Block-VI

Project & Operations Management

Operations Control

Block

VI

OPERATIONS CONTROL

Ref. No. POM SLM 102021B6

For any clarification regarding this book, the students may please write to The ICFAI Foundation for Higher Education (IFHE), Hyderabad specifying the unit and page number.

While every possible care has been taken in type-setting and printing this book, The ICFAI Foundation for Higher Education (IFHE), Hyderabad welcomes suggestions from students for improvement in future editions.

Our E-mail id: cwfeedback@icfaiuniversity.in

Center for Distance and Online Education (CDOE)
The ICFAI Foundation for Higher Education
(Deemed-to-be-University Under Section 3 of UGC Act, 1956)
Donthanapally, Shankarapalli Road, Hyderabad- 501203.

BLOCK VI: DESIGN OF FACILITIES AND OPERATIONS PLANNING

The sixth block of the course on Project & Operations Management deals with operations control. The block contains six units. The first unit explains operations scheduling. The second unit focuses on enterprise resource planning. The third unit examines the concept of supply chain management. The fourth unit deals with Just-In-Time manufacturing system. The fifth unit discusses productivity and quality management, and the sixth unit deals with facilities and maintenance management.

The first unit, *Operations Scheduling*, discusses the purpose of scheduling. The unit focuses on the various scheduling methods and activities. It deals with scheduling by type of operations, and scheduling personnel in service operations. The unit also provides an idea about the various techniques used for scheduling.

The second unit, *Enterprise Resource Planning*, deals with evolution of enterprise resource planning (ERP). The unit also explains the concepts of business process reengineering, and business modeling for ERP. It discusses the implementation of ERP. The unit also deals with the use of ERP by organizations to gain a competitive advantage.

The third unit, *Supply Chain Management*, provides an idea about the business drivers in supply chain management. The unit explains the principles of supply chain management, the forces shaping supply chain management. It discusses the supply chain management framework, and the customer focus in supply chain management. It also examines electronic supply chain management.

The fourth unit, *Just-In-Time (JIT) Management System*, explains the concept and importance of JIT system. The unit discusses the advantages of JIT systems. It also examines the characteristics of JIT systems.

The fifth unit, *Productivity and Quality Management*, discusses about productivity, and the strategic role played by quality. The unit discusses the vital role played by inspection in quality control, and the concept of cost of quality. It also explains the statistical concepts in quality control, and about acceptance plans. The unit also examines the use of computers in quality control, and the concept of total quality management.

The sixth unit, *Facilities and Maintenance Management*, discusses facilities management, and the necessity of maintenance management. The unit explains the various types of maintenance, and the economics of maintenance. It examines how to evaluate the preventive maintenance policies, and the modern approaches to preventive maintenance. The unit also deals with the recent trends in maintenance.

Unit 25

Operations Scheduling

Structure

25.1 Introduction

In the last unit of the previous block, we have discussed materials management. We have learnt that materials management encompasses all operations management functions from purchasing to the final delivery of the end items. In this unit, we will discuss operations scheduling.

Scheduling is a process of setting up operation processing times so that jobs will be completed on time. Scheduling of operations helps in providing the best service to customers by making efficient use of the firm's resources.

This unit will discuss the purpose of scheduling. We will discuss the various scheduling methods and activities. We shall then move on to discuss the scheduling by type of operations, and scheduling personnel in service operations. Finally, we would discuss the various techniques used for scheduling.

25.2 Objectives

By the end of this unit, students should be able to:

- State the purpose of scheduling.
- Discuss the various scheduling methods and activities.
- Define scheduling by type of operations.
- Evaluate the role played by scheduling personnel in service operations.
- Explain the various scheduling techniques.

25.3 Purpose of Scheduling

Scheduling of operations helps in maximizing customer satisfaction and minimizing service delays. By properly scheduling their operations, firms can make the optimum allocation of their production capacity and resources to meet customer requirements on time, carry out the production process most efficiently, reduce costs, and increase profitability. Scheduling high capacity would result in facilities remaining idle for a time and in wastage of resources whereas scheduling low capacity would result in incomplete jobs at the specified time, resulting in poor customer service. So firms have to develop their schedules in such a way that the resources are optimally allocated to meet customer requirements.

25.4 Scheduling Methods

Many methods can be used for scheduling operations. Selection of a scheduling method depends mainly on the volume of production and the nature of the operation. Scheduling operations are classified into: forward scheduling, backward scheduling, and a combination of both.

25.4.1 Forward Scheduling

In this method, the actual production activities start when a job order is received. The operations manager schedules each operation forward in time starting from the date of production. This method is used to determine the start and finish times for jobs to be done by assigning them to the earliest available time slots at the work center. Forward scheduling is used in fabrication operations where products are customized based on customer specifications.

25.4.2 Backward Scheduling

In this method, orders are scheduled based on their due dates. The operations manager obtains the due dates for the job orders and develops the schedule backward, thereby determining the latest point when the production activity can be started in order to complete the order on time. The start and finish times for jobs are assigned to the latest available time slots. This method is also used in service organizations when the demand for services is anticipated earlier.

Depending on the nature of the job, firms use either forward or backward scheduling. Both these methods are also useful to wholesalers and retailers. For example, wholesalers use forward scheduling for replenishing stock, while backward scheduling is used for making arrangements for special events like marriages.

Example: Gamma Machines Limited has two job orders, X and Y. Both orders have to be processed on two machines 1 and 2. The route sheets for the jobs are given in the table. Both the jobs should be ready in the next eight hours and both the machines are to start processing now. Develop schedules for both the jobs using forward and backward scheduling.

Job X Route Sheet			Job Y Route Sheet		
Routing Sequence	**Machine**	**Processing Time (hours)**	**Routing Sequence**	**Machine**	**Processing Time (hours)**
1	1	2	1	1	2
2	2	3	2	2	3
3	1	1			
Total		**6**	**Total**		**5**

Solution:

		Forward Scheduling						Backward Scheduling					
		M 1			M 2			M1			M 2		
Cumulative Time (Hours)	8					Y2			X3			Y2	
	7											X2	
	6		X3										
	5					X2							
	4		Y1						X1			Y2	
	3												
	2		X1						Y1				
	1												

Activity: Classy Machines Limited has two job orders, A and B. Both orders have to be processed on two machines 1 and 2. The route sheets for the jobs are given in the table. Both jobs should be ready in the next eight hours and both the machines are to start processing now. Develop schedules for both the jobs using forward and backward scheduling.

Job A Route Sheet			Job B Route Sheet		
Routing Sequence	**Machine**	**Processing Time (hours)**	**Routing Sequence**	**Machine**	**Processing Time (hours**
1	1	3	1	1	3
2	2	1	2	2	2
3	1	2			
Total		**6**	**Total**		**5**

Answer:

Check Your Progress - 1

1. In which type of scheduling method, are orders scheduled according to their due dates?
   a. Forward
   b. Backward
   c. Routing
   d. Hybrid
2. Which of the following is **not** a basic objective of scheduling activities?
   a. To meet customer requirements on time
   b. To carry out the production process most efficiently
   c. To minimize service delays
   d. To minimize inventory costs

Exercises

(Questions A to F)

Use the following table to answer the following **six** questions. The table shows two jobs on two machines and their respective routing sequences. Both jobs should be completed in 9 hours.

Job X Route Sheet			**Job Y Route Sheet**		
Routing Sequence	**Machine**	**Processing Time (hours)**	**Routing Sequence**	**Machine**	**Processing Time (hours**
1	1	3	1	2	2
2	2	2	2	1	3
3	1	2		2	1
Total		**7**	**Total**		**6**

A. What will be the representation of forward scheduling for Jobs X and Y?

B. What will be the representation of backward scheduling for Jobs X and Y?

C. Using forward scheduling, what is the earliest finish time of Job X?

D. What is the earliest finish time of Job Y in forward scheduling?

E. What is the latest start time for Job X in backward scheduling?

F. What is the latest start time for Job Y in backward scheduling?

25.5 Scheduling Activities

The scheduling process involves three activities: routing, loading, and dispatching.

25.5.1 Routing

Routing gives the specifications of the work-flow. It provides the sequence of operations and processes to be followed in order to produce a particular product. Routing determines what work is to be done, and where and how it is to be done. The operations manager develops routing sheets (hard copy) or routing files (electronic copy for computerized organizations) that provide detailed information regarding the sequence in which a product is manufactured.

25.5.2 Loading

Loading is the process of assigning specific jobs to each work center for the planning period. The capacity limitations of each work center have to be considered for loading in order to assign jobs to the work centers. In general, operations managers load jobs onto a work center up to its standard capacity. Loading helps in minimizing costs by reducing machine idle time, the amount of inventory, etc. It also includes the task of sequencing jobs so that the machine idle times are minimized and the jobs are completed within the least possible time.

25.5.3 Dispatching

Dispatching is the final act of releasing job orders to the workers to go ahead with the production process. The following dispatching or priority rules are used by manufacturing and service firms for scheduling their production activities:

- *Earliest due date* – In this method, firms prioritize their jobs based on their earliest due date.
- *Longest processing time* – In this method, jobs that have the longest processing time are loaded first onto the work center as they are considered more valuable to the organization.
- *Shortest processing time* – In this method, firms prioritize their jobs on the basis of the shortest processing time of jobs. Under this rule, jobs with shorter processing times get completed earlier than jobs with longer processing times. This rule ensures that minimum number of jobs are left for processing.
- *First in, first serve* – In this method, firms process their jobs in the order of their arrival.
- *Slack time remaining (STR)* – In this method, the slack time of each job is calculated which is the difference between the time remaining in the due date and the processing time required.

Example: Fifth Avenue Bakery specializes in making deliveries of varieties of chocolate cakes. Due to the Christmas season and New Year, the orders have increased. On a particular day, the following are the movements of the customers:

Customer	Arrival	Making Time (Hours)	Due Time (Hours)
A	9 am	4	6
B	11 am	3	4
C	1 pm	5	8
D	3 pm	1	2
E	5 pm	2	3

Earliest Due Date, Longest Processing Time, Shortest Processing Time, First In First Serve, and Slack Time Remaining. Also calculate the average delay of a job in each case.

Solution:

a. Earliest Due Date

The order of jobs according to their earliest due date is, D – E – B – A – C.

Customer	Making Time	Due Time	Flow Time	Delay
D	1	2	0+1=1	0
E	2	3	1+2=3	0
B	3	4	3+3=6	2
A	4	6	6+4=10	4
C	5	8	10+5=15	7

b. Longest Processing Time

The order of jobs according to their longest processing time is, C – A – B – E – D.

Customer	Making time	Due time	Flow time	Delay
C	5	8	0+5=5	0
A	4	6	5+4=9	3
B	3	4	9+3=12	8
E	2	3	12+2=14	11
D	1	2	14+1=15	13

c. Shortest Processing Time

The order of jobs according to their shortest processing time is, D – E – B – A – C.

Customer	Making time	Due time	Flow time	Delay
D	1	2	0+1=1	0
E	2	3	1+2=3	0
B	3	4	3+3=6	2
A	4	6	6+4=10	4
C	5	8	10+5=15	7

d. First In First Serve Schedule

The arrival of the jobs is in the order A – B – C – D – E.

Customer	Making time	Due time	Flow time	Delay
A	4	6	0+4=4	0
B	3	4	4+3=7	3
C	5	8	7+5=12	4
D	1	2	12+1=13	11
E	2	3	13+2=15	12

e. Slack Time Remaining

The slack times of the jobs A, B, C, D, and E are (6-4), (4-3), (8-5), (2-1), and (3-2) respectively. B, D, and E have the same slack time values. Since the processing time of D is lower than the processing times of B and E, job D is dispatched before jobs B and E. Similarly, since the processing time of E is lower than the processing time of B, job E will be dispatched before job B. Therefore, the order of jobs according their slack time remaining is D – E – B – A – C.

Customer	Slack Time	Making Time	Due Time	Flow Time	Delay
D	2-1 = 1	1	2	0+1=1	0
E	3-2 = 1	2	3	1+2=3	0
B	4-3 = 1	3	4	3+3=6	2
A	6-4 = 2	4	6	6+4=10	4
C	8-5 = 3	5	8	10+5=15	7

The average delay for the job is (0+0+2+4+7)/5 = 13/5 = 2.6 hours.

Activity: Kubera Printer Works is involved in printing and binding works. The company has received orders from four customers P, Q, R, and S (in the same order) at the beginning of the week.

Customer	Making Time (hours)	Due Time (hours)
P	3	4
Q	5	7
R	4	6
S	2	5

Find out the order in which these customers are to be served considering the following:

Earliest Due Date, Longest Processing Time, Shortest Processing Time, First In First Serve, and Slack Time Remaining. Also calculate the average delay of a job in each case.

Answer:

Check Your Progress - 2

3. In which scheduling activity is the capacity limitation of each work center to be considered while assigning jobs?
   a. Loading
   b. Sequencing
   c. Expediting
   d. Routing
4. Which scheduling activity describes the 'specification of work flow' in operations scheduling?
   a. Routing
   b. Loading
   c. Dispatching
   d. All of the above

5. Assigning specific jobs to each work center for the planning period is called _____.
   a. Routing
   b. Loading
   c. Dispatching
   d. None of the above
6. Which of the following dispatching rules do firms use when they want to maximize the number of completed jobs and reduce the number of jobs in waiting?
   a. Longest processing time
   b. Shortest processing time
   c. First in, first serve
   d. Slack time remaining

Exercises

(Questions G to Q)

Sriram Welders undertakes customized welding and fabrication works for different customers across the country. Jobs A, B, C, D and E are to be taken up at the beginning of the week. Processing times and due dates for these jobs are given in the following table. Use this data to answer the following **eleven** questions.

Job (In Order of Arrival)	Processing Times (days)	Due date (Days Hence)
A	4	4
B	5	8
C	4	6
D	2	5
E	3	7

G. What is the order in which jobs are taken for processing using the earliest due date rule?

H. What is the average time of a job using the earliest due date rule?

I. The shortest processing time among all jobs is for job D. What is the total delay for job D if the longest processing time rule is used?

J. What is the average delay using the longest processing time rule?

K. What is the delay for the last job processed using the first in-first serve rule?

L. What is the average delay when the first in-first serve rule is used?

M. Using the slack time remaining (STR) rule, the job with the shortest slack time is dispatched first. Which of the following jobs have the shortest slack time?

N. What is the time delay for the last job processed using the slack time remaining (STR) rule?

O. What is the average delay if the STR rule is used to dispatch jobs?

P. What is the average time if the shortest processing time rule is used?

Q. Which dispatching rule would you suggest to Sriram Welders if the objective is to reduce the average delay in the work?

25.6 Scheduling by Type of Operations

Operations managers have to schedule inventories for manufacturing operations, undertake coordination between vendors and workers, ensure that there is no wastage of resources, and also make sure that the idle time of the machinery and the equipment is minimal. In service operations, services are delivered only when they are demanded. Therefore, scheduling should be done based on demand requirements rather than on inventory requirements.

25.6.1 Job Operations

Job operations involve manufacturing of products or delivery of services in low volumes on the basis of orders. Therefore, there are considerable variations in the materials used, set up time, etc. Scheduling is done as per the customers' requirements. Gantt charts, job sequencing methods, and critical ratio are the methods used for scheduling these operations.

25.6.2 Repetitive Operations

Repetitive or continuous operations involve mass production of a product or a service. Therefore, there are few variations in the production process. These operations use trained labor and equipment designed for a narrow range of applications. There is a need to control flow of materials and application of labor resources to minimize idle time. Scheduling for these operations focuses on matching customer demand with the production activities of the firm and avoiding delays in the flow of materials. JIT principles and queuing analysis are the methods used for scheduling these operations.

25.6.3 Labor-Intensive Operations

As the work involved in labor-intensive operations is routine, managers consider the opinions of employees while scheduling their work times. Operations managers use certain personnel-related scheduling approaches like:

- *Flextime* – Employees choose their work timings, provided that a specified number of hours are completed in a week.
- *Flextour* – Employees choose their start time, but must work each day for eight hours.
- *Staggered times* – Employees select their work hours from a list of available shifts.

- *Compressed workweek* – Employees work for ten hours a day for four days in a week.
- *Part time* – Employees work for less than forty hours, usually twenty hours per week on a temporary basis. The benefits that firms derive by using part-time workers are reduced personnel costs as part-time workers do not get any fringe benefits and improved performance of the firm as part-time workers are less likely to find their jobs monotonous. The benefit to the employees is that a part-time job can be taken up in addition to a regular job.

25.6.4 Service Operations

Scheduling service operations is different from scheduling manufacturing operations as services cannot be stored to meet the demand at peak hours. For example, unused seats in a plane cannot be stored for future use. Demand fluctuates highly in service operations. For example, a deadline to pay telephone bills creates a peak in demand for bill paying facilities on the due date. Service operations, in general, are operated on a first in-first serve basis. Scheduling provides both better customer service and more efficient use of service facilities. However, there is a trade-off between the two as service facilities are normally limited and over-utilization of staff and facilities may adversely affect quality. During peak times, demand is met by engaging part-time workers. However, this is not always possible as the capacity of the service facilities is fixed. Therefore, different methods are used by operations managers to deal with such constraints and to schedule their operations. Some of the methods used to meet customer demand under situations of limited availability of service facilities are:

Appointment systems – Firms use appointment systems to schedule their resources to satisfy the requirements of individual customers. Using this system, the operations manager can control customer arrival timings so that the firm's resources can be fully utilized. In this system, customers are allotted a time, called the appointment time, to meet the service provider.

Reservation systems – Firms use reservation systems to schedule multiple resources and facilities together to meet the demands of several customers. For example, a hotel can schedule all its resources like room, bed, food, and other facilities to serve a customer when he/she reserves a room. These systems also allow firms to discontinue unprofitable business operations. For example, several travel agencies mention a disclaimer in their contractual agreement that allow them to cancel the tour if a sufficient number of customers do not make bookings on a tour.

Strategic product pricing – Strategic product pricing helps firms to adjust to fluctuations in demand. For example, the use of electricity increases during summer. Thus, the electricity companies adopt a summer price strategy where they hike the electricity charges during the season.

Check Your Progress - 3

7. In which of the following type of labor-intensive scheduling approach, are employees given the freedom of choosing their start time, but have to work for eight hours each day?
   a. Flextime approach
   b. Flextour approach
   c. Compressed work week
   d. Staggered times approach
8. Repetitive operations normally involve mass production of a product or a service. Which of the following is **not** a characteristic of repetitive operations?
   a. Mass production of a product
   b. Need to control flow of materials and application of labor resources to minimize idle time
   c. Focus on synchronizing customer demand with production activity
   d. There are large variations in the production process and the equipment is designed for a broad range of applications
9. In which of the following personnel scheduling approaches are employees given an option of choosing their work timings, provided they complete a specified number of hours a week?
   a. Flextime approach
   b. Flextour approach
   c. Compressed work week
   d. Staggered times
10. The scheduling of operations is different for different types of operations. In which of the following operations is flow of material given utmost importance?
   a. Job operations
   b. Repetitive operations
   c. Labor-intensive operations
   d. All of the above

25.7 Scheduling Personnel in Service Operations

Service firms have to meet varying demand requirements across different time periods. They make use of different schedules to meet the demand accordingly. A service organization can develop weekly, daily and hourly schedules. A weekly schedule for each employee with two consecutive days off in a week can be drawn

up using scheduling consecutive days off approach. Scheduling daily work time helps determine the least number of workers required to accomplish the daily work load. Service requirements may vary from hour to hour in service firms such as hotels and restaurants. So these firms engage more workers when the demand is high using the scheduling hourly work time approach. Let us understand the scheduling daily work time approach with an example.

Example: A firm is engaged in manufacturing four types of toys A, B, C and D. Each toy is manufactured through three functions: molding, assembly, and decorating work. The following table provides the production rate (number of units per hour) of each function for each type of product.

Product	Volume	Production Rate (units per hour)		
		Molding	Assembly	Decorating work
X	200	2.5	3.5	5.26
Y	100	1.5	3	2
Z	150	2	4	3

Solution: Based on the above information, we calculate the time required for completing each function of all types of products.

Product	Processing times			Total time
	Molding	Assembly	Decorating work	
X	80	57	38	177
Y	67	33	50	150
Z	75	38	50	163
Total	**222**	**128**	**138**	**488**

By assuming each employee works for eight hours a day, we obtain the number of employees required by dividing the total number of hours with 8.

Therefore, the number of employees required for molding is 222/8 = 27.75, assembly work is 128/8 = 16, and decorating work is 138/8 = 17.25.

Here, rounding off of the number of employees should be such that actual number of employees is greater than or equal to the calculated number of employees. In this way, employees would have a margin of processing time and not ending up a partial employee short. So, the actual number of employees required for molding should be rounded up from 27.75 to 28, assembly work remain same as 16, and decorating work should be rounded up from 17.25 to 18. In total, 63 employees are actually required to complete all the work.

Please note that the three jobs viz. molding, assembling and decorating needs three different skill sets. The skill of the employees working on the respective function would be experts and in real world, managers should avoid any cross-scheduling of employees across various expertise domains.

In total, 61 employees are required to complete all the work.

So, the firm should engage 27 employees for molding work, 16 employees for assembly and 17 employees for decorating work; and one employee can be engaged in molding work for 75 percent of time (6 hours a day) and decorating work for 25 percent of time (2 hours a day).

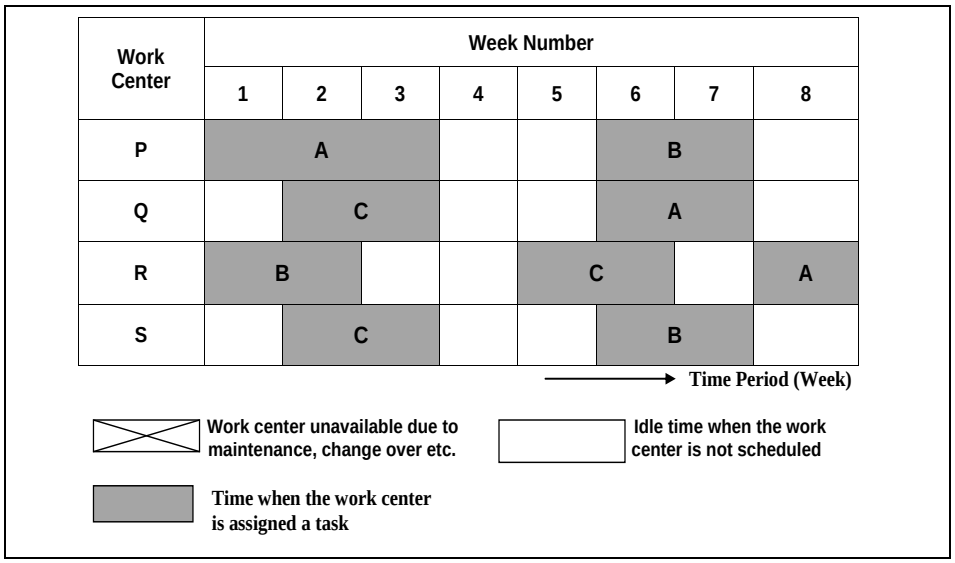
25.8 Scheduling Techniques

Operations managers use several techniques like Gantt charts, job sequencing rules, queuing theory, and critical ratio cyclic scheduling methods, to schedule jobs in various departments.

25.8.1 Gantt Charts

The Gantt charts named after Henry L. Gantt are a graphical display of the duration of a set of activities. These are simple bar charts used to schedule any type of operation. They display the use of resources over a period of time graphically. The vertical axis of the chart represents the firm's facility and the horizontal axis represents the schedule duration. Gantt charts help communicate important job information easily and clearly. However, they do not consider hurdles like production breakdown and human performance. They are useful only when the number of work centers is limited, the job times are long, and the job routings are short. Gantt charts are of two types: Workload charts and Scheduling charts.

Figure 25.1: Gantt Workload Chart



Workload charts – Workload charts are used to represent workload levels for equipment, work centers, or departments. The vertical axis of the chart represents the machines or any other facilities used to manufacture or process job orders and the horizontal axis represents the time taken. Refer Figure 25.1 for a typical workload chart. Here, the vertical axis represents the machines P, Q, R, and S

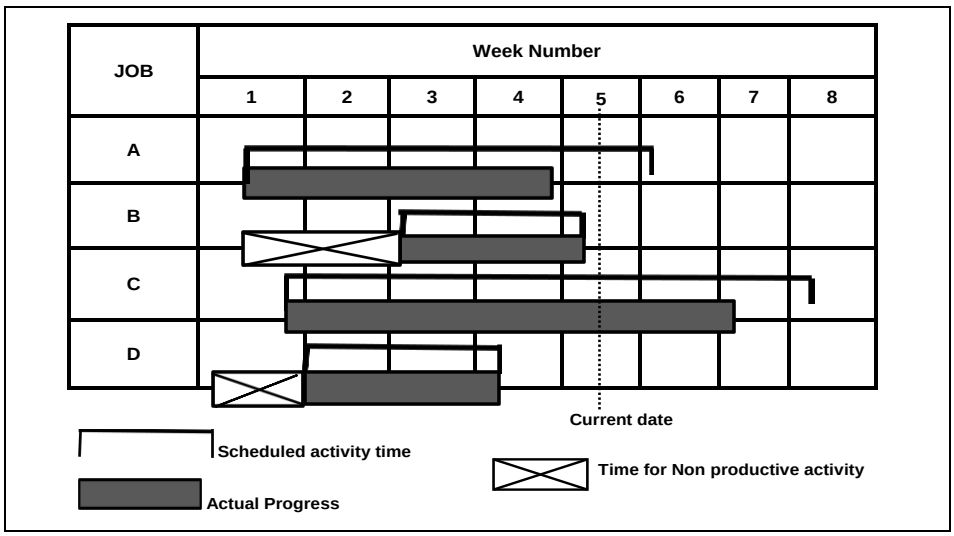
used to process the job orders A, B, and C represented on the horizontal axis. Each of these machines is assigned to a number of jobs shown as rectangular boxes. The length of the rectangle represents the time requirement of that job. The time estimates used in these charts are obtained from standard time estimates. After working for a specified period, the machine requires some maintenance activity. Through the charts, the manager can plan for routine maintenance for each facility. The charts also depict the idle time for each machine. The idle time of a machine is represented by the space between two consecutive jobs. Thus, the manager can identify the idle times of various machines and fill them with unplanned jobs to enhance the overall productivity.

Scheduling charts – Scheduling charts depict the progress of the jobs as they pass through various work centers. These charts are useful when a particular job requires the use of several machines. Refer Figure 25.2 for a typical scheduling chart. The chart shows the progress of jobs A, B, C, and D through various work centers. The dotted vertical line represents the current date. In the figure, the dotted line is at the middle of week five. The chart shows that job A is half a week behind schedule, job B is completed on schedule, job C is ahead of schedule, and job D has been completed on schedule.

25.8.2 Johnson's Job Sequencing Rules

Job sequencing is very important for the proper scheduling of jobs. It maximizes the operations efficiency, minimizes the processing time of jobs, and reduces the processing costs of the firm over a period of time. Jobs processed in a single stage of production can be simply scheduled one after another whereas for those involving two or more stages of production, firms should ensure that jobs are sequenced in a way which minimizes the idle time. Operations managers use Johnson's rules to develop a job sequence that minimizes the total time span required in completing the given jobs.

Figure 25.2: Gantt Scheduling Chart



Johnson's rule for two-stage production - Assume that the firm has to perform 'n' jobs and each job involves processing on two machines A and B in the order AB. For example, the job involves first the printing operation in machine A and then the binding operation in machine B. There are 'n' numbers of books that are to be printed and then bound. Assume the expected processing times of these jobs are A_1, A_2,---A_n on machine A and B_1, B_2,---B_n on machine B. We should determine the sequence in which the n jobs should be processed using the two machines in order to minimize the total elapsed time. To solve the above problem, Johnson and Bellman developed the following steps:

a) Identify the least processing time in A1, A2,--- An; and B1, B2,--- Bn. If there is a tie, select either of the processing times.

b) If the least processing time is A_r (r^{th} job on machine A), then the r^{th} job is placed at the beginning of the sequence. If it is B_s (s^{th} job on machine B), then the s^{th} job is placed at the end of the sequence. If $A_r = B_s$, then the r^{th} job is placed at the beginning and the s^{th} job is placed at the end of the sequence.

c) If there is a tie for the least processing times on machine A, then any of the jobs can be placed at the beginning of the sequence. If there is a tie for the least processing times on machine B, any of the jobs can be placed at the end of the sequence.

d) Identify the next least processing time and repeat the above steps. The process is continued till all the jobs have been assigned in a sequence. The sequence obtained is called the optimum sequence.

e) After finding out the optimum sequence, the total elapsed time and idle time on machines A and B are calculated using the following formulae:

Total elapsed time = Time between starting of the first job and the last job in the optimum sequence.

Idle time on machine A = The difference between the time when the last job in the optimum sequence is completed on machine B and the time when the last job is completed on machine A.

Idle time on machine B = (Time taken by machine A to complete the first job in the optimum sequence) + $\sum$ [(time when k^{th} job starts on machine B) – (time when $(k-1)^{th}$ job finishes on machine B)]

Example: A firm processes six types of jobs on two machines: machine A and machine B.

The processing times for each type of job (in hours) on both machine A and machine B are given here.

Machines/Jobs	**1**	**2**	**3**	**4**	**5**	**6**
Machine A	6	6	4	6	5	8
Machine B	4	2	10	5	3	6

Using this information, determine an optimum sequence to process the various jobs so that the total elapsed time is the minimum. Also calculate the total idle time on machine A and machine B.

Solution:

Here, the least processing time is 2 hours for job 2 and it occurs on machine B. So this job is placed at the end of the sequence, i.e. in the 6th place. This job is assigned first and performed last.

					2

Now, the next least processing time is 3 hours for job 5 on machine B. So, job 5 is placed at the end of the sequence next to job 2 i.e., in the 5th place.

				5	2

Now, the minimal values are 4 hours for job 3 on machine A and 4 hours for job 1 on machine B. So job 3 is placed at the beginning of the sequence i.e. in the 1st place and job 1 is placed before job 5 at the end of the sequence i.e. in the 4th place.

