using the informed opinion of knowledgeable people. However, to obtain better results, judgemental methods are used in conjunction with other categories of methods.

Detailed description of the forecasting methods follows.

Quantitative Methods

These methods seek to identify patterns in the past data. In order to systematically analyse data, managers use a *time series analysis*. In this, analysts plot demand data on a time scale, study the plots and look for consistent shapes or patterns. (See Fig. 3.2)

Demand pattern becomes continuous when, it is constant and does not consistently increase or decrease. The sales of a product in the mature stage of its life cycle may show a horizontal demand pattern.

Linear trend emerges when, demand increases or decreases from one period to the next. The sales of products in the growth stage of the product life cycle tend to show an upward trend, whereas those in decline, tend to show a downward trend.[2]

The cyclical pattern pertains to the influence of seasonal factors that have impact on demand, either positively or negatively. For example, the demand for woollen wear will be high in winter and low during summer.

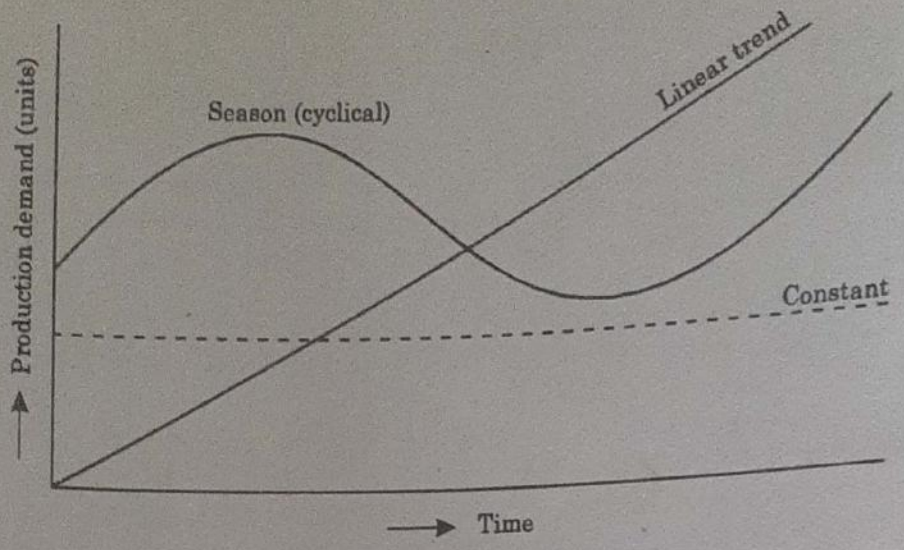


Fig. 3.2 Demand Patterns

(*Source :* Everette E. Adam, Jr. and Ronald J. Ebert, *Production and Operations Management*, p.81)

Common Time Series Models

The most common and relatively easiest methods for developing a forecast from past data are simple moving averages, weighted moving averages, exponential smoothing and regression analysis.

Simple Moving Average (SMA)

In this model, the arithmetic average of the actual sales for a specific number of recent past time periods is taken as the forecast for the next time period.

$$SMA = \frac{\text{Sum of demands for all periods}}{\text{Chosen number of periods}}$$

$$SMA = \frac{\sum_{i=1}^{n} D_i}{n} = \frac{1}{n}(D_1 + D_2 + D_3 \ldots . D_n)$$

Where, n = the chosen number of periods

i = 1 is the oldest period in the n-period average

i = n is the most recent period

D_i = the demand in the 'i'th period

The following illustrates the SMA model :

A T.V. manufacturer has experienced following demands for TV sets during the past six months:

Month	*T.V. Sets*
January	20,000
February	30,000
March	20,000
April	40,000
May	50,000
June	60,000

The plant manager desires a forecast for July, using a six-period moving average. The forecast for July shall be:

$$SMA = \frac{\sum_{i=1}^{n=6} D_i}{n} = \frac{20,000+30,000+20,000+40,000+50,000+60,000}{6}$$

SMA = 36,700

Using a six month moving average, the July forecast is 36,700. Using a three months data, the forecast for July shall be:

$$SMA = \frac{\sum_{i=1}^{n=3} D_i}{n} = \frac{40,000+50,000+60,000}{3} = 50,000$$

This forecast may be more accurate than the forecast based on six months data.

We may use the data of the immediate previous month for forecast. Thus, the forecast for July shall be 60,000 which is the Fig. of sales for the month of June.

Weighted Moving Average (WMA)

WMA is like the SMA model described above, except that, instead of an arithmetic average of past sales, a weighted average of past sales is the forecast for the next time period. A WMA allows for varying, not equal weighting of old demands.

