Economics of Maintenance and Spares Management

7

This Module Includes

Economics of Maintenance and Spares Management

SLOB Mapped against the Module

To appreciate the importance and gather knowledge about processesfor spares management in mitigatingrelated risks and optimising costs.

Module Learning Objectives:

After studying this module, the students will be able to:

- Understand the difference between preventive maintenance and breakdown maintenance
- Understand the concept of maintenance management
- Understand the objective and types of spare parts management inMaintenance Management
- Understand cost control and unique problem associated with spare partsmanagement

Breakdown Maintenance

7.1

Here the production facility is run without much routine maintenance until it is breakdown. Once the machine breakdown it is taken for repair and inspected to find out the defects. After identifying the defect, the required repair is planned and the spares are procured to repair the machine. As the breakdowns are random in nature and the machine cannot be used during the repair period, production hours are lost hence the productivity is reduced. Repair maintenance is not a recommended practice, in general, but many a time many organizations prefer this, because they do not want to keep the machine idle for maintenance. But they ignore the fact that the break down repair costs more than the regular maintenance practice. It is however, an economical way of maintaining certain non-critical items whose repair and down time costs are less this way than with any other system of maintenance.

Preventive Maintenance

7.2

A system of scheduled, planned or preventive maintenance tries to minimize the problems of breakdown maintenance. It locates weak parts in all equipments, provides them regular inspection and minor repairs thereby reducing the danger of unanticipated breakdowns. The underlying principle of preventive maintenance is that prevention is better than cure. It involves periodic inspection of equipment and machinery to uncover conditions that lead to production breakdown and harmful depreciation. The system of preventive maintenance varies from plant to plant depending on the requirement of the plant. Any company, adopting the preventive maintenance should keep the record of failure of various components and equipment, which help the maintenance department to statistically analyze the failure pattern and replace the item before it fails, so that the breakdown can be eliminated. This reduces the unanticipated breakdowns, increases the availability of the equipment for production purpose, maintain optimum productive efficiency of equipment and machinery reduces the work content of maintenance job, increases productivity and safety of life of worker.

Production department or maintenance department depending on the size of the plant generally takes up preventive maintenance work. As the preventive maintenance is a costly affair, it is better to maintain records of cost (both labour, materials used and spares used) and a valuation of the work done by the department will show us what benefits are derived from preventive maintenance. The analytical approach to evaluate the work done by preventive maintenance is

(i) (Inspections incomplete) / (Inspections scheduled) × 100 should be less than 10%

(ii) (Hours worked for maintenance) / (Scheduled hours) × 100 = Performance of the department.

(iii) Down time to be given as a ratio of the available hours and to be compared against a standard to be worked out for each company or against a figure of the past. The ratio is given as:

= Down time in hours/ Available hours (where Available Hours = working days × hours per day × number of machines). Here down time is the total time of stoppage of the machine for scheduled and unscheduled maintenance work.

(iv) Frequency of break downs = (Number of break downs) / (Available machine hours)

(v) Effectiveness of planning = (Labour hours on scheduled maintenance) / (Total labour hours spent on maintenance).

OR

(Down time due to scheduled maintenance)/(Down time due to total maintenance work)

Advantages of preventive maintenance:

(i) Reduced breakdowns and downtime,

(ii) Greater safety to workers,

(iii) Fewer large scale repairs,

(iv) Less standby or reserve equipment or spares,

(v) Lower unit cost of the product manufactured,

(vi) Better product quality,

(vii) Increased equipments life and

(viii) Better industrial relations.

Routine Maintenance 7.3

It includes lubrication, cleaning, periodic overhaul; etc. This is done while the equipment is running or during pre-planned shut-downs. Running maintenance is the work which can be carried out while the facility is in service.

Maintenance Techniques

It can be discussed as under:

In some cases the loss and inconvenience due to breakdown of equipment is so high that standby equipment is kept. As soon as the original equipment fails, the standby facility is employed to avoid interruption and downtime. Standby machines are often kept to reduce the loss due to the breakdown of a key machine. Breakdown maintenance also requires use of standby machines. The main question here is how many standby machines to keep and for how long. In order to decide this, a cost benefit analysis of standby machines should be made. There are various costs involved in standby machines. First, there is interest cost on capital investment. Secondly, space is needed to keep standby machines. Thirdly, there is depreciation in the value of standby machines. Fourthly, periodic checking and servicing is necessary to keep the standby machines in good condition. The benefits of standby machines consist of protection against a complete shutdown or shut down of operations. It avoids loss of production and, therefore, it is necessary to estimate loss of future failures a table of expected costs and benefits can be prepared.

Shifting production during breakdown. Under this method spare capacity is maintained not in the form of standby machines but by allowing rest to running machines at intervals and by rotation. If one machine in a production line requires shutdown, the output is maintained by shifting to under uitilised machines in other lines. For such application, the capacities of different machines must be properly matched.

Maintenance Organization

At least 50 to 60 percent of investment of any organization is spent on Building and Production facilities. Hence, it is worthwhile to give due consideration for effective maintenance of these items. The maintenance department will looks after the upkeep of equipments, buildings and other. For effective contribution of its work, the maintenance department must have proper place in the organization and it must also have a good organizational structure. While organizing a maintenance department one must remember that there should be clear division of authority with little or no overlap. Vertical lines of authority and responsibility must be kept as short as possible. Keep the span of control to an extent of 3 to 6 for a manager. The organizational structure should be flexible. The structure should be designed to suit the types of maintenance work involved. Depending on the need, the maintenance activity may be centralized or decentralized.

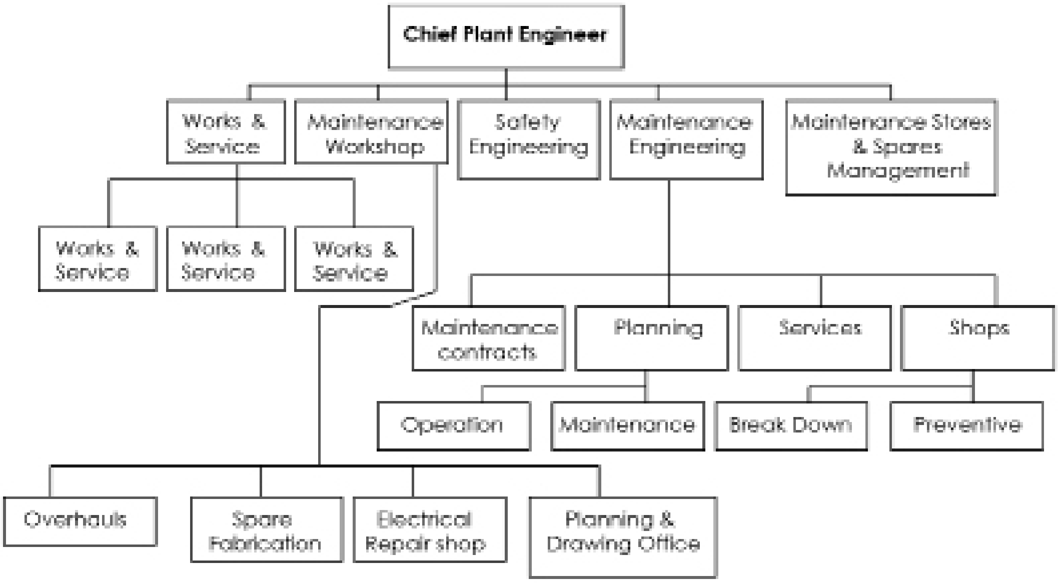


Figure 7.1: Outline of a maintenance department of a large organisation

Organizing Maintenance Work

In order to facilitate proper control of maintenance work; we must enforce three rules as below.

Maintenance Request

This must be made in writing to a central point in the organization. No work should be carried out without the knowledge and approval of maintenance superviser - if this discipline is not followed by the organization, it leads to wastage of skilled manpower and inability of the maintenance personnel to schedule essential maintenance work.

Maintenance Stores

Non-availability of vital spare parts when required to meet an emergency like breakdown, may lead to excessive shutdown of the plant and equipment. A large number of items or materials are required to be stored and it involves investing valuable funds from the working capital. A proper stores management is essential as a backup service of good maintenance.

Records of Maintenance Work Done

Paper work for maintenance is crucial for establishing a good maintenance organization and is often neglected. The records of maintenance work carried out from time to time have to be kept equipment wise. History cards or logbooks of all the plants and equipment must be compiled meticulously giving details of materials used, components replaced and time spent by the workforce.

Creation and maintaining this database is essential for proper planning and control, which alone will lead to effective and efficient maintenance.

To get the full benefits of effective maintenance the following requirement is to be fulfilled:

(i) Good Supervision and administration of maintenance department,

(ii) Good and clear instructions to be given to maintenance crew regarding the repair,

(iii) Proper control of work in coordination with production department,

(iv) Good training should be given to the maintenance personnel,

(v) Good scheduled maintenance program should be chalked out,

(vi) Proper maintenance record keeping is a must,

(vii) There should be adequate stock of spare parts, particularly insurance spares.

Maintenance Problem

The main problem in maintenance analysis is to minimise the overall cost of maintenance without sacrificing the objectives. There are two alternatives before management. One is to repair a machine or equipment only when it breaks down. This will save expense of inspection and replacement of a part before its lifetime ends. The other alternative is to replace the equipment before the expiry of its working life. This will involve cost of periodic shutdown for check up and repairs. However, it will avoid the loss due to sudden failure or breakdown.

The two types of cost - cost of premature replacement and cost of breakdown - need to be balanced. The objective is to minimise total maintenance cost and downtime. Economic analysis is helpful in finding a judicious combination of two types of maintenance. The relationship between preventive maintenance time and repair time is also significant. Preventive maintenance policy is justified only when the average downtime and its cost is less than the average time taken to carry out breakdown repairs. If the machine happens to be part of production line, the breakdown of a machine would throw the entire production line out of gear while a preventive maintenance schedule might enable the repair to be performed during a scheduled idle time of the line.