3			1	5	2

Now, the next least time is 5 hours for job 4 on machine B. We put job 4 in 3rd place and the remaining job 6 in the 2nd place. So the optimum sequence obtained is:

3	6	4	1	5	2

We now develop the schedule of each job in the optimum sequence.

Schedule of 6 Jobs on 2-Machines

Job-Sequence	Machine A			Machine B		
	Time In	Processing Time	Time Out	Time In	Processing Time	Time Out
3	0	4	4	4	10	14
6	4	8	12	14	6	20
4	12	6	18	20	5	25
1	18	6	24	25	4	29
5	24	5	29	29	3	32
2	29	6	35	35	2	37

Therefore, the total elapsed time is 37 hours.

The idle time for machine A = 37 – 35 = 2 hours

The idle time for machine B = 4 + (35 – 32) = 4 + 3 = 7 hours

Total idle time = 2 + 7 = 9 hours

Activity: A firm is involved in processing six types of jobs on two machines X and Y. The processing times for each type of job (in hours) on both machine X and machine Y are given here.

Machines/Jobs	**1**	**2**	**3**	**4**	**5**	**6**
Machine X	40	110	60	30	100	110
Machine Y	80	105	100	70	40	20

Determine an optimum sequence to process the various jobs so that the total elapsed time is the minimum. Also calculate the total idle time on machine X and machine Y.

Answer:

Johnson's rule for three-stage production - In an n-job and three-machine sequencing problem, three machines A, B, and C, are involved, and each job is processed in the order ABC. Suppose the expected processing time for n-jobs on the three machines A, B, and C are A_1, A_2,---A_n; B_1, B_2,--- B_n; C_1, C_2,--- C_n. We should determine the sequence in which these n-jobs should be processed on the three machines to minimize the total operation time. In this procedure, any one of the following conditions should be satisfied:

a) The smallest processing time on machine A should be greater than or equal to the largest processing time on machine B.

b) The smallest processing time on machine C should be greater than or equal to the largest processing time on machine B.

Assume that there are two machines, G and H, and the corresponding times of these machines G_i and Hi are obtained as:

$G_i = A_i + B_i$

$H_i = B_i + C_i$

We solve the problem in terms of n jobs and two machines, with an order of GH. The resulting optimum sequence will also become the optimum sequence for the problem of 3 machines and n-jobs.

Example: A firm is involved in five types of jobs, each of which must be processed on three machines, A, B, and C in the order ABC.

The processing time of each job (in hours) on the three machines is given here:

Job	Processing Times		
	A	B	C
1	8	5	4
2	10	6	9
3	6	2	8
4	7	3	6
5	11	4	5

Determine the sequence for the five jobs that minimizes the total operation time. Also find the idle time of each machine A, B, and C.

Solution:

First we check whether the problem satisfies the conditions discussed earlier.

The smallest processing time on machine A is 6 and it is greater than or equal to the largest processing time on machine B, i.e. 6.

Therefore, we can use Johnson's n-jobs, 3 - machine procedure to solve the problem.

Job	Processing Times	
	G = A + B	H = B + C
1	13	9
2	16	15
3	8	10
4	10	9
5	15	9

The optimum sequence is, 3, 2, 5, 4, and 1.

Now, we calculate the total operation time with the optimum sequence obtained.

Schedule of 5 jobs on 3-machines

Job Sequence	Machine A			Machine B			Machine C		
	Time in	Processing Time	Time out	Time in	Processing Time	Time out	Time in	Processing Time	Time out
3	0	6	6	6	2	8	8	8	16
2	6	10	16	16	6	22	22	9	31
5	16	11	27	27	4	31	31	5	36
4	27	7	34	34	3	37	37	6	43
1	34	8	42	42	5	47	47	4	51

Thus, the total operation time is 51 hours.

Idle time on machine A = 51 – 42 = 9 hours.

Idle time on machine B = 6 + [(16 – 8) + (27 –22) + (34 – 31) + (42 – 37)] + (51 – 47)

= 6 + 8 + 5 + 3 + 5 + 4 = 31 hours.

Idle time on machine C = 8 + [(22 – 16) + (37 – 36) + (47 – 43)] = 8 + 6 + 1 + 4 = 19 hours.

Total idle time = 9 + 31 + 19 = 59 hours

Activity: A firm is involved in five types of jobs, each of which must be processed on three machines, X, Y, and Z in the order XYZ. The processing time of each job (in hours) on the three machines is given here:

Job	**Processing Times**		
	$\mathbf{X_i}$	$\mathbf{Y_i}$	$\mathbf{Z_i}$
1	19	11	9
2	20	13	19
3	13	6	17
4	17	7	15
5	22	10	11

Determine the sequence for the five jobs that minimizes the total operation time. Also find the idle time of each machine X, Y, and Z.

Answer:

Johnson's rule for n-jobs and m-machines - The process of sequencing n-jobs through m-machines is as follows:

a) Suppose there are n jobs, 1, 2, 3 ...n and m-machines; A_1, A_2, $A_3 \ldots A_{m-1}$, A_m. Suppose the processing times of job 1 on m-machines are A_{11}, A_{12}, $A_{13} \ldots A_{1m}$. For job 2, they are A_{21}, A_{22}, A_{23}, $A_{24} \ldots A_{2m}$. Similarly, for job n, they are A_{n1}, A_{n2}, $A_{n3} \ldots A_{nm}$. Check whether any one of the following conditions is satisfied:

- The minimum time on machine A_1 is greater than or equal to maximum time on machines A_2, A_3,…..A_{m-1}
- The minimum time on machine A_m is greater than or equal to maximum time on machines A_2, $A_3 \ldots A_{m-1}$.

b) Convert the m-machine problem into an equivalent two-machine problem by introducing two fictitious machines, G and H. The processing times of these machines are calculated as,

$G_i = A_{i1}+A_{i2}+A_{i3}+\ldots+A_{im-1}$

$H_i= A_{i2}+A_{i3}+A_{i4}+\ldots+A_{im}$

Then the optimum sequence is determined for these two machines.

Example: Determine the optimum sequence of processing for the given sequencing problem of four jobs: A, B, C, D and four machines: P, Q, R, and S.

Job	**Machines**			
	P	**Q**	**R**	**S**
A	13	8	7	14
B	12	6	8	19
C	9	7	5	15
D	8	5	6	15

Also find the total elapsed time and idle time on each machine.

Solution:

Here, minimum time on P = 8,

Maximum time on Q and R are 8 and 8 respectively.

Since the minimum on machine P is equal to the maximum time on machines Q and R respectively, the problem can be solved using this method.

Now we take two fictitious machines, G and H whose processing times are

Job	**G = P + Q + R**	**H = Q + R + S**
A	28	29
B	26	33
C	21	27
D	19	26

Now we consider this as an n-job, 2-machine problem.

The optimum sequence is obtained as:

D	C	B	A

The calculation of total elapsed time is shown here.

Job	Machine P			Machine Q			Machine R			Machine S		
	In	Processing	Out	In	Processing	Out	In	Processing	Out	In	Processing	Out
D	0	8	8	8	5	13	13	6	19	19	15	34
C	8	9	17	17	7	24	24	5	29	34	15	49
B	17	12	29	29	6	35	35	8	43	49	19	68
A	29	13	42	42	8	50	50	7	57	68	14	82

The total elapsed time is 82 hours.

The idle time of machine P is (82-42) = 40 hours.

The idle time of machine Q = 8 + [(17–13) + (29–24) + (42–35)] + (82–50) =

= 8 + 4 + 5 + 7 + 32 = 56 hours

The idle time of machine R is, 13 + [(24–19) + (35–29) + (50–43)] + (82–57) =

= 13 + 5 + 6 + 7 + 25 = 56 hours.

The idle time of machine S = 19 hours

Total idle time = 40 + 56 + 56 + 19 = 171 hours

Activity: Determine the optimum sequence of processing for the given sequencing problem of four jobs: P, Q, R, S and four machines: A, B, C, and D. Also find the total elapsed time and idle time on each machine.

Job	Machines			
	A	**B**	**C**	**D**
P	11	8	6	10
Q	10	7	5	8
R	9	5	3	7
S	13	9	4	10

Answer:

Queuing Analysis

Queuing analysis involves the study of waiting lines and queuing systems. A queue refers to customers or units waiting for a service. A queue is formed if the rate of arrival of customers exceeds the service rate and customers or units have to wait to receive the service. The waiting time often proves costly for service firms and needs to be minimized. Increasing the capacity of service facilities reduces the queue, but the facilities become idle when the customer arrival rate slows down. Queuing analysis is used for balancing the costs of waiting time with the costs of providing additional service facilities. It helps them to determine the optimum number of service stations required. The disadvantages of queuing models are a) Poisson distribution cannot effectively represent real life situations, like arrivals at a shopping center, b) arrivals are assumed to come from an infinite population, c) the waiting space available for the population arriving at the service facility is considered infinite, and d) the effects of long queues on new arrivals are not considered.

Critical Ratio Method

The Critical Ratio Method is a technique of job sequencing used to verify whether a job is being operated on schedule. The operations manager calculates the critical ratio of a job as the ratio of the actual time remaining to complete the job and the scheduled time remaining to complete the job.

$$\text{Critical Ratio} = \frac{\text{Actual time remaining}}{\text{work remaining}}$$

The operation is considered to be behind schedule if the critical ratio is less than one. If it is more than one, the operation is considered to have been processed ahead of schedule. The method is used to revise the job status from time to time and to re-prioritize them.

Example: Alpha Manufacturing Ltd. has started three jobs that require 29, 19, and 26 days to complete, respectively. The managing director of the company has engaged three teams to execute each of these jobs. After 15 days, the operations managers of the three jobs state that the number of days required to complete the jobs are 17, 10, and 12 respectively. Calculate the critical ratio of each job and find out which job is to be given priority.

Solution: The critical ratios and priorities are as follows:

Job	Critical Ratio	Priority Order
A	(29-15)/17 = 1.21	0.82
B	(19-15)/10 = 2.5	0.3
C	(26-15)/12 = 1.09	0.92

The job with lower critical ratio will be given the top priority to be sequenced in the next day's production activities.

Production Scheduling refers to the decision-making process of defining manufacturing schedules on both a goods and resource level. Optimal production scheduling is vital to ensure that all available resources are effectively utilized to maximize throughput, minimize inventory, optimize machine utilization, and increase profits. Exhibit 25.1 presents use of Data science in scheduling for optimal results.

Exhibit 25.1: Production Scheduling & Data Science: A Perfect Match

Organizations apply the following methods in conjunction with one another for scheduling. The explosion in the availability of big data along with the technological development of modern machine learning (ML) and artificial intelligence (AI) algorithms provides ways to address certain pitfalls like Suboptimal results, Computational complexity, Uncertainty and responding to real-world events

- Reducing uncertainty: More accurate demand/supply forecasts can be done with time-series forecasting, and accurate equipment availability forecasts can be based on time-to-failure and survival analysis.
- Faster decision-making: The use of AI/ML allows scheduling decisions to improve on rule-of-thumb-based methods.

Some Examples of Data Science-Based Production Schedule Optimization

- Dow Chemical Company has developed AlphaDow, a reinforcement learning-based industrial production scheduling system, to ingest and analyze massive quantities of data during training and are extremely fast in production allowing for efficient real-time adaptation to new information.
- A research study showed improvement in copper production by 7% by devising a self-learning artificial intelligence-based production scheduling algorithm for an industrial mining complex.
- In a large manufacturing client project, Aimpoint Digital team employed data mining and discrete event simulation techniques to quantify the uncertainty based on historical data, generating millions as additional revenue.
- By combining data science methods with traditional optimization and simulation for production scheduling, we can generate an optimal production scheduling system that is robust to uncertainties inherent in the real world.

https://aimpointdigital.com/production-scheduling/ aug 2021

Activity: Phi Manufacturing Ltd. has started three jobs that require 32, 23, and 29 days to complete, respectively. The managing director of the company has engaged three teams to execute each of these jobs. After 20 days, the operations managers of the three jobs state that the number of days required to complete the jobs are 15, 11, and 13 respectively. Calculate the critical ratio of each job and find out which job is to be given priority.

Answer:

Cyclic Scheduling Method

In a service context, managers often face problem of scheduling part time workers having similar skill sets, on various work days. The uncertainty in demand, high cost of long term hiring, jobs require the low level of skill set, and abundance of employees ensure that a service organization has to dynamically schedule the employees. The method is used for developing varying schedules in service sector to keep number of employees at minimum level.

The algorithm:

Step 1 identify day(s) with least total requirements of servers. Circle that/those number(s) depending on off days policy of the service organization.

Step 2 Subtract 1 from all requirement days from first row 1 from all day's requirements except circled days or the day that has a value zero requirement and record it in a new row with server. In case of tie-breaker situation consider leave policy of the organization. Subsequently, select a random day for tie-breaking.

Step 3. Repeat Step 1 and 2 till all the days have Zero requirements of employees. Let us understand the algorithm with a simple example. On the circled days in row representing respective employees would be the off days for them. Ensure to consider Sunday and Monday, and Saturday and Sunday as consecutive days only in case rescheduling is not done on every Sunday.

Example**:** A haircut saloon is in a university campus. The saloon has students coming in all seven days of the week but has a fluctuating demand. The owner of saloon want is able to list number of required employees on various days of week on the basis of past experience. The owner decides a weekly off policy that an employee can take weekly off on any two consecutive days of the week. The daily employee requirements are given in Table.

Week day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Employees required each day	6	5	3	4	5	6	7

Solution:

Step1: As day off policy allows one day leave so, identify one day with least requirements of servers. Circle those number. Employee 1 works throughout the week except Wednesday and Thursday.

Week day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Employees required each day	6	5	(3)	(4)	5	6	7

Step 2: Subtract 1 from all requirement days from first row 1 from all day's requirements except circled day and record it in a new row with server as required workforce throughout week.

Week day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Employees required each day	6	5	(3)	(4)	5	6	7
Emp1	5	4	3	4	4	5	6

Now repeat Step 1, identify days pair on which second employee could take weekly off. Compare net requirement of employees in each day pairs. The net requirement for Monday and Tuesday is 5 +4 =9, Tuesday and Wednesday is 4+3 =7, for Wednesday and Thursday is 3+4 = 7, for Thursday and Friday is 4+4 =8, for Friday and Saturday is 4+5=9, for Saturday and Sunday is 5+6 =11, and for Sunday and Monday is, 6+5 =11. Here we got two pair with net requirement of 7 employees. We select Tuesday and Wednesday, arbitrarily. Thus, after step 2 tabe is updated as following.

Week day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Employees required each day	6	5	(3)	(4)	5	6	7
Emp1	5	4	(3)	4	4	5	6
EMP2	4	(4)	3	3	3	4	5

We repeat Steps 1 and 2, keep comparing net requirements of employees and complete the table till all the days' requirements are met, considering weekly off policy of Saloon.

Week day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Employees required each day	6	5	3	4	5	6	7
Emp1	5	4	3	4	4	5	6
EMP2	4	4	3	3	3	4	5
Emp3	3	3	2	3	3	3	4
Emp4	2	3	2	2	2	2	3
Emp5	1	2	1	1	2	2	2
Emp6	0	1	1	1	1	1	1
Emp7	0	0	0	0	0	0	1

The schedule is ready for the Saloon. The saloon owner would need 6 full time employees and one employee to work on Sundays. However the owner may hire the seventh employee full time as a backup in case another employee decides to take a sick day or a day off to attend a family responsibility.

Check Your Progress - 4

11. Critical ratio method is a sequencing technique used by the operations managers in scheduling work. Identify the correct formula for calculating the critical ratio.
    a. Total time to complete the job / work remaining
    b. Actual time remaining / work still remaining
    c. Actual work remaining / planned time remaining
    d. Total time remaining / actual time remaining
12. Operations managers generally use several techniques to schedule jobs in various departments. How does the sequencing of jobs using Johnson's job sequencing rules help a firm?
    a. It minimizes processing time
    b. It maximizes operating efficiency
    c. It reduces processing costs
    d. All of the above
13. Operations managers generally use several techniques to schedule jobs in various departments. Which of the following is one of them?
    a. Routing
    b. Loading
    c. Scheduling
    d. Critical ratio

14. Which of the following scheduling methods is more suitable for an industry where jobs are processed in multiple stages of production?
    a. Line balancing
    b. Sequencing rules
    c. CRAFT
    d. Linear programming
15. Which of the following statements about queuing analysis is **incorrect**?
    a. Study of waiting lines and queuing systems.
    b. Helps balance the costs of waiting time with the costs of providing additional service facilities.
    c. It helps maximize the number of service workstations required.
    d. A queue will result if customer arrival rate is greater than service delivery rate.
16. The critical ratio method is a job sequencing technique that an operations manager can use to verify whether a job is being performed on schedule. In this technique, _____ the critical ratio, _____ the priority.
    a. Lower, lower
    b. Higher, higher
    c. Lower, higher
    d. Higher, lower
17. Under Johnson's sequencing rule, a problem of m machines and n jobs can be simplified into two fictitious machines and n jobs. Using this criterion, identify the correct mathematical representation of simplifying m machines into two machines.
    a. $G_i = A_{i1}+A_{i2}+A_{i3}+\ldots+A_{im}$
       $H_i = A_{i2}+A_{i3}+A_{i4}+\ldots+A_{im}$
    b. $G_i = A_{i1}+A_{i2}+A_{i3}+\ldots+A_{im}$
       $H_i = A_{i2}+A_{i3}+A_{i4}+\ldots+A_{im-1}$
    c. $G_i = A_{i1}+A_{i2}+A_{i3}+\ldots+A_{im-1}$
       $H_i = A_{i2}+A_{i3}+A_{i4}+\ldots+A_{im}$
    d. $G_i = A_{i1}+A_{i2}+A_{i3}+\ldots+A_{im-1}$
       $H_i = A_{i2}+A_{i3}+A_{i4}+\ldots+A_{im-1}$
18. Which of the following situations leads to the formation of a queue in a service organization?
    a. Rate of arrival of customers is less than rate at which service is rendered
    b. Rate of arrival of customers is equal to the rate at which service is rendered
    c. Rate of arrival of customers is greater than the rate at which service is rendered
    d. Both b and c

19. Which of the following is **not** a benefit associated with queuing analysis?
    a. To minimize waiting costs
    b. To determine optimum number of work/service stations
    c. To balance waiting costs with the costs of providing additional service stations
    d. To minimize processing time of jobs

Exercises

(Questions R to T)

Crescent SoftDesign, a designing company, currently has five projects A, B, C, D, and E on hand which require150 days, 135 days, 180 days, 140 days and 120 days respectively to complete. After 100 days, the operations manager identifies that these projects still require 60 days, 30 days, 70 days, 45 days and 30 days respectively for completion. Based on the given information, answer the following **three** questions.

R. Which of the projects has the least critical ratio?

S. Which of projects is(are) ahead of schedule?

T. Using the critical ratio method, give the order of priority based on the revised time of completion after 100 days?

(Questions U & V)

Given below is a Workload Gantt chart where X, Y, Z represents three machines. A, B, and C represent jobs to be performed on these machines during a particular week. Answer the following **two** questions.

Work Center	Week Number							
	1	2	3	4	5	6	7	8
X	A			B		C		
Y		C				A		
Z	B				C			A

U. Calculate the number of weeks required to complete job A.

V. From the Gantt chart select the machine most utilized.

W. Jobs A – G involve processing on workstation 1 and 2. The time required at each workstation for each job is given in the table below. Use Johnson's rule to sequence these jobs.

(Questions X & Y)

Jagson Ltd. has started three jobs and engaged three teams to execute each job. Today is day 20. The due dates and scheduled time remaining for each job are given in the table below. Answer the following **two** questions.

Job	Due Date	Work Days Remaining
1	25	7
2	32	14
3	27	5

X. Calculate the critical ratios for job 1, 2 & 3 respectively?

Y. Which job should get highest priority?

25.9 Summary

- Organizations schedule their activities to meet customers' requirements on time and improve their operational efficiency.
- Operations can be scheduled in different ways. Broadly they can be divided into forward scheduling, backward scheduling, and a combination of both.
- Scheduling activities include routing, loading, and dispatching. Routing gives the sequence of operations and the work centers that perform the work.
- The various priority rules in dispatching are: earliest due date, longest processing time, shortest processing time, first in first serve, and slack time remaining.
- Depending on the type of operation, the method of scheduling also differs.
- Service operations can be scheduled by following various approaches like appointment systems, reservation systems, and strategic product pricing.
- The scheduling of personnel in service organizations will vary depending on demand. This can be done on a weekly basis, daily basis or hourly basis.
- Operations managers follow several scheduling techniques such as Gantt charts, Johnson's job sequencing rules, queuing analysis, and the critical ratio method to schedule operations.

25.10 Glossary

Backward scheduling: In this, orders are scheduled based on their due dates. The operations manager obtains the due dates for the job orders and develops the schedule backward, thereby determining the latest point when the production activity can be started in order to complete the order on time.

Compressed workweek: Employees work for ten hours a day for four days in a week.

Critical Ratio Method: The ratio of the actual time remaining to complete the job and the scheduled time remaining to complete the job.

Dispatching: It is the final act of releasing job orders to the workers to go ahead with the production process. As the work involved in labor-intensive operations is routine, managers consider the opinions of employees while scheduling their work times.

Flextime: Employees choose their work timings, provided that a specified number of hours are completed in a week.

Flextour: Employees choose their start time, but must work each day for eight hours.

Forward scheduling: In this method, the actual production activities start when a job order is received. The operations manager schedules each operation forward in time starting from the date of production.

Gantt charts: A graphical display of the duration of a set of activities. These are simple bar charts used to schedule any type of operation. They display the use of resources over a period of time graphically.

Johnson's job sequencing rules: It is very important for the proper scheduling of jobs. It maximizes the operations efficiency, minimizes the processing time of jobs, and reduces the processing costs of the firm over a period of time.

Loading: It is the process of assigning specific jobs to each work center for the planning period. It also includes the task of sequencing jobs so that the machine idle times are minimized and the jobs are completed within the least possible time.

Part time: Employees work for less than forty hours, usually twenty hours per week on a temporary basis.

Queue: Customers or units waiting for a service. A queue is formed if the rate of arrival of customers exceeds the service rate and customers or units have to wait to receive the service.

Queuing analysis: The study of waiting lines and queuing systems. It is used for balancing the costs of waiting time with the costs of providing additional service facilities. It helps them to determine the optimum number of service stations required.

Routing: It provides the sequence of operations and processes to be followed in order to produce a particular product. It determines what work is to be done, and where and how it is to be done.

Scheduling charts: They depict the progress of the jobs as they pass through various work centers. These charts are useful when a particular job requires the use of several machines.

Scheduling: A process of setting up operation processing times so that jobs will be completed on time. It helps in providing the best service to customers by making efficient use of the firm's resources.

Staggered times: Employees select their work hours from a list of available shifts.

Workload charts: These are used to represent workload levels for equipment, work centers, or departments. The vertical axis of the chart represents the machines or any other facilities used to manufacture or process job orders and the horizontal axis represents the time taken.

25.11 Self-Assessment Exercises

1. Scheduling is a process of setting up operation processing times so that the jobs will be completed on time. Explain the purpose and importance of scheduling operations in an organization.
2. Organizations use various methods for scheduling operations. Explain them in detail.
3. Scheduling of operations helps in maximizing customer satisfaction and minimizing service delays. Explain the scheduling process in detail.
4. Operations scheduling is different for different operations. Why? Explain in detail.
5. Operations managers use several techniques to schedule jobs in various departments. What are the various scheduling techniques that operations managers use?

25.12 Suggested Readings/Reference Material

1. Janat Shah, Supply Chain Management:: Text And Cases, Pearson India, 2017
2. Gerardus Blokdyk, Enterprise Resource Planning A Complete Guide - 2020, 5STARCooks March, 2021
3. Peter Szende, Alec N Dalton, Yoo, Operations Management in the Hospitality Industry, Emerald Publishing, June 2021
4. Yacob Khojasteh, Production Management: Advanced Models, Tools, and Applications for Pull Systems, Productivity Press; October, 2017
5. Ramesh Upadhyay & Jitendra Narayan Kumar, Facility Management, Notion Press, January 2017

25.13 Answers to Check Your Progress Questions

Following are the answers to the Check Your Progress Questions given in the Unit.

1. (b) Backward

The backward scheduling method schedules orders as per their due dates. The operations manager schedules production activity based on due dates for job orders so that the production activity can be timed to complete the order on time. Forward and hybrid scheduling are also types of scheduling methods. Routing is a scheduling activity.

2. (d) To minimize inventory costs

Minimizing inventory costs is the objective of inventory management. Scheduling is concerned with meeting customer requirements on time by carrying out the production process efficiently and by reducing service delays.

3. (a) Loading

When assigning specific jobs to each work center, loading decides capacity limitations of centers as well.

4. (a) Routing

It explains the sequence of operations and processes to be followed to produce a particular product. Routing determines what work is to be done and where and how it is to be done. Hence, routing describes the 'specification of workflow.'

5. (b) Loading

Loading is defined as assigning specific jobs to each work center for the planning period. Loading of jobs is done upto the standard capacity of the workstation.

6. (b) Shortest processing time

Here, jobs are processed in the shortest time. Under this rule, jobs with shorter processing times get completed earlier than jobs with longer processing times. This rule ensures that minimum number of jobs are left for processing.

7. (b) Flextour approach

Under Flextour, employees are given some freedom in choosing their start time, but they must work eight hours a day.

8. (d) There are large variations in the production process and the equipment is designed for a broad range of applications

There are few variations in the production process for repetitive operations. In these operations, labor is trained and the equipment designed for a narrow range of applications.

9. (a) Flextime approach

Under flextime, employees are given the option of choosing their work timings provided they work for a specified number of hours in a given time period, say a week.

10. (b) Repetitive operations

Repetitive operations are also called continuous operations as they are performed continuously to produce goods in bulk. Here, stock-outs can hinder the production process and lead to high costs for the firm.

11. (b) Actual time remaining / work still remaining

Critical ratio is calculated by dividing the actual time remaining to complete work by work remaining (in time units). If the critical ratio of an operation is less than one, the operation is behind schedule. If the critical ratio is more than one the operation is being processed ahead of schedule.

12. (d) All of the above

Johnson's job sequencing rules help the operations managers in minimizing processing time, maximizing the operating efficiency, and reducing the operating costs.

13. (d) Critical ratio

The critical ratio method is a job sequencing technique an operations manager can use to verify whether a job is on schedule. Whatever the method employed, the process of scheduling involves three activities: routing, loading and dispatching.

14. (b) Sequencing rules

When jobs are processed in a single stage of production, they can be scheduled one after another. If two or more stages of production are required, firms should ensure that jobs are sequenced in a way that idle time is minimized. Operations managers can use job sequencing rules and develop a job sequence that minimizes total time required to complete a given job.

15. (c) It helps maximize the number of service workstations required.

Queuing analysis helps determine the optimum (not maximum) number of workstations required to meet demand.

16. (c) Lower, higher

The lower the critical ratio, the higher the priority in sequencing the job in the next day's production activities.

17. (c) $G_i = A_{i1}+A_{i2}+A_{i3}+\ldots+A_{im-1}$

$H_i = A_{i2}+A_{i3}+A_{i4}+\ldots+A_{im}$

A problem of n jobs and m machines can be simplified to n jobs and two machines to use Johnson's sequencing rule. Two fictitious machines (G_i and H_i) are introduced where

$G_i = A_{i1}+A_{i2}+A_{i3}+\ldots+A_{im-1}$ and $H_i = A_{i2}+A_{i3}+A_{i4}+\ldots+A_{im}$

18. (c) Rate of arrival of customers is greater than the rate at which service is rendered

In a service organization, when the arrival rate of customers is greater than the rate at which service is rendered to each customer a queue forms.

19. (d) To minimize processing time of jobs

Waiting time in a queue often proves costly to service firms and so they use queuing analysis to minimize this as far as possible. Queuing also helps operations managers to determine the optimum number of service stations required, which can lead them to striking a balance between waiting costs and cost of providing additional service stations. Johnson's job sequencing rules is useful for proper scheduling of jobs. It helps firms minimize the processing time of jobs.

Unit 26

Enterprise Resource Planning

Structure

26.1 Introduction

In the last section of the previous unit, we have discussed the scheduling techniques such as Gantt charts, Johnson's job sequencing rules, queuing analysis, and the critical ratio method used by operations managers to schedule operations. In this unit, we will discuss enterprise resource planning.

The necessity of organizations to integrate different business processes for smooth functioning is fulfilled by Enterprise Resource Planning or the ERP system. ERP uses a single database that stores information from different functional domains. This database meets the information needs of different entities. Through this integrated approach, the production department located in one geographical area can send financial information to the head office and the marketing information of one location can be accessed by the production department at another location, so that the market changes can be identified and the appropriate responses designed. Proper ERP implementation facilitates effective decision-making by providing relevant and timely information to the management.

Definition of Process

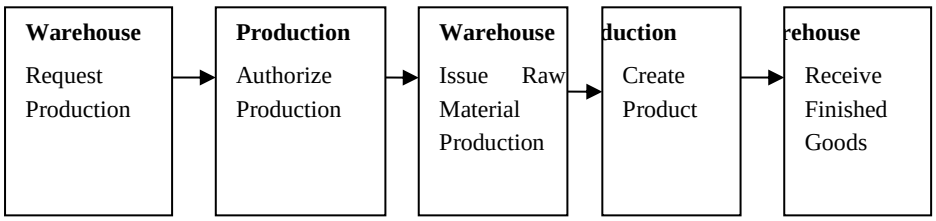
- Business processes are sequences and combinations of different activities that deliver value to a customer (Coulson- Thomas 1996).
- A business process as an activity cycle that is taken as a whole, and that realizes a business objective (Omrani, 1992).

