UNIT 13 SCHEDULING & SEQUENCING

Objectives

Perusal of this unit will enhance student's :

- Understanding of the importance of scheduling and sequencing in operations management
- Appreciation of the role played by effective scheduling and sequencing in reducing incidence of changes and cutting down manufacturing cycle time
- Learning of the criticality of correct scheduling and sequencing in improving response and imparting flexibility to cope with changing needs and wants of customers
- Acquiring working knowledge of various techniques for scheduling and sequencing of mass, batch and job shop types of production systems
- Capability in understanding the role of computers and information technology in obtaining optimal solutions to problems of scheduling and sequencing in very short time.

Structure

13.1 INTRODUCTION

Scheduling is the preparation of timetable of activities or action plan for a specific period. Since it has to be drawn up before the commencement of that period - a day, a week, a fortnight or a month, it incorporates projected future activities and events of a firm.

It is not unusual for companies to prepare a timetable of labour requirements to meet target production levels within a specific period; it would be of little value if materials required for performing those operations are not available. Similarly, a good schedule of activities cannot be prepared until we have frozen the method of manufacturing (sequence of manufacturing process), we ensure that machines are available and in running condition, all production accessories like jigs, fixtures, tools, dies, punches, gauges have not only been designed, but also fabricated and are ready for use, we have drawn up all productions schedules and sequences including route cards, progress sheets etc. and we have reliable source of electricity supply or alternatively, standby arrangement for power generation and supply.

Scheduling of industrial activities or tasks is therefore, a very complex operation as it involves simultaneous consideration of all the above factors besides the demands of customers and commitments made to them by the sales personnel.

13.2 SITUATIONS REQUIRING SCHEDULING

Scheduling problems are not only common when programming an individual machine or equipment but also for programming the entire manufacturing plant. Obviously, the purpose of such scheduling would be to maximize the number of on-time deliveries to customers.

There are a large variety of situations where scheduling can be very useful. For example:

a) Running a large number of programmes on a computer or a computer terminal or networked personal computer (PC) in a specified time period.

b) Processing of applications for loan or credit facilities at a commercial bank – the objectives of scheduling may vary from one bank to another.

c) Scheduling of pathological tests on a patient in the hospital so that overall time for obtaining the results is minimum.

d) Scheduling of all activities prior to the landing of aircrafts at an airstrip to ensure safety to passengers and aeroplanes.

Arbitrary scheduling will invariably lead to solutions that are not compatible and optimal for meeting company's objectives.

13.3 CLASSIFYING PRODUCTION SYSTEMS

Production systems present a very wide spectrum of patterns of working for the conversion of input resources like men, machines, methods, measurement, message (information and communication), motive power (energy), money acid management into output in the form of goods and services which are valued by customers. Production systems can he classified into three categories as below:

a) Mass Production

When goods and services are produced by performing same activities in specified sequence repetitively, we call it a flow shop or mass production system. It uses special purpose machinery designed and built to perform specific individual operations in that company. Henry Ford, the guru of mass production, introduced 'assembly line' concept in 1913 for assembling Fords Cars in large quantities. Henry Ford opined that any task, however gigantic and daunting, when split into small elements, becomes easy to learn and perform. The entire job was divided into small elements which were grouped together to form stages of manufacture on a flow line basis. The material between the stages may be moved manually (as in the case of assembly benches for manufacturing electric fans etc) or on conveyors moving at predetermined speed (for instance, for assembling TV sets or Maruti Cars).

b) Batch Production

When a range of products have to be manufactured in quantities which are reasonable hut not large enough to go in for dedicated production line (or assembly line), we go in for production in batches or lots which are convenient and acceptable without adding to the cost of manufacturing.

