UNITIII PRODUCT PLANNING AND PROCESS PLANNING

Quantity determination in batch production-Machine capacity, balancing- Analysis of process capabilities in a multi product system.

BATCH PRODUCTION

Unlike mass production systems which tend to be organized as product layouts with machines or equipment arranged according to the product flow, batch production normally is done employing a process layout. Here similar machines or equipment are grouped in departments and different jobs will follow their own route depending on requirements. Apart from the greater flexibility afforded by process layouts as compared to product layouts some of the advantages and disadvantages of process layouts are summarised below:

Advantages:

i) Better utilisation of machines is possible; consequently, fewer machines are required.

ii) A high degree of flexibility exists vis-a-vis equipment or manpower allocation for specific tasks.

iii) Comparatively low investment in machines is needed.

iv) There is generally greater job satisfaction for the operator owing to the diversity of jobs handled.

v) Specialised supervision is possible.

Disadvantages:

i) Since longer and irregular flow lines result, material handling is more expensive.

ii) Production planning and control systems are more involved.

iii) Total production time is usually longer.

iv) Comparatively large amounts of in-process inventory result.

v) Space and capital are tied up by work in process.

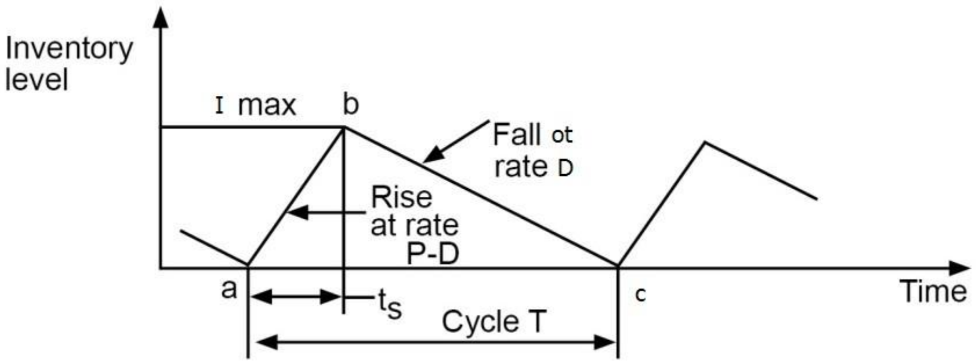
vi) Because of the diversity of jobs in specialised departments, higher grades of skill are required.

DETERMINE THE OPTIMUM BATCH SIZE

Single Product Case

Let us consider a situation for the production of a single product on a machine under the following set of assumptions.

- there is a continuous demand for the product at rate D units per year
- production rate for the product is P units per year ($P > D$)
- set up cost per batch of size Q is fixed at A (independent of Q)
- unit variable cost of production is C per piece



Single product model with constant demand and no shortages

- inventory carrying cost per unit per year (Rs./unit/year) = h = i C where i is theannual inventory carrying cost rate

- no shortages are allowed

Figure shows the change in inventory level within a cycle T. When production starts at point a, the inventory level will increase at a rate P-D (canyou see why?) until the maximum is attained at point b. The inventory level will decrease at a rate D during the rest of the cycle till point c is reached at which a new batch of size Q is initiated and a similar cycle continous.

It is easy to see from Figure I that

Time to produce a lot Q = t_s = Q/ P... (6.1)