- According to Harrington, (1991) Process can be defined as an activity or group of activities that take input, process that input to increase its value, and provide output.
- Process is "a set of logically related tasks performed to achieve a defined business outcome", (Davenport and Short 1990).
- According to Pall (1987) a business process is a logical organization which gathers energy, people, equipment, supplies and procedures to produce the final result

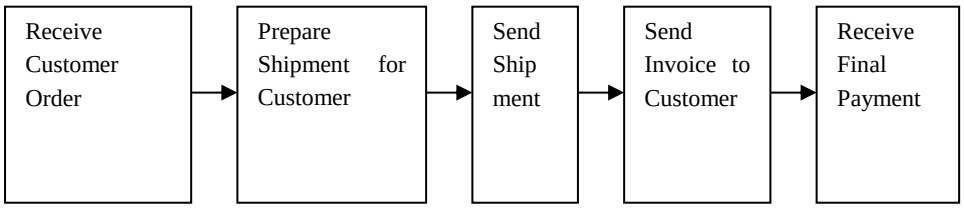
Based on above, different business processes is required to create and deliver the product and services. So three kinds of core or fundamental business processes help to fulfill the demand such as buy, make and sell.

Procurement process (Buy): Procurement process focused on procuring raw material to create product and services. Suppose a company want to manufacture bicycle. The company requires different components –such as tire, wheels, chain, seat, nuts and bolts, and handle from different vendors to make bicycle. The procurement process is given below:

Production Process (Make): Before production process, company person has to determine how much material is needed, who will procure and by which date. After receiving the material, production will take place. The production process is given below:



Fulfillment Process (Sell): The fulfillment process takes place after the production process. This process always focused on fulfills the customer order.



This chapter will introduce you to the evolution of ERP. We will discuss the concept of business process reengineering, and then study business modeling for ERP. We shall then move on to discuss the implementation of ERP. Finally, we shall discuss how ERP can be used by organizations to gain competitive advantage.

This unit will introduce you to the evolution of ERP. We will discuss the concept of business process reengineering, and then study business modeling for ERP. We shall then move on to discuss the implementation of ERP. Finally, we shall discuss how ERP can be used by organizations to gain competitive advantage.

26.2 Objectives

By the end of this unit, students should be able to:

- Explain the evolution of ERP.
- Discuss business process reengineering.
- Define business modeling for ERP.
- Evaluate the ERP implementation process.
- Assess the role played by ERP in helping organizations gain competitive advantage.

26.3 Evolution of ERP

Organizations were always working towards integrating all their business units to enhance productivity but the tools to achieve this integration were not available. The increase in advanced software tools over the years led to the development of software packages that allowed timely information sharing and allowed the integration of different functional units.

- The history of ERP can be traced back to 1972 when five employees of IBM left the company and established SAP (Systems, Application, and Products in Data Processing) in Walldorf, Germany. SAP was the first company to develop and maintain ERP software.
- The development of ERP can be traced back to the concepts of MRP and MRP II. MRP (Material Requirement Planning) systems are used in manufacturing to automate inventory management and production processes. MRP II (Material Requirement Planning) is an extension of MRP, developed with the objective of automating all the manufacturing functions and providing an interface with other functional domains.
- ERP extends the functionality of MRP and MRP II systems to provide complete business solutions. ERP has the ability to integrate different business entities without being restricted by geographical and functional differences.

Why ERP is required

Suppose a customer approach to sales team to buy a particular product then sales team approach to inventory department to check the availability of product. If product is not available in the inventory department then sales team approach to production department to produce the product. Next, production department team

check with the inventory department for availability of raw material. If raw materials is not available within inventory department then production department team buy the inventory from selected vendor then production department forward the raw material to shop floor execution for production purpose. Once the production has completed then shop floor execution team forward to sales team to handover the material to customer. Now, sales team updates the finance department about generated revenue for the product. Same, production department team update with the finance department which payment to made different vendor for raw material. All department approach to hr department for any human resource related issue. This is the typical business process for manufacturing. All process will take place physically. So it will take more time to complete all the process because there is no centralize process. For the above process, every organization need ERP system to get immediate results, faster communication and decision making etc.

26.4 Business Process Reengineering

Business process reengineering is defined as the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service, and speed. (Hammer and Champy, 1993).

- Business Process Reengineering (BPR) advocates a complete overhaul of the existing systems and processes in an organization in order to increase productivity, reduce costs, and improve business practices.
- Business process is defined as a set of logically related tasks performed to achieve a defined business outcome. BPR transforms labor- and machinery-based productivity into knowledge- and information-based productivity.
- The relationship between a company and its customers has gained new dimensions and expanded from the buying and selling of products to customer service, consulting, and pricing to production and distribution. Due to products and services being more widely available, customers have become increasingly selective. BPR makes companies more customer-focused and responsive to changes in the marketplace.
- Business process reengineering focuses on the strategic, value-added business processes rather than on the functions, tasks, jobs, and people and product lines (Muthu *et al*., 1999).
- According to Davenport and Short (1990) BPR as the analysis and design of work flows and processes within and between organizations

26.4.1 BPR and IT

The extensive application of IT in business has forced organizations to go in for BPR as implementation of IT requires changes in business processes. Through

BPR, organizations can take full advantage of the benefits offered by IT as BPR and IT are inter-related.

Activity: Zack & Cody Inc is a 20-year-old textile manufacturing company. Whenever the company felt that it needed to restructure, the first step it took was to lay off employees. Recently, the management decided to restructure the entire organization. It again decided to start with downsizing. However, the senior managers and the middle level managers protested against the management's decision and suggested that the company should go in for business process reengineering. Which do you think is a better option: downsizing or going in for business process reengineering? In what way do you think reengineering would help a company like Zack & Cody?

Answer:

Check Your Progress - 1

1. Which among the following options involves a fundamental rethinking and radical redesigning of the business processes in order to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service, and speed?
   a. Supply chain management
   b. Enterprise resource planning
   c. Business process reengineering
   d. Manufacturing resource planning
2. All the statements given below are true regarding business process reengineering, **except**:
   a. It advocates a complete overhaul of the existing systems and processes in an organization in order to increase productivity, reduce costs and improve business practices.
   b. It transforms knowledge and information-based productivity into labor and machinery-based productivity.
   c. It makes companies more customer-focused and responsive to changes in the marketplace.
   d. It helps organizations take full advantage of the benefits offered by information technology.
3. Which of the following statements is **not** correct regarding the evolution of Enterprise Resource Planning (ERP)?
   a. The history of ERP can be traced back to 1972.
   b. IBM was the first company to develop and maintain ERP software.

c. ERP extends the functionality of MRP and MRP II systems to provide complete business solutions.

d. ERP has the ability to integrate different business entities without being restricted by geographical and functional differences.

4. Which among the following can be defined as a set of logically related tasks carried out to achieve a defined business outcome?

   a. Strategies

   b. Activity

   c. Business model

   d. Business process

26.5 Business Modeling for ERP

Business modeling is a forerunner of BPR, ERP implementation, etc.

A business model is a representation of various business systems and processes, and their interconnections and interdependencies. It provides a general overview of the operations of a business without giving the technical details of the processes and systems. Broadly, it defines the activities performed and the workflow structure.

A good business model should be clear, consistent, and absolute. A business model is developed on the basis of the organization's goals, objectives, and strategic plans. It shows how various business processes exchange information among themselves and the underlying database.

An ERP system is implemented to provide the requisite information to individuals to enable them to perform business processes more efficiently and effectively.

26.5.1 Integrated Data Model

One of the critical steps in ERP implementation is the development of an integrated data model. The model ensures that the ERP system is able to integrate and provide coordination between various departments, functions, and levels of management. Integration enables the smooth flow of information that helps in the decision-making process, minimizes data redundancy, and ensures the availability of right information to all concerned. A well-designed data model for the ERP system should integrate information from various processes and functions. Issues like security, confidentiality, accuracy, during the integration process leads to generation of a data model that represents the entire organization with an integrated data flow structure.

26.6 ERP Implementation

The following issues should be considered for successful ERP implementation:

Functionality – The functions of the ERP package should complement the prevailing best business practices in the company's field of operation.

Technology – The ERP package should be scalable and should support open and non-proprietary technology standards. This would reduce risk and ensure compatibility of the systems with other IT solutions.

Implementability – The ERP package should be easy to configure and use, and flexible enough to accommodate the optimization of business processes.

26.6.1 ERP Implementation Methodology

The following are the different stages in a typical ERP implementation program:

Identify the Needs for the ERP package – In this stage, the needs that are to be satisfied by adopting the ERP package are identified. Companies can then evaluate how ERP implementation can help satisfy these needs.

Evaluating the "as-is" Situation of the Business – In this stage, the various processes involved in the working of the organization are identified.

Decisions about the Desired "Would-Be" Situations for the Business – In this stage, the desired attributes for each of the processes are identified. Performance standards are set for each process by using benchmarking techniques.

Reengineering of Business Processes to Achieve the Desired Results – Organizations can achieve the desired standards in business processes by reengineering their current processes.

Evaluation of Available ERP Packages – After conceptualizing the process of designing the business processes, the ERP packages are evaluated to identify the package that will provide a comprehensive solution to the organization's requirements. The points that need to be considered for selecting a package are:

Global Presence – The ERP package should be globally acceptable.

Local Presence – The package should also be able to handle country-specific business practices.

R & D Investment – Selection should be based on the amount of R&D put in by the ERP vendor.

Target Market – The type of industry for which the package is being designed is to be considered.

Price – The selection depends upon the price of the ERP.

Modularity – The package should be available in separate modules.

Ease and cost of implementation – As the process of ERP implementation calls for organizational structural changes, it should be quick, trouble-free, and should allow smooth transition from the old systems.

Installation of requisite hardware and networks – After selecting the package, the hardware requirements like servers, PC workstations, network equipment, etc. should be considered.

26.6.2 Implementation of ERP packages

The following are the steps involved in ERP implementation:

Formation of implementation teams: The ERP implementation team should consist of personnel from IT and other functions along with implementation consultants. A steering committee is to be formed to continuously monitor the implementation process to identify deviations, cost overruns, resource requirements, etc., during the process. To carry out successful ERP implementation, the members of the steering committee should be able to understand business redesign and integration. The steering team should be trained in process mapping and reengineering methodology and it should be fully involved in the process redesign so that it can guide the team members (implementation team) properly.

Preparation of implementation plan: Various elements of the implementation process are identified and a comprehensive plan is devised to cover those elements. The activities of the plan are scheduled using PERT/CPM techniques. The plan should include training for project teams, mapping business processes onto the software, function- or module-wise implementation, customization, transferring data from existing systems, trial runs, parallel run, and transition.

Mapping of business processes onto the package: In this stage, the reengineered business processes are mapped onto the software. Gaps are identified if the requirements are not fulfilled by the available system.

Gap analysis: Gap analysis helps in identifying the areas that are not handled by the standard system. Results from Gap analysis are divided into gaps that can be eliminated with minimal programming, gaps that require extensive rework and additional resources, gaps that cannot be handled by the system. For the first category of gaps, the project team can take action, while for the second and third categories, the steering committee should take action such as allocating extra resources, if required.

Customization: Customization of the ERP package is done by gathering information from mapping and the gap analysis. After identifying the customization needs, functional teams are given the responsibility of customizing the package to meet the firm’s requirements and finalize the structure of the package.

Uploading of data from existing systems: After finalizing the structure of the package, the information from the old systems is transferred to the new system. Errors or discrepancies during the transfer are verified by double-checking the transfer.

Test runs: Test runs are conducted to see how the system performs after customization and master data transfer.

User training: End users are trained based on their functional requirements and are informed about the functionality of the new system.

Parallel run: In this stage, both the old system and the new system are put into operation simultaneously. This helps in a smooth transition from the old system to the new without hampering operations.

Migration to the new system: The organization migrates to the new system after ensuring that the parallel run is error-free and the users feel confident about operating the new system.

User documentation: This provides detailed information on how to carry out transactions.

System monitoring and fine-tuning: IT personnel should monitor the performance of the system to keep it optimal. If needed, they should fine-tune the database.

26.6.3 Guidelines for ERP Implementation

To benefit from the ERP system, organizations should follow the following guidelines:

Define corporate needs and culture: Defining corporate needs before ERP implementation helps the organization to assess its readiness to change. ERP implementation involves redefining the roles of different functional departments, and the authority and responsibility of individuals throughout the organization.

Complete business process change: Before going in for actual implementation, a short business process redesign exercise should be carried out on the basis of the ERP package structure so that there is no variation between the required functionalities and those provided by the package, and to assess the implications of the changes.

Communicate across the organization: The different entities involved or affected by ERP implementation will be aware of its effects on their jobs through communication.

Provide strong leadership: The successful implementation of an ERP system requires strong leadership.

Select a balanced team: Because of the size and complexity of ERP implementation and maintenance, a balanced team of professionals from different functions is essential.

Select a good method of implementation: Project leaders should set the targets to be achieved in the various phases of implementation and continuously review the progress against the targets. They should clearly define the project scope, develop the work breakdown structure (WBS), and estimate the time required to complete each activity identified in the WBS. This helps them reach a realistic project plan. They need to ensure that the quality of the system is maintained.

Organization-wide training: ERP is a complex and organization-wide system that requires training to derive the full advantage of the capabilities of the system. The steering team should be trained in process analysis and redesign, the IT personnel should be aware of the package architecture, design, and configuration, and the functional managers should learn how the system performs and how it can be useful in the decision-making process.

Activity: Utopia Ltd is a US company which has been implementing ERP for the past five years. However, the management of the company felt that it was not reaping the benefits of ERP. It therefore, appointed an outside consultant to find out the reasons for this. The consultant found that the company had failed to implement ERP properly. She stated that Utopia was facing the same kind of situations that other companies who had failed to implement ERP properly were facing. Do you think the company failed to take into account the factors which are necessary for implementing ERP? What are the ERP implementation problems faced by companies like Utopia?

Answer:

Check Your Progress - 2

5. Strong leadership is an important success factor in implementing an ERP system. Which of the following will enable the steering committee to produce successful results in ERP implementation?
   i. The committee should understand the redesign and integration
   ii. The committee should be trained in process mapping
   iii. The committee should be fully involved in process redesign so that it can guide the team members
   a. Only i
   b. i and ii
   c. ii and iii
   d. i, ii, and iii
6. Business modeling is a precursor to business process reengineering, ERP implementation, etc. What is the purpose of business modeling?
   a. To provide details of activities performed and workflow structure
   b. To provide an overview of operations without focusing on processes and systems

c. To provide details of processes and systems

d. Both a & b

7. A good business model should be comprehensible, coherent and complete. Which of the following is **not** a primary basis for developing a business model?

   a. Goals

   b. Objectives

   c. Strategic plans

   d. Market structure

8. The key activity of _____ is to monitor the implementation process continuously in order to identify deviations, cost overruns, resource requirements, etc., during implementation.

   a. Project member

   b. Project leader

   c. Project team

   d. Steering committee

9. Which of the following types of information are required to customize an ERP package as per an organization's requirements?

   i. Information from mapping of business processes

   ii. Information from gap analysis

   iii. Market information

   iv. Information about the company's competitors

   a. Only i

   b. i and ii

   c. ii and iii

   d. Only iii

10. One of the critical steps of ERP implementation is the development of an integrated data model. How does this help an organization?

    i. Increases connectivity between departments

    ii. Helps in smooth flow of information between departments

    iii. Increases data redundancy

    iv. Ensures availability of right information

    a. i, ii, iii

    b. i, ii, iv

    c. ii, iii, iv

    d. i, ii, iii, iv

11. What is the basic objective behind defining corporate needs of an organization before ERP implementation?
    a. To assess the readiness of the organization to accept change
    b. To identify the gaps in terms of handling information
    c. To facilitate speedy implementation
    d. All of the above
12. An organization is required to undergo a brief business process redesign exercise before actual ERP implementation. Why?
    a. To assess the readiness of the organization to change
    b. To assess the implications of the changes
    c. To facilitate speedy implementation
    d. To identify the gaps in terms of handling information

26.7 ERP and Competitive Advantage

An organization should have a competitive advantage over others to attract and retain business. An organization can gain a competitive advantage by understanding the scope of a particular market and identifying the various inherent differences between various markets. ERP enables the organization to optimize and organize different qualifiers and order-winners to gain a competitive advantage in the market. Qualifiers are the most basic attributes that an organization must possess before any customer decides to deal with it. They provide the initial impetus to customers to deal with an organization. But to close a deal, organizations must have order-winners, which could be price advantage, quality, etc. The following are some of the order-winners and qualifiers:

Price – The ERP package helps in identifying the cost centers and assists in devising plans to reduce the production costs. The company can become cost-efficient by setting up cost targets and an accurate monitoring system. ERP should be implemented in areas where significant costs are involved so that appropriate resource allocations can be made and management attention can be focused on them.

Delivery Reliability and Speed – Customers judge an organization's competitiveness through delivery reliability. ERP can streamline procurement and distribution activities and reduce the lead-time involved in purchasing raw materials and the distribution of finished products.

Quality – ERP helps in achieving the quality objectives by bridging the gap between the existing process and the best process.

Product Range – Organizations need a variety of products in their product line to satisfy the requirements of different segments of the market and to face the growing competition. ERP with an integrated functionality and a common database enhances the capabilities that assist organizations in this direction.

Enterprise resource planning (ERP) solutions are being used to support most business functions, from back-end processes like accounting, HR, procurement and manufacturing to front-office functions such as sales force automation (SFA), marketing automation and ecommerce. Exhibit 26.1 presents trends of ERP in 2021.

Exhibit 26.1: 8 ERP Trends for 2021

ERP systems continue to evolve to incorporate new technologies and support a broader range of functions. Find here eight major trends to keep an eye on in 2021 and beyond.

1. *Cloud ERP:* Businesses are adopting cloud ERP to take advantage of a simpler deployment, lower costs, elasticity, new functionality, less need for internal IT resources, and the ability to easily add users and functions to accommodate business growth. A 2020 survey of finance executives indicated that 20% expect to spend more on cloud ERP technologies.
2. *Two-Tier ERP:* Two-tier ERP is one of the top ERP trends in 2021. Two-tier ERP is a strategy that enables organizations to leverage their investment in existing ERP systems at the corporate level (tier 1), while subsidiaries and divisions operate using a different ERP solution (tier 2), which is often cloud-based. The effectiveness of this approach depends in part on the ability to exchange data between the tiers.
3. *Digital Transformation:* Digital transformation refers to integrating digital technology into all business functions to improve daily operations. This approach can often boost revenue and competitiveness while increasing employee productivity and improving customer service and communication. Since an ERP suite typically touches most areas of a company, it's a logical place to start to facilitate this transformation.
4. *Other Technology Integrated With ERP:* Companies are integrating their business applications with other new technologies, including IoT, to improve core processes. For example, retailers use warehouse management systems that collect data from mobile scanners and smart conveyers to track the movement of goods within the warehouse. Some companies integrate ERP with ecommerce to improve online order workflows, automatically triggering order fulfillment, updating inventory levels and recording payment. The year ahead will also see a greater connection between social media and ERP
5. *Personalization*: As companies focus on delivering more personalized, relevant experiences to customers, they need ERP systems that can accommodate those needs with features like highly customizable dashboards.

Contd….

One emerging trend is the growing popularity of AI-based assistive and conversational user interfaces such as chatbots, which can interpret user voice or text input and respond to questions using customer and order information stored within the ERP.

6. *AI*-Powered Insights and Improvements: Artificial intelligence and machine learning capabilities embedded into ERP systems work behind the scenes to help meet increased demand for personalization and improve a broad range of business processes. AI can deliver significant benefits for businesses.
7. Predictive Analytics: A focus in 2021 and beyond is using predictive analytics to uncover and address what is likely to happen in the future. For example, software with machine learning capabilities can comb through a maintenance company's data about machine repairs to predict when breakdowns are likely to occur. The organization can optimize maintenance schedules so it services or replaces parts right before they cause problems.
8. Mobile ERP: ERP providers are making mobile apps as the norm. ERP solutions are evolving to provide on-the-go access to critical business data, allowing employees to conduct both back-end and front-end tasks no matter where they are, from the warehouse floor to a retail checkout terminal to an airport. Mobile ERP can also encourage collaboration for dispersed workforces in different time zones.

https://www.netsuite.com/portal/resource/articles/erp/erp-trends.shtml

Activity: The top management of Happy Living, a healthcare organization, decided to go in for ERP, which is used by the manufacturing sector. The company's employees were surprised by the management's decision. The management of the company explained the importance of the ERP system in its business. Do you think the management's decision is right? Can ERP be applied in the service sector? What could be the possible benefits that a healthcare company like Happy Living could derive through the use of ERP?

Answer:

ERP in Project and Operations Management

ERP represents one of the most important and demanding application software in the present corporate environment. Most of the organization wants to implement

ERP system in their organization due to competition and better services to the client. If you consider ERP system in project then it requires Planning, monitoring, and tracking of all the activities. This helps the organization to get right information on right time. In present scenario, ERP plays a great role such as planning, tracking all the activities, billing and profitability.

ERP supports a project manager to get quick results, check the status, and get 24x7 accesses to all project related activities. This helps to upgrades all the activities with respect to the project. Most of the ERP implementation takes place in the organization and it's rarely any ERP implementations fail. In current scenario Enterprise Resource Planning offers a complete project management solution to get outstanding results.

Different aspects of project management using ERP

- Project planning: planning is the first stage of every project and using ERP system helps to do in proper manner. It has centralized data base in which all updated information provides real time data. This database provides support to manager to define various activities and how to achieve those activities.
- Tracking: in this step, tracking of individual task and utilization of resources can be checked using ERP software. This tracking helps the organization or project manager to get different issues which can be identifies and solved them to minimize the risk. It includes track and record of project information, resources performance and millstone achieved.
- Billing: in ERP, planned budget details helps to consolidate revenue and expenses for a particular project. It's project manager responsibility to analyze the flow of fund during the project execution. All transaction details help the manager to calculate the cost and profit.
- Profitability: using project management module under ERP helps the project manager to examine the profitability. Project manager can assess planned expenses, actual expenses, profitability and also forecast the future probabilities throughout the data.

Check Your Progress - 3

13. If HDFC Bank offers a wide range of products that cover every market segment; it can be termed as an order winner with respect to _____.
    a. Price
    b. Product range
    c. Quality
    d. Delivery reliability

14. When an ERP marketer uses price as an order winner, it should focus on certain areas to reduce the costs involved during ERP implementation. Which of the following will **not** facilitate this objective?
    a. Identify the cost centers and devise plans to reduce production costs
    b. Set up tough cost targets
    c. Set up tough quality targets
    d. Set up a rigorous monitoring system to make the production process cost efficient
15. _____ are the most basic attributes that an organization must possess before any customer decides to deal with it, while _____ are the attributes required by organizations to close a deal with the customers.
    a. Qualifiers, targets
    b. Qualifiers, order-winners
    c. Targets, order-winners
    d. Order-winners, qualifiers
16. Which of the following are order-winners and qualifiers for organizations?
    i. Price and quality
    ii. Speed of delivery
    iii. Speed of reliability
    iv. Product range
    a. Only i, ii, and iii
    b. Only i, iii, and iv
    c. Only ii, iii, and iv
    d. i, ii, iii, and iv

26.8 Summary

- ERP is an organization-wide system that allows coordination among various functions.
- BPR advocates the complete overhaul of the existing systems and processes in a firm.
- BPR makes the company more customer-focused and responsive to changes in the market.
- Changes in BPR are implemented by redefining the company's activities in holistic and process-oriented terms rather than automation of the business processes.
- Business modeling is one of the first activities in any ERP project.
- ERP implementation is an event that involves the entire organization.

- The steps involved in ERP implementation are: identifying the need for an ERP package, evaluating the "as-is" situation of the business, taking decisions about the desired "would-be" situation for the business, reengineering business processes to achieve the desired results, evaluating the available ERP packages, installing the requisite hardware and networks, and implementing of the ERP package.

26.9 Glossary

Business model: A representation of various business systems and processes, and their interconnections and interdependencies. It provides a general overview of the operations of a business without giving the technical details of the processes and systems.

Business process reengineering: The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service, and speed.

Business process: A set of logically related tasks performed to achieve a defined business outcome.

Enterprise Resource Planning: An organization-wide system that allows coordination among various functions.

Gap analysis: It helps in identifying the areas that are not handled by the standard system. Results from Gap analysis are divided into gaps that can be eliminated with minimal programming, gaps that require extensive rework and additional resources, and gaps that cannot be handled by the system.

Manufacturing Resource Planning (MRP): It is used in manufacturing to automate inventory management and production processes.

Manufacturing Resource Planning II (MRP II): It is an extension of MRP, developed with the objective of automating all the manufacturing functions and providing an interface with other functional domains.

26.10 Self-Assessment Exercises

1. The proper implementation of Enterprise Resource Planning (ERP) facilitates effective decision-making. What is ERP? Explain the evolution of ERP and its importance.
2. Business Process Reengineering (BPR) advocates a complete overhaul of the existing systems and processes in an organization in order to increase productivity, reduce costs, and improve business practices. What do you understand by BPR? Explain the use of IT in BPR.
3. Business modeling is a forerunner of BPR, ERP implementation, etc. Explain the significance of business modeling in ERP.

4. Considerable risks are involved in ERP implementation due to its complexity and time constraints. What are the factors to be considered for successful implementation of ERP? Explain the various steps involved.
5. ERP enables the organization to optimize and organize different qualifiers and order-winners to gain a competitive advantage in the market. How can an organization use ERP as a competitive advantage to compete with others?

26.11 Suggested Readings/Reference Material

1. Janat Shah, Supply Chain Management:: Text And Cases, Pearson India, 2017
2. Gerardus Blokdyk, Enterprise Resource Planning A Complete Guide - 2020, 5STARCooks March, 2021
3. Peter Szende, Alec N Dalton, Yoo, Operations Management in the Hospitality Industry, Emerald Publishing, June 2021
4. Yacob Khojasteh, Production Management: Advanced Models, Tools, and Applications for Pull Systems, Productivity Press; October , 2017
5. Ramesh Upadhyay & Jitendra Narayan Kumar, Facility Management, Notion Press, January 2017

Additonal Reference

1. "ERP Implementation" <http://www.projectperfect.com.au/info_erp_imp.php>
2. "ABCs of ERP" <http://www.cio.com/research/erp/edit/erpbasics.html>
3. "ERP" <http://www.erpfans.com/erpfans/erpdefinition/erp001.html>
4. "ERP Implementation" <http://searchopensource.techtarget.com/originalContent/0,289142,sid39_gci1100450,00.html>

26.12 Answers to Check Your Progress Questions

Following are the answers to the Check Your Progress Questions given in the Unit.

1. (c) Business process reengineering

Business reengineering involves a fundamental rethinking and radical redesigning of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service, and speed. It advocates a complete overhaul of the existing systems and processes in an organization in order to increase productivity, reduce costs, and improve business practices.

2. **(b) It transforms knowledge and information-based productivity into labor and machinery-based productivity.**

   Business process reengineering advocates a complete overhaul of the existing systems and processes in an organization in order to increase productivity, reduce costs, and improve business practices. It transforms labor and machinery-based productivity into knowledge and information-based productivity.

3. **(b) IBM was the first company to develop and maintain ERP software.**

   The history of ERP can be traced back to 1972 when five employees of IBM left the company and established SAP (Systems, Application, and Products in Data Processing) in Germany. SAP was the first company to develop and maintain ERP software. The development of ERP can be traced back to the concepts of MRP and MRP II.

4. **(d) Business process**

   Business process is defined as a set of logically related tasks performed to achieve a defined business outcome. Strategies are broad, long-term plans, conceived to achieve business objectives and are developed at the corporate, business and functional levels. An activity is an element of work performed during the course of a project. A business model is a representation of various business systems and processes, and their interconnections and interdependencies.

5. **(d) i, ii and iii**

   To carryout successful ERP implementation, the members of the steering committee should be able to understand business redesign and integration. The steering team should be trained in process mapping and reengineering methodology and it should be fully involved in the process redesign so that it can guide the team members (implementation team) properly.

6. **(b) To provide an overview of operations without focusing on processes and systems**

   The purpose of business modeling is to provide a general overview of the operations of a business without going into the technical details of processes and systems. It defines the activities performed and workflow structure in a broad manner.

7. **(d) Market structure**

   A good business model should be comprehensible, coherent and complete. It should define clearly the different systems and subsystems of a business. A business model is developed on the basis of the organization's goals, objectives and strategic plans. The market structure is external to the

organization and is one of the many factors that helps decide on the organization's goals, objectives and strategic plans.

8. (d) Steering committee

The key activity of the steering committee is to monitor the ERP implementation process continuously in order to identify deviations, cost overruns, resource requirements etc., during ERP implementation.

9. (b) i and ii

Information gathered from mapping and gap analysis is used for customization of the ERP package. The other two options are not basic requirements for customizing an ERP package.

10. (b) i, ii, iv

Integration of data across departments helps in better connectivity and smooth flow of information. It reduces data redundancy and ensures availability of right information to the concerned department or personnel.

11. (a) To assess the readiness of the organization to accept change

Defining corporate needs before ERP implementation helps the organization to assess its readiness to change. Implementing an ERP system involves the redefinition of the roles of different functional departments and the authority and responsibility of individuals throughout the organization. Hence, organizations have to adapt to these changes as quickly as possible.

12. (b) To assess the implications of the changes

Even though an organization may be willing to adapt to changes, it may not be able to assess the implications of the changes. Hence, it must undergo a brief business process redesign exercise before actual implementation.

13. (b) Product range

Product range implies all the products that are offered by an organization. HDFC Bank offers a wide range of products like deposits, loans, bank accounts, NRI products, insurance products, investment products like mutual funds, pension plans, etc.

14. (c) Set up tough quality targets

Tough quality targets can be set up if the organization uses quality as the order winner. Further, when quality is given more importance, price of the product shoots up as quality never comes cheap.

15. (b) Qualifiers, order-winners

Qualifiers are the most basic attributes that an organization must possess before any customer decides to deal with it. They provide the initial impetus to customers to deal with an organization. But to close a deal, organizations must have order-winners, which could be price advantage, quality, etc.

16. (d) i, ii, iii, and iv

Qualifiers provide the initial impetus to customers to deal with an organization. Organizations have order-winners to close a deal. Some of the order-winners and qualifiers for organizations are price, product range, delivery speed, and delivery reliability.

Unit 27

Supply Chain Management

Structure

27.1 Introduction

In the last section of the previous unit, we have discussed how enterprise resource planning helps organizations gain competitive advantage. We have learnt that enterprise resource planning enables the organization to optimize and organize different qualifiers and order-winners to gain a competitive advantage in the market. In this unit, we will discuss supply chain management.