In batch production systems, general purpose machines and equipment are used and these are grouped together functionwise. All turning machines are located in one area and the department may he referred to as "turning shop Similarly, the manufacturing plant may have drilling, grinding milling, sub assembly, assembly, painting and testing shops. In such situations, material is moved in batches of say 50, 100, 1000 etc from one shop to another until it is packed and dispatched to its destinations. Flow of material within the firm tends to be complex and distances traveled are longer as they are circuitous.

c) Job Shop Production

In jobbing production system, variety of products is larger than the batch production and quantities to he produced at a time are significantly lower. In jobbing industry, it is very difficult to predict the type of work and its requirement in terms of demand. Besides, each order or job maybe quite different in terms of operations, their sequence and time taken at a workstation.

A job shop would also use general-purpose machines, grouped together into departments only when the total volume of business is large. Job shops are usually small and suffer from lack of support services and functions. Uneven loads at different machines or departments is quite common in practice.

13.4 SCHEDULING MASS PRODUCTION SYSTEMS

Mass production systems are appropriate when volume of demand is large and product variety small. It can take the form of continuous production lines working round the clock, seven days a week as in many chemical and processing plants or it can be an intermittent assembly line like assembly of cars on two shift basis.

It would be ideal production system if we have to produce large volumes of one product (without any changes of design) continuously. For example, Maruti Udyog Ltd has several assembly lines for assembling different models of cars. However, owing to large volumes, one assembly line is totally dedicated to Maruti 800 model sold domestically. Currently, the volume of demand is so high that additional quantities are manufactured on the second assembly line which caters for the `tatkal' and `export model'. Assembly line technology is used very widely for assembling TV sets, electrical appliances, computers, electronic goods, toys etc.

Assembly lines are typically as below :

Let us assume that the work content of each of the eight stages of assembly of an appliance is as below :

Stages	Work Contact (minutes)	Idle Time (minutes)
S1	4.90	0.10
S2	4.90	0.10
S3	4.80	0.20
S4	5.00	-
S5	4.90	0.10
S6	4.90	0.10
S7	4.90	0.10
S8	4.70	0.30
TOTAL	**39.00**	**1.00**

If each person is given one assembly independently, he will be able to assemble the following number of appliances :

Available time	=	8 x 60 minutes
(8 hours of work)	=	480 minutes
Personal time	=	30 minutes
Working time	=	450 minutes

Total no. of appliances that will

be assembled in a day by one person = $\frac{450}{39}$ =11.54

say11

if we engage 8 person in the assembly of these electrical appliances, we shall get a daily production of 8 x 11 = 88 appliances.

a) However, if we can go in for assembly line splitting/ he entire manufacturing line of 39 minutes into eight stages as shown above, the throughput rate of the system will be constrained by the slowest stage viz S4 which is 5 minutes.

Production of appliances per day	=	450/5
	=	90

This approach is extremely important for high volume mass production systems and is known as Line Balancing.

b) If through a re-arrangement of some elements of task either by better grouping or by making slight changes in tooling etc, we are able to modify the work content of eight stages as below :

Stages	Work Content (minutes)	Idle Time (minutes)
S1	4.88	0
S2	4.88	0
S3	4.86	0.02
S4	4.86	0.02
S5	4.88	-
S6	4.88	-
S7	4.88	-
S8	4.88	-
	39.0	0.04

In this revised line balancing of tasks at different stages,

production of appliances per day = 450/4.88

= 92.2

say 92

c) Usually it is more rewarding to change the design of the appliance or layout of components within the same appliance so that there is a decrease in the total work content of the job in such a way that the bottleneck stage (S-4) stands to gain the most.

Stages	Work Content (minutes)	Idle Time (minutes)
S1	4.75	0.03
S2	4.76	0.02
S3	4.78	-
S4	4.70	0.08
S5	4.74	0.06
S6	4.75	0.05
S7	4.76	0.04
S8	4.76	0.04
	38.00	0.32

In this revised line balancing,

production of appliances per day = 450/4.78

= 94.14

say 94

It is observed that with small changes in the work content of stages of production on the assembly line, we are able to increase the output rate. Parameter of line efficiency is often used for measuring the effectiveness of line balancing.