Replacement of Machine

7.4

Wear and obsolescence are the two main causes for replacement of machinery in every aspect of life. The reduction of wear is therefore a primary concern while designing appliances. Wear and tear due to passage of time and/or normal usage of plant and machinery is an accepted fact. Technological obsolescence is a major danger which business firms face in modern era. With the development of new and better techniques or equipment of performing a particular function, existing equipment and machines become uneconomical. Whenever a firm decides to switch over to new machines or improved product designs, existing machine designs are said to be obsolete. Hence, obsolescence is a major issue in the procurement and installation of machinery and equipment. A machine is technically obsolete when another machine can do the same job more efficiently, with reduced time and also at a lower cost. Technological obsolescence arises due to continuous improvements in the methods and techniques of production and sometime the rate of improvement is so fast that it becomes economical to replace the machinery before its expected life. A machine may be replaced to reduce the running costs of the concerned machine and the new machines productivity will be more. In replacement decisions, the basic problem is to decide whether to replace a machine or equipment at present or at a future date. It is, therefore, necessary to determine whether obsolescence or deterioration has reached the point where the reduction in operating costs expected from replacement justifies the net capital expenditure involved in installing the new machine and disposing of the old one.

Any function aimed at bringing back or restoring an item to its original or acceptable condition or to keep it and retain its health as well as workability is known as Maintenance.

Objectives of Maintenance:

(i) To keep all the production facilities and other allied facilities such as building and premises, power supply system, etc in an optimum working condition,

(ii) To ensure specified accuracy to products and time schedule of delivery to customers,

(iii) To keep the down time of the machine at minimum, so that the production program is not disturbed,

(iv) To keep the production cycle with in the stipulated range,

(v) To modify the machine tools to meet the augmented need for production,

(vi) To improve productivity of existing machine tools and to avoid sinking of additional capital,

(vii) To keep the maintenance cost at a minimum as far as possible, there by keeping the factory Overheads at minimum,

(viii) To extend the useful life of plant and machinery, without sacrificing the level of performance.

Illustration 1

M/s Nirmala Toolkit Pvt. Ltd. has a workshop comprising of 20 tool machines of similar type. To improve the preventive maintenance plan, the workshop manager collects the data of failure history of the machines as under

Elapsed time after Maintenance attention (in month)	Probability of failure
1	0.20
2	0.15
3	0.15
4	0.15
5	0.15
6	0.20

It costs ₹ 150 to attend a failed machine and rectify the same. Compute the yearly cost of servicing the broken down machines.

Solution:

Expected time before failure.

= 0.20×1 + 0.15×2 + 0.15×3 + 0.15×4 + 0.15×5 + 0.20×6 = 3.5 months

Therefore number or repair/machine/annum = 12/3.5

Considering 20 machines and ₹ 150 to attend a failed machine the yearly cost of servicing

= 12/3.5 × 20 × 150 = ₹ 10286.

Illustration 2

A Public transport system is experiencing the following number of breakdowns for months over the past 2 years in their new fleet of vehicles:

Number of breakdowns	**0**	**1**	**2**	**3**	**4**
Number of months this occurred	**2**	**8**	**10**	**3**	**1**

Each break down costs the firm an average of ₹ 2,800. For a cost of ₹ 1,500 per month, preventive maintenance can be carried out to limit the breakdowns to an average of one per month. Which policy is suitable for the firm?

Solution:

Converting the frequencies to a probability distribution and determining the expected cost/month of breakdowns we get:

No. of breakdowns (x)	Frequency in months (f)	Probability ($p = f/\Sigma f$)	Expected no. of breakdowns (px)
0	2	0.083	0.000
1	8	0.333	0.333
2	10	0.417	0.834
3	3	0.125	0.375
4	1	0.042	0.168
	$\Sigma f = 24$	$\Sigma p = 1$	Total 1.710 = Σpx

Expected Breakdown cost per month; Expected no. of breakdowns per month × cost of each breakdown = 1.710 × ₹ 2800 = ₹ 4788.

Preventive maintenance cost per month: -

Average cost of one breakdown/month	=	₹ 2, 800
Maintenance contract cost/month	=	₹ 1,500
Total	=	₹ 4,300

Thus, preventive maintenance policy is suitable for the firm.

Illustration 3

Indian Electronics, manufactures TV sets and carries out the picture tube testing for 2000 hours. A sample of 100 tubes was put through this quality test during which two tubes failed. If the average usage of TV by the customer is 4 hours/day and if 10,000 TV sets were sold, then in one year how many tubes were expected to fail and what is the mean time between failures for these tubes?

Solution:

The total test time = (100 tubes) × 2000 hours = 200,000 tube-hours.

There are two tubes which have failed and hence the total time is to be adjusted for the number of hours lost due to the failures during the testing.

The lost hours are computed as $= 2 \times \frac{2000}{2} = 2000$ hours.

The assumption is made here is that each of the failed tubes have lasted an average of half of the test period. Therefore, the test shows that there are two failures during (2,00,000 – 2000) = 1,98,000 tube hours of testing. During 365 days a year (four hours a day) for 10,000 tubes the number of expected failures

$\frac{1,98,000}{2} \times 10,000 \times 365 \times 4 = 147.47 = 148$ tubes approximately.

Mean time between failures = $\frac{\text{1,98,000 tubes hrs. of testing}}{\text{2 failure}}$

= 99,000 tubes hours per failure = $\frac{99,000}{4 \times 365}$ = 67.8 tubes year per failure

Illustration 4

M/s XYZ Pvt. Ltd has 50 identical machines in its facilities. The company has the recorded figure for cost of preventive maintenance (Cp) and cost of breakdown maintenance (Cb) as ₹ 20 and ₹ 100 respectively. The company wants to reduce the breakdown occurrence while minimizing Cp. Given is the data on breakdown occurance.

Probabilities of machine breakdown, by month:

Months after servicing that breakdown occurs (i)	Probability that breakdown will occur (Pi)	$i.P_i$
1	0.10	0.10
2	0.05	0.10
3	0.05	0.15
4	0.10	0.40
5	0.15	0.75
6	0.15	0.90
7	0.20	1.40
8	0.20	1.60
Total	1.00	5.40

Solution:

The mean time before failure is 5.4 months and the expected cost with no preventive maintenance would be 100 $\times \frac{50}{5.4}$ = ₹ 925.93 per month. The following calculations show B_j, the expected number of breakdowns between preventive maintenance intervals, for the possible intervals, that may be considered.

$B_1 = MP_1 = 50\,(0.10) = 5$

$B_2 = m\,(P_1 + P_2) + B_1P_1 = 50(0.10+0.05) + 5(0.10) = 8$

$B_3 = 50\,(0.10 + 0.05 + 0.05) + 8\,(0.10) + 5\,(0.05) = 11.05$

Accordingly, $B_4 = 16.75$, $B_5 = 25.63$, $B_6 = 35.5$, $B_7 = 48.72$, $B_8 = 63.46$.

The costs of various preventive maintenance intervals are summarised in the table below :

Cost of alternative preventive maintenance intervals –

Number of months between preventive services (j)	Bj Expected Number of Breakdown in j months	Expected cost/ month to Repair Breakdown $C_R \times Bj/j$	Cost per month for preventive service every j month $C_R(M)/j$	Total expected cost per month of preventive maintenance and repair
(1)	(2)	(3)	(4)	(5)
1	5.00	500.00	1000.00	1500.00
2	8.00	400.00	500.00	900.00
3	11.05	368.33	333.33	701.66
4	16.75	418.75	250.00	668.75
5	25.63	512.60	200.00	712.60
6	35.50	591.67	166.67	758.34
7	48.72	696.00	142.86	838.86
8	63.46	793.25	125.00	918.25

A policy of performing preventive maintenance every 4 months results in the lowest average cost, about ₹ 669. This amount is ₹ 257 per month less than the ₹ 926 expected cost without preventive maintenance. This policy would reduce the costs by (257 ÷ 926) × 100 = 27.75% below the cost of repairing the machines only when they breakdown.

Illustration 5

Assume the following three breakdown probability distribution

Month following Maintenance	Probability of Breakdown		
	(1)	(2)	(3)
1	0.5	0.1	0.1
2	0.1	0.1	0.1
3	0.1	0.1	0.5
4	0.1	0.1	0.1
5	0.1	0.2	0.1
6	0.1	0.4	0.1

Which, if any, of these distributions lend themselves to a preventive maintenance program? Why?

Solution:

Policy 1:

Month following Maintenance (i)	Probability of Breakdown (p)	Average free run time ($i * p$)
1	0.5	0.5
2	0.1	0.2
3	0.1	0.3
4	0.1	0.4
5	0.1	0.5
6	0.1	0.6
		∑2.5months/breakdown/machine

Therefore the average number of breakdowns for the pool of say 100 machines per month will be:

For 1 machine in 2.5 months 1 breakdown

So for 1 machine in 1 month (1/2.5) breakdown

So for 100 machines in 1 month (100/2.5) = 40 breakdowns

Policy 2:

Month following Maintenance (i)	Probability of Breakdown (p)	Average free run time ($i * p$)
1	0.1	0.1
2	0.1	0.2
3	0.1	0.3
4	0.1	0.4
5	0.2	1.0
6	0.4	2.4
		∑4.4months/breakdown/machine

Therefore the average number of breakdowns for the pool of say 100 machines per month will be:

For 1 machine in 4.4 months 1 breakdown

So for 1 machine in 1 month (1/4.4) breakdown

So for 100 machines in 1 month (100/4.4) = 22.73 breakdowns

Policy 3:

Month following Maintenance (i)	Probability of Breakdown (p)	Average free run time ($i * p$)
1	0.1	0.1
2	0.1	0.2
3	0.5	1.5
4	0.1	0.4
5	0.1	0.5
6	0.1	0.6
		∑3.3months/breakdown/machine

Therefore the average number of breakdowns for the pool of say 100 machines per month will be:

For 1 machine in 3.3 months 1 breakdown

So for 1 machine in 1 month (1/3.3) breakdown

So for 100 machines in 1 month (100/3.3) = 30.30 breakdowns

Preventive maintenance programs are generally applicable to breakdown distributions with low variability. Policy 2 has the lowest variability as no of breakdowns in a month for a pool of say 100 machines are 22.73---the lowest among three policies.

Therefore we may conclude that policy 2 could lead to a preventive maintenance program.