Thus, $WMA = \sum_{t=1}^{n} C_t\, Dt$, Where D_t is the demand during time period 't', C_t is the weight given to that demand and 'n' is the chosen number of periods

Also, $0 \le C_t \le 1$

and $\sum_{t=1}^{n} C_t = 1$

For example, suppose n is three, we could weigh the most-recent period twice as heavily as the other periods by setting C_1 = .25, C_2 = .25 and C_3 = .50. WMA shall be:

= .25 (40,000) + .25 (50,000) + .50 (60,000)

= 52,500

Exponential Smoothing Models

In these methods, the forecasted sales for the last period are modified by information about the forecast error of the last periods. This modification of the last year's forecasts are the forecasts for the next time periods.

In these methods, the weight assigned to a previous period's demand decreases exponentially as that data gets older. Thus, recent demand data receive a higher weight than does the older demand data.

Regression Analysis

Regression analysis is a forecasting technique that establishes a relationship between variables - one dependent and other(s) independent. In simple regression, there is only one independent variable. In multiple regression there is more than one independent variable. If the historical data set is a time series, the independent variable is the time period and the dependent variable in sales forecasting, is sales. A regression model does not have to be based on a time series, in such cases, the knowledge of future values of the independent variable is used to predict future values of the dependent variable. Regression is normally used in long-range forecasting, but, if care is taken in selecting the number of periods included in the historical data and that data set is projected only a few periods into the future, then regression may also be used for short-range forecasting.

Weakness of Time Series Analysis

Time series analysis basically depends on past data. This dependence on historical data is itself one of the weaknesses of the time series analysis, and the validity of forecast depends upon the similarity between past trends and future conditions. Any significant departure from historical trends will weaken the forecast dramatically. Unfortunately, departures from historical trends seem to be occurring with increasing frequency.

A second potential weakness in time series analysis is that, it provides quantitative answers. Managers must take care that, they do not place too much confidence in these results. The use of numbers and equations often gives a misleading appearance of scientific accuracy.

Qualitative or Judgemental Methods

A *qualitative forecast* is one, that is not based exclusively on a mathematical model. These methods are usually based on judgement about the causal factors that underlie the sales of particular products or services and on opinions about the relative likelihood of these causal factors being present in the future.

Judgemental methods are useful when historical data are not available. In the absence of past data, statistical methods have no validity. Past data, even when they exist, may not be representative of future conditions. Qualitative forecasts are the only alternatives available. Further, in these days of management science and computers, qualitative forecasts assume greater relevance.

The most popular judgmental forecasting methods are: Executive Committee Consensus, Delphi Method, Survey of Salesforce, Survey of Customers, Historical Analogy and Market Research.

Executive Committee Consensus/Jury of Executive's Opinion

Here, a committee of executives from different departments is constituted and is entrusted with the responsibility of developing a forecast. The Committee may use many inputs from all parts of the organisation and may have staff analysts provide analysis as needed. Such forecasts tend to be compromised ones, not reflecting the extremes that might be present, if they were prepared by individuals. However, that is the most commonly used method of forecast.

The Delphi Method

First developed by Rand Corporation, Delphi is the most sought after meth...
The method seeks to eliminate the undesirable conse...
do exist when experts ...

The Delphi method draws on a pool of experts from both inside and outside the organisation. Members are so drawn that, each one is an expert in one aspect of the problem and none is conversant with all aspects of the issue. In general, the method proceeds on the following lines:

1. Each expert in the group, makes independent predictions in the form of brief statements.
2. The coordinator edits and clarifies these statements.
3. The coordinator provides a series of written questions to the experts, that include feedback supplied by the other experts.
4. Steps 1 to 3 are repeated several times, till consensus is obtained. As many as six rounds may be needed to reach the convergence.

Survey of Salesforce/Field Expectation Method

Individual members of salesforce are required to submit sales forecasts of their respective regions. These estimates are combined to form an estimate of sales for all regions. Managers must then, transform this estimate into a sales forecast to ensure realistic estimates. This is a popular forecasting method for companies that have a good communication system in force and that have salesforce who sells directly to customers.

Survey of Customers/User's Expectation Method

In this method, estimates of future sales are obtained directly from customers. Individual customers are surveyed to determine what quantities of the company's products they intend to purchase in each future time period. A sales forecast is determined by combining individual customers' responses, and where customers are limited in number, this method is highly useful.

Historical Analogy

This method ties the estimate of future sales of product to knowledge of a similar product's sales. Knowledge of one product's sales during various stages of its product life cycle is applied to the estimate of sale for a similar product. For example, an assumption can be made that, colour television would follow the general sales pattern experienced with black and white television. Where a product is new, this method is particularly useful.

Market Surveys

In the market research method, questionnaires, telephone talks or field interviews form the basis for predicting market demand for products.

Market surveys are ordinarily preferred for new products or for existing products to be introduced into new market segments.

Choice of a Model

We have, till now, discussed both quantitative as well as qualitative techniques of forecasting. Managers now have a problem of selecting a particular model out of many. The criteria for selecting a technique include accuracy, cost, ease of application and specific requirements of a planning situation. It has been proved that not one method meets all the criteria, but a combination of the techniques will be more effective in any given situation.