It is the ratio of the total stage time and total cycle time

Line efficiency $= \dfrac{39 \times 100}{8 \times 4.88}$ for case (b)

= 99.89%

Line efficiency $= \dfrac{39 \times 100}{8 \times 4.88}$ case (c)

= 99.37%

Activity A

Maruti 800 is assembled on a conveyor belt with 30 stages, roughly well balanced in terms of cycle time for each stage. The slowest stage has a cycle time of 1.5 minutes and the cycle time at other stages is no more than 1.4 minutes. Each stage is manned by 3 to 5 workers depending upon the total work content at that stage. What would be the increase in production per shift if the work content of the slowest stage is brought lower than 1.4 minutes.

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13.5 SCHEDULING BATCH PRODUCTION SYSTEMS

Batch production systems are very common as in a large number of industries. Quite a few products are required to be manufactured in quantities which are not large enough for assembly line technology. In these situations, similar machine and processes are grouped together into specialist shops and departments and materials are moved from one to another in line with the requirement of process sequence. Various issues that often crop up in batch production are :

a) Determining optimum size of batch / lot size

When production of annual requirements of a product is split into batches so as to meet the demands of market without building high levels of inventory, we have to determine the optimum batch or lot size for production. The various costs involved are cost of setting up or changeover and the cost of stockholding or carrying inventory. Let us assume :

A	=	annual demand in quantity or units
C	=	change even or setting up costs
N	=	number of production batches per year
R	=	economic batch size
U	=	unit cost of production
i	=	cost of carrying inventory in fractions

Cost of changeover per year $= x.c$

$$= \frac{A}{Q} \times C$$

Cost of carrying inventory $= \frac{Q}{2} \times u \times i$

Cost of stocks $= A x u$

Total cost (TC) $= \frac{A}{Q} \times C + \frac{Q}{2} \times u \times i + A \times u$

Differentiating w.r.t. Q

$$\frac{dTC}{dQ} = \frac{-AC}{Q^2} + \frac{ui}{2} + 0$$

Differentiating second time w.r.t Q

$$= \frac{2AC}{Q^3} + 0 \text{ which is positive}$$

Consequently, value of Q obtained when first derivative will be equal to zero, will correspond to overall cost minimisation i.e.

$$= \frac{-AC}{Q^2} + \frac{ui}{2} = 0$$

$$\frac{Q^2}{AC} = \frac{2}{ui}$$

$$\text{Or, } Q = \sqrt{\frac{2AC}{ui}}$$

Often, a batch size `Q' is made at a machine and then transferred in one lot to the next machine in sequence.

Another variant of this mode of production is when the material is transferred to the next stage while the lot is being manufactured at the first machine.

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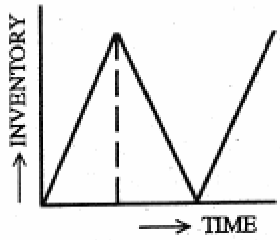

If A = annual rate of demand

P = annual rate of production

Such that P > A

When we start the batch, inventory will rise at the rate of P-A

Time to produce $Q = \frac{Q}{P}$

Maximum inventory = Time to produce lot Q × (P-A)

$$= \frac{Q}{P} \times (P - A)$$

$$= Q(1 - \frac{A}{P})$$

Average inventory $= \frac{1}{2} Q(1 - \frac{A}{P})$

Substituting the required value of average inventory in the above, we get

$$TC = (A/Q) \times C + ½Q(1\text{-}A/P)u.i + A.u$$

$$DTC/dQ = -Ac/Q^2 + (1\text{-} A/P)(u.i)/2 + 0$$

Since the second derivative will be positive, value of Q for overall cost minimization can be determined by

$$-AC/Q^2 + (1\text{-}A/P)(u.i)/2 = 0$$

$$Q^2/AC = \frac{2}{\{(1\text{-}A/P)u.i\}}$$

$$Q = \sqrt{\frac{2AC}{(1-A/P)\,ui}}$$

Activity B

For an item of product, annual demand is 26,000 units and can be produced at the rate of 1000 pieces per week, at a cost of 1000 pieces per week, at a cost of Rs 26/- per unit. If the cost of changeover is Rs 50/- per occasion and cost of carrying inventory is 20%, what is the economic size of production batch ?