Illustration 6

Assume the following three breakdown probability distribution

Month following Maintenance	Probability of Breakdown
1	0
2	0.1
3	0.1
4	0.1
5	0.2
6	0.5

Let us take Average Repair Cost on breakdown C_R = ₹100 & Cost of Preventive maintenance C_{PM} = ₹75, Cost of Individual Replacement CI = ₹80, Cost of Group Replacement = ₹50/machine

For a pool of 100 machines, Could you recommend PM? When you will go for Replacement?

Solution:

Month following Maintenance (*i*)	Probability of Breakdown (*p*)	Average free run time (*i* * *p*)
1	0.0	0.0
2	0.1	0.2
3	0.1	0.3
4	0.1	0.4
5	0.2	1.0
6	0.5	3.0
		∑4.9 months/breakdown/machine

Therefore the average number of breakdowns for the pool of say 100 machines per month will be:

For 1 machine in 4.9 months 1 breakdown

So for 1 machine in 1 month (1/4.9) breakdown

So for 100 machines in 1 month (100/4.9) = 20.40816 breakdowns

Repair Policy Cost = Average number of repairs per month × Average repair cost on breakdown

= 20.40816 × 100 = ₹2,040.816.

Preventive Maintenance Costs for the Six Preventive Maintenance Cycles:

Table-I

Preventive Maintenance Cycle (n) , months	Expected Breakdowns in PM Cycle	Average No of Breakdowns per month (Col.2/ Col.1)	Expected Monthly Breakdown Cost (Col.3 x ₹100)	Expected Monthly PM Cost (₹75 x 100)/ Col.1	Expected Monthly Cost of each PM cycle (Col.4 + Col.5)
1	0	0	0.00	7500	7500.00
2	10	5	500.00	3750	4250.00
3	20	6.667	666.70	2500	3166.70
4	31	7.75	775.00	1875	2650.00
5	53	10.6	1060.00	1500	2560.00
6	106.1	17.683	1768.30	1250	3018.30

Computation of Col. 2:

Month 1: 100*0.0 = 0

Month 2: 100*(0.0+0.1) +0*0.0 = 10

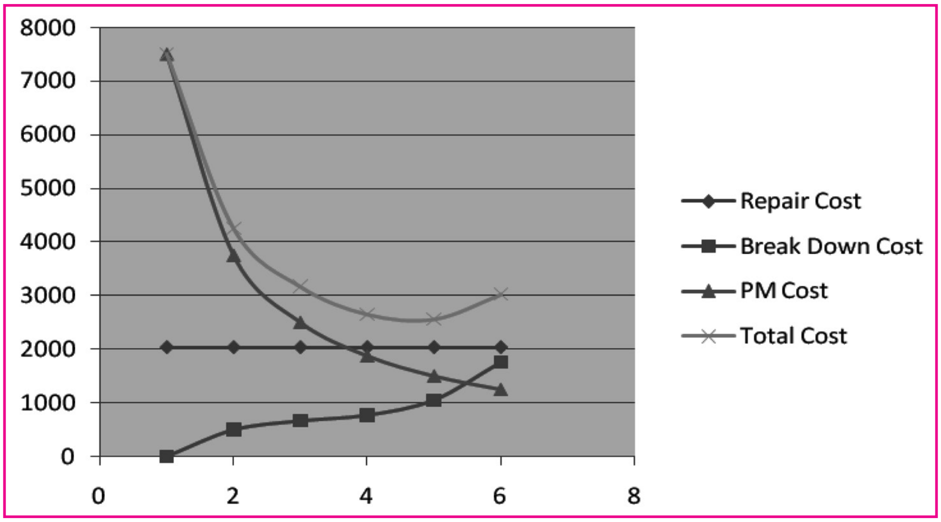
Month 3: 100*(0.0+0.1+0.1) + 0*0.1 +10*0.0 = 20

Month 4: 100*(0.0+0.1+0.1+0.1) + 0*0.1+10*0.1+20*0.0 = 31

Month 5: 100*(0.0+0.1+0.1+0.1+0.2) +0*0.1+10*0.1+20*0.1+31*0.0 = 53

Month 6: 100*(0.0+0.1+0.1+0.1+0.2+0.5) +0*0.2+10*0.1+20*0.1+31*0.1+53*0.0 = 106.1

Graphical Representation Policy 1:



So from the above it is clearly observed that PM policy is inferior to Repair policy. But will repair policy sustainable? Answer is NO. After continuing for some time with repair policy cost effectiveness of the policy will be lost and at this stage we have to replace ---either individual machines or in blocks.

To do this analysis we will follow the steps below mentioned:

Step-I: Determination of Number of failures in different weeks.

Table-II

Preventive Maintenance Cycle (n), months	Probability of Breakdown (*p*)	Expected Breakdowns in PM Cycle
1	0.0	0
2	0.1	10
3	0.1	20
4	0.1	31
5	0.2	53
6	0.5	106.1

Column 2 of Table 1

Step-2: Determination of Average Cost of Different Policies

Table-III

Months	No of Individual Replacements	Cost of Replacements			
		Individual (Col2 x 80)	Group (100 X 50)	Total (Col3 +Col4)	Average Cost (Col5/Col1)
1	0	0	5000	5000	5000
2	10	800	5000	5800	2900
3	20	1600	5000	6600	2200
4	31	2480	5000	7480	1870
5	53	4240	5000	9240	1848
6	106.1	8488	5000	13488	2248

From the table it is observed that the minimum cost per month is obtained by replacing all the machines (whether failed or not) after every 5 months. Thus optimal replacement time interval = 5 months.

But we can go for a policy "Replace as and when a machine fail" and in that case there will not be any group replacement.

To check the feasibility of "Replace as and when a machine fails" the computation will be as following:

Life (months)	Mean value (Xi)	Probability (pi)	pi x Xi
0-1	0.5	0.0	0
1-2	1.5	0.1	0.15
2-3	2.5	0.1	0.25
3-4	3.5	0.1	0.35
4-5	4.5	0.2	0.9
5-6	5.5	0.5	2.75
			4.4

Mean life of a machine is = 4.4

Expected no of failures of a machine during a week = No of Machines/ Mean life of a machine

= 100/4.4 = 22.727

Weekly replacement cost = Expected no of replacements X cost of replacements

= 22.727 X 80

= 1818.16

Since the cost of the policy of individual replacement i.e. "Replace as and when a machine fail" is less than that of the group replacement, it is advisable to go for individual replacement.

Illustration 7

Refer Illustraton No. 5. Let us take Average Repair Cost on breakdown C_R = ₹90 & Cost of Preventive maintenance C_{PM} = ₹30

Could you prove your conclusion given in A1 for a pool of 100 machines?

Answer:

Repair Policy Cost of Policy 1 = Average number of repairs per month × Average repair cost on breakdown = 40 × 90 = ₹3,600.

Data taken from Solution 5.

Preventive Maintenance Costs for the Six Preventive Maintenance Cycles:

Table-I

Preventive Maintenance Cycle (n), months	Expected Breakdowns in PM Cycle	Average No of Breakdowns per month (Col.2/ Col.1)	Expected Monthly Breakdown Cost (Col.3 x ₹90)	Expected Monthly PM Cost (₹30 x 100)/ Col.1	Expected Monthly Cost of each PM cycle (Col.4 + Col.5)
1	50.00	50.00	4500.00	3000	7500.00
2	85.00	42.50	3825.00	1500	5325.00
3	117.50	39.17	3525.30	1000	4525.30
4	152.25	38.06	3425.40	750	4175.40
5	191.38	38.28	3445.20	600	4045.20
6	236.16	39.36	3542.40	500	4042.40

Computation of Col. 2:

Month 1: 100*0.5 = 50

Month 2: 100*(0.5+0.1) +50*0.5 = 85

Month 3: 100*(0.5+0.1+0.1) + 50*0.1 +85*0.5 = 117.5

Month 4: 100*(0.5+0.1+0.1+0.1) + 50*0.1+85*0.1+117.5*0.5 = 152.25

Month 5: 100*(0.5+0.1+0.1+0.1+0.1) +50*0.1+85*0.1+117.5*0.1+152.25*0.5 = 191.38

Month 6: 100*(0.5+0.1+0.1+0.1+0.1+0.1) +50*0.1+85*0.1+117.5*0.1+152.25*0.1+191.38*0.5 = 236.16

Graphical Representation Policy 1:

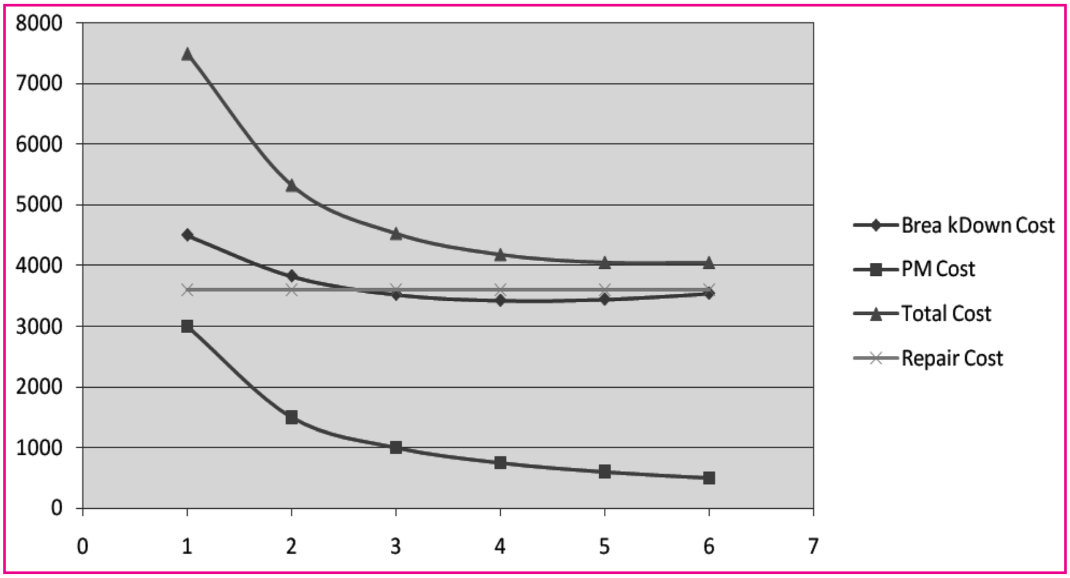


Fig -I

Repair Policy Cost of Policy 2 = Average number of repairs per month × Average repair cost on breakdown = 22.73 × 90 = ₹2,045.7 (Data taken from Solution 5).