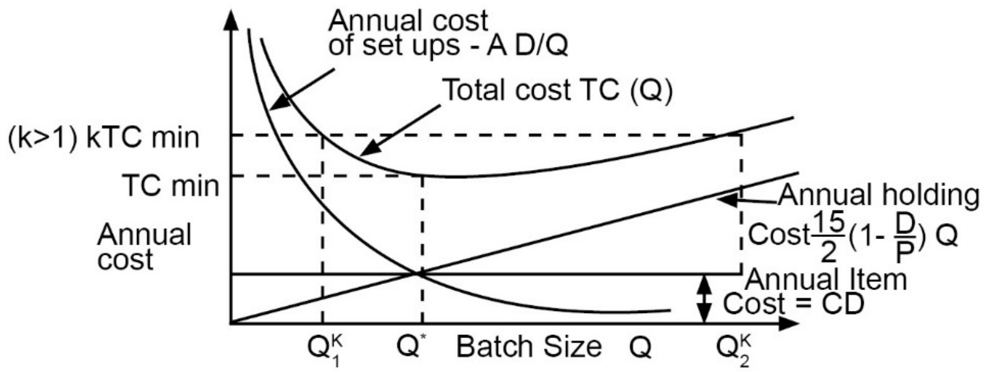
Maximum inventory level = 1_{max} = t_s (P-D)

The total cost is built up of two conflicting components—the set up cost (which favours large batch sizes) and the inventory holding cost (which favours small batch sizes). Our approach, therefore, is to develop an expression for the total annual cost in terms of the decision variable (which is the batch size Q in this case) and then to mathematically determine theoptimum.

This can be done as follows:

The average cost per cycle of length T is the sum of the set up cost, item variable cost and the carrying cost

where I is the average inventory over the cycle T. The average inventory I over the cycle T may be determined from Figure I as the area of the triangle abc divided by T



Total Annual cost as a function of batch size

OPERATION SCHEDULING

- In the past, manufacturing operations struggled with the concept of keeping production on time and efficient. As this problem became prevalent and technology improved, operations scheduling became a viable option for manufacturers that were seeking efficiency improvement.
- **Operations scheduling** pertains to establishing both timing and utilization of resources within an organization. Within operations scheduling, scheduling coincides with the utilization of equipment, scheduling of human labor, and materials receipt.
- Operations scheduling can enable production to have a schedule to follow and ensure for accurate delivery times while also keeping an eye on inventory levels

PRODUCT SEQUENCING

- The order in which jobs pass through the machines or work stations is called sequencing.
- **Sequencing** means grouping production operations into production batches and arranging them by priority ..... By utilizing the lean philosophy, small quantities are produced in chronologic order to reduce the inventories.
- Sequencing gives the idea of the order in which things happen or come in event. Suppose there are 'n' jobs (1,2,3,......n) each of which has to be processed one at a time at 'm' machine (A,B,C......). The arrangement of these flows is called job **sequencing.**

Priority Sequencing Rules

Priority sales are used to decide which job will be processed next at work centre, where several jobs are waiting to be processed. The jobs waiting for processing are sequenced using one of many priority sequencing rules. It is assumed that the work centre can process only one job at a time. A large number of sequencing rules are used in research and in practice to sequence the jobs waiting for processing at a work centre.

The relative priorities are based on certain rules as discussed in the following:

1. First Come, First Served (FCFS) rule: This is a fair approach particularly applicable to people. In case of inventory management, it is First In First Out (FIFO). That means the 1stpiece of inventory at a storage area is the 1st one to be used.

2. The shortest processing time (SPT) rule: SPT rule sequences jobs in increasing order oftheir processing times (including set up).

3. The Earliest Due Date (EDD) rule: Sequences jobs in order of their due dates, earliest first.

4. The critical ratio (CR) rule: Sequences jobs in increasing order of their critical ratio.

$$CR = \frac{Due\ Date - Today^{F}sDate}{Remaining\ Processing\ Time}$$

If CR>1 The job is ahead of

schedule.If CR<1 The job is behind

schedule.

If CR=1 The job is exactly on schedule.

5. The Slack Time Remaining (STR) rule: It employs that the next job processed is the onethat has the least amount of slack time.

Slack = (Due date – Today's date) – Remaining processing time

The job's priority is determined by dividing the slack by the number of the operations that remain including the operation which is being scheduled.