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b) Line of Balance (LOB) for Production Control

This technique is very useful when production is organized in batches. This **technique** is used to compare progress on each operation with the progress that would be required to meet the delivery requirements to cope with the market demand. It consists of the following steps.

i) Cumulative delivery schedule

This is the starting point. The delivery commitment is drawn up in the form of a graph on time-scale and is positioned on the left hand top half of the paper.

ii) Relationship Diagram

This is drawn below the cummulative delivery schedule. It represents the entire process of manufacturing starting from the end point backwards. All the major transition points, called the control points are identified in the diagram alongwith the time lag from the end point.

iii) Line of Balance Chart

This is drawn on the right hand top half along side the cumulative delivery schedule and vertical co-ordinate (y axis) is same as in the delivery graph. Along the X-axis, all the control points identified in the Relationship Diagram, corresponding to Control points, bar diagram is drawn for different points on time.

Illustration

An order has been pieced on a supplier of vital defence equipment and following delivery dates have been agreed:-

3rd Week	10	Units
4th Week	20	Units
5th Week	20	Units
6th Week	20	Units
7th Week	20	Units
8th Week	20	Units
9th Week	20	Units
10th Week	20	Units
11th Week	20	Units
12th Week	20	Units
13th Week	10	Units
Total	200	Units

The details of manufacturing process have been examined and agreed with the supplier. It has been decided to visit the supplier at the end of the 6th, 9th and 120 week to ensure against delays so that eventual delivery commitments are complied with.

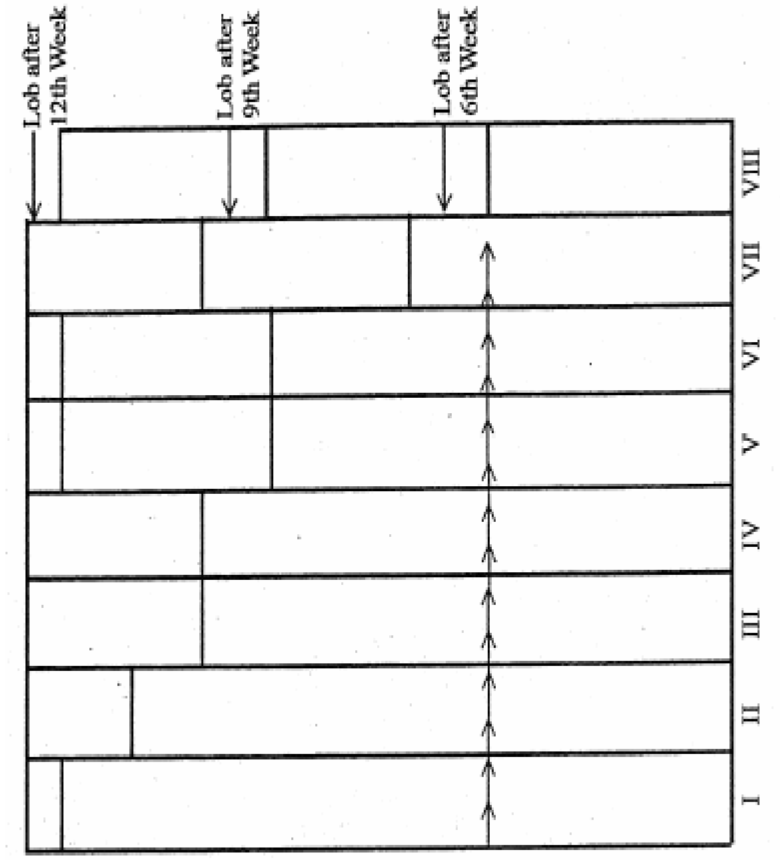
The technique of LOB can be illustrated graphically as shown in figure on the next page