Preventive Maintenance Costs for the Six Preventive Maintenance Cycles

Preventive Maintenance Cycle (n), months	Expected Breakdowns in PM Cycle	Average No of Breakdowns per month (Col.2/Col.1)	Expected Monthly Breakdown Cost (Col.3 × ₹90)	Expected Monthly PM Cost (₹30 × 100)/ Col.1	Expected Monthly Cost of each PM cycle (Col.4 + Col.5)
1	10.00	10.00	900.00	3000	3900.00
2	21.00	10.50	945.00	1500	2445.00
3	33.10	11.03	992.70	1000	1992.70
4	46.41	11.60	1044.00	750	1794.00
5	71.05	14.21	1278.90	600	1878.90
6	119.16	19.86	1787.40	500	2287.40

Computation of Col. 2:

Month 1: 100*0.1 = 10

Month 2: 100*(0.1+0.1) +10*0.1 = 21

Month 3: 100*(0.1+0.1+0.1) + 10*0.1 +21*0.1 = 33.1

Month 4: 100*(0.1+0.1+0.1+0.1) + 10*0.1+21*0.1+33.1*0.1 = 46.41

Month 5: 100*(0.2+0.1+0.1+0.1+0.1) +10*0.1+21*0.1+33.1*0.1+46.41*0.1 = 71.05

Month 6: 100*(0.4+0.2+0.1+0.1+0.1+0.1)+10*0.2+21*0.1+33.1*0.1+46.41*0.1+71.05*0.1= 119.16

Graphical Representation Policy 2:

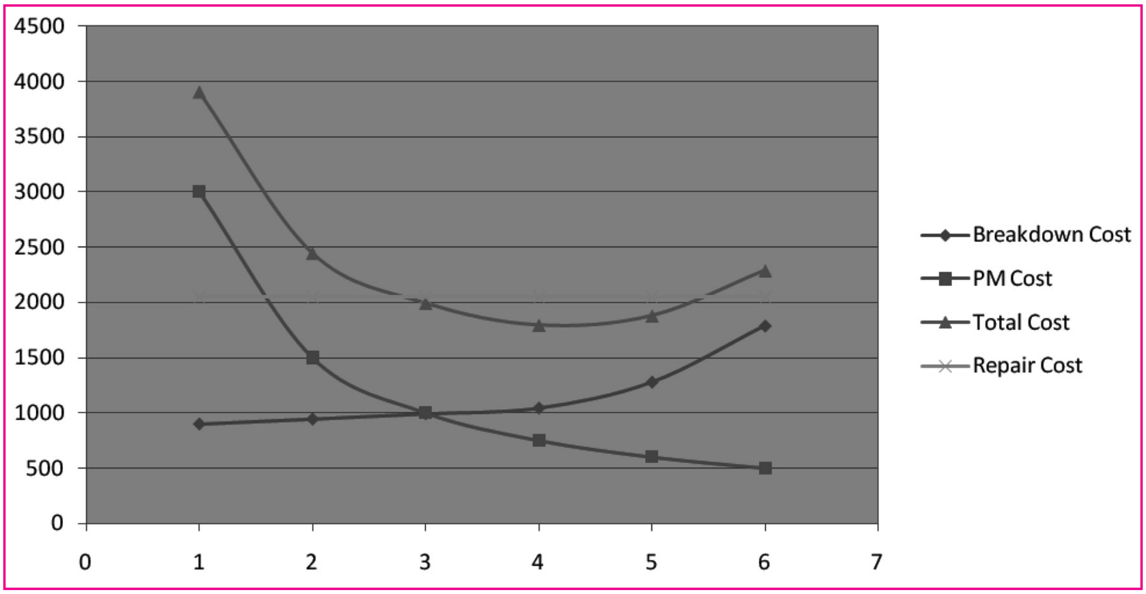


Fig -II

Repair Policy Cost of Policy 3 = Average number of repairs per month × Average repair cost on breakdown = 30.30 × 90 = ₹2,727 (Data taken from Ans 1)

Preventive Maintenance Costs for the Six Preventive Maintenance Cycles

Preventive Maintenance Cycle (n), months	Expected Breakdowns in PM Cycle	Average No of Breakdowns per month (Col.2/Col.1)	Expected Monthly Breakdown Cost (Col.3 x ₹90)	Expected Monthly PM Cost (₹30 x 100)/ Col.1	Expected Monthly Cost of each PM cycle (Col.4 + Col.5)
1	10.00	10.00	900.00	3000	3900.00
2	21.00	10.50	945.00	1500	2445.00
3	73.10	24.37	2193.30	1000	3193.30
4	94.41	23.60	2124.00	750	2874.00
5	118.25	23.65	2128.50	600	2728.50
6	160.92	26.82	2413.80	500	2913.80

Computation of Col. 2:

Month 1: 100*0.1 = 10

Month 2: 100*(0.1+0.1) +10*0.1 = 21

Month 3: 100*(0.5+0.1+0.1) + 10*0.1 +21*0.1 = 73.1

Month 4: 100*(0.1+0.5+0.1+0.1) + 10*0.5+21*0.1+73.1*0.1 = 94.41

Month 5: 100*(0.1+0.1+0.5+0.1+0.1) +10*0.1+21*0.5+73.1*0.1+94.41*0.1 = 118.25

Month 6: 100*(0.1+0.1+0.1+0.5+0.1+0.1)+10*0.1+21*0.1+73.1*0.5+94.41*0.1+118.25*0.1 = 160.92

Graphical Representation Policy 3:

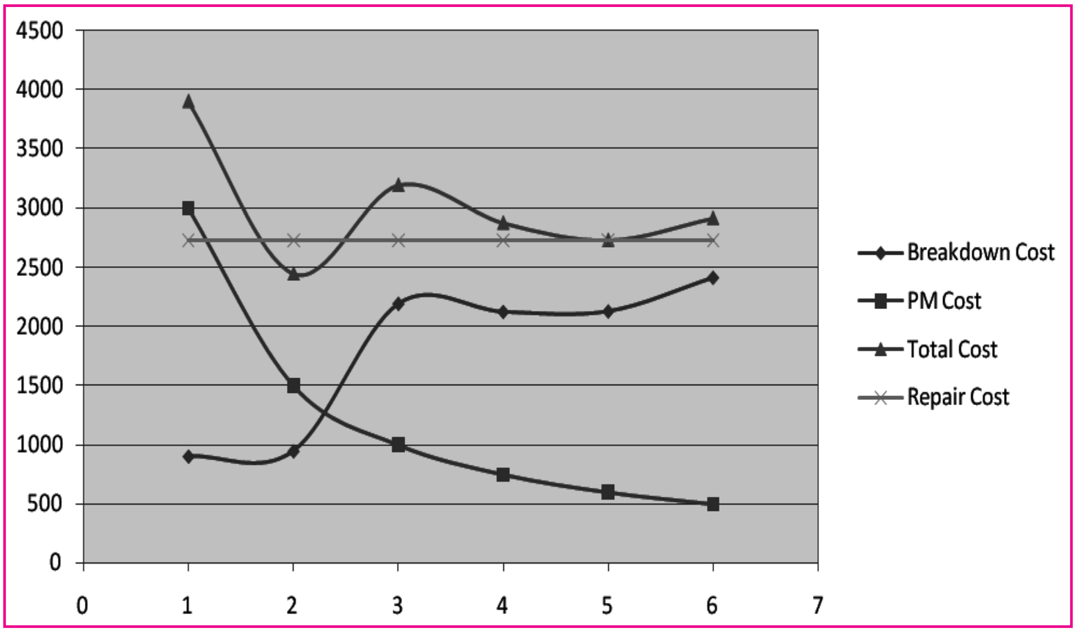


Fig-III

If we refer three graphs it is clear that –

Under Policy 1 (Fig –I) Repair cost ₹3,600 is always less than cost of all PM cycles - Refer Col.6 of Table-I. Therefore if breakdown probability distribution is like under Policy 1, management will opt for policy of repairing machine when it breaks down.

Under Policy 2 (Fig –II) PM cycle of 4 months with the cost of ₹1,794 - Refer Col.6,Row 4 of Table-II, is less than Repair cost ₹2,045.7. Therefore, if breakdown probability distribution is like under Policy 2, management will opt for PM policy of 4 months instead of going for policy of repairing machine when it breaks down. This way management can save ₹251.7.

On similar logic under policy 3 PM is preferable to Repair as and when required policy. But in comparison to policy 2, policy 3 is inferior as Repair cost under policy 2- ₹2,045.7 < Repair cost under policy 3- ₹2,727.

PM policy Cost under policy 2- ₹1,794 < PM policy Cost under policy 3- ₹2,445.

The decision concerning preventive maintenance versus Repair depends on i) factor costs C_R and C_{PM} ii) the breakdown probability distribution; besides other sensitivities.

Spare Parts Management

7.5

Spare Parts Management (SPM) is a complex activity in a large manufacturing plant as it is one of the critical enablers for providing better services to the customers during several stages of the product life cycle. Usually, SPM deals with two types of parts such as one which is required very frequently ("fast moving") and the one which is used quite rarely ("slow moving or non-moving"). While the managers keep stock for the former category, the later posits a greater challenge to the works manager. Further, given the fact of changing consumer preferences and needs coupled with technological progress, organizations are compelled to bring new products and/or differentiate the existing products every now and then, SPM invokes a methodical and record-based careful approach to provide services to the customers those who have bought the products before obsolescence or differentiation. Further, for preventive maintenance also spare parts are required often. Hence, it is necessary to maintain a comprehensive database management for SPM that helps to

(a) Keep records for specific and general purpose spare parts used in preventive and breakdown maintenance

(b) Track the movement of the spare parts and consumption pattern

(c) Plan for future maintenance activities on short and mid-term basis

(d) Demand forecasting for spare parts requirement on short, medium and long-term basis.