SOLVED PROBLEMS

1. The table below shows the monthly demand over 6 months period for a product.

Month	*Demand (units)*
1	120
2	130
3	110
4	140
5	110
6	130

Determine the sales forecast for the 7th month, using a 3 month simple moving average method ?

Solution

Month	*Demand for the month (units)*	*Three month moving total [Total demand during the past 3 months (units)]*	*Three month moving average*
1	120		
2	130	360	$\frac{360}{3} = 120.00$
3	110	380	$\frac{380}{3} = 126.67$
4	140	360	$\frac{360}{3} = 120.00$
5	110	380	$\frac{380}{3} = 126.67$
6	130		

The forecast for the 7th month based on 3 month moving average is 126.67 units.

2. The table below indicates the monthly demand for the 6 months period. The weightage given is 3 for the most recent demand value, 2 for the next most recent value and 1 for the oldest demand value. Determine the 3 month - weighted average and the demand forecast for the 7th month.

Month	*Monthly Demand (Units)*
1	120
2	130
3	110
4	140
5	110
6	130

Solution

Month	*Monthly Demand (Units)*	*3 month weighted moving total*	*3 months weighted moving average* $\left(\frac{\text{3 months weighted moving total}}{\text{Total weight}}\right)$
1	120		
2	130	$120 \times 1 + 130 \times 2 + 110 \times 3 = 710$	$\frac{710}{6} = 118.33$
3	110	$130 \times 1 + 110 \times 2 + 140 \times 3 = 770$	$\frac{770}{6} = 128.33$
4	140	$110 \times 1 + 140 \times 2 + 110 \times 3 = 720$	$\frac{720}{6} = 120.00$
5	110	$140 \times 1 + 110 \times 2 + 130 \times 3 = 750$	$\frac{750}{6} = 125.00$
6	130		

The forecast for the 7th month is 125 units.

3. ABC company used simple exponential smoothing method using an exponential smoothing constant of 0.2 (i.e., $\alpha = 0.2$) to forecast the short term demand. The forecast for the month of July was 500 units whereas the actual sales was only 450 units. What is the forecast for the month of August ?

Solution

$$F_t = F_{t-1} + \alpha(D_{t-1} - F_{t-1})$$

where F_t = Forecast for the current period (say August)

F_{t-1} = Forecast for the previous period (say July)

α = smoothing constant ($\alpha = 0.2$)

D_{t-1} = Actual demand (or sales) for the previous period (say July)

$$\therefore F_t = 500 + 0.2\,(450 - 500)$$
$$= 500 + 0.2\,(-50)$$
$$= 500 - 0.2 \times 50$$
$$= 500 - 10$$
$$= 490 \text{ units}$$

∴ Sales forecast for August is 490 units.

4. A hospital has 9 month moving average forecasting method to predict a particular drug requirements. The actual demand for the item is shown in the table below:

Month	1	2	3	4	5	6	7	8	9
Demand	80	65	90	70	80	100	85	60	75

Using the 9 month moving average, find the exponential smoothing forecast for the 10th month.

Solution

$$\text{9 month moving average} = \frac{\sum_{i=1}^{n} D_i}{n}$$

D_i = demand for the 'i'th month; n = no. of months

$$\text{9 month moving average} = \frac{80+65+90+70+80+100+85+60+75}{9} = \frac{705}{9} = 78.33$$

$$\text{Exponential smoothing constant } \alpha = \frac{2}{n+1} = \frac{2}{9+1} = \frac{2}{10} = 0.2$$

$$\text{Sales forecast for the 10th month } F_t = F_{t-1} + \alpha(D_{t-1} - F_{t-1})$$
$$= 78.33 + 0.2\,(75 - 78.33)$$
$$= 78.33 - 0.2 \times 3.33$$
$$= 78.33 - 0.66 = 77.67 \text{ units}$$

QUESTIONS

1. What is forecasting? Why is it necessary in production function?
2. Bring out the various techniques of forecasting.
3. How does a manager select one particular technique of forecasting out of many?
4. Briefly describe the application of long-range and short-range sales forecasts in production management.

PROBLEMS

1. The table below gives the actual demand in units for the past 10 months period.

Month	1	2	3	4	5	6	7	8	9	10
Demand	100	105	108	110	112	114	120	130	128	140

(a) Compute a simple 5 month moving average to forecast the demand for 11th month.

(b) Compute a weighted 3 month moving average, where the weights are highest for the latest months and discend in order of 3, 2, 1.

2. The number of nurses required to staff the surgical wing at a large hospital varies from quarter to quarter. The last three year's data are shown below.

Year	*Quarter*	*No. of Nurses*
1	1	115
	2	110
	3	108
	4	116
2	1	116
	2	114
	3	110
	4	112
3	1	116
	2	112
	3	110
	4	115