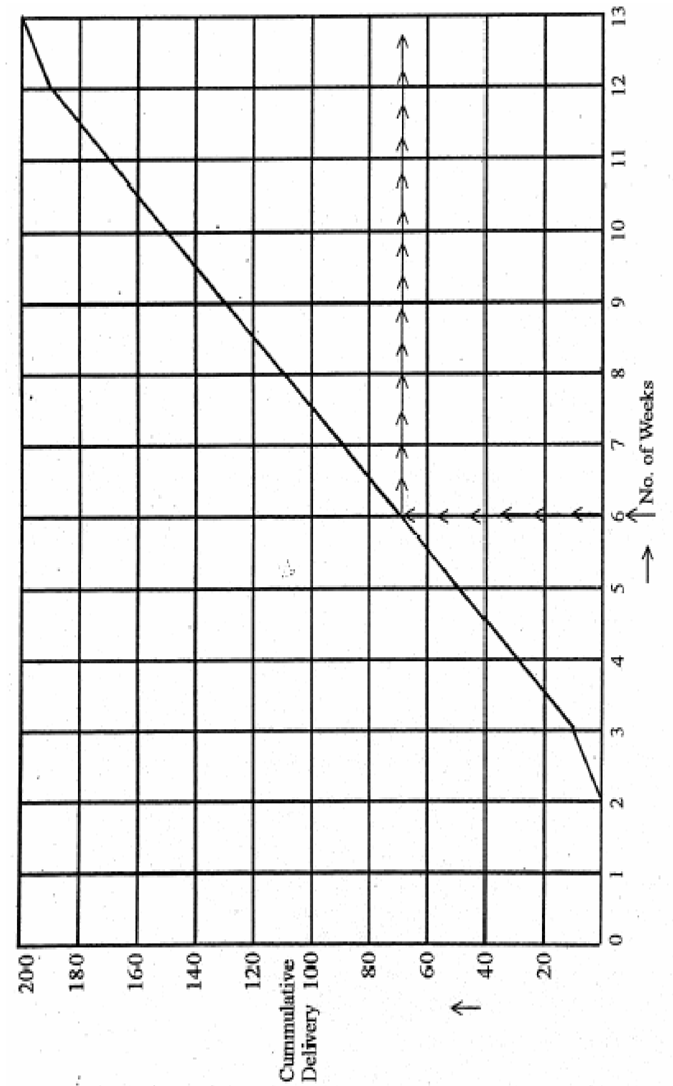
i) Drawing the Cumulative delivery schedule

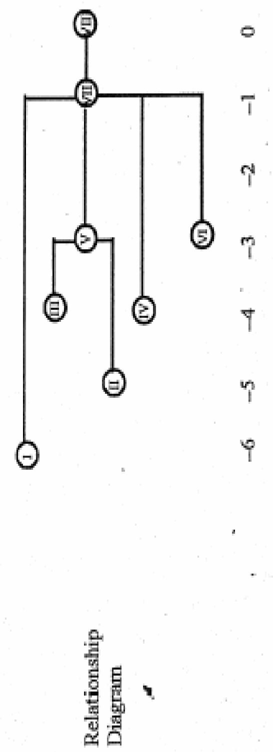
This graph; where time scale is on X-axis and cumulative quantities of output on the Y-axis, is drawn on the left hand top quadrant of a piece of paper. The origin of the time scale may coincide with the date of placement of purchase order or any point later, but must cover the entire period of progressive completion and/or dispatch. We must be very clear of the cut off point, whether it is completion or dispatch.

ii) Drawing of Relationship diagram.

This is similar to a network - in fact, historically, it was the predecessor of networks as it was discovered in 1941. .However, this is drawn backwards starting with the end point which must coincide with the cut-off incorporated in the cumulative delivery schedule drawn above. The entire process of manufacture is blown into sub assemblies, components which may be cast, forged, machined, bought out etc. and extended to the procurement of raw materials and for preparation of drawings as applicable.


Lob after 12th Week
Lob after 9th Week
Lob after 6th Week
I
II
III
IV
V
VI
VII
VIII


Cummulative Delivery
200
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
No. of Weeks


Relationship Diagram
–6
–5
–4
–3
–2
–1
0

The checkpoints in these networks are called control points and they are so chosen as to facilitate easy measurement and control. Usually they coincide with the transition points between departments or functions and are often points of recording and reporting outputs.