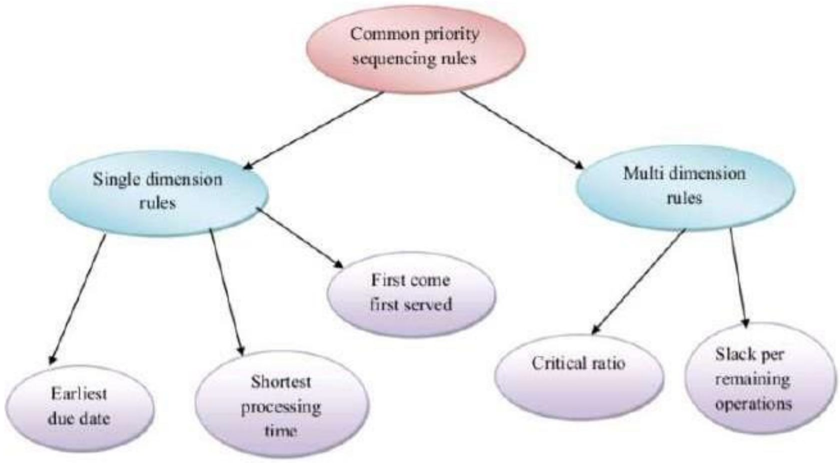


Fig – Sequencing Rules

SEQUENCING OF PRODUCTS IN MULTI - PRODUCT MULTI - STAGE

Consider a problem with five jobs (A, B, C, D, and E) and two machines M1 and M2. All five jobs consist of two operations each. The first operation of each job is processed on machineM1; and the second operation is processed on machine M2.

Table 2.1 gives the machines required for each job and the processing times for each operation of each job

Table 2.1 - Data for a 5-Job 2-Machine Flow Shop Problem

Job	*Operation #1*	*Operation #2*	*Machine for Operation #1*	*Machine for Operation #2*	*Time for Operation #1 (Days)*	*Time for Operation #2 (Days)*
A	A1	A2	M1	M2	8	3
B	B1	B2	M1	M2	5	7
C	C1	C2	M1	M2	6	9
D	D1	D2	M1	M2	7	1
E	E1	E2	M1	M2	4	6

The scheduling objective is to find an optimal sequence that gives the order in which the five jobs will be processed on the two machines to minimize make-span.

Let us find the make-span for one of the sequences, say, A–B–C–D–E, before attempting to find the optimal answer. We will draw a Gantt chart to find make-span. The sequence A–B–C–D–E tells us that A is the first job to be processed, B is the second job, and so on. E is the last job to be processed. The Gantt chart for the sequence A–B–C–D–E is given in Figure 2.17. We must assume that the sequence is the same on both machines. This is also called “no passing” in the scheduling literature. The value of make-span (time to complete all jobs) is 36 days. Our objective is to identify the sequence that minimizes the value of make-span.

Position 1	Position 2	Position 3	Position 4	Position 5

Gantt chart for sequence A–B–C–D–E																																				
Time (days)																																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
M1	A1	A1	A1	A1	A1	A1	A1	A1	B1	B1	B1	B1	B1	C1	C1	C1	C1	C1	C1	D1	D1	D1	D1	D1	D1	D1	E1	E1	E1	E1						
M2									A2	A2	A2			B2	B2	B2	B2	B2	B2	B2	C2	C2	C2	C2	C2	C2	C2	C2	C2	D2	E2	E2	E2	E2	E2	E2

Fig 2.17 – Gantt chart for sequence A–B–C–D–E

Johnson’s Rule

Johnson’s rule is a proven method to give an optimal solution. There are five sequence positions 1–5. Johnson’s rule assigns each job to one of these positions in an optimal manner. This rule also requires that the same optimal sequence is used on both machines. The rule also assumes that no preemption (no passing) is allowed which means that once ajob is started it cannot be interrupted.

We use the following four-step process to find the optimal sequence.

Step 1: Find the minimum processing time considering times on both machines.