A supply chain is the network covering various stages in the process of providing products or services to customers. The supply chain network includes manufacturers, suppliers, transporters, warehouses, distributors, retailers, etc. Supply Chain Management (SCM) integrates procurement, operations, and logistics to provide value added products or services to customers.

This unit will explain the business drivers in supply chain management. We will discuss the principles of supply chain management, and the forces shaping supply chain management. We shall then move on to discuss the supply chain management framework, and the customer focus in supply chain management. Finally, we would discuss electronic supply chain management.

27.2 Objectives

By the end of this unit, students should be able to:

- Discuss the business drivers in supply chain management.
- Explain the principles of supply chain management.

- Determine the forces shaping supply chain management.
- Evaluate the supply chain management framework.
- Assess customer focus in supply chain management.
- Define electronic supply chain management.

Supply chain management

The term "supply chain management" arose in the late 1980s and came into widespread use in the 1990s. Prior to that time, businesses used terms such as "logistics" and "operations management" instead. Some definitions of a supply chain are offered below:

- "A supply chain is the alignment of firms that bring products or services to market."—from Lambert, Stock, and Ellram in their book Fundamentals of Logistics Management (Lambert, Douglas M., James R. Stock, and Lisa M. Ellram, 1998, Fundamentals of Logistics Management, Boston, MA: Irwin/McGraw-Hill, Chapter 14)
- "A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves."—from Chopra and Meindl in their book Supply Chain Management: Strategy, Planning, and Operations (Chopra, Sunil, and Peter Meindl, 2001, Supply Chain Management: Strategy, Planning, and Operations, Upper Saddle River, NJ: Prentice-Hall, Inc. Chapter 1).
- "A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers."—from Ganeshan and Harrison at Penn State University in their article An Introduction to Supply Chain Management published at http://silmaril.smeal.psu.edu/supply_chain_intro.html
- (Ganeshan, Ram, and Terry P. Harrison, 1995, "An Introduction to Supply Chain Management," Department of Management Sciences and Information Systems, 303 Beam Business Building, Penn State University, University Park, PA).

If this is what a supply chain is then we can define supply chain management as the things we do to influence the behavior of the supply chain and get the results we want. Some definitions of supply chain management are:

- "The systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the

long-term performance of the individual companies and the supply chain as a whole."—from Mentzer, DeWitt, Deebler, Min, Nix, Smith, and Zacharia in their article Defining Supply Chain Management in the Journal of Business Logistics (Mentzer, John T.,William DeWitt, James S. Keebler, Soonhong Min, Nancy W. Nix, Carlo D. Smith, and Zach G. Zacharia, 2001, "Defining Supply Chain Management," Journal of Business Logistics,Vol. 22, No. 2, p. 18).

- "Supply chain management is the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served."

27.3 Business Drivers in Supply Chain Management

There are mainly six drivers of supply chain performance. These drivers interact with each other and drive the performance of supply chain. First we define each driver and discuss its impact on the performance of the supply chain.

1. ***Facilities*** are the actual physical locations in the supply chain network where products is stored, assembled, or fabricated. The two major types of facilities are production sites and storage sites. Decisions regarding the role, location, capacity and flexibility of facilities have a significant impact on the supply chain's performance. For instance, an auto-parts distributor striving for responsiveness could have many warehousing facilities located close to customers even though this practice reduces efficiency. Alternatively, a high-efficiency distributor would have fewer warehouses to increase efficiency despite the fact that this practice will reduce responsiveness.
2. ***Inventory*** encompasses all raw materials, work in process, and finished goods within a supply chain. Changing inventory policies can dramatically alter the supply chain's efficiency and responsiveness. For example, a clothing retailer can make itself more responsive by stocking large amounts of inventory and satisfying customer demand from stock. A large inventory, however, increases the retailer's cost, thereby making it less efficient. Reducing inventory makes the retailer more efficient but hurts its responsiveness.
3. ***Transportation*** entails moving inventory from point to point in the supply chain. Transportation can take the form of many combinations of modes and routes, each with its own performance characteristics. Transportation choices have a large impact on supply chain responsiveness and efficiency. For example, a mail-order catalogue company can use a faster mode of transportation such as FedEx to ship products, thus making its supply chain more responsive, but also less efficient given the high costs associated with using FedEx. Or the company can use slower but cheaper ground

transportation to ship the product, making the supply chain efficient but limiting its responsiveness.

4. ***Information*** consists of data and analysis concerning facilities, inventory, transportation, costs, prices, and customers throughout the supply chain. Information is potentially the biggest driver of performance in the supply chain because it directly affects each of the other drivers. Information presents management with the opportunity to make supply chains more responsive *and* more efficient. For example, with information on customer demand patterns, a pharmaceutical company can produce and stock drugs in anticipation of customer demand, which makes the supply chain very responsive because customers will find the drugs they need when they need them. This demand information can also make the supply chain more efficient because the pharmaceutical firm is better able to forecast demand and produce only the required amount. Information can also make this supply chain more efficient by providing managers with shipping options, for instance, that allow them to choose the lowest-cost alternative while still meeting the necessary service requirements.
5. ***Sourcing*** is the choice of who will perform a particular supply chain activity such as production, storage, transportation, or the management of information. At the strategic level, these decisions determine what functions a firm performs and what functions the firm outsources. Sourcing decisions affect both the responsiveness and efficiency of a supply chain. After Motorola outsourced much of its production to contract manufacturers in China, it saw its efficiency improve but its responsiveness suffer because of the long distances. To make up for the drop in responsiveness, Motorola started flying in some of its cell phones from China even though this choice increased transportation cost. Flextronics, an electronics contract manufacturer, is hoping to offer both responsive and efficient sourcing options to its customers. It is trying to make its production facilities in the United States very responsive while keeping its facilities in low-cost countries efficient. Flextronics hopes to become an effective source for all customers using this combination of facilities.
6. ***Pricing*** determines how much a firm will charge for goods and services that it makes available in the supply chain. Pricing affects the behaviour of the buyer of the good or service, thus affecting supply chain performance. For example, if a transportation company varies its charges based on the lead time provided by the customers, it is very likely that customers who value efficiency will order early and customers who value responsiveness will be willing to wait and order just before they need a product transported. Early orders are less likely if prices do not vary with lead time.

Check Your Progress - 1

1. What is the relationship between the location of a facility and the supply chain performance of the firm?
   a. Facilities close to the target market improve the performance of the supply chain
   b. Facilities away from target markets improve the performance of the supply chain
   c. Facilities close to target markets worsen the performance of the supply chain
   d. The location of a facility and supply chain efficiency of a firm are in no way related
2. Which of the following is **not** considered a 'member' of a supply chain?
   a. Manufacturer
   b. Supplier
   c. Distributor
   d. Customer
3. Identify from the following the key drivers driving the supply chain performance.
   i. Inventory
   ii. Transportation
   iii. Facilities
   iv. Information
   a. Only i, ii, and iii
   b. Only i, iii, and iv
   c. Only ii, iii, and iv
   d. i, ii, iii, and iv
4. Which of the following statement is **true** regarding the key drivers driving supply chain performance?
   a. Facilities located closer to the customer enhance responsiveness, but leads to low maintenance costs.
   b. Inventory that includes raw materials, work-in-progress materials and finished goods influence the supply chain.
   c. In case of land or sea transport, the cost efficiency decreases but responsiveness increases.
   d. In case of air transport, the responsiveness decreases while the cost efficiency increases due to high air transport costs.

27.4 Principles of Supply Chain Management

The principles of SCM allow organizations to maintain a balance between customers' expectations and their own objectives.

Segment Customers Based on Service Needs – Organizations have to segment markets based on the specific needs of their customers. After segmenting, organizations can develop a supply chain plan that considers the specific requirements of different segments.

Customize the Logistics Network – Companies usually design logistics systems either to meet average service requirements of all customers or to satisfy the toughest requirements of a single customer. However, both these approaches lead to poor resource utilization. Hence, organizations customize their logistics network so that they can supply items to customers based on their specific requirements.

Plan Based on Market Demand – Conventionally, each department in an organization develops demand forecasts independently for the same set of products and they differ drastically thus making the supply chain inefficient. A company should therefore ensure that every link in the supply chain is involved in collaborative forecasting.

Enhance Ability to Meet Customer Requirements – Manufacturers can gain a competitive advantage if they reduce the lead-time along the supply chain and the time for converting raw material to finished product and provide products based on the requirements of specific customers.

Improve Relationships with the Suppliers – By maintaining strong and long-term relationships with their suppliers, organizations can derive significant cost advantages. To improve supplier satisfaction, organizations should have clear and mutually understood rules of relationship. Organizations should show commitment for long-term profitability and success of suppliers. This commitment would require suppliers' involvement in new product development and improvements in current products or services. But focus on discounts to increase short-term profits will hamper development and maintenance of long-term relationships with suppliers.

Have a Supply Chain-Wide Technology Strategy – Organizations should replace inflexible and poorly integrated systems with enterprise-wide systems. Fragmented systems capture data but cannot translate it into business intelligence that enhances the capability of business operations. Therefore, an IT system should integrate three kinds of capabilities: in the short term, it should be able to handle day-today transactions, so that demand and supply are aligned to a certain extent by the sharing of information; in the medium term, it should help in planning and decision-making and effective resource allocation through a master production schedule; and in the long term, it should provide top managers with tools for strategic analysis.

Devise a Complete Supply Chain Performance Measure – Organizations should develop a broad system to measure the overall performance of the supply chain system instead of narrow performance measures.

27.5 Forces Shaping Supply Chain Management

The effectiveness of SCM is influenced by various business and economic forces:

Consumer Demand – Customers' expectations regarding quality, speed of service, choice, and price have notably increased. Firms aim to meet these expectations by providing cheaper products within the least possible time. All these objectives are fulfilled by SCM.

Globalization – Organizations can benefit from the competitive advantages of other economies. For example, US and European companies have outsourced their operations to Asian or Latin American countries and gained significant advantages.

Competition – Technological advancements, increased globalization, easy access to information, etc., has increased competition in every business. Improvements in information flow and transportation, small companies are able to compete with bigger players globally.

Information and Communication – The information explosion brought about by improved communications systems has supported the supply chain decisions and has resulted in the worldwide expansion of supply chain activities.

Government Regulation – Regulations and policies framed by governments of other countries have a direct effect on the organization's supply chain decisions. International trade organizations like the WTO and other regional trade agreements have tried to bring about consistent regulations in all countries.

Environment – Supply chain decisions are influenced by a growing concern for the environment and government regulations to protect the environment.

Activity: Villa Inc. is a 15-year-old consumer goods manufacturing company. For a decade, the company was successful in the consumer goods industry, but the last five years saw it facing a downturn. It was unable to maintain profitability and market share due to the increased competition and volatile business environment. The management of Villa has therefore decided to restructure its supply chain in order to enhance its operational efficiency. Do you think the company's decision to restructure its supply chain is justified? How can revamping of SCM practices help the company in enhancing its operational efficiency and in gaining profitability and lost market share?

Answer:

Check Your Progress - 2

5. If an organization follows the principles of supply chain management, it can attain a balance between customers' expectations and growth and profitability objectives. Which of the following is **not** a 'principle' of supply chain management?
   a. Quality and performance management
   b. Customize the logistics network
   c. Enhance ability to meet customer requirements
   d. Have a supply chain-wide technology strategy
6. Which of the following statements about designing of a logistics network in a supply chain is **incorrect**?
   a. Firms design a logistic network to meet average requirements of all customers
   b. Firms design a logistic network to meet even the toughest requirements of a single customer
   c. Firms never custom design a logistic network to meet the individual requirements of customers
   d. Firms design a logistic network so that some amount of customization is built in to meet the requirements of customers
7. The health and well-being of suppliers is critical for organizations, which largely depend on suppliers for their requirements. Which of the following hampers development and maintenance of long-term relationships with suppliers?
   a. Show commitment for long-term profitability of suppliers
   b. Lay down mutually understood rules for building a long-term relationship
   c. Strive for heavy discounts to improve the organization's short-term profitability
   d. All of the above
8. Identify the statement that **does not** hold true regarding the principles of supply chain management.
   a. Organizations have to segment markets based on the specific needs of their customers.
   b. Companies usually design logistics systems either to meet average service requirements of all customers or to satisfy the toughest requirements of a single customer.
   c. Each department in an organization develops demand forecasts independently for the same set of products and they differ drastically thus making the supply chain inefficient.

d. Manufacturers can gain competitive advantage if they increase the lead-time along the supply chain and the time for converting raw material to finished product.

9. Which of the following statement is **not correct** regarding the forces shaping supply chain management?
   a. Customers' expectations regarding quality, speed of service, choice, and price have notably increased.
   b. Technological advancements, increased globalization, easy access to information, etc., has increased competition in every business.
   c. The information explosion brought about by improved communication systems has supported the supply chain decisions and has resulted in the worldwide expansion of supply chain activities.
   d. Regulations and policies framed by the governments of other countries have an indirect effect on the organization's supply chain decisions.

27.6 Supply Chain Management Framework

The SCM framework is based on a functional model of the SCM system. It is a development tool that assists in the development of a well-integrated SCM system in an organization. The framework consists of several components that define key functions, processes, and best practices. Organizational behaviors like SCM enablers support the organization's overall performance.

27.6.1 The Seven SCM Components

SCM components represent business processes and practices. Following are the seven SCM components:

- **SCM leadership –** This component provides a direction to the SCM system. It is constituted by managers from the different functional areas. The overall performance of the SCM system depends on the interaction between these functional heads and the senior management.
- **SCM strategy –**The SCM strategy forms an outline for supply chain operations that support and are consistent with the manufacturing and marketing objectives of the organization.
- **Operational planning –** This component defines the operational requirements for maintaining a supply chain which are specified in terms of tasks, resource requirements, and measurements.
- **Business relationship management –** Organizations and supply chain partners are dependent on each other. It is imperative to have a favorable environment that facilitates communication and negotiation between the organization and its supply chain partners. The relationship can be improved by having long-term contracts, and by using inputs from different levels of management and supply chain partners in the communication and decision making processes.

- **Order-to-delivery process –** The order-to-delivery process defines how effectively an organization can direct the flow of products from the suppliers to the company. It includes processes like order releases, receiving, inspection of incoming material, accounts payable, and materials handling. The order-to-delivery process can be used to evaluate suppliers' performance on the basis of criteria like on-time delivery, cost, defects, lead time, flexibility in scheduled time, etc.
- **Quality and performance management –** This component is concerned with the initiatives that organizations and suppliers take to improve and maintain quality standards. The quality and performance component helps identify the quality defects in suppliers' products, and facilitates cooperation between suppliers and the manufacturer to improve the quality.
- **Human resources management** – This component deals with the training of personnel to improve their skills, knowledge, and attitudes to enhance the supply chain performance.

27.6.2 The Six SCM Enablers

The SCM enablers are a group of carefully conceived and defined behaviors and approaches that allow, encourage, and reinforce a firm's commitment to high performance SCM practices. The following are the SCM enablers:

- **Alignment –** Alignment refers to matching the corporate and business unit goals. It is a key organizational behavior within the SCM system and includes consistency in processes, actions, and decisions across the business units to support the SCM processes. For better alignment, the company leadership should set goals, objectives, and strategies that support successful supplier relationships.
- **Customer-supplier focus –** The customer-supplier focus aims to plan the organization's processes in such a way that they are able to understand and react to customer requirements quickly. To improve suppliers' satisfaction, organizations should have clear and mutually understood and agreed rules of relationship and should show commitment for their suppliers' long-term profitability and success.
- **Design –** Design is the feature of products, processes, systems, and services that ensures their successful functioning. It is a comprehensive process, which, after considering feedback from customers and suppliers, defines the overall external and internal requirements to the organization.
- **Measurement –** Measurement is a tool that organizations use to quantify information about inputs, outputs, and the performance dimensions of products, processes, and services. It evaluates the performance of different business processes, and of supplier activities in terms of delivery performance, quality of material supplied, etc.

- **Participation/involvement –** Stakeholders must be involved in the decision-making process to ensure the success of products, processes, systems, and services. Organizational efficiency and performance can be improved by utilizing the available resources in terms of talents and energies of employees and external stakeholders.
- Periodic review – Continuous improvement is based on the periodic review of all the business processes, programs, and systems. These reviews indicate the difference between the expected performance and the actual performance and the reasons for the deviations.

Supply Chain Innovations Can Provide Positive Impact on People, Performance and Industries. Exhibit 27.1 presents trends of SCM in 2021.

Exhibit 27.1: Gartner Identifies the Top Supply Chain Technology Themes in 2021

Gartner, Inc. has identified the top 8 supply chain technology themes in 2021. The top supply chain technology themes in 2021 are:

Hyperautomation: Hyperautomation describes the combination of technologies such as machine learning (ML), artificial intelligence (AI) and robotic process automation (RPA) that can facilitate or automate tasks that originally required some form of human judgment or action. Hyperautomation is expected to augment human capabilities and supporting the creation of an autonomous supply chain.

Digital Supply Chain Twin (DSCT): The DSCT is a digital representation of the physical supply chain. It is the basis for local and end-to-end (E2E) decision making for the supply chain and ensures that this decision making is aligned horizontally and vertically throughout the network.

Immersive Experience and Applications: Immersive experience technologies presents new interaction models through the product life cycle, not only with humans, but with other processes, machines and applications, and benefit in safer working environments, faster repair times, improved work error rate, better collaboration and retention of skills and knowledge"

Edge Ecosystems: Edge ecosystems allow supply chain technology leaders to reassign and replan large swaths of data processing capacity to the edges of enterprises, where things and people produce or make decisions.

Supply Chain Security: Supply chain security brings together a more comprehensive approach to embrace security risks such as counterfeits or cybercrime holistically across the E2E supply chain.

Contd….

Environmental Social Governance (ESG): Global supply chains have a pivotal role to play in their contribution to both map and assess ESG risks and opportunities.

Organizations need technologies to map and prepare for ESG opportunities, risks and impacts.

Embedded AI and Analytics: Embedded AI and analytics are software capabilities that deliver real-time reporting, interactive data visualization and advanced analytics and intelligence directly into an enterprise business application.

Augmented Data Intelligence: Augmented data intelligence is a combination of several technologies that facilitate advanced data processing on top of a data lake/platform and further allow for the delivery of insightful information, predictions and suggestions.

https://www.gartner.com/en/newsroom/press-releases/2021-06-09-gartner-identifies-the-top-supply-chain-technology-themes-in-2021 June 2021

Activity: Paradise Inc., a retailing company, has decided to make efficient use of the SCM system that it recently developed, in order to increase its profits, market share, and competitive position. It has appointed Sheetal, an SCM consultant, to assist the company in the process. Sheetal has suggested that the company go in for supply chain integration. The company, which is not aware of the significance of supply chain integration, has requested Sheetal to explain in detail about it. Help Sheetal in the process. Do you think Sheetal's suggestion of integrating the supply chain functions is a better option for the company? What are the key issues to be considered by Paradise to integrate its supply chain functions?

Answer:

Check Your Progress - 3

10. Order-to-delivery process is an SCM component. It can be used to evaluate the performance of a _____ on the basis of on-time delivery, costs, defects, etc.
    a. Production manager
    b. Supplier
    c. Purchase manager
    d. Distributor

11. Every organization takes steps to maintain certain standards in terms of quality. Which of the following 'components' of SCM is **not** concerned with these initiatives?
    i. Human resources management
    ii. Order-to-delivery process
    iii. Business relationship management
    iv. Quality and performance management
    a. i and ii
    b. i, ii, iii
    c. ii, iii, iv
    d. i, iii, iv
12. Measurement is an SCM 'enabler'. How are measurements helpful in supply chain management?
    i. They provide information about inputs, outputs, performance etc.
    ii. They are used to evaluate the performance of business processes
    iii. They provide insights into supplier's performance in terms of delivery performance, quality of material supplied etc
    iv. They ensure periodic evaluation of the performance of processes, programs and systems that support continuous improvement
    a. i and ii
    b. i, ii and iv
    c. ii, iii, iv
    d. i, ii, iii
13. _____ is an SCM enabler that refers to matching the corporate and business unit goals. It is a key organizational behavior within the SCM system and includes consistency in processes, actions and decisions across the business units to support the SCM processes.
    a. Design
    b. Alignment
    c. Measurement
    d. Periodic review
14. Identify the statements that hold **true** regarding design, an SCM enabler.
    i. It includes consistency in processes, actions, and decisions across the business units to support the SCM processes.
    ii. It is the feature of products, processes, systems and services that ensures their successful functioning.
    iii. It is a tool that organizations use to quantify information about inputs, outputs and the performance dimensions of products, processes and services.

iv. It is a comprehensive process, which, after considering feedback from the customers and suppliers, defines the overall external and internal requirements to the organization.

a. Only i and ii

b. Only i and iii

c. Only ii and iv

d. Only iii and iv

27.7 Customer Focus in Supply Chain Management

The current competitive environment is the outcome of the convergence of various forces on all supply chain members and to compete in it, organizations need to do more than optimize their supply chain activities. These forces include the development of new technologies, increase in communication capabilities, increasing demand for better quality and customer services, and the demand for quick and efficient response to market. Earlier, supply chain members who were away from the end consumers stressed factors that directly affected their own immediate customer and supplier. But now, they too need to focus on the end customers and see how these forces affect their end customers. The key to survival depends on the supply chain members' focus on the demand side of the supply chain equation. From the corporate perspective, end-use forces will influence the way things are done in the supply chain and determine the best operational practices for meeting the requirements of the end users. From the consumers' perspective, end-use forces like technology and changing lifestyles will help in determining the supply chain. Thus, customer focused analysis influences the objectives and goals of supply chain activities. The efficacy of "push" and "pull" strategies has always been debatable. Of late, the consumer provides both the strategies in the demand-chain management process.

27.7.1 Demand-Chains: A Focus on End Users

Instead of building and operating a supply chain from manufacturer to market, demand-chain leaders focus on developing alliances with those channel partners who can meet customer requirements. The focus on end-users directed the attention of all supply chain partners to the demand side of the supply chain equation and made them rethink their roles in the supply chain. The roles and responsibilities of players in today's emerging demand chains have changed compared to those in traditional chains. In a demand chain, the products are developed based on consumer research and information gathered by any of the supply chain partners and not necessarily by the manufacturers. For example, retailers provide comprehensive information on consumer spending patterns and preferences to the manufacturer and this information helps in producing products with attributes that meet customer requirements.

Consumers are now interacting with different entities in the purchasing process. Therefore, every member of the demand chain needs to monitor consumer needs and wants. This knowledge makes it easier for all the members to identify the product and packaging requirements and marketing opportunities, and to determine the need for brand extension. The success of a product and the channel members depends on the level of participation and coordination between the channel members from the time the product is conceptualized to the time it is launched in the market. This is essential if supply chains are to be transformed into demand chains.

27.7.2 Broad Trends and Misconceptions

While developing a demand chain, channel partners should be aware of the broad demand trends in consumer markets based on demographics, lifestyle, and other social factors. For example, the overall size of the average family has shrunk due to a fall in the birth rate in industrialized nations, thus bringing down the number of new consumers. Also, the workforce size has contracted due to an increase in automation. These changes influence the way in which consumers purchase goods and where they purchase them. The failure to accept these changes leads to two general misconceptions about the working of the demand chain.

Misconception # 1 – *Customers will always buy from retailers*. Consumers are actively looking for new sources from which to obtain products and services. In this process, to get value for money, they are prepared to buy products and services from any0020channel member who can provide them with quality products, timely delivery, and a reasonable price.

Misconception # 2 – *Business-to-business companies or industrial organizations need to monitor only their customers*. In industrial organizations, solving customers' problems sometimes means solving your customer's customers' problems. All customer/industrial demand for products or services across the supply chain is derived from end-user demand. Industrial customers will not order more parts if consumers are not buying their end products.

27.7.3 Creating the Demand Chains of the Future

Demand chains are intended to bring together channel members to delight customers and solve their problems by

- Gathering and analyzing information about consumers, their problems, and their needs.
- Identifying and choosing the right channel partners.
- Developing a system for information sharing among channel partners.
- Developing products and services, which are capable of solving customers' problems.
- Choosing the most optimal transportation and distribution methods.

Check Your Progress - 4

15. Which of the following supply chain members traditionally assumed the role of monitoring consumer preferences?
    a. Retailer
    b. Wholesaler
    c. Distributor
    d. Manufacture
16. Which of the following are common misconceptions about the working of the demand chain?
    i. All customers buy from retailers
    ii. Industrial marketers should focus on client preferences and not end users
    iii. All members of the supply chain should work in unison to improve profitability
    iv. To improve supply chain efficiency it is necessary to have a supply chain-wide technology strategy
    a. Only i
    b. i and iv
    c. i and ii
    d. i, iii and iv
17. Demand chains help in bringing together channel members by delighting customers and solving problems. Which of the following strategies are used by demand chains to solve problems?
    i. Gather and analyze information about consumers, their problems, and their needs.
    ii. Identify and choose the right channel partners.
    iii. Develop a system for information sharing among channel partners.
    iv. Develop products and services, which are capable of solving customers' problems.
    a. Only i, ii, and iii
    b. Only i, iii, and iv
    c. Only ii, iii, and iv
    d. i, ii, iii, and iv
18. The current competitive environment is the outcome of the convergence of various forces on all supply chain members. Which of the following are those forces?
    i. Development of new technologies
    ii. Increase in communication capabilities
    iii. Demand for quick and efficient response to market

iv. Increasing demand for better quality and customer services

a. Only i, ii, and iii

b. Only i, iii, and iv

c. Only ii, iii, and iv

d. i, ii, iii, and iv

27.8 Electronic Supply Chain Management

Information technology has become a part of SCM. Electronic SCM or ESCM is business-to-business integration through the Internet.

27.8.1 ESCM – Advantages

ESCM has many advantages including timely order-processing, improved inventory tracking and management, improved accuracy in order fulfillment, support for JIT manufacturing, etc.

- **Cost saving –** Organizations can gain huge cost savings by integrating the different supply chain levels. The communication cost and time is greatly reduced with the help of internet.
- **Reduction in inventory levels –** ESCM covers the suppliers' activities, and provides instant information to them about the status of inventory levels.
- **Reduction in procurement costs –** ESCM helps supply chain partners communicate through the Internet. Communication through Internet is quicker and cost effective. A company can reduce procurement costs significantly by providing its suppliers with instant access to information regarding inventory and procurement.
- **Reduction in cycle time –** ESCM ensures that organizations get timely and accurate forecasts regarding product or service demand. This allows proper production planning based on actual requirements, resulting in reduction of cycle time for production activities and stock-out costs.

27.8.2 ESCM – Implementation

The following activities should be undertaken for improving ESCM implementation:

- Understand and evaluate the level of integration within the organization.
- Determine the number of suppliers who have a direct influence over the products or services that are delivered to the customers, across the entire supply chain.
- Divide suppliers into different categories: first tier, second tier, and so on.
- Define the customer base in term of sales, profitability, size, etc.
- Improve the information infrastructure within the organization to accommodate ESCM requirements.

- Constitute a team with representation from various functions within the organization and representatives from suppliers and customers to plan and carry out the implementation.
- Identify leaders who are capable of guiding the implementation process competently.

27.8.3 Issues Relating to ESCM

ESCM allows effective sharing of information like forecasts and orders among the supply chain partners. Utilizing customer and supplier related data through Internet technologies results in a virtual corporation that aids the direct flow of information between various supply chain partners. To enhance the efficiency of ESCM, the organization should deal with the following issues:

- **Security issues –** As information is shared or exchanged over the Internet, the organization has to ensure that the right person accesses it. This can be done by encrypting the data to make it secure and allowing supply chain members to view only the information which is relevant to them.
- **Changes to existing business processes –** An electronic supply chain significantly transforms a business process. The changes arise in the way companies deal with each other. Channel partners should be willing to share information regarding inventory levels, production schedules, forecasts, promotion plans, etc. A culture of openness and trust should be developed between all the channel partners.

Activity: Ganesha Ltd. is a diversified company engaged in construction, financial services, fertilizers, and retailing businesses spread over different countries. The company has been facing challenges because of its business being diversified and staggered. The company has therefore decided to streamline its operations, restructure its supplier network, and improve the efficiency of its supply chain. It has decided to give more importance to the use of information technology in its supply chain. Do you think the company was right in its decision to use IT in making its operations efficient? What do you think will be the role played by suppliers in enhancing the efficiency of the supply chain? How can an efficient supply chain help a company like Ganesha Inc to compete strongly in the market?

Answer:

Check Your Progress - 5

19. How does electronic supply chain management cut procurement costs?
    a. By transporting goods quickly
    b. By enabling customers to directly order products
    c. By reducing communication costs
    d. By providing suppliers instant access to information
20. Electronic supply chain management has many benefits, but together with the benefits, there are issues that must be addressed to improve the efficiency of ESCM. Which of the following can be considered the most sensitive issue?
    a. Information security
    b. Order taking
    c. Order delivery
    d. Customer information
21. Arrange the following steps in electronic supply chain management implementation in the correct sequence.
    v. Understand and evaluate the level of integration within the organization.
    vi. Determine the number of suppliers who have direct influence over the products or services delivered to customers across the entire supply chain.
    vii. Divide suppliers into different categories: first tier, second tier and so on.
    viii. Define customer base in term of sales, profitability, size, etc.
    ix. Improve information infrastructure within the organization to accommodate ESCM requirements.
    x. Constitute a team with representation from various functions within the organization and representatives from suppliers and customers to plan and implement.
    xi. Identify leaders who are capable of guiding the implementation process competently.
    a. iv, iii, ii, v, vi, vii. i
    b. i, ii, iii, iv, v, vi, vii
    c. iv, v, vi, vii, i, ii, iii
    d. i, ii, iii, iv, vii, vi, v
22. Which of the following is **not** correct regarding the advantages of an electronic supply chain management?
    a. Reduction in inventory levels
    b. Increased cycle time
    c. Improved accuracy in order fulfillment
    d. Timely order-processing

27.9 Summary

- A supply chain consists of suppliers, manufacturers, distributors, and retailers whose combined efforts result in production, selling, and delivery of products and services.
- The objectives of SCM are to reduce operation costs, improve coordination between channel partners, reduce lead time, improve the reliability of the delivery system, etc.
- The key drivers of SCM that determine the overall competitiveness and responsiveness of the organization relate to inventory, transportation, facilities and information.
- The complete supply chain is made up of many channel partners and many processes. These processes can be viewed from two perspectives: the cycle view and the push/pull view.
- SCM encompasses several activities and partners. The forces which are responsible for making the supply chain effective are consumer demand, globalization and so on.
- The supply chain enablers which determine its performance are alignment, measurement, participation and involvement, customer-supplier focus, design, and periodic review.
- The scope of SCM has increased significantly of late. For many big enterprises, supply chain activities span countries or continents.