It is perhaps easy to understand that upstream control points would be ahead of the end control point in terms of output at. any given time. It is preferable to draw these control points by adopting a time scale for the processing time lags between them. Since the time scale is from right to left (reverse of the normal one), these have been shown on a negative scale.

iii) Drawing the Line of Balance Chart

Once the above two data have been recorded as above, we are ready to draw the LOB chart for any date of interest. The procedure is simple as it is iterative :

1) On the date, we want to monitor the progress of work on the job, we plot it on the cumulative delivery schedule. For example, if we have to draw the LOB chart on the 6th week after the issue of the purchase order, we trace it on the 6" week and trace the point on the cumulative curve to read the tout! output on the end-control point on that date and plot it on the corresponding bar diagram on the right hand top half of the paper. (e.g. Control point VIII)
2) For the other control points, the methodology is fairly simple. For example, for control point VII, we plot it on the cumulative delivery schedule one week to the right of the date, because total quantity of output cumulatively has to he more than the quantity at the end control point VIII and higher quantity in the cumulative delivery schedule is obtained only when it is plotted on the right - exact point is determined by the processing the time lag of the manufacturing process. By following this procedure, target quantities for each of the control points identified in the relationship diagram can be determined.
3) There is one exception when. for any control point, the plot on the right of the date for which LOB chart is being drawn, goes beyond the cumulative delivery schedule, it has to he limited to the end point of the delivery schedule - cumulative quantities for any control point cannot exceed the total quantity on order.
4) The approach is to de-emphasize the focus only on the end point. of completion while scheduling the jobs in production - for achieving completion of the job, we need to control other important transition points in the manufacturing process-usually coinciding with the inter department transfer point. These control points are so chosen as to permit easy counting and measuring or a routine for reporting.

Activity C

Prepare a schedule for different departments if we have to complete a batch of 1,000 pieces in ten weeks as below :-

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Week No	Quantity of Finished Product (as packed)
1	60
2	80
3	100
4	120
5	120
6	120
7	120
8	120
9	120
10	40
Total	1000

The process of manufacturing, starting from the end point of completion, is as below:-

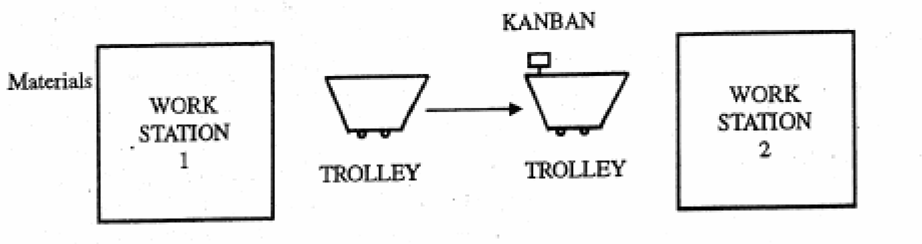
The products have to be packed before they can despatch - 10 to a box. The assembly must be completed one week before so that final testing and packing can be done. The bought out components should reach the factory two weeks before the assembly. In-house machined components must be started four weeks before the assembly which takes one week. Similarly sheet metal components must start three weeks before the assembly. Raw materials for the same should be received in the factory two weeks before the start of sheet metal processing can commence. Final assembly also requires a subassembly done in another department and this subassembly also takes one week to complete and must be available to the final assembly department just in time. The sub assembly being a specialist item, contains a bought out unit which must be available at least two weeks before the sub assembly starts. The housing unit is manufactured in house and must be ready in time for starting the sub assembly, but the process of making the housing takes two weeks.

(c) Kanban System of Production Scheduling

Japan has made rapid strides in developing and perfecting imaginative and comprehensive production systems - the most important of which is revolutionary in concept and these are known as Just-in-Time (JIT) systems which now comprise. of a cluster of techniques. One such technique is called the Kanban system.