Step 2: Identify the corresponding job and the corresponding machine for the minimumtime identified at Step 1.

Step 3: Scheduling rule

a. If the machine identified in Step 2 is machine M1, then the job identified in Step 2 will be scheduled in the first available schedule position.

b. If the machine identified in Step 2 is machine M2, then the job identified in Step 2 will be scheduled in the last available schedule position.

Step 4: Remove the job from consideration whose position has been fixed in Step 3 and goto Step 1.

Continue this process until all jobs have been scheduled.

Job	Operation #1	Operation #2	Machine for Operation #1	Machine for Operation #2	Time for Operation #1 (Days)	Time for Operation #2 (Days)
A	A1	A2	M1	M2	8	3
B	B1	B2	M1	M2	5	7
C	C1	C2	M1	M2	6	9
D	D1	D2	M1	M2	7	1
E	E1	E2	M1	M2	4	6

Fig 2.18 – Iteration 1

Iteration 1 (see Figure 2.18)

Step 1: The minimum time is 1.

Step 2: The job is D and the machine is M2.

Step 3: Since the machine identified at Step 2 is machine M2, the job D will be assigned to the last available sequence position which is position 5; and the resulting partial sequence is given below.

Step 4: Delete job D from consideration.

Position 1	Position 2	Position 3	Position 4	D

Job	Oper-ation #1	Oper-ation #2	Machine for Oper-ation #1	Machine for Oper-ation #2	Time for Oper-ation #1 (Days)	Time for Oper-ation #2 (Days)	
A	A1	A2	M1	M2	8	3	
B	B1	B2	M1	M2	5	7	
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~1~~	Scheduled
E	E1	E2	M1	M2	4	6	

Fig 2.19 – Iteration 2

Iteration 2 (see Figure 2.19)

Step 1: The next minimum time is 3.

Step 2: The job is A and the machine is M2.

Step 3: The job A will be assigned to the last available schedule position, which is position 4.After assigning job A to position 4, the partial sequence is given below.

Step 4: Delete job A from consideration

Position 1	Position 2	Position 3	A	D

Job	Oper-ation #1	Oper-ation #2	Machine for Oper-ation #1	Machine for Oper-ation #2	Time for Oper-ation #1 (Days)	Time for Oper-ation #2 (Days)	
~~A~~	~~A1~~	~~A2~~	~~M1~~	~~M2~~	~~8~~	~~3~~	Scheduled
B	B1	B2	M1	M2	5	7	
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~1~~	Scheduled
E	E1	E2	M1	M2	4	6	

Fig 2.20 – Iteration 3

Iteration 3 (see Figure 2.20)

Step 1: The minimum time is 4.

Step 2: The job is E and machine is M1.

Step 3: The job E will be assigned to the first available schedule position, which is position 1. The partial sequence after assigning job E to position 1 is given below.

Step 4: Delete job E from consideration.

E	Position 2	Position 3	A	D

Job	Operation #1	Operation #2	Machine for Operation #1	Machine for Operation #2	Time for Operation #1 (Days)	Time for Operation #2 (Days)	
~~A~~	~~A1~~	~~A2~~	~~M1~~	~~M2~~	~~8~~	~~3~~	Scheduled
B	B1	B2	M1	M2	5	7	
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~1~~	Scheduled
~~E~~	~~E1~~	~~E2~~	~~M1~~	~~M2~~	~~4~~	~~6~~	Scheduled

Fig 2.21 – Iteration 4

Iteration 4 (see Figure 2.21)

Step 1: The minimum time is 5.

Step 2: The job is B and machine is M1.

Step 3: The job B will be assigned to the first available schedule position, which is position 2. The partial sequence after assigning job B to position 2 is given below.