27.10 Glossary

Supply chain management components: The supply chain management components are leadership, strategy, operational planning, business relationship management, order-to-delivery process, quality and performance management, and human resources management.

Supply chain management enablers: The supply chain management enablers are alignment, customer-supplier focus, design, measurement, participation/ involvement, and periodic review.

Supply chain management framework: It is a development tool that assists in the development of a well-integrated supply chain management system in an organization. The framework consists of several components that define key functions, processes, and best practices.

Supply chain management: It integrates procurement, operations, and logistics to provide value added products or services to customers.

Supply chain: A network covering various stages in the process of providing products or services to customers. It includes manufacturers, suppliers, transporters, warehouses, distributors, retailers, etc.

27.11 Self-Assessment Exercises

1. Supply Chain Management (SCM) is one of the key focus areas for organizations to reduce costs and enhance the efficiency of the production process. What is SCM? What are the key drivers of supply chain performance?
2. The principles of SCM allow organizations to maintain a balance between customers' expectations and their own objectives. What are the principles of SCM? Explain the forces shaping supply chain management.
3. The SCM framework consists of several components that define key functions, processes, and best practices. Explain in detail about the supply chain management framework.
4. As new areas of competition have emerged in the supply chain, organizations are now competing on flexibility, speed, and productivity, and focusing on meeting consumer demand. Why is customer focus important in supply chain management?
5. Organizations are integrating their supply chains through the use of information technology. Explain the importance of Electronic SCM (ESCM) in this context.
6. ESCM allows effective sharing of information like forecasts and orders among the supply chain partners. Explain the activities that should be undertaken and issues to be considered to improve the efficiency of ESCM.

27.12 Suggested Readings/Reference Material

1. Janat Shah, Supply Chain Management:: Text And Cases, Pearson India, 2017
2. Gerardus Blokdyk, Enterprise Resource Planning A Complete Guide - 2020, 5STARCooks March , 2021
3. Peter Szende, Alec N Dalton, Yoo, Operations Management in the Hospitality Industry, Emerald Publishing, June 2021
4. Yacob Khojasteh, Production Management: Advanced Models, Tools, and Applications for Pull Systems, Productivity Press; October , 2017
5. Ramesh Upadhyay & Jitendra Narayan Kumar, Facility Management, Notion Press, January 2017

Addiitonal References

1. "ABCs of Supply Chain Management" <http://www.cio.com/research/scm/edit/012202_scm.html>
2. "Introduction to Supply Chain Management" <http://logistics.about.com/od/supplychainintroduction/a/into_scm.htm>
3. "Supply Chain Management" <http://mba.tuck.dartmouth.edu/pages/faculty/dave.pyke/case_studies/supply_chain_or_ms.pdf>

4. "Supply Chain Management" <http://en.wikipedia.org/wiki/Supply_chain_management>
5. "Electronic Supply Chain Management" <http://faculty.ksu.edu.sa/nizarhussain/Documents/Electronic%20Supply%20Chain%20Management-%20Some%20latest%20issues%20and%20Practices.pdf>
6. "Web-based Supply Chain Management" <http://www.engr.sjsu.edu/fayad/designfest/SupplyChain_02.pdf>

27.13 Answers to Check Your Progress Questions

Following are the answers to the Check Your Progress Questions given in the Unit.

1. **(a) Facilities close to the target market improve the performance of the supply chain**

   The capacity and location of a facility has a significant effect on the performance of the supply chain. More facilities close to the customer may improve supply chain effectiveness although cost of maintenance of so many facilities will be high.

2. **(d) Customer**

   Supply chain members include manufacturers, suppliers, distributors, wholesalers, retailers, logistic service providers, etc. Customers are the basis for all supply chain activities. Supply chain members strive hard to meet customer demand for products they deal with.

3. **(d) i, ii, iii, and iv**

   SCM is one of the key focus areas for organizations to reduce costs and enhance the efficiency of the production process. The supply chain performance is driven by four key drivers – inventory, transportation, facilities, and information.

4. **(b) Inventory that includes raw materials, work-in-progress materials, and finished goods influence the supply chain.**

   All the statements are false regarding the key drivers driving supply chain performance, except statement (b). Setting up facilities closer to the customers enhances responsiveness but leads to high maintenance costs. For instance, facilities such as warehouses need to be set up closer to the customers to suit their requirements. However, maintenance of these facilities from time-to-time leads to incurrence of high costs. Alternatively, companies can opt for fewer warehouses. Though these reduce the maintenance costs, they adversely affect the responsiveness. In case of land or sea transport, its cost efficiency increases but responsiveness decreases. In case of air

transport, the responsiveness increases while the cost efficiency decreases due to high air transport costs.

5. **(a) Quality and performance management**

   Quality and performance management is a component of SCM and not considered a principle of SCM. All other options mentioned are principles of supply chain management.

6. **(c) Firms never custom design a logistic network to meet the individual requirements of customers**

   Companies usually design logistics systems either to meet average service requirements of all customers or to satisfy the toughest requirements of a single customer. However, both these approaches lead to poor resource utilization. Hence, a certain amount of customization is built into the network to meet specific requirements of customers.

7. **(c) Strive for heavy discounts to improve the organization's short-term profitability**

   To improve supplier satisfaction, organizations should have clear and mutually understood rules of relationship. Organizations should show commitment for long-term profitability and success of suppliers. This commitment would require suppliers' involvement in new product development and improvements in current products or services. But focus on discounts to increase short-term profits will hamper development and maintenance of long-term relationships with suppliers.

8. **(d) Manufacturers can gain competitive advantage if they increase the lead-time along the supply chain and the time for converting raw material to finished product.**

   All the statements are true regarding the principles of supply chain management, except statement (d). Manufacturers can gain competitive advantage if they reduce the lead-time along the supply chain and the time for converting raw material to finished product and provide products based on the requirements of specific customers.

9. **(d) Regulations and policies framed by governments of other countries have an indirect effect on the organization's supply chain decisions.**

   All the statements are true regarding the forces shaping supply chain management, except statement (d). An organization's supply chain decisions have to consider the regulations and policies of other countries as well. Trade barriers, duties and other such trade related decisions are in the hands of the governments of various countries. These rules and regulations directly affect the functioning of supply chain entities.

10. (b) Supplier

The order-to-delivery process can be used to evaluate suppliers' performance on the basis of criteria like on-time delivery, cost, defects, lead time, and flexibility in scheduled time.

11. (b) i, ii, iii

The quality and performance component is related to initiatives that organizations and suppliers take towards improving and maintaining quality standards. It helps identify quality defects in supplier products and facilitates cooperation between suppliers and the manufacturer to improve the quality of items supplied.

12. (d) i, ii, iii

Measurements provide information on inputs, outputs, performance of business processes, supplier's performance, etc. The latter can be measured using metrics like on-time delivery performance, quality, etc. Periodic evaluation of performance of processes, programs and systems is associated with periodic review, another SCM enabler.

13. (d) Alignment

Alignment refers to matching the corporate and business unit goals. It is a key organizational behavior within the SCM system and includes consistency in processes, actions and decisions across the business units to support the SCM processes. For better alignment, the company leadership should set goals, objectives and strategies that support successful supplier relationships.

14. (c) Only ii and iv

Options ii and iv refer to design. Option i refers to alignment and option iii refers to measurement, both SCM enablers.

15. (a) Retailer

Traditionally, retailers have been the closest to consumers. Owing to this proximity, retailers assume the role of monitoring consumer preferences. But the use of the Internet and direct sales are changing all that. Consumers are now interacting with different entities in the purchasing process.

16. (c) i and ii

There are two common misconceptions about the working of the demand chain. One is that all consumers buy from retailers. This can be true in most cases but many consumers are shifting to other channel members who deliver products at the right time and at reasonable prices. The second misconception is that industrial marketers should monitor only their customers and need not bother about end-users. They should not ignore the fact that the demand for their products is based on end-users.

17. (d) i, ii, iii, and iv

Demand chains are intended to bring together channel members to satisfy customers and solve their problems by gathering and analyzing information about consumers, their problems, and their needs; identifying and choosing the right channel partners; developing a system for information sharing among channel partners; developing products and services, which are capable of solving customers' problems; and choosing the most optimal transportation and distribution methods.

18. (d) i, ii, iii, and iv

The current competitive environment is the outcome of the convergence of various forces on all supply chain members and to compete in it, organizations need to do more than optimize their supply chain activities. These forces include the development of new technologies, increase in communication capabilities, increasing demand for better quality and customer services, and the demand for quick and efficient response to market.

19. (c) By reducing communication costs

ESCM helps supply chain partners communicate through the Internet. Communication through Internet is quicker and cost effective. As the supplier can access information regarding inventory and procurement automatically, the purchasing department can lessen its involvement in minor transactions and focus on high value activities like vendor selection and sourcing. The other two options are not related to procurement.

20. (a) Information security

Security of information is the most sensitive issue when information is shared or exchanged over the Internet. An organization has to ensure that the rightful recipient views the information. All other options are some types of information shared over the Internet between supply chain partners.

21. (b) i, ii, iii, iv, v, vi, vii

To improve ESCM implementation, the following activities should be undertaken:

1) Understand and evaluate the level of integration within the organization, 2) Determine the number of suppliers with direct influence over products or services delivered to customers across the entire supply chain, 3) Divide suppliers into different categories: first tier, second tier and so on, 4) Define customer base in term of sales, profitability, size, etc., 5) Improve information infrastructure within the organization to accommodate ESCM requirements, 6) Constitute a team with representation from various functions within the organization and representatives from suppliers and customers to plan and carry out implementation, 7) Identify leaders capable of guiding the implementation process competently.

22. (b) Increased cycle time

Electronic supply chain management (ESCM) has many advantages including timely order-processing, improved inventory tracking and management, improved accuracy in order fulfillment and support for JIT manufacturing. The other advantages of ESCM include savings in cost, reduction in inventory levels, reduction in procurement costs and reduction in cycle time.

Unit 28

Just-In-Time (JIT) Manufacturing System

Structure

28.1 Introduction

In the last section of the previous unit, we have discussed electronic supply chain management (ESCM). We have learnt that ESCM offers many advantages such as timely order-processing, improved inventory tracking and management, and improved accuracy in order fulfillment to organizations. In this unit, we will discuss the Just-In-Time (JIT) manufacturing system.

The JIT manufacturing system is a planning system for manufacturing processes that helps in achieving high-volume production using the minimal inventories. The system eliminates the inventory of raw materials, work in progress, and finished goods by making them available as and when required. The items are picked up by the worker and fed directly into the production process. The finished goods are produced only at the time they are required for sale. The implementation of the JIT system requires complete transformation of methods of designing products and services, assigning responsibilities to workers, and organizing work.

This unit will introduce you to the concept of the JIT system. We shall then move on to discuss the advantages of JIT systems. Finally, we would discuss the characteristics of JIT systems.

28.2 Objectives

By the end of this unit, students should be able to:

- Explain the concept of the JIT system.
- Discuss the advantages of JIT systems.
- Evaluate the characteristics of JIT systems.

28.3 The Concept of the JIT System

The JIT concept states: 'nothing is produced until it is required.' According to the JIT system, the finished goods are assembled just before they are sold, the sub-assemblies are made just before the products are assembled and the components are fabricated just before the sub-assemblies are made. Here, the work-in-process inventory is always kept at a low level, thus reducing the production lead times. The firms should achieve and maintain high performance levels in all their operational areas to facilitate the smooth flow of materials in the JIT systems. The JIT system involves the active participation, involvement, and cooperation of all its employees. The JIT manufacturing system is based on the concept of continuous improvement, which includes the two mutually supporting components of people involvement and total quality control.

28.3.1 People Involvement

The HRM component plays a vital role in the implementation of the JIT manufacturing system. The successful implementation of a JIT program requires teamwork, discipline, and supplier involvement.

Teamwork: Teamwork involves activities like suggestion programs, and quality circle programs, which enable employees to actively participate. Suggestion programs are conducted to encourage the employees to give their ideas on how to improve a process. In quality circles, people working in similar types of operations meet at regular intervals and discuss ways of improving the quality of their processes.

Discipline: Firms use the creativity of workers along with their teamwork and discipline to produce good quality products and services.

Supplier Involvement: JIT firms maintain fewer suppliers, but they are more than one. Firms can allow suppliers to participate in design review and to suggest new designs and methods for improving product quality or productivity. JIT firms enter into contracts with their suppliers instead of inviting competitive bids from a set of suppliers. The contract should be beneficial for both the supplier as well as the firm. The JIT firm can share its production plans and schedules with its suppliers so that they can plan their business and capacity requirements beforehand. Linear production schedules relate to the development of production schedules with uniform workloads. The suppliers should tailor their schedules to the JIT firm's needs as they contribute to the improvement of the firm's manufacturing operations. The maintenance of linear production schedules requires the identification and elimination of production bottlenecks, a balance in the production system, and a reduction in set-up time.

28.3.2 Total Quality Control

A firm can produce high quality products only through the combined efforts of all the departments including the purchase department, quality control

department, and personnel department. The concept of 'immediate customer' helps the firms to achieve the required quality levels.

28.3.3 Concept of Immediate Customer

A JIT firm uses the concept of 'immediate customer' where each worker in the firm considers the next worker who continues the production process as the customer. Therefore, it is the responsibility of the worker to ensure that the product is processed to meet specifications and quality requirements before passing it on to the next worker. Only items of acceptable quality are delivered to the immediate customer. In case a worker delivers a defective item or an improperly finished item to his/her immediate customer, the worker who identifies the defect is authorized to stop the process and take necessary actions thereafter.

JIT as a Philosophy

1 Elimination of waste

Any activity that does not add value to the product or service in the eyes of the customer is a waste. Poor product design such as the inclusion of fancy functions not required by the customer is a waste. A product design causing difficulty in manufacturing is a waste. Standardization reduces the planning and control efforts, the number of parts, and the inventory required. A poor product design without enough standardization leads to waste. In addition to waste resulting from poor design, Toyota identifies seven examples of waste resulting from poor manufacturing methods.

1. Waste of overproduction

Over production is the production of goods more than what are immediately Just-In-Time Manufacturing needed. Overproduction causes extra material handling, quality problems, and unnecessary inventories. Consuming materials for unnecessary products may cause a shortage of material for other products that are needed. Never overproduce products to keep men and machines busy. If the required loading is less than the capacity, leave it alone. The labor can be switched to other departments, cleaning or maintaining the machines, accepting training and education, etc.

2. Waste of waiting

A material waiting in queue is a waste. An operator waiting for material or instruction and having no productive work to do is a waste.

3. Waste of movement

Poor plant layout results in materials having to be moved extra distances and cause unnecessary material handling costs. Work centers should be close to each other in order to reduce the move distance. Someone may say that close

work centers provide no room for WIP inventories. That is fine! No room for WIP inventory forces the WIP to decrease.

4. Waste of inventories

Inventory causes costs of interest, space, record keeping, and obsolescence. Moreover, inventory can mask problems which could cause more inventory buildup. For example, WIP inventory between work centers can hide the symptoms of an unbalanced production rate. Finished goods inventory can mask poor forecasting, poor quality, and poor production control. Inventory is not an asset; it is a waste!

5. Waste of motion

Improper methods of performing tasks by the operators cause wasted motions. Reaching far for materials or machine buttons is a waste of motion. Searching for tools is a waste of motion. Any activity that does not add value to the products should be eliminated. Bad layout or training causes waste of motion. Just-In-Time Manufacturing

6. Waste of making defects

The cost of scraps is a waste. But it is the least important compared with other wastes caused by making defects. Defects interrupt the smooth flow of materials in the production line. If the scrap is not identified, next workstation will try using it to produce more wastes, or waste time waiting for good materials.

7. Waste of process itself

Bad process design is a waste. For example, wrong type or size of machines, wrong tools, and wrong fixtures are wastes.

The principle of eliminating the wastes includes:

1. All waste should be eliminated.
2. Waste can gradually be eliminated by removing small amounts of inventory from the system, correcting the problems that ensue, and then, removing more inventory.
3. The customers' definitions of quality should drive product design and manufacturing system.
4. Manufacturing flexibility is essential to maintain high quality and low cost with an increasingly differentiated product line.
5. Mutual respect and support should exist among an organization, its employees, its suppliers, and its customers.
6. A team effort is required to achieve world class manufacturing capability.
7. The employee who performs a task is the best source of suggested improvements.

2 Continuous improvement/One Less at a Time

JIT improves the manufacturing system gradually rather than drastically, as in business process reengineering (BPR). This gradual continuous improvement is defined by APICS Dictionary as "one less at a time": a process of gradually reducing the lot size of the number of items in the manufacturing pipeline to expose, prioritize, and eliminate waste. "One less at a Just-In-Time Manufacturing time" is a constant, step-by-step methodology for making JIT work in any manufacturing environment. JIT is a never-ending series of small, controlled steps, not one great leap forward. In the JIT philosophy, not the same product is produced over and over again; instead, the same process is used repeatedly to produce different products. The procedure of "one less at a time" is as follows:

1. If the inventory is equal to zero then stop, else
2. Select the most prioritized process to be improved.
3. Improve the process.
4. Is the process economical? If no, go to step 3.
5. Reduce the inventory by a small amount.
6. **Go to step 1.**

The third step "Improve the process" in the above procedure can be broken down into following steps:

1. Observe the existing method and collect related data on the selected process.
2. Investigate and analyze the data to generate alternatives to improve the process.
3. Evaluate the alternatives to determine the new method for the process.
4. Install the new method and educate the operator.
5. Maintain the new method.

Problems as opportunities

JIT philosophy sees the problems as the opportunities. A problem is an opportunity to improve. JIT exposes problems rather than covering them.

3 Quality at the source

Defects may occur at the design stage, any workstation in the production line, or the suppliers' plants. Quality does not come from inspection. It does not come from manufacturing either. Quality comes from good design. The quality of a product is determined at the design stage, including product design and process design. A poor design will never result in good quality. In a production line, it is not adequate to One inventory Less setup time lot size

lead time production distribution frequency planning accuracy forecast accuracy schedule stability flexibility of process & personnel paper work material handling move distance transportation cost quality of product & process quantity of part numbers links to other dept. links to suppliers links to customers number of suppliers preventive maintenance inspect the products at the end the line. Inspections should be executed by the operators themselves at each step of the line before the parts are passed on to the following process. The operator in the next workstation has no obligation to inspect an incoming part. A defect must be screened out immediately after it occurs. For purchased parts, the inspection should be completed before delivery. Incoming inspection is not required.

Simplification

Simplicity is a key to successful manufacturing. Products should be designed to be easy to manufacture, install, and repair. Only 2 or 3 levels should exist in the bill of material. Suppliers deliver the materials regularly and purchase orders are not required. Materials are stored at the point of use (POU), and picking orders are not required. Work centers produce the items when they are consumed and shop orders are not required. Material inventory records are not updated until the finished goods are reported complete. Simplifying the system is central to the philosophy of JIT.

4 Visual Control

Visible control tools are used wherever possible. Cards attached to the materials, containers at sight, tags in stock indicating order points, etc. are examples of visual control tools. These signals are processed by human intelligence at the speed of light, and are superior to any computer in the world. JIT philosophy reminds us that natural human senses are effective tools but are frequently ignored.

5 Focus on Customer Needs

In JIT philosophy, only values in customers' eyes are real values. Values perceived by engineers but not accepted by customers are wastes. All activities from production design, material procurement, fabrication, assembly, distribution to after service, focus on customer needs. Any motion of the operator on the shop floor not adding value to customer needs is a waste.

6 Production to Customer Demand

In JIT philosophy, only immediate customer demands are produced. Extra items not required immediately by the customers are not put into production. Without customer demand, there should be no production.

7 Respect for Individual

Each individual in a company is an important asset. Education and training are frequently conducted to enhance the capability of the employees. Employee involvement and empowerment are part of JIT philosophies

8 JIT as an Environment

In addition to philosophical concepts, JIT also provides an environment in which products are manufactured in a simpler way.

9 Repetitive Manufacturing

Repetitive manufacturing is the production of discrete items in a production line with fixed routings. The items can be a product or a family of products. The product is standard or made from standard modules. The manufacturing environment is make-to-order (MTO) or assemble-to-order (ATO). The production line consists of workstations located close together and in sequence. Materials flow from a workstation to the next at a relatively constant rate. Material handling systems are normally used to move the materials from process to process in the production line. Normally, the capacity of the production line is kept sufficient. The repetitive manufacturing is based on an uninterrupted flow of materials.

10 Total Quality Management (TQM)

Total quality management is a management approach used to achieve quality improvement and long-term success through customer satisfaction. TQM involves all members of the organization, and is meant to improve the quality of all processes, products, services, operations, and corporate culture. TQM activities follow a plan-do-check-action (PDCA) cycle to improve the quality. In the "plan" step, the problem is defined, the symptoms are explained, and the key performance measures are determined. In the "do" step, the cause of the symptoms is identified. The causes of the causes are also investigated until the root cause is uncovered. Then, an approach to solve the problem is developed and implemented. The performance measures can be changed in this step. In the "check" step, the effectiveness of the proposed approach is observed by using the performance measures. In the "action" step, the results are studied to determine what was learned and what can be predicted. The improvement process is standardized to apply to similar problems. In the PDCA cycle, the steps are not necessarily followed strictly sequentially. For example, if we find a proposed approach is not affirmative in "check" step, we may jump to the "do" stage to revise the approach.

11 Total Productive Maintenance (TPM)

"Preventive maintenance" is a restrictive term which mentally prohibits us from thinking more broadly. TPM means preventive maintenance and

continuing efforts to adapt, modify, and refine equipment in order to increase flexibility, reduce material handling, and promote continuous flows. It is operator-oriented maintenance involving all qualified employees in all maintenance activities. (Apics, 1995)

12 Total Employee Involvement (TEI)

Elimination of waste and continuous improvement are the central ideas of the JIT philosophy. They can be accomplished only when employees are cooperative. A successful JIT environment should have the cooperation and involvement of everyone in the organization. Traditionally, operators take orders from management and do what they are asked to do, while management is in charge of planning, supervising, inspecting, etc. In a JIT environment, operators take responsibility for controlling the equipment, inspecting for quality, correcting the deviations, maintaining the machines, and improving the processes. Many of the tasks traditionally done by the management become the duties of the line workers under JIT. Managers are not playing the game; they are coaches and the line workers are the players. The mission of a coach is to train the players.

13 Supplier Partnership

In order to establish a smooth flow of materials into the factory, a close and reliable relationship with the suppliers is very important. Supplier partnership is the establishment of a working relationship with a supplier whereby the two organizations act as one. Relationships with the suppliers should be based on mutual trust, cooperation, and long-term commitment.

14 As a Control Technique

In daily operations, JIT provides useful control methods. The characteristics of a JIT control technique include uniform loading, repetitive processes, pull system, using production cards, and synchronized production.

15 Pull System

JIT control pulls materials from the previous workstation. The workstation replenishes any materials consumed by its following workstation. Since only the consumed materials are produced, the inventories between workstations never accumulate. For the first workstation of the factory, the supplier is its preceding workstation. For the last workstation in a factory, the customer is its following workstation. Customers pull the products from the factory, and factory pulls the materials from the suppliers.

16 Uniform Loading

The loads for jobs in every workstation are equal. This makes the pull system possible. If uneven loading exists, the following workstation may have to wait for the materials from the preceding workstation. Uniform loading allows the

materials to flow through the production line smoothly. Every workstation runs at a constant rate. If the demand increases, the production rates in all workstation increase together. If the demand drops, all workstations may have the same level of idleness.

17 Production Card

JIT control uses various cards to transmit production signals. During the production, these cards are attached to and detached from the materials. Production signals are transmitted from the following workstation back to the preceding workstation. The cards have various shapes and colors to indicate different purposes. Sometimes material containers or the material itself are themselves the signals.

18 Synchronized Production

Synchronized production is a manufacturing practice in which production activities in each workstation are synchronized with certain control signals. The production rates of workstations are related to each other, and the work-in-process inventories are limited to a predetermined level. Synchronized production can be seen in JIT environments or theory-of-constraints (TOC) environments. The control signals are carried by kanbans in a JIT environment.

Exhibit 28.1 shows the operations practices of Ford

Exhibit 28.1: JIT at Ford Valencia

The Model T developed by Henry Ford consisted of about 10,000 parts of motors, transmissions, and other components. Ford was continuously expanding his existing facilities and building newer ones to aid the flow, storage, and handling of materials from its large number of suppliers. He believed that figures were facts and never relied on expert opinion. Ford called the system 'speeding up the turnover', which was innovative and instructive and used it to begin backward integration of the firm.

Additionally, in order to ensure continuous flow of manufacturing, Ford acquired iron ore fields, coal mines, a railroad, coal and ore boats, timberlands, stamping mills, and foundries. By effectively planning and coordinating the input of materials, Ford was able to reduce the manufacturing cycle time and the inventory carrying costs. Within 14 days, raw materials were sourced, transformed into automobiles, and were sent to the dealers.

Taiichi Ohno, a mechanical engineer and manager for Toyota, studied and redesigned the techniques used by Ford into just-in-time inventory. Ohno observed that while some workers overproduced and created inventory, others were idle waiting for parts. This resulted in the creation of Kanban, in which tags accompanied each part or batch of work in process.

Contd….

The tags alerted the workers about what needed to be done. For example, when a part or container of parts was used in the production process, the tag was returned to the supplier, suggesting the need to restock. As each work station required parts, the card would move backward from site to site and then forward with the resupply. In an ideal situation, the inventory would be zero, with each part arriving just when it was needed.

Source: https://logisticsmgepsupv.wordpress.com/2018/03/25/ford-valencia-just-in-time-and-just-in-sequence/, March 2018

Activity: Great Automobiles Inc is an automobile manufacturing company. The company has decided to adopt the JIT manufacturing system. The company is under the impression that JIT involves assembling finished goods just before they are sold. The operations manager decides to explain to the company the importance of people and quality control in the JIT manufacturing system. Assist him in the process. In what way do you think people play a role in the JIT system and who are the people involved in the system?

Answer:

Check Your Progress - 1

1. Which of the following are essential conditions for a JIT system to be successful?
   i. Teamwork
   ii. Discipline
   iii. Supplier involvement
   a. Only i and ii
   b. Only i and iii
   c. Only ii and iii
   d. i, ii, and iii
2. "Nothing is produced until it is required" is a fact practiced in which concept?
   a. Make-to-stock process
   b. Materials requirement planning
   c. Just-in-time manufacturing
   d. Inventory management

3. JIT adopts the concept of 'immediate customer' to increase product quality and improve customer service. What does the term 'immediate customer' signify?
   a. Every worker in the JIT firm is considered a customer
   b. A person outside the firm who buys its products for use or consumption
   c. Each worker in the firm considers the next worker in the production line as a customer
   d. Each worker is fully responsible for a task and inspect his or her own work
4. Which of the following is **not** a characteristic of JIT system?
   a. The JIT firm shares production plans and schedules with suppliers
   b. The JIT firm can provide assistance to suppliers to improve quality and productivity
   c. The JIT firm invites suppliers to participate in product design and suggests changes and/or improvements
   d. The JIT firm always maintains only one supplier for each type of material

28.4 Advantages of JIT Systems

The advantages of JIT systems to firms are increased utilization of machinery and equipment, reduced investment in inventory, improvement in the quality of product or service, reduction in space requirements of the firm, reduction in production cycle time, zero inventory storage and maintenance costs, closer relationship with suppliers, reduction in formal paper work, and higher involvement of employees as they are responsible for producing good quality goods.

The advantages of JIT systems to suppliers are long-term guaranteed contract for supply of materials, steady and continuous demand for their materials, less expenditure on promotional activities, and timely payment for materials supplied.

Activity: Sweekar is a small chocolate manufacturing company. In order to increase its production capacity, the company decides to change its manufacturing system and expand its operations. It seeks the advice of a consultant who suggests that the company go leaner and adopt JIT. The management is surprised to learn that lean manufacturing and JIT can be applied to a small company. The consultant explains to the company about JIT and lean manufacturing and how they are helpful for any company. Help the consultant in convincing Sweekar by highlighting the importance of JIT and lean manufacturing in general and explaining how they help companies compete successfully in global markets.

Answer:

28.5 Characteristics of JIT Systems

The proper implementation of the JIT principles helps in producing products and services at the quality and price demanded by customers. The following are the characteristics of a JIT system:

28.5.1 Uniform Workstation Loads

By using the JIT system, firms can maintain uniform work-loads at the workstations. For example, Toyota plans to produce 24,000 cars in the current month. By carrying out the production for five days per week, the company can produce 1200 cars each day. By carrying out production in two shifts a day, the company can produce 600 cars per shift. In this way, the JIT system helps in maintaining uniform workloads at each work center.

28.5.2 Small Lot Sizes

In a JIT manufacturing system, firms maintain inventory in the smallest possible lot sizes. This is done to reduce the cycle inventory, cut lead times, and achieve a uniform workload. Smaller lots have a lower waiting time in the production process when compared to the larger lots.

28.5.3 Closer Supplier Ties

JIT firms should maintain long-term relationships with their suppliers as they are responsible for providing the timely delivery of good quality inventory. The relationship should be profitable for both the suppliers and the firm. Both the parties should work toward the betterment of each other while abiding to the terms of the contract.

28.5.4 Maintenance of High Quality

In the JIT system, quality control begins from the source where the workers are encouraged to maintain the quality of work. The production process is stopped immediately when a quality problem is identified and is continued only after the problem has been sorted out.