Literal meaning of Kanban is visual record, hence it is also referred to as Card system. It can be either a two-card system as introduced and practiced in Toyota Motor Company's Takahama plant or it can be the more popular one-card system.

Material flow and work-in-progress is regulated in production shops through these Kanbans (cards). A typical process is illustrated below:-



Work station (WS-2) is the customer, he will decide when he needs the next lot of material. For this, he will transfer the Kanban to WS-1 only when its incoming trolley is nearly empty - the worker at WS-1 cannot transfer the material until he receives the Kanban from his customer stage. By controlling the no. of Kanbans in the production process, work-in-progress is reduced and materials arrive into the next workstation just-in-time.

In two-kanban system, two types of cards are used - one for transportation between the workstations and is known as conveyance Kanban and the second, for production at the workstation itself and is called the production kanban.

This process of sequencing production is different from the traditional one - it preaches that we should manufacture (or buy) only that much as required (or demanded) by the next stage. This principle is described as Demand -Pull system in contrast with the traditional principle of pushing production.

It focuses on the ideal principle, as is common in assembly lines when one component is worked at a time and passed onto the next stage just-in-time for the operator to pick up and do his/her part of the job on a continued basis.

Kanban system links up the supplying workstation with the receiving workstation and it leads to a number of advantages as below:-

i) It reduces / eliminates transportation and handling considerably.

ii) It eliminates delays in, a batch size of production by adopting a one-piece flow or minimal lot size flow between workstations.

iii) It leads to reduction in manufacturing cycle times and set-up times.

iv) It facilitates producing what is required and not what may be required.

v) It eliminates `production-to-stock' approach of Demand - Push system & encourages high degree of responsiveness among individual operators for meeting variance in demands at different workstation.

vi) Control of work-in-progress inventory is achieved not by magnitude of demand & supply but by improving individual's capacity to respond to demand fluctuations that are generally unavoidable.

vii) It leads to high degree of employee involvement.

13.6 SCHEDULING JOB PRODUCTION SYSTEMS

Unlike in batch production, demand is not predictable in jobshop work, where each job is unique and so is its sequence of processing time for each of the work stage. Jobshops are, therefore characterised by a number of general purpose machines and is typified by a large variety of jobs. A job moves from one machine to another workstation has to wait there (as if in a queue) before it is taken up. Conversely, a machine or workstations may complete all pending jobs and is idle as it is waiting for the next job (which may not be in the pipeline!)

Optimal sequencing procedures has been developed for various situations as below:

-- `n' jobs and one machine

-- `n' jobs and two machines

-- Two jobs and ‘m’ machines

However, there are no optimal rules for jobshops with more than two jobs and to machines, which, in real life, is the most likely situation.

Traditionally, managers have been guided by commonsense principles of reducing congestion in the shop, maximising machine utilization etc. Several principles or rules have been developed to decide the next job to be selected from amongst the various jobs waiting for loading on the machine. A few of these rules are as below :-

a) Earliest Due Date First (EDO)

Herein the jobs due for completion earliest is given the first priority for scheduling on the machine.

b) First In Shop First Served (FISTS)

If this rule is applied, the job that arrived in the shop first is chosen for scheduling on the machine

c) First Come First Served (FCFS)

Under this rule, first priority for scheduling is given to the job that arrived at the machine first.

d) Least Slack Time (LST)

If this principle is followed, first priority is assigned to the job that has the least slack time available. Slack time is the free time available after subtracting the time required by the job to be processed through remaining work stages. For example, if we are 11 days away from the due date of a job and the time taken for the remaining three stages is 4+2+1 respectively, then the slack time is four being the difference between the due date and the time required to complete the remaining work on the job.

e) Shortest Processing Time (SPT)

Herein, first priority is accorded to the job that have the shortest processing time on the machine. This is often followed even by the doctors whose waiting rooms get congested with patients waiting to consult.

f) Least Work Remaining (LWR)

Highest priority, under the rule, is given to the job with the least amount of processing time remaining to complete the job. The rules, also called *dispatching rules* can be extended. However, managers must evaluate, through comparative study, which of the rules is most rewarding in a job shop.