Step 4: Delete job B from consideration

E	B	Position 3	A	D

Job	Operation #1	Operation #2	Machine for Operation #1	Machine for Operation #2	Time for Operation #1 (Days)	Time for Operation #2 (Days)	
~~A~~	~~A1~~	~~A2~~	~~M1~~	~~M2~~	~~8~~	~~3~~	Scheduled
~~B~~	~~B1~~	~~B2~~	~~M1~~	~~M2~~	~~5~~	~~7~~	Scheduled
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~1~~	Scheduled
~~E~~	~~E1~~	~~E2~~	~~M1~~	~~M2~~	~~4~~	~~6~~	Scheduled

Fig 2.22 – Iteration 5

Iteration 5 (see Figure 2.22)

The only unscheduled job at this stage is C and it will be assigned to the remaining unassigned position 3.

The final sequence is given below.

E	B	C	A	D

Finding Make-Span

The sequence E–B–C–A–D identified by Johnson's rule guarantees the minimum value of make-span. However, Johnson's rule does not give the value of make-span. It only identifies the best sequence. The value of make-span is obtained either by drawing the Gantt chart ora computerized algorithm can be used. The Gantt chart for this optimal sequence is given in Figure 2.23. The value of make-span is 31 days.

This is the optimal answer.

Gantt chart for sequence E–B–C–A–D																																				
Time (days)																																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
M1	E1	E1	E1	E1	B1	B1	B1	B1	B1	C1	C1	C1	C1	C1	C1	A1	A1	A1	A1	A1	A1	A1	A1	D1	D1	D1	D1	D1	D1	D1						
M2					E2	E2	E2	E2	E2	E2	B2	B2	B2	B2	B2	B2	B2	C2	C2	C2	C2	C2	C2	C2	C2	C2	A2	A2	A2		D2					

Fig 2.23 – Gantt chart for sequence E–B–C–A–D.

PLANT CAPACITY

Plant capacity (production capacity) refers to the volume or number of units that can be manufactured during a given period.

➢ Factors affecting determination of Plant Capacity

a. Market demand for a product/service.
b. The amount of capital that can be invested.
c. Level of integration (i.e. vertical integration).
d. Type of technology selected.
e. Dynamic nature of all factors affecting determination of plant capacity, viz., changes in the product design, process technology, market conditions and product life cycle, etc.
f. Difficulty in forecasting future demand and future technology.
g. Obsolescence of product and technology over a period of time.

h. Present demand and future demand both over short-range, intermediate-range and long-range time horizons.

i. Flexibility for capacity additions.

Several factors have a bearing on the capacity decision.

1. Technological requirement

   For many industrial projects, particularly in process type industries, there is certain minimum economic size determined by the technological factor.

2. Input constraints

   In a developing country like India, there may be constraints on the availability of certain inputs. Power supply may be limited; basic raw materials may be scarce; foreign exchange available for imports may be inadequate. Constraints of these kinds should be borne in mind while choosing the plant capacity.

3. Investment cost

   When serious input constrains does not obtain the relationship between capacity and investment cost is an important consideration. Typically, the investment cost per unit of capacity decreases as the plant capacity increases. This relationship may be expressed as follows:

Examples suppose the known investment cost for 5,000 units of capacity for the manufacture of a certain item is Rs 10, 00,000. What will be the investment cost for 10,000 units of capacity if the capacity – cost factor is 0.6.

The derived investment cost for 10,000 units of capacity may be obtained as follows:

- C1 = 10, 00,000 * (10,000/5,000)0.6 = Rs 15, 16,000

4. Market conditions

   The anticipated market for the product or service has an important bearing on plant capacity. If the market for the product is likely to be very strong, a plant of higher capacity is preferable. If the market is likely to be uncertain, it might be advantageous to start with a smaller capacity. If the market, starting from a small base, is expected to grow rapidly, the initial capacity may be higher than the initial level of demand-further additions to capacity may be affected with the growth of market.

5. Resources of the firm

   The resources, managerial and financial, available to a firm define a limit on its capacity decision. Obviously, a firm cannot choose a scale of operations beyond its financial resources and managerial capacity.