28.5.5 Quick and Economic Set Ups

Generally, firms manufacture their products in large lots leading to a lower number of machine set-ups. Firms using the JIT system experience a larger number of set-ups as they produce in small lots. JIT firms, therefore, need quick and inexpensive set-ups in order to minimize the disadvantages of having more set-ups. JIT firms engage specialists and consultants to train their workers to reduce set-up times. The following is the procedure to reduce set-up times:

1. **Analyze existing set-up procedures:** The existing set-up procedure is recorded on videotapes and the management collects information from its employees relating to the execution of these set-up procedures. The procedures are then analyzed to determine ways to improve them.

2. **Separation of internal and external set-up activities:** External set-up activities are those that can be performed without stopping the current production process. The set-up process can be improved by separating external set-up activities from internal set-up activities and then developing a plan to perform the external activities while the production process is in progress. Thus, the time is saved on the production process.
3. **Convert internal set-up activities into external set-up activities:** The management of the firm should then try to convert its internal set-up activities into external activities by changing work methods, adding work aids, or by purchasing duplicate sets of tools or equipment. The following are some procedures that would enable conversion of internal set-up activities into external set-up activities:

a) ***Heating:*** Instead of heating materials before beginning a production process as a part of the internal set-up, materials can be preheated outside the set-up so that the actual heating activity can be finished in less time.

b) ***Cleaning:*** Workers can replace contaminated equipment with a clean set to continue the production process while the contaminated equipment is cleaned externally.

c) ***Streamline work:*** Set-up times can be reduced by simplifying the internal activities and by streamlining the work in a firm. For example, a set of tools can be provided to each work center so that workers need not wait for a standard tool required while another process is going on.

d) Flexible facilities and multi-skilled workforce

JIT production systems are advantageous for firms that produce the same product constantly. As the production process is repetitive in nature, the movement of materials can be reduced by placing the equipment in cells (a cell is a grouping of several types of machines in which each machine repeatedly performs a single operation) instead of keeping them in functional departments. Such flexible facilities reduce the need for materials handling equipment and in turn the material-handling costs, and improve the speed of production, thereby allowing quicker deliveries. In a JIT production system, the entire workforce is trained continuously at regular intervals to develop a variety of skills to perform any function the firm requires. Firms can develop flexible workforces through cross-training in which a worker is trained to perform more than one operation rather than being limited to the single operation assigned to him. Cross-training of the workforce and establishing U-form cells makes the production process more flexible. Arranging facilities in U-form and processing production in small lot sizes makes it easy for the firm to identify defects that occur at any stage in the production process.

28.5.6 Preventive Maintenance

In order to reduce the occurrence of defects, firms should carry out preventive maintenance. In preventive maintenance, the parts that are likely to produce defects are replaced, rather than the defects that arise during production being repaired. Workers are given the responsibility of maintaining their machinery and equipment and are also trained to solve or repair common problems. The following are the important principles and actions that improve equipment maintenance:

- Design simple equipment and standardize replacement parts.
- Collect information about the frequency and causes of failure of machines.
- Replace worn out parts of the equipment, after periodic checks.
- Purchase all spare parts that are necessary during repair work.

28.5.7 Continuous Improvement

In a JIT system, firms adopt continuous improvement in quality and productivity by identifying areas that require improvement. Problems are detected before they occur and are solved in the minimum possible time, to ensure smooth flow of work. For manufacturing operations, the percentage of scrap can be reduced by following better work methods and training employees. A proper master production schedule and flexible workforce can be developed to eliminate the capacity imbalances. Manufacturing operations can be improved on a continuous basis through the complete involvement of employees and the management. For service operations, the process of continuous improvement aims at reducing the number of people involved in providing the service, without affecting the quality and rate of service. JIT is a powerful tool for reducing the firm's inventory and improving productivity. However, implementation of JIT principles is difficult as barriers in the form of workers' resistance to change, difficulty in accomplishing zero lead-time, zero safety stock, and zero idle time have to be overcome. Support and commitment from the top management and extensive employee training lead to the successful implementation of JIT.

Activity: Safety Inc is a manufacturing company using the JIT manufacturing system of production. The company realized that it was not successful in implementing the system and therefore, appointed a consultant to find out the reason. The consultant found that the company had failed to implement the system because of lack of flexibility in production. He further explained the reasons for failure in implementing the JIT system by companies like Safety Inc. What do you think are the factors that contribute to successful implementation of the JIT system?

Answer:

Check Your Progress - 2

5. How are workers in a JIT firm different from that of a non-JIT firm?

   i. JIT workers are trained continuously

   ii. JIT workers are trained to perform multiple jobs

   iii. JIT workers are specialized in a particular operation

   a. Only i

   b. i and iii

   c. i and ii

   d. i, ii and iii

6. Having quick and economic set-ups is a characteristic of a JIT system. Firms adopt a procedure to reduce set-up times. Arrange the steps in the correct sequence.

   i. Analyze existing set-up procedures

   ii. Separation of internal and external set-up activities

   iii. Convert internal set-up activities into external set-up activities

   a. i, ii, iii

   b. ii, iii, i

   c. i, iii, ii

   d. iii, i, ii

7. Which of the following is a feature of the JIT strategy related to production?

   a. Produce in small lots

   b. Every worker is responsible to the immediate customer (worker)

   c. Continuous improvement

   d. Customer satisfaction

8. Which one of the following is **not** a result of implementing JIT systems?

   a. Small lot sizes

   b. Varying workstation loads

   c. Quick and economic set-ups

   d. Preventive maintenance

9. Which of the following is **not** a characteristic of the JIT system?

   a. Uniform workstation loads

   b. Large lot sizes

   c. Quick and economic set-ups

   d. Flexible facilities

10. Firms that practice JIT production systems require reliable suppliers. Therefore, JIT firms maintain long-term business relationships with a few selected suppliers. Which of the following is true about a supplier relationship under the JIT system?

    a. The JIT firm derives more mileage than the supplier from the relationship in the long run

    b. The supplier derives more mileage from the relationship

    c. The relationship should be profitable to both the firm and the supplier

    d. The supplier need not stick to the terms of supply under the contract

11. Quick and economic set-ups is a characteristic of a JIT system. What does this signify?

    i. Lesser inventory

    ii. Smaller production lot size

    iii. Higher number of set-ups

    iv. Higher costs

    a. i, ii, and iii

    b. ii, iii, and iv

    c. i, iii, and iv

    d. i, ii, iii, and iv

28.6 Summary

- The JIT manufacturing system achieves high-volume production using minimal inventories.
- In the JIT system, inventory is always kept at a low level, thus reducing the production lead times.
- Firms can maintain consistent quality of products and processes by coordinating the various production processes.
- Successful implementation of a JIT program requires teamwork, discipline, and supplier involvement.
- The JIT manufacturing system is based on the concept of continuous improvement which includes the two mutually supporting components of people involvement and total quality control.
- The JIT system entails uniform workstation loads, small lot sizes, closer supplier ties, maintenance of high quality, quick and economic set-ups, flexible facilities, and multi-skilled workforce, preventive maintenance, and continuous improvement.

28.7 Glossary

Concept of immediate customer: A firm following the just-in-time manufacturing system uses this concept where each worker in the firm considers the next worker who continues the production process as the customer.

Just-In-Time system: It states: 'nothing is produced until it is required.' The finished goods are assembled just before they are sold, the sub-assemblies are made just before the products are assembled and the components are fabricated just before the sub-assemblies are made.

28.8 Self-Assessment Exercises

1. The JIT concept states: 'nothing is produced until it is required.' Substantiate.
2. A JIT system contributes to improving the productivity and profitability of a firm. How can firms adopting the JIT technique and their suppliers benefit from the JIT system?
3. The JIT system minimizes the firm's idle resources, aims at the continuous improvement of a process, and ensures the desired quality of the end-product or service. Describe the characteristics of the JIT system in detail.

28.9 Suggested Reading/Reference Material

1. Hiroyuki Hirano, JIT Implementation Manual -- The Complete Guide to Just-In-Time Manufacturing, Volume 3 -- Flow Manufacturing -- Multi-Process Operations and Kanban, Productivity Press, Nov, 2019
2. Nikhil Halwan, Just-in-Time Manufacturing in the Indian Automotive Industry, Published by the Indian Automotive Industry, May 23, 2017
3. Is a complete shift from the JIT manufacturing model possible?, ET Auto, January 27, 2021
4. R. Periaswamy, Voice of the Vanguards, JIT at TVS Motor Company, Published by TVS Motor Company, 10 Feb, 2018
5. JIT at Tata Motors, Pantnagar, facility, https://www.tatamotors.com/about-us/facilities/pantnagar/, 2019

28.10 Answers to Check Your Progress Questions

Following are the answers to the Check Your Progress Questions given in the Unit.

1. (d) i, ii, and iii

Teamwork, discipline, and supplier involvement are considered important elements for successful implementation of the JIT system in an organization.

2. **(c) Just-in-time manufacturing**

   The Just-in-time concept states that 'nothing is produced until it is required.' The practice of JIT aims at assembling finished products just before they are sold, sub-assembling just before products are assembled and fabricating components just before sub-assemblies are done.

3. **(c) Each worker in the firm considers the next worker in the production line as a customer**

   In a JIT firm each worker considers his/her next worker in a production line as his/her customer. This is because the work done by him/her passes to the next worker for further processing.

4. **(d) The JIT firm always maintains only one supplier for each type of material**

   JIT firms maintain fewer suppliers, but they are more than one. JIT firms normally share their production plans and schedules with suppliers to enhance their understanding of the production and supply the material at the right time. They also help suppliers with their expertise and suggest ways to improve quality and productivity. This will help firms improve the quality of end products. When the firms plan to introduce new products, they also take suggestions from suppliers regarding product design and types of materials that can be used to improve quality as well as profitability.

5. **(c) i and ii**

   In a JIT production system, workers must be capable of performing more than one operation. Hence, the entire workforce is trained continuously (at regular intervals) to develop a variety of skills to perform any function the firm requires. A worker is trained to perform several operations rather than being limited to a single assigned operation.

6. **(a) i, ii, iii**

   The successful implementation of a JIT system is greatly dependent on its ability to reduce set-up times. JIT firms engage specialists and consultants to train workers to reduce set-up times. Firms adopt the following steps to reduce set-up times: 1) Analyze existing set-up procedures, 2) Separation of internal and external set-up activities and 3) Convert internal set-up activities into external set-up activities.

7. **(a) Produce in small lots**

   Traditionally, firms manufacture products in large lots, resulting in a lower number of machine set-ups. But JIT manufacturing firms undergo a larger number of set-ups as they produce in small lots.

8. (b) Varying workstation loads

Just-in-time manufacturing helps firms maintain uniform loads at workstations. Some of the characteristics of a JIT system are uniform workstation loads, small lot sizes, closer supplier ties, maintenance of high quality, quick and economic setups, flexible facilities and multi-skilled workforce, preventive maintenance, and continuous improvement.

9. (b) Large lot sizes

Firms that follow JIT type of manufacturing system maintain inventory in the smallest possible lot sizes. This is required as small lot sizes reduce cycle inventory (the excess of inventory, above the safety stock, that is carried between two orders), cut lead times and also help in achieving a uniform workload. JIT manufacturing systems follow uniform workstation loads where material is fed to the workstation uniformly and uniform output is produced across different workstations. Besides, these firms have flexible facilities and quick and economic set-ups.

10. (c) The relationship should be profitable to both the firm and the supplier

Under the JIT system, the relationship should be profitable to both the supplier and the JIT firm in the long run. Hence, the JIT firm and the supplier should work towards the betterment of each other by abiding to the terms of the contract.

11. (a) i, ii and iii

Traditionally, firms manufacture products in large lots, resulting in a lower number of machine set-ups. But JIT manufacturing firms undergo a larger number of set-ups as they produce in small lots. Therefore, JIT manufacturing firms require quick and inexpensive setups to minimize the disadvantages of having more number of set-ups and higher costs.

Unit 29

Productivity and Quality Management

Structure

29.1 Introduction

In the last section of the previous unit, we have discussed the characteristics of Just-In-Time (JIT) manufacturing systems. We have learnt that proper implementation of the JIT concept helps in producing products and services at the quality and price demanded by customers. In this unit, we will discuss productivity and quality management.

Performance can be split into qualitative and quantitative performance. Productivity is the measure of quantitative performance of an organization. It is the output produced using a given set of inputs. Productivity provides a good measure of performance at the national, industry, or individual business level. Walter Stewhart marked the beginning of the quality movement by developing the first process control chart in 1920. Quality, which was not the top priority in organizations initially, began gaining importance with the growing competition and more demanding consumers. Quality control begins from the time raw materials are procured based on appropriate specifications.

This unit will introduce you to productivity, and the strategic role played by quality. We will discuss the vital role played by inspection in quality control, and then study the cost of quality. We shall then move on to discuss the statistical concepts in quality control, and about acceptance plans. Finally, we would discuss the use of computers in quality control, and the concept of total quality management.

29.2 Objectives

By the end of this unit, students should be able to:

- Define productivity.
- Assess the strategic role of quality.
- Explain the role of inspection in quality control.
- Determine the cost of quality.
- Analyze the statistical concepts in quality control.
- Define acceptance plans.
- Discuss the role played by computers in quality control.
- Reproduce the concepts of total quality management (TQM).

29.3 Productivity

Productivity is the ratio of the output produced to that of the inputs consumed. Hence, it is a measure of the efficiency of the firm in terms of products produced. For instance, the number of motor cycles produced per day is a typical measure of productivity. Productivity helps the operations managers to control the production process and match it with that of the market demand. Productivity is calculated by the formula:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}.$$

Inputs: All the factors that are used in the production process of a product are considered the inputs of that product. Inputs can be viewed in terms of costs, tangible and intangible assets etc, and can be measured in different units. Typical tangible production inputs include quantity of material used, number of workers employed, number of man hours consumed, amount of power consumed, etc. Intangible inputs include training, leadership skills, workers' knowledge, etc.

Outputs: Inputs are converted into output through production process. Output can be quantified in terms of number of units produced, number of customers serviced, etc. Common examples include 50 million tons of cement, 4000 telephone units, etc. Output in service organizations can also be intangible like customer satisfaction, customer delight etc.

29.3.1 Components of Productivity

Productivity can be improved in many ways such as by procuring quality raw material at the lowest possible cost, adopting an optimal mix of production factors, and training the workers. These different factors/components independently influence the productivity in different ways. The components can be categorized to include price efficiency, allocative efficiency, technical efficiency, and scale efficiency.

29.3.2 Factors Affecting Productivity

Productivity is one of the important performance indicators of an organization. Increased productivity enhances the image of the organization and is one of the key factors that affect the competitiveness of the organization. Some of the factors affecting productivity of an organization are listed as follows.

- Bottlenecks in the form of poor layout designs, slow processing equipment, and inventory shortages can reduce the productivity of an organization.
- Shortage of skilled manpower and lack of training on advanced technologies can also reduce productivity.
- Poor scheduling methods lead to more waiting time in the production process. More waiting time leads to increased cycle time and reduced productivity.
- Strikes and worker agitations also cause break in production that in turn affects the productivity of the organization.

29.3.3 Measuring Productivity

Productivity can be measured in relation to a single factor (single factor productivity), a combination of factors (multifactor productivity), or all the factors taken together (total productivity). Single factor productivity implies productivity is measured considering only a single factor, say labor or raw material. Multifactor productivity implies two or more factors are considered to measure productivity. When all the factors of production are used to measure productivity, then it is termed total productivity.

$$\text{Labor productivity} = \frac{\text{Goods and/or services produced (output)}}{\text{Labor hours/man hours spent (output)}}$$

$$\text{Multifactor productivity} = \frac{\text{Goods and/or services produced (output)}}{\text{Quantity of raw material and components used}}$$

$$\text{Total productivity} = \frac{\text{Goods and/or services produced (output)}}{\text{[Labor + capital + energy + technology + materials] (inputs)}}$$

Activity: Tarun Motor Works is a small scale unit manufacturing 0.5hp motors. It has 10 workers in the workshop and they work for 8 hrs a day. Every motor uses 2kg of copper wire and 6 components. If five motors are manufactured daily on an average, (a) what is the labor productivity? (b) What is the multifactor productivity of the usage of copper wire and components?

Answer:

Measuring knowledge workers' productivity: It is difficult to measure the productivity when intangible and qualitative factors like knowledge of the workers, leadership skills etc, are involved. The quality of knowledge workers' output cannot be immediately determined in many cases. For instance, a strategic decision taken by a top level manager can take a few years to bear fruit. Hence, until the output is not quantified, productivity cannot be measured. Further, when the knowledge workers provide their services to other organizational units it becomes difficult to quantify their contribution. For example, if a sales manager's knowledge is used in the development of company forecast, it is difficult to quantify the extent of involvement of the sales manager in the development of the forecast.

Measuring productivity of service organizations: Intangibility in services makes it difficult to produce tangible results. This in turn further affects the ability of the service organizations to measure the productivity. To overcome this difficulty, the service organizations make use of indirect means to measure productivity. For instance, many service organizations use time sheets to measure the amount of time spent by the employees on each task. This helps them estimate the time spent by the employee(s) on servicing a single customer. Time sheets are helpful in both routine service activities like that of a call center executive outbound) and customized service offerings like in health clubs, restaurants, counseling etc. Usually productivity in service organizations is measured in terms of number of tasks performed, or number of customers serviced in a given period of time.

Check Your Progress - 1

1. Identify from the following, the factors that affect the productivity of an organization.
   i. Bottlenecks in the form of poor layout designs and slow processing equipment.
   ii. Shortage of skilled manpower and lack of training on advanced technologies.

iii. Poor scheduling methods leading to more waiting time in the production process.

iv. Strikes and worker agitations causing break in production.

a. Only i, ii, and iii

b. Only i, iii, and iv

c. Only ii, iii, and iv

d. i, ii, iii, and iv

2. _____ is a measure of the efficiency of the firm in terms of products produced, and can be calculated as the ratio of the output produced to that of the inputs consumed.

a. Quality

b. Scheduling

c. Productivity

d. Reengineering

3. All the statements given below are **true** regarding productivity, except:

i. Productivity can be measured in relation to a single factor, a combination of factors, or all the factors taken together.

ii. When two or more factors of production are considered to measure productivity, it is called as total productivity.

iii. It is very easy to measure the productivity when intangible and qualitative factors like knowledge of the workers and leadership skills are involved.

iv. Generally, productivity in service organizations is measured in terms of number of tasks performed, or number of customers serviced in a given period of time.

a. Only i and ii

b. Only i and iv

c. Only ii and iii

d. Only iii and iv

4. Quality control is an important function that helps increase customer satisfaction. At which of the following stages does quality control begin?

a. Procurement of raw material

b. Start of production

c. Finished goods inventory

d. Dispatch to customers

5. Bottlenecks in the production process can hamper productivity. Which among the following **cannot** be an example of a bottleneck that can hamper productivity?

a. Layout

b. Slow processing equipment

c. Proper scheduling

d. Inventory shortage

6. Which of the following can be a measure of output associated with productivity in service organizations?
   a. Number of calls made by a telemarketer
   b. Number of complaints received by a call center
   c. Amount of time spent in counseling a student
   d. Number of cars serviced in a period

29.4 Evolution of Quality Management

Quality Management evolved over decades, even though the very first stage of 'inspection' still dominates many organizations across the world. The evolution may be depicted as below. However, it is established that depending upon the stage of QM, focus shifts from inspection to control, assurance and management, ultimately making quality 'responsibility of everybody', including the stakeholders.

Inspection is focused around sorting the product through a 'go', 'no-go' approach. Inspection may be done at any stage, namely incoming, in-process or final stages in the supply chain. Sometimes it may be required at the supplier's and customer's premises depending upon the contractual obligations. The operator has no opportunity or responsibility to find out why a product is getting rejected, nor anything to do with repair or salvaging it.

Quality Control establishes standards for inspection, root-cause analysis for rejects and effects corrective actions. It will also help process control and application of Statistical tools and techniques transforms it into Statistical Process Control (SPC). ISO 9000 (1987) is treated as a quality control standard.

Quality Assurance focuses more on giving confidence to the customer that all activities and processes are being conducted as per set standards and the product's quality is as committed. It has given scope for designing quality into the product through Quality Engineering, training for quality and other activities to ensure smooth process management.

Quality Management shifted the responsibility for quality to the top management and focused on all functions of management like planning, controlling, organizing and leading. It has received parity with all other management disciplines and management started reviewing quality performance either as a part of production review or as a separate quality Review. Quality Planning and Quality Improvement received special attention. Voice of the customer was being heard through customer feedback, complaints and customer satisfaction surveys.

Total Quality Management (TQM) brought about a paradigm shift in attitude towards quality. Its focus shifted from quality management to 'quality in management' encompassing everything it does. It is thus a holistic, humanistic approach and is totally customer-focused encompassing all activities and processes. TQM is the foundation for all Business Excellence Models. In a TQM

organization, quality happens automatically as a work ethic without being prompted by any external force except customer delight. The latest version (2008) of ISO 9000 is considered a TQM standard and the organizations which are wedded to TQM philosophy and associated practices are reaping benefits in the form of enhanced market shares, increased customer satisfaction, lower employ attritions and improved brand image. Six Sigma like techniques aim at running processes towards perfection so that such strategies like Lean and JIT can be realized more effectively. It is being increasingly realized that quality of products and services is the most cost-effective way to ensure customer satisfaction and respectable market share towards business excellence and organizational prosperity.

29.5 Strategic Role of Quality

Until recently, quality was considered as a defensive function which helped in developing new markets and increasing market share. The basic purpose of quality control was then to reduce the number of customer complaints. It was therefore dependent on inspection rather than on prevention. However, of late, companies have begun to realize the importance of using quality as an offensive strategic weapon. A company can compete on the quality functions such as performance (a car could be compared on performance characteristics such as acceleration, mileage, and speed), features of the product, reliability (the probability of a product's failure within a specified time period), conformance (ability of the product and its individual components to meet the established standards), durability (the operational life of a product), serviceability (It is the readiness of the product to be serviced back to the operational mode), aesthetics and perceived quality (customer's perception about the quality of a product).

29.6 Role of Inspection in Quality Control

As the number of items being inspected increases, the inspection cost increases while the cost of undetected faults decreases. At a particular point, there is an optimal trade-off between the inspection cost and the cost of undetected faults, and at this point, the total quality control cost will be the minimum. Costs incurred for personnel training, supervision of inspectors, inspection facilities, conducting tests, etc. come under inspection costs whereas the costs of undetected faults include customer complaints, loss of goodwill, product replacement cost, etc. The output for most of the product and services cannot be inspected as it would be uneconomical and in cases where destructive testing is done, it would be impossible. The efficiency of the inspections could be enhanced by carrying them out.

1. After operations that are most likely to produce faulty items,
2. Before costly operations commence,
3. Before operations that can cover up defects take place,
4. Before undertaking assembly operations that cannot be undone, and
5. When the finished product is ready for delivery.

Activity: Skato Ltd is a company engaged in manufacturing different types of skates and skate boards. The company recently set up a product development wing to develop new kinds of products. The new product development team is planning to come out with a new type of skates which will serve multiple purposes. Skanda is the quality manager in the team. The team has been concentrating on developing a good quality product that serves all the purposes for which it is meant. However, it has neglected to consider the other aspects of the product such as durability, serviceability, performance, and reliability. Skanda is in the process of explaining to the team the importance of all these aspects in developing a new product. Assist her in the process. Do you think a product (irrespective of price) should be developed after considering the various quality aspects like those stated here?

Answer:

Check Your Progress - 2

7. A company can compete on different quality functions. Which of the following is **not** a function of quality?
   a. Performance
   b. Features
   c. Reliability
   d. Warranty
8. At one point cost of inspection and cost of undetected faults is optimum. What does this statement signify?
   a. The cost of inspection is high
   b. The cost of undetected faults is high
   c. The total cost of quality control is minimal
   d. The average cost of quality control is minimal
9. At one point, there is an optimal trade-off between the cost of inspection and the cost of an undetected fault. At this point, the cost of total quality control is minimal. Which of the following is **not** an inspection cost?
   a. Cost of training personnel
   b. Loss of goodwill
   c. Supervision of inspectors
   d. Cost of inspection facilities

10. Match the following quality functions with their respective descriptions.
    i. Reliability
    ii. Conformance
    iii. Perceived quality
    p. Ability of the product and its individual components to meet the established standards
    q. Customer's views about the quality of a product
    r. Probability of a product's failure within a specified time period
    a. i/r, ii/q, iii/p
    b. i/r, ii/p, iii/q
    c. i/q, ii/p, iii/r
    d. i/q, ii/r, iii/p

29.7 The Cost of Quality

The cost of quality is the total of the cost of prevention (Companies incur prevention costs to prevent defective goods and services from being manufactured or delivered to the consumers), the cost of detection/appraisal (costs associated with the evaluation of quality and the performance of products and machines), and the cost of failure (costs that occur in non-conforming and non-performing products). The costs of failure are divided into external and internal failure costs. Internal failure costs are incurred when defects are found before the products are delivered to the consumers and they can be eliminated if the defects are minimized or eliminated within the system. These costs are incurred due to scrap, repair, retesting of repaired products, downtime, losses due to process variability, disposal of defective items, etc. External failure costs are incurred when the defects are found after the products are delivered to the consumers. These costs include cost of returned material, warranty charges, field survey costs, legal expenses due to lawsuits, loss of sales, cost of concessions, etc.

Activity: Edmond, the quality manager of a manufacturing company, is calculating the cost of quality of a new product that has been recently developed. His subordinate Rupert, a newcomer, is assisting him in the process. Rupert observed that Edmond has taken into account the prevention costs, the appraisal costs, and the failure costs to arrive at the cost of quality. He is wondering how to arrive at the cost of quality, which is intangible in nature. Can you explain to him the importance of quality, and the way it can be calculated and the different types of costs involved in the process?

Answer:

29.8 Statistical Concepts in Quality Control

Statistical techniques are used in identifying variations in the process which could affect the quality of the final product or service.

29.8.1 Control Charts

Control charts are used for monitoring quality and are easy to develop, analyze, and understand. Different measurement criteria are plotted on a chart with a central line representing the mean value and two control limits above and below the central value. The process is said to be in control if the noted variable and attribute values fall between the control limits. If the values fall outside the control limits, then the process is said to be out of control, and remedial actions have to be taken to correct the differences.

29.8.2 Essential Steps in Starting the Control Chart

Steps for establishing the basic procedures for a quality control program:

1. Select the quality characteristics that are to be controlled (including the limits of variations).
2. Analyze the production process to determine the kind and location of the probable causes of irregularities.
3. Determine how the inspection data is to be collected and recorded.
4. Choose the statistical measures that are to be used in the chart.
5. Select a control chart to ensure that the control limits calculated are correct for the data. The selection depends on the format of the data being collected, which can be either in the variables or attributes format. The selected variables refer to the measurable characteristics of a product or service such as length, weight, thickness, etc. In the attributes format, the items inspected are classified as conforming or non-conforming.

Control Charts for Variables: These charts are used for maintaining quality standards for a process by evaluating measurable product or service variables like thickness, length, tensile strength, and queue waiting time. These charts are used for evaluating the mean and variability of the process distribution. The X-Chart and the R-Chart are types of control charts for variables. The X-Chart is used to find the central tendency of the inspected samples while R-Chart displays the variability of the process. Both X-Chart and R-Chart are used simultaneously to get a meaningful analysis. The upper and lower control limits for X-chart are given by the equations

$$UCL = \bar{\bar{x}} + A_2 \bar{R} \text{ and } LCL = \bar{\bar{x}} - A_2 \bar{R}$$

Control limits for R-chart is given by the formula

$$UCL = D_3 \bar{R} \text{ and } LCL = D_4 \bar{R}$$

Control Charts for Attributes: In these charts, a measurable variable like weight, length, width, etc. is used in the inspection process. After inspection, the items are identified as defective or non-defective if the quality characteristics are not quantifiable. The C-Chart and the P-Chart are the types of control charts for attributes. P-Chart is used to find the proportion of defective items in a given sample while C-Chart is used to find the total number of defects in an item when the item has multiple defects.

Check Your Progress - 3

11. Control charts are used extensively to monitor quality. Suppose some individual parts measured are below the lower control limit. What does this clearly indicate?
    a. The process is out of control and the cause should be established
    b. The process is in control
    c. The process is within established control limits with natural causes of variation
    d. The process is outside established control limits with only natural causes of variation
12. The cost of quality can be divided into different categories. Evaluating quality and performance of products and machinery is associated with which type of costs?
    a. Prevention costs
    b. Failure costs
    c. Appraisal costs
    d. Both a & b
13. Failure costs, which are a type of quality costs, can be divided into internal and external failure costs. Which of the following is **not** an internal cost?
    a. Scrap costs
    b. Downtime costs
    c. Retesting costs
    d. Cost of returned products
14. Control charts are used extensively to monitor quality. They can be categorized under control charts for variables and control charts for attributes. Which of the following come under the former?
    i. X-chart
    ii. R-chart
    iii. P-chart
    iv. C-chart

a. i & ii
b. ii & iii
c. i & iii
d. ii & iv

15. Which of the following control charts is used to determine the proportion of defective items in a selected sample?
    a. X-chart
    b. R-chart
    c. P-chart
    d. C-chart
16. Companies incur _____ costs to avoid defective goods and services from being manufactured or delivered to the consumers.
    a. Failure
    b. Detection
    c. Appraisal
    d. Prevention

Exercise

A. Small boxes of peanuts are labeled 'net weight 250 gm'. To construct control charts, random samples of 4 boxes were weighed. You can assume the value of D_3 as 2.11 for the sample. Based on observations given in the table below, determine the upper control limit for the R-chart.