(e) Plan for collaboration with spare parts vendors and managing them

(f) Optimize the spare parts inventory

Preventive maintainance is very important but failure cannot be able to eliminated. To avoid failures spare parts play a vital role. Failure statistics are usefull in calculatingspare parts for preventive maintainance and breakdown maintainance also. Spares can be classified as per sevice level/understocking cost.

- **Regular spares**

  The spare parts required regularly and in substantial number.Both reliabilty and per unit cost of these items are less.

  Service level = Ku/Ku + Ko, Ku = Oppertunity cost of understock of one unit Ko = Opertunity cost of overstock of one unit.

- **Insurance spares**

  An insurance spare is a spare part that you hold in your spare parts inventory, that you would not expect to use in the, normal life of the plant and equipment but if not available when needed it would result in significant losses.

- **Capital spares**

  Capital spares are spare parts which, although acknowledged to have a long life or a small chance of failure, would cause a long shutdown of equipment because it would take along time to get a replacement for them.
  $S_{i=0}^{N-1} P_i \leq C3 - C / C3 \leq \sum Pi$

- **Rotable spares**

  Rotable items are generally thought of as items of plant or assets that periodically are changed out for repair or overall.

  The management of rotable items and repairable spare parts is different to the management of other inventory items and proper control requires greater cooperation between maintenance and stores/inventory management. The successful management of these items is far more active than other spare parts as maintenance and store/ inventory personnel must work together to ensure that there is visibility of the status of items.

Illustration 5

Compute the requirement of spares for breakdown maintenance for an item that exhibits a Poissonian behavior for failure rates with a mean breakdown rate of five items per month. If the lead time for procuring these spares is one month and a service level of 90 per cent is to be used, what buffer stock of these items should be maintained? (A fixed re-order quantity system of inventory is being used).

Solution:

Buffer stock is required to cover the lead time only, i.e. to cover one month's period.

Mean consumption rate = 5 per month

Referring to the Poisson distribution table for a = 5, we have for

x = 7. ... Cumulative probability = 0.867

x = 8 ... Cumulative probability = 0.932

Thus, with seven items only 86.7 per cent service level is attained; with eight items 93.2 per cent service level is obtained. Since one would err on the higher side of the service level, the value of x = 8 is chosen.

This means, the amount of spares stock that has to be kept must correspond to a maximum demand rate Dmax of eight during the lead time. In other words we should keep a Buffer Stock = Dmax - Daverage

during a lead time = 8 - 5 = 3 items.

Thus, buffer stock desired is three numbers of the given spare part.

Illustration 6

The main shaft of an equipment has a very high reliability of 0.990. The equipment comes from Russia and has a high downtime cost associated with the failure of this shaft. This is estimated at ₹ 2 crore as the costs of sales lost and other relevant costs. However, this spare is quoted at ₹ 10 lakh at present. Should the shaft spare be procured along with the equipment and kept or not?

Solution:

The expected cost of down-time

= (Probability of failure) × (Cost when break-down occurs)

= (1 – 0.990) × (₹ 2 crore) = ₹ 2 lakh

However, the cost of procuring the spare now is ₹ 10 lakh. Therefore, expected cost of downtime is less than the cost of spare; hence the spare need not be bought along with the equipment.

Illustration 7

PQR company has kept records of breakdowns of its machines for 300 days work year as shown below:

No. of breakdown	Frequency in days
0 1 2 3 4	40 150 70 30 10
	300

The firm estimates that each breakdown costs ₹ 650 and is considering adopting a preventive maintenance program which would cost ₹ 200 per day and limit the number of breakdown to an average of one per day. What is the expected annual savings from preventive maintenance program?

Solution :

Step 1 : To determine the expected number of breakdowns per year:

No. of breakdowns (x)	Frequency of breakdowns in days i.e, f(x)	Probability distribution of breakdowns P(x)	Expected value of breakdowns X P(x)
0 1 2 3 4	40 150 70 30 10	40/300 = 0.133 150/300 = 0.500 70/300 = 0.233 30/300 = 0.100 10/300= 0.033	Nil 0.500 0.466 0.300 0.132
Total	300	1.000	1.400

Step 2 :

Total no. of breakdowns per day = 1.40

Cost of breakdown per day = 1.40 × 650 = ₹ 910

Cost of preventive maintenance programme per day = ₹ 200+ ₹ 650 = ₹ 850

Expected annual savings from the preventive maintenance programme = (910 – 850) × 300 days

= 60×300 = ₹ 18,000

Illustration 8

A firm is using a machine whose purchase price is ₹ 15,000. The installation charges amount to ₹ 3,500 and the machine has a scrap value of only ₹ 1,500 because the firm has a monopoly of this type of work. The maintenance cost in various years is given in the following table:

Year	1	2	3	4	5	6	7	8	9
Maintenance Cost (₹)	260	760	1100	1600	2200	3000	4100	4900	6100

The firm wants to determine after how many years should the machine be replaced on economic considerations, assuming that the machine replacement can be done only at the year end.

Solution:

Cost of machine, C = ₹ 15,000 + ₹ 3,500 = ₹ 18,500

Scrap value, S = ₹ 1,500.

Year	Maintenance Cost, M_1 (₹)	Cumulative Maintenance Cost, ΣM_1 (₹)	Cost of Machine – Scrap Value (₹)	Total Cost $T_{(n)}$ (₹)	Annual Cost $A_{(n)}$ (₹)
(i)	(ii)	(iii)	(iv)	(v)= (iii)+(iv)	(vi)=(v)/n
1	260	260	17,000	17,260	17,260
2	760	1,020	17,000	18,020	9,010
3	1,100	2,120	17,000	19,120	6,373
4	1,600	3,720	17,000	20,720	5,180
5	2,200	5,920	17,000	22,920	4,584
6	3,000	8,920	17,000	25,920	4,320
7	4,100	13,020	17,000	30,020	4,288*
8	4,900	17,920	17,000	34,920	4,365
9	6,100	24,020	17,000	41,020	4,557

Lowest average cost is ₹4,288 approx., which corresponds to n = 7 in above table. Thus machine needs to be replaced every 7th year.

Illustration 9

A large computer installation contains 2,000 components of identical nature which are subject to failure as per probability distribution that follows:

Month End:	**1**	**2**	**3**	**4**	**5**
% Failure to date:	**10**	**25**	**50**	**80**	**100**

Components which fail have to be replaced for efficient functioning of the system. If they are replaced as and when failures occur, the cost of replacement per unit is ₹3. Alternatively, if all components are replaced in one lot at periodical intervals and individually replace only such failures as occur between group replacement, the cost of component replaced is ₹ 1.

(a) Assess which policy of replacement would be economical.

(b) If group replacement is economical at current costs, then assess at what cost of individual replacement would group replacement be uneconomical.

(c) How high can the cost per unit in-group replacement be to make a preference for individual replacement policy?

Solution:

(a) Computation of failures & Mean life

Month (X)	Probability of Failure (P)	P X
1	0.10	0.10
2	0.15	0.30
3	0.25	0.75
4	0.30	1.20
5	0.20	1.00
		$\Sigma p_i x_i$ = 3.35 month

Average Life of a component = 3.35 Months

Average No. of Replacements = 2000/3.35 = 597 per month

Cost of Individual Replacement = 597 × ₹ 3 = ₹ 1791 per month

Computation of expected No. of Replacements:

Month	Expected number of components to be replaced by the month end	
1	$N_1 = N_0P_1$ = 2000 × 0.1	200
2	$N_2 = N_0P_2 + N_1P_1$ = 2000 × 0.15 + 200 × 0.1	320
3	$N_3 = N_0P_3 + N_1P_2 + N_2P_1$ = 2000 × 0.25 + 200 × 0.15 + 320 × 0.1	562
4	$N_4 = N_0P_4 + N_1P_3 + N_2P_2 + N_3P_1$ = 2000 × 0.3 + 200 × 0.25 + 320 × 0.15 + 562 × 0.1	754.2
5	$N_5 = N_0P_5 + N_1P_4 + N_2P_3 + N_3P_2 + N_4P_1$ = 2000 × 0.2 + 200 × 0.3 + 320 × 0.25 + 562 × 0.15 + 754.2 × 0.1	699.72

Computation of Average cost

Month (x)	Cumulative number of component Replace individually by month end	Cost		Total Cost (Tc)	Average Cost = Tc/n
		Individual	Group		
		₹	₹	₹	₹ per month
1	200	600	2000	2600	2600
2	520	1560	2000	3560	1780
3	1082	3246	2000	5246	**1748.67***
4	1836.2	5508.6	2000	7508.6	1877.15
5	2535.92	7607.76	2000	9607.76	1921.55

Since the average cost is lowest in 3rd month, the optimal interval i.e. replacement is 3 months. Also the average cost is less than ₹ 1791 of individual replacement, **the group replacement policy is better**.

(b) Let 'K' be the cost of Individual Replacement

Month	Average Cost of Group Replacement	Average cost of Individual Replacement	'K' Value* (₹)
1	(2000 + 200 K)/1	597 K	5.04
2	(2000 + 520 K)/2	597 K	2.97
3	(2000 + 1082 K)/3	597 K	**2.82**
4	(2000 + 1836.2 K)/4	597 K	3.62
5	(2000 + 2535.92 K)/5	597 K	4.45

* To obtai the value of K use the equation Average cost of Individual Replacement = Average Cost of Group Replacement

If group replacement is anything smaller than 2.82, then Group Replacement would be uneconomical.

(c) Let 'a' be the unit cost of Group Replacement Policy

Month	Average Cost of Group Replacement	Average of Individual Replacement	'a' Value (₹)
1	(2000 a + 600)/1	1791	0.60
2	(2000 a + 1560)/2	1791	1.01
3	(2000 a + 3246)/3	1791	**1.06**
4	(2000 a + 5508.6)/4	1791	0.83
5	(2000 a + 7607.76)/5	1791	0.67

When unit cost is more than ₹ 1.06 then Individual Replacement policy would be better.