13.7 GENERAL PRINCIPLES OF SCHEDULING

Two variables - Lost Time and Manufacturing Cycle Time, form the most important criteria in a production system. Let us assume that a job in a shop entails six stages of processing viz. A,B,C,D,E&F and the corresponding processing times are Ta, Tb, Tc, Td, Te, and Tf. The three guiding principles can be stated as below :

a) For Minimum Lost Time and Manufacturing Cycle Time

This is an ideal objective to achieve. Here in, all operations showed have same durations viz.

Ta=Tb=Tc=Td=Te=Tf.

Assembly flow lines are the best examples of scheduling such productions systems. Similarly, with the help of Kanban System, we can design even batch production.

b) For Minimum Lost Time

Each succeeding operation should be longer than its predecessor in the schedule viz. Ta<Tb<Tc<Td<Te<Tf

Jobs wait for minimal time for being loaded onto the subsequent machines.

c) For Minimum Manufacturing Cycle Time

Each succeeding operation should be shorter far_ its predecessor in the schedule Ta>Tb>Tc>Td>Te>Tf

In practice there is usually a severe limitation of availability of resources (capacities) as demand far exceeds the availability.

13.8 SUMMARY

All scheduling decisions deal with the collection of scarce resources to jobs, activities, tasks, or customers. Within the available resources, scheduling seeks to satisfy the conflicting objectives of low inventories, high efficiency and good customer services. Scheduling, however, differ between mass production, batch production & job shop production. The production line is utilized to the extent needed for the single product, however for multiple products, a line capacity scheduling is needed for different products. In batch production too little impact will result in low inventories low utilisation of labour and machines, and fast customer service. Too much impact will result in high utilisation and long customers delivery times. For scheduling individual jobs, either sequencing on dispatching rules may be used. If sequencing is used a gantt chart is developed which shows exactly when each operation is planned for each job. When dispatching rules are used, jobs are selected for the next operation on the basis of prescribed priority rule. Scheduling system in general should answer the following questions (1) What delivery date do I promise? (2) How much capacity do I need? (3) When should I start each particular activity, or task? (4) How do I make sure that the job is completed on time? To take care of this dynamism of operations of the situation it can be computerised.

13.9 SELF-ASSESSMENT EXERCISES

1) What is Line-Balancing of assembly operations? Illustrate with examples

2) What approach would you suggest for increasing throughput rate of assembly lines and why?

3) Describe Economic Batch size of production? What are the cost factors involved in the above and how are they evaluated for determining the Economic Batch Size?

4) What are the two approaches of determining the Economic Batch size of production and how do they differ from each other?

5) Theoretically, what would be the ideal size of batch? Which technique in modern management envisions this approach in total operation management?

6) Compare and contrast `push' type of production system with pull type of production system and justify which one is better?

7) Is mass production, batch or job shop type of production system going to be the trend in the future and why?

8) What are the general principles in guiding scheduling and sequencing?

9) In your opinion, is mass production/ assembly line system the most optimal? Justify with reasons.

10) What is the role of computers in scheduling and sequencing of operations?

11) Describe Line of Balance Technique for batch production. Compare it with the network analysis technique of project management.

12) What is Kanban system of production? Describe its working details.

13) Compare and contrast one-card and two-card Kanban system.

14) What are the different criteria for scheduling jobshop production system and give their justification

13.10 FURTHER READINGS

1) Joseph G. Monks; *Operations Management -Theory and Problems,* McGraw-Hill International

2) James B. Dilworth, *Production and Operations Management -Manufacturing & Services.* McGraw-Hill International

3) Alan Mulrleman, John Oakland & Keith Lockyer, Production and Operations Management, Macmilan.

4) Elwood S. Buffa, Rakesh K. Sarin, Modern Production/Operations Management, John Wiley & Sons.

5) Everette E Adam Jr. & Ronald J. Ebert, Production and Operations Management, Prentice Hall India.

6) K.G. Lockyer, Production Control *in Practice,* Pitman.