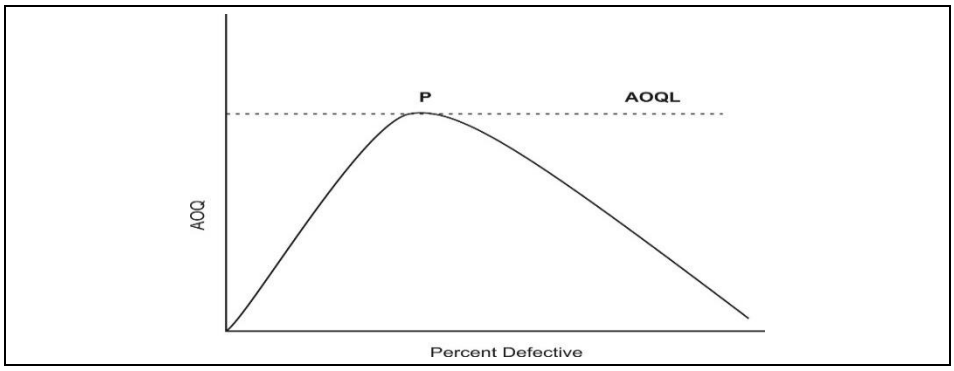
Sample	Mean Weight (X)	Range (R)
1	240	30
2	260	20
3	250	20
4	270	30
5	240	60
TOTAL	**1260**	**160**

29.9 Acceptance Plans

Acceptance plans are used for verifying the quality of raw material inputs, parts and components, and finished goods. A manager can accept or reject a lot based on these plans. If a lot is accepted, it is placed in the inventory for use whereas if it is rejected, it is returned to the supplier. If the lot of finished goods is accepted, it is sent to the consumers and if it is rejected, it is put through 100% inspections and the defective items are replaced by non-defective items. The main criterion for acceptance plans is to accept or reject a sample. For attributes, what is the

maximum percentage of defectives that can be found in a sample and still be accepted? For variables, what is the largest and the smallest sample mean and sample range? Given here is acceptance sampling based on average outgoing quality and operating characteristics.

Figure 29.1: Average Outgoing Quality (AOQ) Curve



Average Outgoing Quality (AOQ) Curve: The AOQ indicates the average defects in a lot that is assumed to have been inspected completely with all the defects or defective items having been removed or replaced. When the number of defects or non-conforming units in a lot is not too much, it means the AOQ (proportion of non-conforming units in the released lot) is less. The probability of rejecting lots increases with an increase in the proportion of defective items in the lot. These rejected lots are put to 100% inspection. The AOQ level is enhanced as more lots are put through 100% inspection. The maximum AOQ for any acceptance plan is the Average Outgoing Quality Limit (AOQL), which indicates the point at which the AOQ reaches the critical level. Any lot with the AOQ value of more than AOQL must not be sold to the final customers. Figure shows the AOQ curve characteristics when AOQ is plotted against percent defective. At the beginning, the curve takes an upward trend as there is an increase in the number of defective units, which increases the AOQ for the sampling plan. Point P is the maximum level for AOQ. The entire lot is rejected and every item in the lot is inspected, if the percent defectives exceed the critical point P. As the inspection increases, the defectives in the outgoing lot decrease, thereby improving the AOQ.

Operating Characteristics (OC) Curve: An inspection of all the items in a lot is not practical or feasible. By drawing a random sample, one can make an inference about the quality of all items in the lot though it reveals only the quality of the items present in the sample. The OC curve shows how well an acceptance plan differentiates between good and bad lots. Assume that a good lot does not have more than 1% defectives. This is called the *Acceptable Quality Level (AQL)*. If there are only 1% of actual defectives, the probability of accepting the lot will be 95% and the probability of rejecting the lot will be 5%. The probability of rejecting the lot at AQL is called a *producer's risk or Type I error*. In a sampling

plan, there is always a risk that a good lot will be rejected, which is the producer's risk. The consumer also faces a risk. Assume that a bad lot has 5% or more defectives. This is called the *Lot Tolerance Percent Defective (LTPD)*. The probability of accepting a lot with this percent of defectives is the *consumer's risk or Type II error*. Acceptance plans generally do not have large sample sizes because their inspection costs are higher and therefore while designing them they make a trade-off. Acceptance plans are designed with sample sizes that offer a balance between inspection costs and the cost of undetected defects. OC curves are not used for making day-to-day decisions about accepting or rejecting lots. Acceptance plans are used for ascertaining whether raw materials, purchased parts, and finished goods meet prescribed quality standards and based on these plans, operations managers can either accept or reject a lot.

Six Sigma

1 What is six sigma?

Before moving forward in order to understand the concept of six sigma, let us first understand the term sigma and statistics.

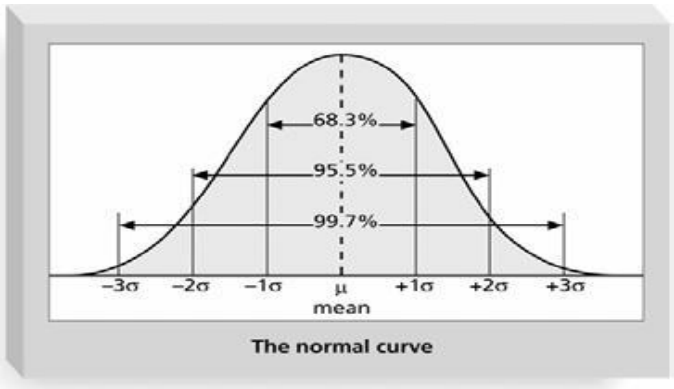
2 Sigma

The term sigma means standard deviation. Standard deviation measures how much variation exists in a distribution of data. It is a key factor in determining the acceptable number of defective units found in a population. Six sigma projects strive for no more than 3.4 defects per million opportunities, yet this number is confusing to many statisticians.

3 Standard Deviation

Small standard deviation means that data cluster closely around the middle of a distribution and there is little variability among the data. Normal distribution is the bell-shaped curve that is symmetrical about the mean or average value of a population.

Figure 29.2 Normal Distribution and Standard Deviation



Source: ICFAI Research Center

Definition

Six sigma at many organizations simply means a measure of quality that strives for near perfection. Six sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process-- from manufacturing to transactional and from product to service.

Six sigma means a failure rate of 3.4 parts per million or 99.9997% perfect. However, the term in practice is used to denote more than simply counting defects. Six sigma can now imply a whole culture of strategies, tools and statistical methodologies to improve the bottom line of companies. In all, six sigma is a rigorous analytical process for anticipating and solving problems. The objective of six sigma is to improve profits through defect reduction, yield improvement, improved consumer satisfaction and best-in-class product/process performance.

Unlike the statistical term, "sigma" is a measure of conformance to specification. Table below shows examples.

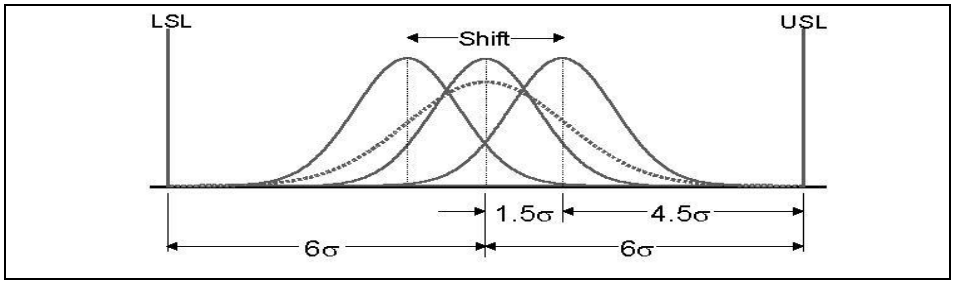
Six Sigma and Defective Units

Table 29.1 Data for the short-term process output

Specification Range (in +/- Sigma)	Percent of Population Within Range	Defective Units
1	68.27	317,300,000
2	95.45	45,400,000
3	99.73	2,700,000
4	99.9937	63,000
5	99.999943	57
6	99.9999998	2

As non-conforming rate decreases, "sigma" rating increases. The sigma rating is based on the distribution of a process output as related to a customer requirement. Figure below shows the short-term process output (solid blue) which is centered in the specification. The short-term variability of the process output is such that the Upper Specification Limit (USL) and the Lower Specification Limit (LSL) are both six standard deviations (called σ or sigma in statistical parlance) away from the center. Recognizing that most of the processes shift somewhat over a long period of time, an arbitrary change of plus or minus 1.5σ is expected to happen, leaving 4.5σ between the shifted average and the specification limit. This means that a process running at a six sigma level in the short term can tolerate a relatively large amount of drift and still make only 3.4 PPM nonconforming over the long term with the dashed blue line.

Figure 29.3 Short-term process output



Source: ICFAI Research Center

Phases of Six Sigma

There are six generic implementation phases for six sigma. These are as follows:

- Establish management commitment
- Business diagnostics
- Develop the management infrastructure
- Business process identification and metrics
- Project selection
- Deployment
- Training
- Project execution
- Review

Why is it important?

World-class companies typically operate at about four sigma or 99% perfection. To get to the six-sigma level means cutting down on huge costs and thereby wasted dollars. For example, if you were at four-sigma level, you would be producing products at the rate of 6,200 defectives for every million you produce vs. 3.4 defectives if you are at the six-sigma level. Moreover, six sigma improvement projects typically return in excess of $150k to $250k per project with a black belt returning as much as $1 million to the bottom line each year.

The popularity of six sigma is growing. Some of the companies that have successfully implemented six sigma are as follows:

- Motorola (1987)
- Texas Instruments (1988)
- IBM (1990)
- Asea Brown Boveri (1993)
- Allied Signal/Kodak (1994)
- GE (1995)
- Whirlpool
- PACCAR
- Invensys and Polaroid (1996/98)

Recently, Ford, DuPont, Dow Chemical, Microsoft and American Express have started working on instituting six sigma processes.

When to use it?

Bottom line drives management action. What is your cost of (poor) quality? First you need to determine that. If properly implemented, six sigma implementation can become a profit center for the company. Jack Welch at GE claims that the returns on six sigma implementation amount to about $500 million as of 1998. Remember that six sigma is complementary to other initiatives such as ISO or QS 9000 (which is mainly procedural), total quality management (which ismainly cultural), and statistical process control (which is primarily statistical process monitoring).

How to use it?

Six sigma focuses on process quality. As such, it falls into the category of a process capability (Cp) technique. Traditionally, a process is considered capable if the natural spread, plus and minus three sigma (a yield of 99.73%), was less than the engineering tolerance. A later refinement considered the process location as well as its spread (Cpk) and tightened the minimum acceptable so that the process was at least four sigma from the nearest engineering requirement. Six sigma requires that processes operate such that the nearest engineering requirement is at least plus or minus six sigma from the process mean. This requires considerable scientific and testing actions. Often, thousands of tests are run on multiple variables to get an understanding of what is going on. Once you determine the process variables, using the other process analysis techniques, you need to consider the ones causing the major losses and work on making them more capable.

- Understand who your consumers are and what your product/service is
- Review consumer surveys, concession reports and other data
- Screen and prioritize issues by severity, frequency/likelihood of occurrence etc
- Determine the internal processes causing most of the pain
- Find out why and where the defects are occurring
- Devise ways to address these defects effectively
- Setup a good metrics (six sigma places a lot of emphasis on measurement)

There are a variety of nicknames for the principle players in the initiative.

- Champions
- Executives with knowledge of six sigma methods
- Define projects
- Black belts

- Full-time position
- Lead improvement projects
- Serve as change agents
- Provide consulting to middle management
- Master black belts
    a. Full-time position
    b. Have additional training beyond black belt training o Can train and coach black belts
    c. Provide consulting to management and champions
- Green belts
    a. Have black belt training, but stay in present position

Check Your Progress - 4

17. _____ are used for verifying the quality of raw material inputs, parts and components and finished goods.
    a. Attributes
    b. Acceptance plans
    c. Control charts for attributes
    d. Control charts for variables
18. Identify the statement that **does not** hold true regarding acceptance plans.
    a. Acceptance plans are used for verifying the quality of raw material inputs, parts and components and finished goods.
    b. The main criterion for acceptance plans is to accept or reject a sample.
    c. If a lot is accepted, it is returned to the supplier for use.
    d. If the lot of finished goods is rejected, it is put through 100% inspection and the defective items are replaced by non-defective items.
19. What is the condition in which a customer runs the risk of accepting a lot with has 5% or more defectives?
    a. Cost of prevention
    b. Type I error
    c. Type II error
    d. Cost of detection
20. What explains how well an acceptance plan differentiates between good lots and bad lots?
    a. AOQ
    b. OC curve
    c. Lot Tolerance Percent Defective
    d. Acceptable Quality Level

29.10 Computers in Quality Control

Computer programs provide timely and relevant information regarding the quality of output. The time between product inspection at various stages and posting of information on control charts can be reduced as control charts can be prepared quickly using computers. Computer programs are used for making lot acceptance decisions. These programs set the conditions for acceptance, receive sample measurements, and recommend an acceptance decision. The lead time can be minimized, and materials can be moved into production quickly.

29.11 Concept of TQM

Total Quality Management (TQM) is a philosophy that seeks organization-wide improvement through the involvement of every individual in the organization. TQM is different from traditional quality control methods. Where the former suggests that it is the responsibility of everyone to maintain quality standards, the latter restricts quality maintenance to the quality personnel and manufacturing departments. Basically, quality meant products meeting the specifications and any defects in them were attributed to the manufacturing department. However, the fact that the performance of the manufacturing department was dependent upon the performance of other departments (like the purchase department), etc. was not taken into consideration. The TQM philosophy takes a broader view and fixes the responsibility of quality control on everyone, where the aim of the entire organization is to satisfy the customer. In TQM, customers are divided into external customers and internal customers. External customers are those who use the goods and services offered by the company and internal customers are the employees of the organization. The TQM philosophy states that each department in the organization should treat the other departments as its customers. TQM uses various tools and techniques like Kaizen, Continuous Improvement, Quality Circles, Quality Improvement Teams (QITs), Total Productivity Management, etc. whose main focus is on team building and empowering employees.

Activity: Collin International Ltd. is a sports goods manufacturing company. The management of the company realized that its quality management initiatives were not helping the company achieve its target of zero defects in its products. The company thought that the manufacturing department was faulty in the process and therefore began to warn them. The head of operations observed that the company needed to implement TQM, as the quality management was restricted only to the manufacturing department of the company and not to the entire company. The head of operations is trying to convince the management of Collin about the need to implement TQM throughout the company. Assist him in the process.

Answer:

29.11.1 TQM Principles

The following are the principles of TQM that organizations ought to practice to survive in the highly competitive world.

Systematic improvement: TQM as a philosophy involves systematic improvement of all the processes and systems in the organization irrespective of the functions and departments.

Customer focused: Under TQM, customer needs and requirements are identified and evaluated first and then requisite products are developed to suit those needs. This leads to increased customer satisfaction and delight.

Continuous improvement: Quality in TQM concept is not an end in itself, but is seen as a continuous process of improvement. Continuous quality improvement makes the organization more dynamic and a learning organization. A learning organization always strives to satisfy its customers in better ways.

Problem prevention: The concept of TQM always emphasizes on preventing a problem rather than finding ways to solve it after it has erupted. Thus TQM concept is a proactive approach to problem solving (problem prevention).

Universal responsibility: The TQM concept emphasizes that every employee in the organization is responsible for the implementation of quality and its improvement.

Designing quality products: The quality of the end product is very much dependent on the design of the product. Hence quality improvement in designing of products is emphasized in TQM.

According to Genichi Taguchi, the three important aspects of design quality are meeting customer requirements, capability of process, and standardization to improve quality.

29.11.2 Teachings of Quality Gurus

The field of quality globalised the word ‘guru’ by producing a number of proponents of various models for quality management. Even though, there are many gurus, only a few prominent ones are covered below as they have created a global impact over the past few decades.

1. **W Edwards Deming:** Deming placed great importance and responsibility on management, at both the individual and company level, believing management to be responsible for 94% of quality problems. His fourteen point plan is a complete philosophy of management, that can be applied to small or large organizations in the public, private or service sectors:

    1. Create constancy of purpose towards improvement of product and service.
    2. Adopt the new philosophy. We can no longer live with commonly accepted levels of delay, mistakes and defective workmanship.

3. Cease dependence on mass inspection. Instead, require statistical evidence that quality is built in.
4. End the practice of awarding business on the basis of price.
5. Find problems. It is management's job to work continually on the system.
6. Institute modern methods of training on the job.
7. Institute modern methods of supervision of production workers. The responsibility of foremen must be changed from numbers to quality.
8. Drive out fear, so that everyone may work effectively for the company.
9. Break down barriers between departments.
10. Eliminate numerical goals, posters and slogans for the workforce asking for new levels of productivity without providing methods.
11. Eliminate work standards that prescribe numerical quotas.
12. Remove barriers that stand between the hourly worker and their right to pride of workmanship.
13. Institute a vigorous program of education and retraining.
14. Create a structure in top management that will push on the above points every day

Deming also encouraged a systematic approach to problem solving which is PLAN-DO-CHECK-ACT Simply it is known as PDCA. The PDCA cycle is also known as Deming cycle (or) Shewhart cycle although it was developed by a colleague of Deming, Dr.Shewhart.

2. **Dr. Joseph M Juran:** Juran developed the quality trilogy- quality planning, quality control and quality improvements.Good quality management requires actions to be planned,implemented and controlled. Once the process achieves control at one level of quality performance, then plans are made to improve using QC tools and techniques such as Pareto analysis. This activity even fully achieves break through to an improved level. This is again controlled to prevent any deterioration. Juran believed quality is associated with customer satisfaction and dissatisfaction with the product, and emphasized the necessity for ongoing quality improvement through a succession of small improvements projects carried out through out the organisation Juran's main contribution was he defined quality as "fitness for use" and developed the concept of cost of quality addressing failure and prevention costs. Exhibit 29.1 identifies Juran's approach to quality management.

Exhibit 29.1: Juran's 10-step Approach to Quality Management

1. Build awareness of the need and opportunity for improvements.
2. Set goals for improvements
3. Organise to reach the goals
4. Provide training
5. Carry out projects to solve problems
6. Report progress
7. Give recognition
8. Communicate results
9. Keep score of improvements achieved
10. Maintain momentum.

Juran concentrated not just on the end customer, but on other external and internal customer. Each person along the chain, from product designer to final user, is a supplier and a customer. In addition the person will be part of a process carrying out some transformation or activity.

3. **Armand V Feigenbaum:** Feigenbaum is an American quality control expert and businessman. He devised the concept of total quality control, the forerunner for Total Quality Management (TQM) He defined it as: An effective system for integrating quality development, quality maintenance and quality improvements, effort of the various groups within an a organisation, so as to enable production and service at the most economical levels that allow full customer satisfaction.

   The concept of a hidden plant: The idea that so much extra work is performed in correcting mistakes that there is effectively a hidden plant within any factory.

   Accountability for quality: Because quality is everybody's job it may become nobody's job- the idea that quality must be actively managed and have visibility at the highest level of management.

4. **Kaoru Ishikawa:** Ishikawa is a Japanese university professor and quality management innovator. Ishikawa made many contributions to quality-Ishikawa's viewpoint, company wide quality control, and emphasis on human side of quality, the Ishikawa diagram and use of the seven basic quality tools. These QC tools are used to analyse problem and develop improvements. The most widely known is the Ishikwa diagram or fish bone diagram or case and effective analysis. Exhibit 29.2 lists the 7 basic QC tools of Ishikawa

Exhibit 29.2: Ishikawa's Basic 7 QC Tools

1. Pareto analysis
2. Cause and effective analysis
3. Stratification
4. Check sheet
5. Histograms
6. Scatter chart
7. Process control chart

5. **Genichi Taguchi:** Taguchi methodology is fundamentally prototyping techniques that enable engineers / designs to produce a robust design which can survive repetitive manufacturing in order to deliver the functionality required by the customer.

   Taguchi suggested product development in three stages:

   1. System design stage: Non statistical stage for engineering marketing and customer knowledge.
   2. Parameter stage: How the product should perform against defined parameters, the robust solution of cost effective manufacturing, irrespective of the operating parameters.
   3. Tolerance around the desired setting finished the balance between manufacturing cost and loss.
   4. Taguchi's main contribution: Focused on product design quality and Developed Taguchi's loss function.

6. **Philip B Crosby**: Crosby is known for the concepts of "Quality is Free" and "Zero Defects", and his quality improvement process is based on his four absolutes of quality. Exhibit 29.3 presents Crosby's four absolutes of quality.

Exhibit 29.3: Crosby's Absolutes of Quality

1. Quality is conformance to requirements
2. The system of quality is prevention
3. The performance standard is zero defect
4. The measurement of quality is the price of non-conformance

His fourteen steps to quality improvement are:

1. Management is committed to a formalized quality policy.
2. Form a management level quality improvement team (QIT) with responsibility for quality improvement process planning and administration.
3. Determine where current and potential quality problems lie.
4. Evaluate the cost of quality and explain its use as a management tool to measure waste.
5. Raise quality awareness and personal concern for quality amongst all employees.
6. Take corrective actions, using established formal systems to remove the root causes of problems.
7. Establish a zero defects committee and program.
8. Train all employees in quality improvement.
9. Hold a Zero Defects Day to broadcast the change and as a management re-commitment and employee commitment.
10. Encourage individuals and groups to set improvement goals.
11. Encourage employees to communicate to management any obstacles they face in attaining their improvement goals.
12. Give formal recognition to all participants.
13. Establish quality councils for quality management information sharing.

Summary of the teachings of Quality Gurus

1. It is management's responsibility to provide commitment, leadership, empowerment, encouragement, and the appropriate support to technical and human processes. It is top management's responsibility to determine the environment and framework of operations within a firm. Top management should promote a customer-centric quality culture.
2. The strategy, policy, and firm-wide evaluation activities are emphasised.
3. The importance of employee education and training is emphasised in changing employees' beliefs, behaviour, and attitudes; enhancing employees' abilities in carrying out their duties.
4. Employees should be recognized and rewarded for their quality improvement efforts.
5. It is very important to control the processes and improve quality system and product design. The emphasis is on prevention of product defects, not inspection after the event.
6. Quality is a systematic firm-wide activity from suppliers to customers. All functional areas, such as marketing, design, supply chain, engineering, purchasing, manufacturing, inspection, shipping, accounting, installation and service, should be involved in achieving business excellence.

Check Your Progress - 5

21. Universal responsibility is one of the principles of TQM. Identify the statement that best represents and underlines the spirit of this principle.
    a. Top management is responsible for the quality of products entering the market.
    b. Production department is responsible for product quality.
    c. Every employee at every level in the organization is responsible for quality.
    d. Emphasis is on continuous improvement in process, skill sets, systems, or operations.
22. Under TQM, every department in an organization should treat every other department as its _____.
    a. Producer
    b. Customer
    c. Distributors
    d. Supplier
23. All the statements given below are **true** regarding total quality management, except:
    a. It is a philosophy that seeks organization-wide improvement through the involvement of every individual in the organization.
    b. It restricts quality maintenance to quality personnel and manufacturing departments.
    c. It takes a broader view and fixes the responsibility of quality control on everyone, where the aim of the entire organization is to satisfy the customer.
    d. It states that each department in the organization should treat the other departments as its customers.
24. Which of the following is **not** a principle of total quality management?
    a. Systematic improvement
    b. Focus on customers
    c. Continuous improvement
    d. Top management responsibility
25. Identify from the following, the important aspects of design quality as proposed by Genichi Taguchi.
    i. Capability of process
    ii. Meeting customer requirements
    iii. Customizing the logistics network

iv. Standardization to improve quality

a. Only i, ii, and iii

b. Only i, ii, and iv

c. Only ii, iii, and iv

d. i, ii, iii, and iv

29.12 Summary

- Productivity is an important performance indicator and measures the efficiency of production process in a firm.
- Productivity can be measured by considering a single factor (single factor productivity) like raw material or multiple factors like raw material, components, labor, etc (multiple factor productivity). Total productivity measures the productivity by considering all the factors of production.
- Measuring the productivity of knowledge workers and service organizations is difficult as they involve many intangible components.
- Operations managers have begun to pursue quality standards in products and services to satisfy the demands of the consumers for good quality goods and services.
- Quality control begins from the time raw materials are procured based on appropriate specifications.
- A company can compete on the quality functions of performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality.
- The cost of quality is the total of the cost of prevention, the cost of detection/appraisal, and the cost of failure.
- Prevention costs are incurred by a company to prevent defective goods and services from being manufactured or delivered to the consumers.
- Detection/appraisal costs are associated with the evaluation of quality and performance of products and machines.
- Failure costs occur in non-conforming and non-performing products and are divided into external and internal failure costs.
- Control charts are used for monitoring quality and are easy to develop, analyze, and understand. There are two types of control charts – control charts for variables and control charts for attributes.
- X-Charts illustrate the central tendency of a sample, R-Charts illustrate the variability of a process, P-charts identify the proportion of defects in a given sample and C-Charts identify the number of defects in a sample item when the item has multiple defects.

- Acceptance plans are used for verifying the quality of raw material inputs, parts, and components, and finished goods.
- The quality of products and processes can be improved by using computer-based systems like robots, flexible manufacturing systems, automated assembly systems, numerically controlled machines, etc.
- Total Quality Management (TQM) is a philosophy that seeks organization-wide improvement through the involvement of every individual in the organization.
- TQM uses various tools and techniques like Kaizen, Continuous Improvement, Quality Circles, Quality Improvement Teams (QITs), Total Productivity Management, etc.
- The principles of TQM have been instrumental in implementing the concept in organizations and improving the quality across every sphere of the organization.

29.13 Glossary

Acceptance plans: These are used for verifying the quality of raw material inputs, parts and components, and finished goods. A manager can accept or reject a lot based on these plans.

Control charts for attributes: In these charts, a measurable variable like weight, length, width, etc. is used in the inspection process. After inspection, the items are identified as defective or non-defective if the quality characteristics are not quantifiable.

Control charts for variables: These charts are used for maintaining quality standards for a process by evaluating measurable product or service variables like thickness, length, tensile strength, and queue waiting time.

Control charts: These are used for monitoring quality and are easy to develop, analyze, and understand. Different measurement criteria are plotted on a chart with a central line representing the mean value and two control limits above and below the central value. The process is said to be in control if the noted variable and attribute values fall between the control limits. If the values fall outside the control limits, then the process is said to be out of control, and remedial actions have to be taken to correct the differences.

Cost of detection/appraisal: Costs associated with the evaluation of quality and the performance of products and machines.

Cost of failure: Costs that occur in non-conforming and non-performing products.

Cost of prevention: Costs incurred to prevent defective goods and services from being manufactured or delivered to the consumers.

Cost of quality: The total of the cost of prevention, cost of detection/appraisal, and the cost of failure.

External failure costs: Costs incurred when the defects are found after the products are delivered to the customer.

Internal failure costs: Costs incurred when defects are found before the products are delivered to the consumers and they can be eliminated if the defects are minimized or eliminated within the system.

Multifactor productivity: Productivity is measured considering two or more factors.

Productivity: It is a measure of the efficiency of the firm in terms of products produced. It is calculated as the ratio of the output produced to that of the inputs consumed.

Single factor productivity: Productivity is measured considering only a single factor, say labor or raw material.

Total productivity: Productivity is measured considering all the factors of production.

Total Quality Management: A philosophy that seeks organization-wide improvement through the involvement of every individual in the organization. It suggests that it is the responsibility of everyone to maintain quality standards.

29.14 Self-Assessment Exercises

1. What is productivity and what factors affect productivity in an organization? Explain how productivity measurement varies in manufacturing and service organizations.
2. Quality control begins from the time raw materials are procured based on appropriate specifications. Explain the importance and role played by quality control in business organizations.
3. Companies have been using quality as an offensive strategic weapon against their competitors. Explain the different quality functions or dimensions which can be used by a company to gain an advantage over its competitors.
4. Inspection plays a vital role in quality control. Explain the role of inspection in quality control. What do you mean by the cost of quality?
5. Statistical techniques are used in identifying variations in the process which could affect the quality of the final product or service. Describe the various statistical concepts involved in quality control. Also explain in detail the procedure for implementing a quality control program.
6. A manager can accept or reject a lot based on acceptance plans. What are acceptance plans? Explain in detail about the Average Outgoing Quality (AOQ) curve and Operating Characteristics (OC) curve.
7. Computer systems and databases are used in various quality control programs. How are computers useful in quality control?
8. Total Quality Management (TQM) is a philosophy that seeks organization-wide improvement through the involvement of every individual in the organization. Explain the concept of Total Quality Management (TQM) in detail.

29.15 Suggested Readings/Reference Material

1. How To Measure Productivity and Increase Efficiency in the Workplace, February 12, 2021, Indeed Editorial Team
2. Measuring productivity in Healthcare, https://www.brookings.edu/wp-content/uploads/2016/08/hp-lit-review_final.pdf, 2016
3. Lionel Stebbing, Quality Management in the Service Industry (Ellis Horwood Series in Applied Science and Industrial Technology), ASQ Press, 2016
4. Joseph A. De Feo, Juran's Quality Handbook, Seventh Edition, ASQ Press, 2016
5. Ellis R. Ott, Edward G. Schilling, Dean V. Neubauer Process Quality Control: Troubleshooting and Interpretation of Data, Fourth Edition, ASQ Press, 2016

29.16 Answers to Check Your Progress Questions

Following are the answers to the Check Your Progress Questions given in the Unit.

1. (d) i, ii, iii, and iv

Some of the factors that affect productivity in organizations are (a) bottlenecks in the form of poor layout designs, slow processing equipment and inventory shortages; (b) shortage of skilled manpower and lack of training on advanced technologies; (c) poor scheduling methods leading to more waiting time in the production process; and (d) strikes and worker agitations that cause break in production.

2. (c) Productivity

Productivity is the ratio of the output produced to that of the inputs consumed. Hence, it is a measure of the efficiency of the firm in terms of products produced. Productivity helps the operations managers to control the production process and match it with that of the market demand.

3. (c) Only ii and iii

Productivity can be measured in relation to a single factor (single factor productivity), a combination of factors (multifactor productivity), or all the factors taken together (total productivity). Multifactor productivity implies two or more factors are considered to measure productivity. When all the factors of production are used to measure productivity, then it is termed as total productivity. Productivity is difficult to measure when intangible and qualitative factors like knowledge of the workers and leadership skills are involved.

4. (a) Procurement of raw material

Quality control begins as early as procurement of raw materials. Raw materials have to be procured with the right specifications and in the right quantity. This is part of preventive control.

5. (c) Proper scheduling

Layout, slow processing equipment and inventory shortages can reduce productivity. But, proper scheduling helps the operations mangers increase productivity.