Illustration 10

An electric company which generates and distributes electricity conducted a study on the life of poles. The repatriate life data are given in the following table:

Life data of electric poles

Year after installation:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Percentage poles failing:	**1**	**2**	**3**	**5**	**7**	**12**	**20**	**30**	**16**	**4**

- If the company now installs 5,000 poles and follows a policy of replacing poles only when they fail, how many poles are expected to be replaced each year during the next ten years?

  To simplify the computation assume that failures occur and replacements are made only at the end of a year.
- If the cost of replacing individually is ₹ 160 per pole and if we have a common group replacement policy it costs ₹ 80 per pole, find out the optimal period for group replacement.

Solution:

Chart showing Optimal Replacement Period

Average life of the pole - 1 × 0.01 + 2 × 0.02 + 3 × 0.03 + 4 × 0.05 + 5 × 0.07 + 6 × 0.12 + 7 × 0.20 + 8 × 0.3 + 9 × 0.16 + 10 × 0.04 = 7.05 years.

No. of poles to be replaced every year = $\frac{5000}{7.05} = 709$

Average yearly cost on individual replacement = 709 × ₹160 = ₹1,13,440.

Group Replacement: Initial Cost = 5,000 × ₹80 = ₹4,00,000.

Year	No. of poles to be replaced	Yearly cost of individual replacement @ ₹160/pole (₹)	Cumulative cost of individual replacement (₹)	Total cost of individual replacement as well as group replacement (₹)	Average Annual Cost $= \frac{\text{TotalCost}}{\text{Year}}$ (₹)
1	5,000 × 0.01 = 50	8,000	8,000	4,08,000	4,08,000
2	5,000 × 0.02 + 50 × .01 = 101	16,160	24,160	4,24,160	2,12,080
3	5,000 × 0.03 + 50 × 0.02 + 101 × 0.01 = 152	24,320	48,480	4,48,480	1,49,493
4	5,000 × 0.05 + 50 × 0.03 + 101 × 0.02 + 152 × 0.01 = 256	40,960	89,440	4,89,440	1,22,360
5	5,000 × 0.07 + 50 × 0.05 + 101 × 0.03 + 152 × 0.02 + 256 × 0.01 = 362	57,920	1,47,360	5,47,360	1,09,472
6	5,000 × 1.2 + 50 × 0.07 + 101 × 0.05 + 152 × 0.03 + 256 × 0.02 + 362 × 0.01 = 6023	9,63,680	11,11,040	15,11,040	2,51,840

Optimal replacement at the end of the 5th year.

Illustration 11

Product A has a Mean Time Between Failures (MTBF) of 30 hours and has a Mean Time To Repairs (MTTR) of 5 hours. Product B has a MTBF of 40 hours and has a MTTR of 2 hours.

(i) Which product has the higher reliability?

(ii) Which product has greater maintainability?

(iii) Which product has greater availability?

Solution:

(i) Product B, with higher MTBF (i.e. 40 hours) than Product A (i.e. 30 hours), is more reliable since it has lesser chance of failure during servicing.

(ii) By MTTR we mean the time taken to repair a machine and put it into operation. Thus Product B, with lesser MTTR (i.e., 2 hours) than Product A (i.e., 5 hours), has greater maintainability.

(iii) Availability of a machine/product = $\frac{\text{MTBF}}{\text{MTBF + MTTR}}$

Therefore, Availability of Product A = 30/ (30+5) = 30/35 = 85.714% Availability of Product B = 40/(40+2) = 40/42 = 95.238%

Hence, Product B has more availability.

Illustration 12

Maharashtra Trucking Company (MTC) has a fleet of 50 trucks. The past data on the breakdown of the trucks show the following probability distribution (for a new truck as well as for one which has been repaired after a breakdown).

Months after Maintenance	Probability of Breakdown
1	0.10
2	0.20
3	0.30
4	0.40

Each breakdown costs ₹ 3,000 on an average; which includes cost of time lost and cost of materials and manpower.

The manager of MTC knows the importance of preventive maintenance. He estimates the costs of the preventive maintenance to be ₹ 500 per such preventive action. What should be the appropriate maintenance policy in terms of the mix of preventive and breakdown maintenance

Solution:

First, let us compute the cost of a totally breakdown maintenance policy.

The expected number of months between failures

$= 0.1\ (1) + 0.2\ (2) + 0.3\ (3) + 0.4\ (4) = 3.0$

Cost per month of totally breakdown maintenance policy

$= \frac{\text{(No. of trucks) (Cost per breakdown)}}{\text{(Expected number of months between failure)}}$

$= \frac{(50)(₹\ 3000)}{(3.0)} = ₹\ 50{,}000$

Now let us compute the costs of different periodicities of preventive maintenance.

(i) Preventive maintenance (PM) period one month

No. of breakdowns within the period of one month:

$B_1 = (50) \times (0.1) = 5$

Cost of breakdown = 5 × ₹ 3000 = ₹ 15,000

Cost of preventive maintenance = ₹ 500 × 50 = <u>₹ 25,000</u>

Total Cost during the PM period = ₹ 40,000

Therefore, cost per month for this policy is

= 40,000 ÷ 1 = ₹ 40,000

(ii) Preventive maintenance (PM) period two months

No. of breakdowns within 2 months:

$B_2 = (50) \times (0.1 + 0.2) + (50) \times (0.1) \times (0.1) = 15.5$

Cost of breakdown = (15.5) × ₹ 3000 = ₹ 46,500

Cost of prev. maintenance = ₹ 500 × 50 = ₹ 25,000

Total cost during the PM period = ₹ 71,500

Therefore, cost per month for this policy:

₹ 71,500 ÷ 2 months = ₹ 35,750

(iii) Preventive maintenance period 3 months

No. of breakdowns within 3 months:

$B_3 = (50)\times (0.1 + 0.2 + 0.3) + (50 \times 0.1) (0.1 + 0.2) + (50 \times 0.1 \times 0.1) (0.1)$

$= 30 + 1.5 + 0.05 = 31.55$

Cost of breakdown = 31.55 × ₹ 3000 = ₹ 94,650

Cost of preventive maintenance = 50 × ₹ 500 = ₹ 25,000

Total = ₹ 1,19,650

Therefore, cost per month for this policy

= ₹ 1,19,650 ÷ 3 months = ₹ 39,883.33

(iv) Preventive maintenance period 4 months

No. of breakdowns within 4 months

$B_4 = [(50) \times (1.0)] + [(50) \times (0.1) \times (0.1 + 0.2 + 0.3) + (50\times 0.1 \times 0.1) \times (0.1 + 0.2) + (50 \times 0.1 \times 0.1 \times 0.1) \times (0.1)$
$+ (50 \times 0.1 \times 0.2) \times (0.1)] + [(50 \times 0.2) \times (0.1 + 0.2) + (50 \times 0.2 \times 0.1) \times (0.1)] + [(50 \times 0.3 \times (0.1)]$
$= 57.855$

Cost of breakdown = (57.855) × (₹ 3,000) = ₹ 1,73,565

Cost of preventive maintenance = 50 × ₹ 500 = ₹ 25,000

Total = ₹ 1,98,565

Therefore, cost per month for this policy is ₹ 1,98,565 ÷ 4 months = ₹ 49,641.25

Comparing the costs per month of different policies, we see that the policy of preventive maintenance every two months is the most economic policy.

Exercise

- **Multiple Choice Questions:**

1. Number of product varieties that can be manufactured in Job production is:
   (a) Limited to one or two
   (b) Large varieties of products
   (c) One only
   (d) None of the above.

2. Number of product varieties that can be manufactured in Mass production is:
   (a) One only
   (b) Two only
   (c) Few varities in large volumes
   (d) Large varities in small volumes.

3. In general number of product varities that can be manufactured in Flow production is:
   (a) One only
   (b) Ten to twenty varities
   (c) Large varities
   (d) Five only.

4. Generally the size of the order for production in Job production is:
   (a) Small
   (b) Large
   (c) Medium
   (d) Very large.

5. Generally in continuous production the production is carried out to:
   (a) Customer's order
   (b) Government orders only
   (c) For stock and supply
   (d) Few rich customers.

6. Inventory cost per product in intermittent production is:
   (a) Higher
   (b) Lowest
   (c) Medium
   (c) Abnormal.

7. The material handling cost per unit of product in Continuous production is:
   (a) Highest compared to other systems
   (b) Lower than other systems

(c) Negligible
(d) Cannot say.

8. Routing and Scheduling becomes relatively complicated in
   (a) Job production
   (b) Batch production
   (c) Flow production
   (d) Mass production.

9. The starting point of Production cycle is:
   (a) Product design
   (b) Production Planning
   (c) Routing
   (d) Market research.

10. Variety reduction is generally known as:
   (a) Less varities
   (b) Simplification
   (c) Reduced varities
   (d) None of the above.

11. Preferred numbers are used to:
   (a) To determine the number of varities that are to be manufactured
   (b) To the test the design of the product
   (c) To ascertain the quality level of the product
   (d) To evaluate the production cost.

12. The act of assessing the future and make provisions for it is known as
   (a) Planning
   (b) Forecasting
   (c) Assessment
   (d) Scheduling.

13. For a marketing manager, the sales forecast is:
   (a) Estimate of the amount of unit sales or a specified future period
   (b) Arranging the sales men to different segments of the market
   (c) To distribute the goods through transport to satisfy the market demand
   (d) To plan the sales methods.

14. The time horizon selected for forecasting depends on:
    (a) The salability of the product
    (b) The selling capacity of Salesman
    (c) Purpose for which forecast is made
    (d) Time required for production cycle.

15. For production planning:
    (a) Shot term forecasting is useful
    (b) Medium term forecasting is useful
    (c) Long term forecasting is useful
    (d) Forecasting is not useful.

16. In general, medium range forecasting period will be approximately:
    (a) 5 to 10 Years
    (b) 2 to 3 days
    (c) 3 to 6 months
    (d) 10 to 20 years.

17. The range of Long range forecasting period may be approximately:
    (a) 1 to 2 weeks
    (b) 2 to 3 months
    (c) 1 year
    (d) above 5 years.

18. To plan for future man power requirement:
    (a) Short term forecasting is used
    (b) Long range forecasting is used
    (c) Medium range forecasting is used
    (d) There is no need to use forecasting, as future is uncertain.

19. Long range forecasting is useful in:
    (a) Plan for Research and Development
    (b) To Schedule jobs in Job production
    (c) In purchasing the material to meet the present production demand
    (d) To assess manpower required in the coming month.

20. Medium range forecasting is useful in:
    (a) To assess the loading capacity of the machine

(b) To purchase a materials for next month

(c) To plan for-capacity adjustments

(d) To decide whether to receive production orders or not.

21. To decide work load for men and machines:

(a) Medium range forecasting is used

(b) Short term forecasting is used

(c) Long range forecasting is used

(d) A combination of long range and medium range forecasting is used.

22. Important factor in forecasting production is:

(a) Environmental changes

(b) Available capacity of machines

(c) Disposable income of the consumer

(d) Changes in the preference of the consumer.

23. Application of technology or process to the raw material to add use value is known as:

(a) Product

(b) Production

(c) Application of technology

(d) Combination of technology and process.

24. In Production by disintegration the material undergoes:

(a) Change in economic value only

(b) Change in physical and chemical characteristics

(c) Change in technology only

(d) None of the above.

25. In Production by service, the product undergoes the changes in:

(a) Shape and size of the surface

(b) Shape of the surface only

(c) Size of the surface only

(d) Chemical and Mechanical properties.

26. Use of any process or procedure designed to transform a set of input elements into a set of output elements is known as:

(a) Transformation process

(b) Transformation of input to output

(c) Production

(d) Technology change.

27. Conversion of inputs into outputs is known as:

(a) Application of technology

(b) Operations management

(c) Manufacturing products

(d) Product.

28. The desired objective of Production and Operations Management is:

(a) Use cheap machinery to produce

(b) To train unskilled workers to manufacture goods perfectly

(c) Optimal utilisation of available resources

(d) To earn good profits.

29. The scope of Production Planning and Control is:

(a) Limited to Production of products only

(b) Limited to production of services only

(c) Limited to production of services and products only

(d) Unlimited, can be applied to any type of activity.

30. Manufacturing system often produces:

(a) Standardised products

(b) Standardised products in large volumes

(c) Substandardproducts in large volumes

(d) Products and services in limited volume.

31. The difference between product system and project system is:

(a) Project system the equipment and machinery are fixed where as in product system they are movable

(b) In Product system the machinery and equipment are fixed and in project system they are not fixed

(c) Project system produces only standardized products and product system produces only unstandardised products

(d) Products cannot be stocked whereas projects can be stocked.

32. Most important benefit to the consumer from efficient production system is:

(a) He can save money

(b) He will have product of his choice easily available

(c) He gets increased use value in the product

(d) He can get the product on credit.

33. Two important functions that are to be done by Production department are:
    (a) Forecasting
    (b) Costing
    (c) Scheduling and loading
    (d) Inspecting.

34. Fixing the flow lines of materials in production is known as:
    (a) Scheduling
    (b) Loading
    (c) Planning
    (d) Routing.

35. The act of releasing the production documents to the production department is known as:
    (a) Planning
    (b) Routing
    (c) Dispatching
    (d) Releasing.

36. The activity of specifying when to start the job and when to end the job is known as:
    (a) Plaining
    (b) Scheduling
    (c) Timing
    (d) Follow-up.

37. In an organisation the production planning and control department comes under:
    (a) Planning department
    (b) Manufacturing department
    (c) Personal department
    (d) R & D department.

38. In Job production system, we need:
    (a) More unskilled labours
    (b) Skilled labours
    (c) Semi-skilled labours
    (d) Old people.

39. In Continuous manufacturing system, we need:
    (a) General purpose machines and Skilled labours

(b) Special machine tools and highly skilled labours

(c) Semi automatic machines and unskilled labours

(d) General purpose machines and unskilled labours.

40. Most suitable layout for Job production is:

(a) Line layout

(b) Matrix layout

(c) Process layout

(d) Product layout.

41. Most suitable layout for Continuous production is:

(a) Line layout

(b) Process Layout

(c) Group technology

(d) Matrix layout.

42. One of the product examples for Line layout is:

(a) Repair workshop

(b) Welding shop

(c) Engineering College

(d) Cement.

43. The act of going round the production shop to note down the progress of work and feedback the information is known as:

(a) Follow up

(b) Dispatching

(c) Routing

(d) Trip card.

44. Line of Best fit is another name given to:

(a) Method of Least Squares

(b) Moving average method

(c) Semi average method

(d) Trend line method.

45. One of the important basic objectives of Inventory management is:

(a) To calculate EOQ for all materials in the organisation

(b) To go in person to the market and purchase the materials

(c) To employ the available capital efficiently so as to yield maximum results

(d) Once materials are issued to the departments, personally check how they are used.

46. The best way of improving the productivity of capital is:

(a) Purchase automatic machines

(b) Effective Labour control

(c) To use good financial management

(d) Productivity of capital is to be increased through effective materials management.

47. MRP stands for:

(a) Material Requirement Planning

(b) Material Reordering Planning

(c) Material Requisition Procedure

(d) Material Recording Procedure.

48. JIT stands for:

(a) Just in time purchase

(b) Just in time production

(c) Just in time use of materials

(d) Just in time order the material.

49. The cycle time, selected in balancing a line must be:

(a) Must be greater than the smallest time element given in the problem

(b) Must be less than the highest time element given in the problem

(c) Must be slightly greater than the highest time element given in the problem

(d) Left to the choice of the problem solver.

50. The lead-time is the time:

(a) To placeholders for materials

(b) Time of receiving materials

(c) Time between receipt of material and using materials

(d) Time between placing the order and receiving the materials.

51. Production planning deals with:

(a) What production facilities is required and how these facilities should be laid out in space available

(b) What to produce and when to produce and where to sell

(c) What should be the demand for the product in future?

(d) What is the life of the product?

52. The first stage in production planning is:
    (a) Process Planning
    (b) Factory Planning
    (c) Operation Planning
    (d) Layout planning.

53. In Process Planning we plan:
    (a) Different machines required
    (b) Different operations required
    (c) We plan the flow of material in each department
    (d) We design the product.

54. In Operation Planning:
    (a) The planner plans each operation to be done at work centers and the sequence of operations
    (b) Decide the tools to be used to perform the operations
    (c) Decide the machine to be used to perform the operation
    (d) Decide the materials to be used to produce the product.

55. Before thinking of routing, the production planner has to:
    (a) Decide the optimal allocation of available resources
    (b) To decide what type of labour to be used
    (c) To decide how much of material is required
    (d) To count how many orders he has on his hand.

56. The quantities for which the planner has to prepare production plan are known as:
    (a) Optimal quantity of products
    (b) Material planning
    (c) Quantity planning
    (d) Planning quantity standards.

57. The document, which is used to show planning quantity standards and production plan, is known as:
    (a) Planning specifications
    (b) Route sheet
    (c) Bill of materials
    (d) Operation sheet.

58. In route sheet or operation layout, one has to show:
    (a) A list of Materials to be used

(b) A list of machine tools to be used

(c) Every work center and the operation to be done at that work center

(d) The cost of product.

59. The cycle time in selected in balancing a line must be:

(a) Must be greater than the smallest time element given in the problem

(b) Must be less than the highest time element given in the problem

(c) Must be slightly greater than the highest time element given in the problem

(d) Left to the choice of the problem solver.

60. In solving a problem on LOB, the number of workstations required is given by:

(a) Cycle time/Total time

(b) Cycle time/Element time

(c) Total time/Element time

(d) Total time/ Cycle time.

61. (Total station time/Cycle time × Number of work stations) × 100 is know as:

(a) Line Efficiency

(b) Line smoothness

(c) Balance delay of line

(d) Station efficiency.

62. Final stage of production planning, where production activities are coordinated and projected on a time scale is known as:

(a) Scheduling

(b) Loading

(c) Expediting

(d) Routing.

63. Scheduling shows:

(a) Total cost of production

(b) Total material cost

(c) Which resource should do which job and when

(d) The flow line of materials.

64. Scheduling deals with:

(a) Number of jobs to be done on a machine

(b) Number of machine tools used to do a job

(c) Different materials used in the product

(d) Fixing up starting and finishing times of each operation in doing a job.

65. The study of relationship between the load on hand and capacity of the work centers is known as:

(a) Scheduling

(b) Loading

(c) Routing

(d) Controlling.

66. One of the aims of loading is:

(a) To finish the job as early as possible

(b) To minimise the material utilisation

(c) To improve the quality of product

(d) To keep operator idle time, material waiting time and ancillary machine time at minimum.

67. One of the principles of Scheduling is:

(a) Principle of optimal product design

(b) Principle of selection of best material

(c) Principle of optimal operation sequence

(d) Principle of optimal cost.

68. The method used in scheduling a project is:

(a) A schedule of breakdown of orders

(b) Outline Master Programme

(c) PERT & CPM

(d) Schedule for large and integrated work.

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

(a) Production planning

(b) Long range production planning

(c) Scheduling

(d) Aggregate planning.

70. One of the requirements of Aggregate Planning is:

(a) Both output and sales should be expressed in a logical overall unit of measuring

(b) Appropriate time period

(c) List of all resources available

(d) List of operations required.

71. In aggregate planning, one of the methods in modification of demand is:
    (a) Differential Pricing
    (b) Lay off of employees
    (c) Over time working
    (d) Sub contracting.

72. In aggregate planning one of the methods used to modification of supply is:
    (a) Advertising and sales promotion
    (b) Development of complimentary products
    (c) Backlogging
    (d) Hiring and lay off of employees depending on the situation.

73. The first stage of Production control is:
    (a) Dispatching
    (b) Scheduling
    (c) Routing
    (d) Triggering of production operations and observing the progress and record the deviation.

74. The act of releasing the production documents to production department is known as:
    (a) Routing
    (b) Scheduling
    (c) Expediting
    (d) Dispatching.

75. One of the important production documents is:
    (a) Design sheet of the product
    (b) List of materials
    (c) Route card
    (d) Control chart.

76. One of the important charts used in Programme control is:
    (a) Material chart
    (b) Gantt chart
    (c) Route chart
    (d) Inspection chart.

77. The way in which we can assess the efficiency of the production plant is by:
    (a) Efficient dispatching

(b) By manufacturing a good product

(c) By comparing the actual performance with targets specified in the specified programme

(d) By efficient production planning.

78. Production control concerned with:

(a) Passive assessment of plant performance

(b) Strict control on labours

(c) Good materials management

(d) Good product design.

79. When work centers are used in optimal sequence to do the jobs, we can:

(a) Minimise the set up time

(b) Minimse operation time

(c) Minimise the break down of machines

(d) Minimise the utility of facility.

80. The act of going round the production shop to note down the progress of work and feedback the information is known as:

(a) Follow up

(b) Dispatching

(c) Routing

(d) Trip card.

81. One of the activities of expediting is:

(a) To file the orders in sequence

(b) To decide the sequence of operation

(c) To record the actual production against the scheduled production

(d) To examine the tools used in production.

82. 'Z' chart is a chart used in:

(a) Programme control

(b) Job control

(c) Cost control

(d) Quality control.

83. Z-chart can be used to show:

(a) Process used in production

(b) Quality level of the product

(c) Both the plan and the performance, and deviation from the plan

(d) To show cost structure of the product.

84. Computers are used in Production control in this area:

(a) Follow-up activity

(b) To control labour

(c) To disseminate information

(d) Loading, Scheduling and Assignment works.

85. The following establishes time sequence of operations:

(a) Routing

(b) Sequencing

(c) Scheduling

(d) Dispatching

86. Arrangement of machines depending on sequence of operations happens in:

(a) Process Layout

(b) Product Layout

(c) Hybrid Layout

(d) Group Technology Layout.

87. Linear Programming is a technique used for determining:

(a) Production Programme

(b) Plant Layout

(c) Product Mix

(d) Manufacturing sequence.

88. Issuing necessary orders, and taking necessary steps to ensure that the time targets set in the schedules are are effectively achieved is known as:

(a) Routing

(b) Dispatching

(c) Scheduling

(d) Inspection.

89. Preventive maintenance is useful in reducing:

(a) Inspection Cost

(b) Shutdown Cost

(c) Cost of pre- mature replacement

(d) Set-up cost of machine

90. One of the important charts used in Programme control is:
    (a) Material chart
    (b) Gantt chart
    (c) Route chart
    (d) Inspection chart.

91. Generally the size of the order for production in Job production is:
    (a) Small
    (b) Large
    (c) Medium
    (d) Very large.

92. One of the product examples for Line Layout is :
    (a) Repair Workshop
    (b) Welding shop
    (c) Engineering College
    (d) Cement.

93. The card which is prepared by the dispatching department to book the labour involved in each operation is :
    (a) Labour card
    (b) Wage card
    (c) Credit card
    (d) Job card.

94. Cost reduction can be achieved through :
    (a) Work sampling
    (b) Value analysis
    (c) Quality assurance
    (d) Supply chain management.

95. Addition of value to raw materials through application of technology is :
    (a) Product
    (b) Production
    (c) Advancement
    (d) Transformation.

96. (Total station time/cycle time × Number of work stations) × 100 is known as
    (a) Line efficiency

(b) Line smoothness

(c) Balance delay of line

(d) Station efficiency

97. The most powerful and popular method for solving linear programming problem is
    (a) Simplex method
    (b) Graphical method
    (c) Transportation method
    (d) Assignment method

98. Most suitable layout for continuous production is
    (a) Line layout
    (b) Process layout
    (c) Group technology
    (d) Matrix layout

Answer:

1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
b	c	a	a	c	a	b	b	d	b	a	b	a	c	a	c	d	b	a	c
21.	**22.**	**23.**	**24.**	**25.**	**26.**	**27.**	**28.**	**29.**	**30.**	**31.**	**32.**	**33.**	**34.**	**35.**	**36.**	**37.**	**38.**	**39.**	**40.**
b	b	b	b	d	c	b	c	d	a	b	c	c	d	c	b	b	b	b	c
41.	**42.**	**43.**	**44.**	**45.**	**46.**	**47.**	**48.**	**49.**	**50.**	**51.**	**52.**	**53.**	**54.**	**55.**	**56.**	**57.**	**58.**	**59.**	**60.**
a	d	a	a	c	d	a	b	c	d	a	b	c	a	a	d	a	c	c	d
61.	**62.**	**63.**	**64.**	**65.**	**66.**	**67.**	**68.**	**69.**	**70.**	**71.**	**72.**	**73.**	**74.**	**75.**	**76.**	**77.**	**78.**	**79.**	**80.**
a	a	c	d	b	d	c	c	d	a	a	d	d	d	c	b	c	a	a	a
81.	**82.**	**83.**	**84.**	**85.**	**86.**	**87.**	**88.**	**89.**	**90.**	**91.**	**92.**	**93.**	**94.**	**95.**	**96.**	**97.**	**98.**		
c	a	c	d	c	b	c	b	b	b	a	d	d	b	b	a	a	a		

State True or False.

1. Method Study should precede Work Measurement.
2. Merit Rating is used to determine the cost of a product.
3. Production planning is an essential function in a factory.
4. Training boosts employee morale.
5. A good Materials Handling system always consists of conveyors.
6. Increased productivity leads to cost reduction.

7. Project costs increase as the duration of the project increases.
8. When demand does not exist in the market, we should start Production Incentives.
9. A work stoppage generally reduces the cost of production.
10. No handling is the best handling.
11. It is desirable to conduct work measurement after Method study.
12. Job Evaluation is used to measure absolute job worth.
13. Incentive scheme is introduced by Management with a view to reduce direct labour cost.
14. The increase in productivity can be attributed to the application of Industrial Engineering/Techniques, particularly the work study.
15. Operation process chart incorporates all five symbols.
16. Multiple Activity chart deals with layout problems.
17. Standard performance is the natural rate of working of an average operator when he works tinder proper supervision but without any financial motivation.
18. Allowances for non-availability of materials power failure and breakdown of machines are provided for in the standard time for an operation/job.
19. In carrying-out Job Evaluation studies, point system is the best method.
20. It is justified to consider the effect of working condition both in Work Measurement and Job-Evaluation.
21. Increase in productivity leads to retrenchment of work force.
22. In view of rapid technological advancement we would not concentrate on labour productivity.
23. Piece wage system is a substitute for proper supervision.
24. Personnel Manager has nothing to do with productivity. It is the job of Technical Personnel.
25. Ranking is one of the Job Evaluation Techniques.
26. Results available from work sampling study is not 100% accurate.
27. Since breakdown of Plant and machineries is a random phenomenon, it is impossible to do any work measurement in Maintenance Area.
28. Job Evaluation does not help in performance Rating i. There is no difference between Method study and Value Engineering.
29. Two-handed process chart is the most suitable Recording Technique in Electronics Assembly Industry.
30. Project cost increases as the duration of the project increases.
31. With increase in lot size the setup cost per unit decreases, whereas the inventory carrying cost increases.
32. If the total float value is zero, it means the resources are just sufficient to complete the activity without delay.
33. A special purpose Machine Tool performs only a limited number of specialised operations with great speed and precision.
34. Strikes and lock-out are controllable factors affecting Capacity Planning.

35. Incentives are substitute for lower wages.
36. Linear Programming does not consider uncertainties
37. Depending on the need, the maintenance activity may be centralized or decentralized.
38. In general, long-range forecasting is more useful in production planning.
39. A work stoppage generally reduces the cost of production.
40. There is a limit beyond which labour productivity cannot be improved.
41. When demand does not exist in the market, we should start Production Incentives.
42. Breakdown maintenance doesn't require use of standby machines.
43. Activity Sampling is not a technique of Job Evaluation.
44. A good plant layout is one of the factors in effective utilization of labour.

Answer:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T	F	T	T	F	T	T	F	F	T	T	F	F	T	T
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
F	F	F	T	T	F	F	F	F	T	T	F	F	F	T
31	32	33	34	35	36	37	38	39	40	41	42	43	44	
T	T	T	F	F	T	T	F	F	T	F	F	T	T	

Fill up the blanks

1. Statistical analysis is used to determine the optimum policy of _________ maintenance.
2. Watch and ward personnel are responsible for _________ aspects in a factory.
3. General purpose machine are less prone to _________ .
4. The pattern shop in a factory should ideally be near the _________ .
5. Factor Comparison is a method of _________ .
6. Taylor originated the idea of _________ relationships in an organisation.
7. _________ cannot be delegated.
8. Ergonomics is another name for _________.
9. Gantt chart is used for _________ control.
10. _________ focuses on such areas as inventory goals and wages budgets.
11. IBFS is optimal and unique when all numbers in the _________ are non-negative.
12. The investment on machines in a straight line layout is _________ than the investment on machines in a functional layout.
13. To evaluate the work done by preventive maintenance, _________ is derived at from the total time of stoppage of the machine for scheduled and unscheduled maintenance work.

14. In linear programming, the word 'linear' establishes certain relationships among different _________ .
15. _________ is the interval between placing an order for a particular item and its actual receipt.
16. Product is a combination of potential utilities for a _________ .
17. A jig contains a device for guiding the _________ .
18. Machines are purchased or replaced to _________ the productive capacity.
19. _________ can be determined using the Northwest Corner Rule.
20. A _________ is an appliance which holds the work when it is machined.
21. _________ systems replace human beings to read data from products and documents and interpret the data.
22. The user's expectation method of _________ provides a subjective feel of the market.
23. _________ control is typically found wherever a particular bottleneck machine exist in the process of manufacturing.
24. General purpose machines are less prone to _________.

Answer:

1.	preventive	**2.**	security
3.	obsolescence	**4.**	foundry
5.	job evaluation	**6.**	functional
7.	responsibility	**8.**	human engineering
9.	production	**10.**	Short-range planning
11.	Net Evaluation Table	**12.**	Higher
13.	Down time	**14.**	Variables
15.	Lead time.	**16.**	Consumer.
17.	Tools.	**18.**	Increase
19.	IBFS	**20.**	Fixture
21.	Barcode	**22.**	Sales forecasting
23.	Load	**24.**	Obsolescence