6. (d) Number of cars serviced in a period

Options - (a), (b), and (c) are inputs to calculate productivity in service organizations, while option (d) is an output.

7. (d) Warranty

All the options are functions of quality except warranty, which is an external failure cost, due to poor quality of product.

8. (c) The total cost of quality control is minimal

An optimal trade-off between the cost of inspection and the cost of undetected faults exists when the cost of total quality control is minimal.

9. (b) Loss of goodwill

The cost of undetected faults includes customer complaints, loss of goodwill, product replacement cost, product liability suits, product recall programs and returned products.

10. (b) i/r, ii/p, iii/q

A company can compete on the quality functions such as performance (a car could be compared on performance characteristics such as acceleration, mileage and speed), features of the product, reliability (the probability of a product's failure within a specified time period), conformance (ability of the product and its individual components to meet the established standards), durability (the operational life of a product), serviceability. (It is the readiness of the product to be serviced back to the operational mode), aesthetics and perceived quality (customer's perception about the quality of a product).

11. (a) The process is out of control and the cause should be established

If the values fall outside the control limits then the process is considered out of control. Remedial action has to be taken to rectify these discrepancies.

12. (c) Appraisal costs

Detection or appraisal costs are costs associated with evaluating the quality and performance of products and machines. These include inward materials

inspection, tests and inspection throughout the transformation process, equipment maintenance, etc.

13. (d) Cost of returned products

Cost of returned products is an example of external costs. Internal costs include scrap, repair, retesting of repaired products, downtime, loss due to process variability and disposition of defective items.

14. (a) i and ii

Quality control charts can be broadly classified into control charts for variables and control charts for attributes. Control charts for variables include X-Chart and R-Chart.

15. (c) P-chart

P-chart and C-chart fall under control charts for attributes. P-chart determines the proportion of defects in a given sample while C-chart is used to determine the total number of defects in a product.

16. (d) Prevention

The cost of quality is the total of the cost of prevention (costs incurred to prevent defective goods and services from being manufactured or delivered to the consumers), the cost of detection/appraisal (costs associated with the evaluation of quality and the performance of products and machines), and the cost of failure (costs that occur in non-conforming and non-performing products).

17. (b) Acceptance plans

Acceptance plans are used for verifying the quality of raw material inputs, parts and components and finished goods. A manager can accept or reject a lot based on these plans.

18. (c) If a lot is accepted, it is returned to the supplier for use.

Acceptance plans are used for verifying the quality of raw material inputs, parts and components, and finished goods. A manager can accept or reject a lot based on these plans. If a lot is accepted, it is placed in the inventory for use whereas if it is rejected, it is returned to the supplier. If the lot of finished goods is accepted, it is sent to the consumers and if it is rejected, it is put through 100% inspections and the defective items are replaced by non-defective items.

19. (c) Type II error

The probability of accepting a lot with 5% or more defectives is the consumer's risk or Type II error.

20. (b) OC curve

The operating characteristics (OC) curve is an important feature of acceptance plans. It shows how well an acceptance plan differentiates between good and bad lots. The OC curve is used to determine the limit of average outgoing quality.

21. (c) Every employee at every level in the organization is responsible for quality

Maintaining quality is not just a prerogative of top management or the quality inspection department but every employee at every level. Quality responsibilities result in employees being more committed, motivated and creative in performing assigned tasks.

22. (b) Customer

TQM believes that each department should treat other departments as its customers.

23. (b) It restricts quality maintenance to quality personnel and manufacturing departments.

All the options are true regarding total quality management (TQM), except statement (b). TQM is different from traditional quality control methods. While the traditional quality control methods restrict quality maintenance to the quality personnel and manufacturing departments, TQM suggests that it is the responsibility of everyone to maintain quality standards.

24. (d) Top management responsibility

The principles of total quality management are systematic improvement; focus on customers, continuous improvement, problem prevention, universal responsibility, and designing of quality products. The TQM concept emphasizes on universal responsibility, rather than responsibility of the top management. It states that every employee in the organization is responsible for the implementation of quality and its improvement.

25. (b) Only i, ii, and iv

According to Genichi Taguchi, the three important aspects of design quality are meeting customer requirements, capability of process, and standardization to improve quality. Customizing the logistics network is a principle of supply chain management.

Unit 30

Facilities and Maintenance Management

Structure

30.1 Introduction

In the last section of the previous unit, we have discussed the concept of total quality management (TQM). We have learnt that the TQM philosophy seeks organization-wide improvement through the involvement of every individual in the organization. In this unit, we will discuss facilities and maintenance management.

Managing the facilities of an organization has gained in importance over the years. It has grown from being a secondary function handled by a manager in the personnel department to a major function similar to human resources management, financial management etc. Facilities management is either done in-house or outsourced to external agencies. Maintenance management helps in curtailing the effects of factors like wear and tear, aging, and misuse in machines, and in extending the operational life of the equipment. Through proper maintenance, organizations can retain the productivity of their equipment, increase the operational life of the equipment, reduce the number of breakdowns, minimize losses, and maintain safe working conditions by reducing the probability of accidents. Maintenance also helps in developing a reliable and high quality production system. Organizations tend to ignore the importance of proper and timely maintenance as it is a non-core activity.

This unit will introduce you to facilities management, and explain the necessity of maintenance management. We will discuss the various types of maintenance, and the economics of maintenance. We shall then move on to discuss how to evaluate the preventive maintenance policies, and the modern approaches to preventive maintenance. Finally, we would discuss the recent trends in maintenance.

30.2 Objectives

By the end of this unit, students should be able to:

- Define facilities management.
- Explain the necessity of maintenance management.
- Classify the various types of maintenance.
- Discuss economies of maintenance.
- Evaluate preventive maintenance policies.
- Identify the modern approaches to preventive maintenance, and the recent trends in maintenance.

30.3 Facilities Management

Facilities management can be defined as a field/profession, which integrates people, process and technology with the work environment to enable the organization to carryout its core business operations in the most efficient manner. The primary objective of facilities management is to provide a clean and conducive work environment and enable efficient and effective progress of the core functions of an organization, be it manufacturing, distribution or research. Sometimes, organizations outsource the facilities management function to ensure this focus in core competence. Some of the activities under the purview of facilities management include Housekeeping & janitorial services, Operations and maintenance services, Office administration, reprographics & mail services, Landscaping and horticulture, Pest and rodent control, Waste management, Energy conservation and management, and Communication networks.

30.3.1 Functions of Facilities Manager

The facilities manager develops and executes strategies that are in line with the organizational goals. The most important function of the facilities managers is to manage the facilities economically. The following are the common functions of facilities managers:

- Conduct and participate in planning activities
- Recruit the right people to perform facilities management jobs
- Measure the work performance of the facilities management teams
- Review the current techniques so as to reduce cost of operations
- Develop and maintain a controlling center as a support to facilities management department

30.3.2 Outsourcing of Facilities Management

Facilities management function is usually outsourced to third parties. The entire facilities management function can be outsourced to a single operator or various functions can be outsourced to different operators. A major reason to outsource facilities management is to concentrate on the core business activities. The other advantages of outsourcing include increase in the quality of work, flexibility of operations, and reduced operation costs. Outsourcing is also done when special skills are required to carry out certain facilities management activities like architectural design, hazardous material removal, property appraisal, etc. Another popular reason to outsource facilities management is to reduce the cost of operations. If organizations feel that it is costly to handle certain operations in-house, then such operations are outsourced to external agencies. This helps save operational and maintenance costs. CMC Limited, an IT solutions company, provides facilities management services in the field of IT infrastructure and maintenance. It installs and maintains the IT infrastructure in its clients' premises, which include Indian Railways, Indian Oil Corporation, Kodak India, Bank of Baroda, Bombay Stock Exchange, etc. Exhibit 30.1 shows the offering of facility management services of UDS

Exhibit 30.1: UDS Offers Total Facilities Management Solutions

Updater Services (UDS) provides world class facility management services for companies in India. The portfolio of services includes house keeping, pest control, waste management, mechanical and electrical maintenance, production support services, staffing solutions etc. UDS offers these services individually or integrates them to offer 'Total Facility Management Solutions'

UDS classifies its facilities management services into soft services, hard services, staffing solutions, and hospitality services.

Soft services: The soft services portfolio for facility maintenance and management include Housekeeping & Janitorial Services, Garden & Lawn Maintenance, Pest Control, Waste Management, Vendor Management, and Mail Room Services.

Hard Services: The hard services basically involve the maintenance management activities. They include Mechanical & Electrical Services, HVAC (Operation & Maintenance), Water Management & Plumbing, Energy/Safety Audits, Design Erection & Installation, and Testing & Commissioning.

Staffing Solutions: UDS also carries out the staffing functions. It helps place a wide variety of experienced skilled and semi skilled workforce at various client locations. Personnel are provided for Production Support Services, Office Administration Support, Help Desk Services, and Warehouse & Dispatch Management.

Hospitality services: The services under 'Total Facility Management Solution' include Guest House Management and Catering Services.

Adapted from http://www.updaterservices.com/services/index.php

The costs and benefits involved are explored thoroughly by the organization before outsourcing the facilities management function.

Costs associated with outsourcing: There are certain costs associated with outsourcing the facilities management function. At times these costs may prove to be a burden and hinder the expected savings from outsourcing, in addition to reducing the quality of performance. Some of these costs are loss of control, decrease in flexibility, decrease in staffing quality, decrease in workers availability, and increase in other costs.

Benefits of outsourcing: It is commonly perceived that the benefits of outsourcing far outwit the associated costs. Hence, many organizations world over prefer to outsource their facilities to external agencies. Some of the benefits of outsourcing are reduced costs, increased quality, focus on core competencies, and increase in flexibility.

30.3.3 Facilities Management and Maintenance

Maintenance of facilities is part of the facilities management services and it is the duty of the facilities manager to oversee the maintenance activities of facilities. In large organizations, a dedicated maintenance department would carry out the facilities maintenance throughout the year. But in small organizations, the employees in the departments themselves are expected to take up the additional responsibility of maintenance. Activities under facilities maintenance include carrying out regular preventive maintenance in the facilities, checking for safety in the work environment, allocating budgets for upgrading the environment in the facilities, etc.

Check Your Progress - 1

1. To provide a clean and conducive work environment and enable efficient and effective progress of the core functions of an organization is an objective of _____.
   a. Quality management
   b. Facilities management
   c. Maintenance management
   d. Inventory management
2. Despite several disadvantages, firms prefer to outsource facilities management tasks. Which of the following does not support this statement?
   a. Increases quality of work
   b. Helps develop core competence
   c. Increases flexibility
   d. Increases operational costs

3. Which of the following are the functions of facilities managers?

   i. Conduct and participate in planning activities

   ii. Recruit right people to carry out facilities management jobs

   iii. Measure the work performance of the facilities management teams

   iv. Develop and maintain a controlling center as a support to facilities management department

   a. Only i, ii, and iii

   b. Only i, iii, and iv

   c. Only ii, iii, and iv

   d. i, ii, iii, and iv

4. _____ can be defined as a field/profession, which integrates people, process, and technology with the work environment to enable the organization carry out its core business operations in the most efficient manner.

   a. Quality management

   b. Facilities management

   c. Productivity management

   d. Enterprise resource planning

5. Identify from the following the activities that fall under the purview of facilities management.

   i. Housekeeping services

   ii. Energy management

   iii. Communication networks

   iv. Waste management

   a. Only i, ii, and iii

   b. Only i, iii, and iv

   c. Only ii, iii, and iv

   d. i, ii, iii, and iv

6. Proper maintenance helps organizations:

   i. retain the productivity of their equipment.

   ii. increase the operational life of the equipment.

   iii. reduce the number of breakdowns and minimize losses.

   iv. maintain safe working conditions by reducing the probability of accidents.

   a. Only i, ii, and iii

   b. Only i, iii, and iv

   c. Only ii, iii, and iv

   d. i, ii, iii, and iv

7. _____ helps in curtailing the effects of factors like wear and tear, aging, and misuse in machines and in extending the operational life of the equipment.
   a. Quality management
   b. Facilities management
   c. Productivity management
   d. Maintenance management

30.4 Necessity of Maintenance Management

Maintenance management ensures that systems are working at their optimum efficiency by identifying and locating the source of the problem as early as possible and taking preventive steps to avoid any breakdown. Timely inspection of facilities, appropriate replacement policies for machines and their components, and proper care during the designing and installation phases, all enhance the reliability of the machines and the equipment. Maintenance management is important as the breakdown or malfunctioning of a machine hinders the production process, affects the quality of products, and results in idle time and accidents. Therefore, the maintenance department plans and controls all the maintenance activities to keep the firm's machinery in optimal working condition. The goal of maintenance management is to

a. Maximize the availability (working time) of the firm's assets for production purposes
b. Preserve the value of the firm's machinery and equipment by reducing the rate of deterioration
c. Plan and schedule the maintenance work to anticipate and prevent machine failures and breakdowns
d. Improve the quality of products and increase the firm's productivity
e. Use maintenance personnel and equipment efficiently
f. Minimize or totally eliminate accidents by regular inspection and repairs

Effective maintenance management eliminates equipment errors, and improves the operational capacity, economic lifetime, and salvage value of equipment. In essence, the objective of maintenance management is to minimize loss of productive time, increase the life of the assets, and ensure effective utilization of the assets.

Activity: Michael is the operations manager of an engineering company. Realizing that most of the productive working time is getting wasted due to frequent maintenance problems and repairs of equipment in the factory, he approached the management to tell them about the problems being encountered by the workers and to request them for a maintenance management team in the company. He suggested two alternatives – to have a company-owned

maintenance management team or to outsource the maintenance management activities to original equipment manufacturers (OEMs). However, the management considered this as an additional cost and rejected both proposals. Michael began explaining to the management about the benefits of maintenance management and preventive maintenance. Assist him in the process of convincing the management about the importance of maintenance management.

Answer:

30.4.1 Impact of Poor Maintenance

Poor or improper maintenance of the firm's machines or equipment affects:

- *Production capacity* – As poorly maintained machines do not operate at optimum efficiency.
- *Production costs* – Idle labor during breakdown, repair costs, increased material scrap, lower productivity, etc., add to the production costs.
- *Quality of a product* - Poorly maintained machines affect the quality of the end-products.
- *Safety* - Poorly maintained facilities are prone to accidents and usually compromise the safety of the workers.

30.4.2 Areas of Maintenance

The major areas of maintenance in a firm are mechanical, civil and electrical maintenance. Mechanical maintenance involves the maintenance of the firm's machines and equipment, such as boilers, furnaces, compressors, transport vehicles, etc. Civil maintenance includes building construction and its maintenance, maintenance of service facilities (like water filters, air conditioning, plumbing, etc), drainage systems, fire fighting equipment, security systems, and waste disposal. Electrical maintenance involves maintenance of electrical and electronic equipment such as generators, motors, electrical installations, lighting, telephone systems, etc. A plumber maintains water supply pipes, an electrician takes care of lighting equipment, housekeepers are responsible for cleanliness of buildings and instrumentation personnel maintain and service routers.

Activity: Jesse International is a financial services company based in San Francisco. A year ago, the employees of the company were facing health problems. One of the senior managers identified that the water filters in the company were not being properly maintained and the air-conditioners were not being serviced regularly.

He reported this to the management. The management immediately took steps to service the water filters and air-conditioners. The situation became normal. However, the same situation came up again and this time, the senior manager requested the management to set up a maintenance team to take care of the service facilities. The management refused to consider this, stating that maintenance was necessary for manufacturing companies, not for service companies. The senior manager is trying to convince the top management of the company about areas of maintenance in any company irrespective of the nature of business being carried out. Assist him in the process.

Answer:

Check Your Progress - 2

8. Which of the following is **not** a goal of maintenance management?
   a. Minimizing the availability of the firm's assets for production purposes
   b. Improving the quality of products and increasing the firm's productivity
   c. Using maintenance personnel and equipment efficiently
   d. Preserving the value of a firm's machinery and reducing deterioration
9. Maintenance of air conditioners is an example of which type of maintenance?
   a. Mechanical maintenance
   b. Civil maintenance
   c. Electrical maintenance
   d. All of the above
10. If a 5hp motor is a critical component in the manufacture of a certain product in a large organization, its maintenance is given utmost importance. Who would appropriately undertake maintenance of such equipment?
    a. Machine mechanic
    b. Plumber
    c. Electrician
    d. Supervisor

11. Match the following personnel with their respective maintenance responsibilities.
    i. Plumbing personnel
    ii. Electrical personnel
    iii. Housekeeping personnel
    iv. Instrumentation personnel
    p. Lighting equipment
    q. Electronic routers
    r. Water supply pipes
    s. Buildings
    a. i/p, ii/q, iii/r, iv/s
    b. i/q, ii/p, iii/r, iv/s
    c. i/r, ii/p, iii/s, iv/q
    d. i/r, ii/q, iii/p, iv/s
12. Mr. Suresh Kumar was promoted as maintenance manager in Unicorn Manufacturing. He was a design engineer in the same plant earlier. What benefits can Kumar offer to Unicorn in his new position?
    i. Focus on regular maintenance to improve productivity
    ii. Help increase the life of assets and machinery
    iii. Help preserve the value of equipment
    iv. Minimize the salvage value of machinery
    a. i and ii
    b. iii and iv
    c. i, ii, iii
    d. i, ii, iii, iv
13. Which of the following is **not** an activity of maintenance management?
    a. Improving efficiency of raw material purchase
    b. Minimizing loss of productive time
    c. Prolonging asset life
    d. Effective utilization of assets

30.5 Types of Maintenance

All the activities that keep the production facilities and the equipment in operating condition form a part of the maintenance operations. These activities are divided into preventive maintenance, predictive maintenance, and remedial maintenance.

30.5.1 Preventive Maintenance

Preventive maintenance aims at servicing the machines regularly so that the equipment functions satisfactorily under optimum load conditions without

breakdown or reduction in efficiency. Machines and equipment deteriorate with the passage of time because of wear and tear, improper use, overloading, aging, etc. As a result, there is a reduction in the production rate of the machine, quality of products manufactured, operational life. Preventive maintenance activities are classified into periodic and irregular maintenance activities.

Periodic maintenance activities: Periodic maintenance activities are conducted at regular intervals. These activities are carried out on a weekly or monthly basis or on the basis of machine usage, like, after every 36 hours of operation.

Irregular preventive maintenance activities: Irregular preventive maintenance includes tasks like repairs, overhauls, and cleaning of spills, which are carried out when the routine inspection of a machine reveals the need for servicing before the next periodic preventive maintenance.

Predictive Maintenance

Predictive maintenance is a set of irregular preventive maintenance activities, which detect probable future problems before they occur while the equipment is still performing at a satisfactory level. It involves continuous monitoring of the vital attributes of various systems. Steps are taken to rectify any malfunctions. Preventive maintenance is time-based whereas predictive maintenance is condition-based. Predictive maintenance identifies problems before they become responsible for breakdowns, reduces the amount of unscheduled maintenance activities, reduces the repair and service time as problem-solving is done beforehand, and does not interrupt the normal production activities as maintenance can be scheduled when the equipment in question is idle.

30.5.2 Remedial Maintenance

Remedial maintenance (or breakdown maintenance or corrective maintenance) is carried out when a machine or equipment breaks down or is malfunctioning. Remedial maintenance activities are reactive as they are performed only after a breakdown has occurred, when equipment malfunctions (reduction in vibration, etc.) or operates at a lower speed than desired, produces products of inferior quality. Once the equipment breaks down or stops functioning, the maintenance department analyzes the problem, identifies the causes, and then carries out the necessary repair work to get the equipment back into operational mode as soon as possible. Some objectives of remedial maintenance are to minimize production losses by getting the equipment back into working condition as quickly as possible, to minimize investments in spare parts and standby machines used when equipment is under repair, and to perform appropriate maintenance based on the extent of problem.

Check Your Progress - 3

14. Which of the following is **not** an objective of remedial maintenance?
    a. To minimize production losses by getting equipment back into working condition as quickly as possible
    b. To minimize investments in spare parts and standby machines used when equipment is under repair
    c. To perform appropriate maintenance based on the extent of the problem
    d. Regular monitoring of vital parameters of a machine
15. Preventive maintenance can be classified into periodic maintenance and irregular maintenance. Irregular preventive maintenance does **not** include one of the following.
    a. Repair
    b. Overhaul
    c. Reducing machine vibration
    d. Tasks like cleaning up oil spills
16. Identify the distinct difference between preventive and predictive maintenance
    a. Predictive maintenance is done after a machine breaks down while preventive maintenance is done before a machine breaks down
    b. Preventive maintenance is done after a machine breaks down while predictive maintenance is done before a machine breaks down
    c. Preventive maintenance involves regular servicing of equipment while predictive maintenance involves monitoring equipment continuously
    d. Preventive maintenance focuses on the past while predictive maintenance focuses on the future
17. Krishna, a production worker detected some minor vibrations in a lathe machine that is very sensitive to movement. What does this indicate?
    i. The cutting precision will reduce
    ii. Rate of production can go up
    iii. Quality of product can come down
    iv. The equipment needs maintenance
    a. i, iii, iv
    b. ii, iii, iv
    c. i, ii, iii
    d. i, ii, iii, iv
18. Periodic maintenance is associated with _____.
    a. Preventive maintenance
    b. Predictive maintenance
    c. Remedial maintenance
    d. Mechanical maintenance

19. What is the term used for the maintenance activity that attempts to detect problems while the equipment is still performing at a satisfactory level?
    a. Remedial maintenance
    b. Predictive maintenance
    c. Periodic maintenance
    d. None of the above
20. Remedial maintenance is termed reactive. What does this mean?
    a. Remedial maintenance is taken up when machinery breaks down
    b. Remedial maintenance is done to avoid breakdown
    c. It occurs before purchase of new machinery
    d. It is carried out regularly

30.6 Economics of Maintenance

Improper maintenance of equipment leads to high maintenance costs. Too little preventive maintenance is risky and too much is uneconomical. Firms require some level of preventive maintenance for the smooth functioning of the production process and they have to take decisions on how much to spend on such activities. Product-based organizations and highly automated production units emphasize preventive maintenance and process-based organizations rely on remedial maintenance. Interruptions due to equipment maintenance can be reduced by emphasizing preventive maintenance, improving the capabilities of maintenance personnel through appropriate training, etc. Operations managers aim to reduce the total maintenance cost which is the sum of the preventive and remedial maintenance costs.

Activity: Val is the head of maintenance operations in a manufacturing company. Along with a small team of maintenance specialists, he carries out the maintenance of the machinery and equipment at the plant and at the headquarters. Val has a different method of carrying out maintenance activities. He never waits for the machinery or the equipment to break down. He continuously monitors the performance of the machinery or the equipment and checks whether there is a possibility of it breaking down in the future. Val and his team specialize in detecting problems while the equipment is still performing at a satisfactory level. What type of maintenance is Val and his team performing? Do you think this kind of maintenance is superior to preventive maintenance? Give reasons for your answer.

Answer:

30.7 Evaluation of Preventive Maintenance Policies

Organizations have to determine the exact level of preventive maintenance activities required that will minimize the cost of breakdowns and repairs and also the expenditure on preventive maintenance activities. They should also periodically check whether the level of preventive maintenance activities being carried out is acceptable. The following is the procedure used for the evaluation of preventive maintenance activities.

Let N be the number of identical machines in a production unit, C_p the average cost of preventive maintenance, C_R the cost of major remedial maintenance activities if the machine is run till it breaks down, and P_i the probability for the breakdown of the machine in the i^{th} period after undergoing maintenance.

Then, the Mean Time Between Failures (MTBF) is

$$MTBF = \sum_{i=1}^{n} iP_i ,$$

Where, n = maximum number of periods that a machine will go without failure

If the organization does not undertake any preventive maintenance activity, the expected total cost per period will be

$$T_{c\,(at\,PM=0)} = \frac{C_R N}{\sum iP_i}$$

To evaluate the level of preventive maintenance activities, let us begin with the calculation of the cost of routine preventive maintenance if machines are serviced periodically.

$TC(1) = C_p.N + C_R B_1,$

Where B_1 = number of machines that break down during the first period after service.

$TC(1) = C_p.N + C_R.NP_1,$

Where TC (1) is the total cost, if machines are serviced every period.

By extending this analysis to consider repairing machines every two periods, the number of machines expected to break down between servicing if the service is performed every two periods (B_2) is given as $B_2 = N(P_1 + P_2) + B_1 P_1$

Where B_1P_1 is the number of machines expected to be repaired during the first period and to break down in the second period. In the same way, for period t the number of machines that may break down is given by $B_t = N(P_1 + P_2 + P_3 + \ldots + P_t) + B_{t-1} P_1 + B_{t-2} P_2 + \ldots + B_1 P_{t-1}$

The total cost of t periods if machines are repaired every t periods is $TC(t) = C_p N + C_R B_t$

And the average total cost per period is TC (t)/ t

30.8 Modern Approaches to Preventive Maintenance

In a JIT manufacturing system, in-process inventories and production lot sizes are maintained at a lower level than in a traditional manufacturing system. Any breakdown in a machine creates a shortfall of inputs for all subsequent workstations and results in stoppage of the production process. Therefore, workers are made responsible for conducting preventive maintenance to prevent breakdowns. They have to go through a preventive maintenance checklist before beginning their shifts, inspect their machines thoroughly, and adjust the machine components in case any errors are detected. They must also closely monitor the performance of the machines while they are in operation to detect or predict irregularities, so that problems can be corrected before breakdowns occur. In case of major preventive maintenance, they should assist maintenance specialists in the process.

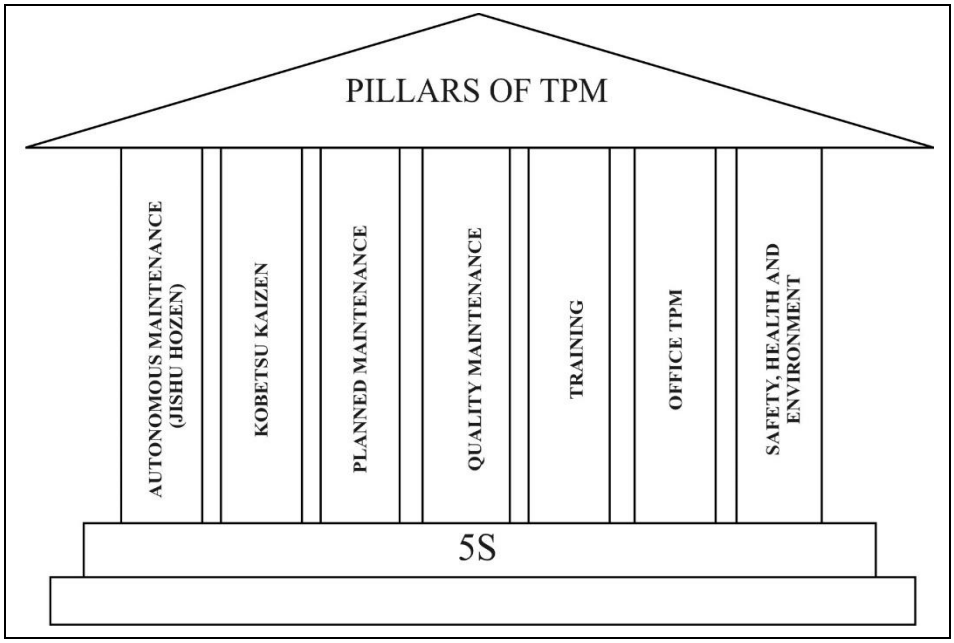
30.9 Recent Trends in Maintenance

Technological changes have resulted in changes in the type of production methodologies being adopted by organizations. Computer aided design, computer aided manufacturing systems, and robotics have resulted in the development of sophisticated electronic controls to monitor machine performance. These have changed the way organizations handle their maintenance activities. Workers are also given training for servicing and repairing sophisticated equipment. Maintenance activities are being subcontracted by companies to external agencies called original equipment manufacturers (OEMs). Computers are also being widely used in maintenance management programs for scheduling maintenance activities, developing maintenance cost reports, checking the status of inventory of spare parts, etc.

30.9.1 Total Productive Maintenance (TPM)

One of the main objectives of TPM is to increase the productivity of plant and equipment with a modest investment in maintenance. Total Quality management (TQM) and Total Productive Maintenance (TPM) are considered as the key operational activities of the quality management system. In order for TPM to be effective, the full support of the total workforce is required. This should result in accomplishing the goal of TPM: "Enhance the volume of the production, employee morale and job satisfaction." Following exhibit 30.3 depicts the pillars of TPM.

Exhibit 30.3: Pillars of TPM



Definition of Total Productive Maintenance: It is a system of maintaining and improving the integrity of production and quality systems through the machines, equipments, processes and employees that add business value to the organization. TPM focuses on keeping all equipment in top working condition to avoid breakdowns and delays in the manufacturing process.

Implementation of Total Productive Maintenance: Following are the steps involved by the implementation of TPM in an organization: Initial evaluation of TPM level, Introductory Education and Propaganda (IEP) for TPM, formation of TPM committee, development of master plan for TPM implementation, stage by stage training to the employees and stakeholders on all eight pillars of TPM, implementation preparation process, establishing the TPM policies and goals and development of a road map for TPM implementation. Another factor, that is crucial for the success of TPM, is the support of top management: "Lack of top management commitment, lack of middle management support and employee resistance to change, as well for the status-conscious and hierarchy-bound middle level executives lacking initiatives" are the main barriers against succeeding.

Objectives of Total Productive Maintenance: One of the main objectives of TPM is to increase the productivity of plant and equipment with a modest investment in maintenance. By investing in, for example, equipment maintenance, equipment losses can be prevented. There are six preventable losses:

1. Breakdown losses caused by the equipment
2. Set-up and adjustment losses
3. Minor stoppage losses

4. Speed losses
5. Quality defect and rework losses
6. Yield losses

Those losses could use further explanation. The first two losses affect the availability of a piece of equipment, the third and fourth losses affect equipment efficiency, and the fifth loss results in reduced quality from output.

Measuring effectiveness of Total Productive Maintenance: A tool for measuring and evaluating the effectiveness of TPM can be found in "Overall Equipment Effectiveness" (OEE). Measuring the effectiveness of TPM is a crucial activity in TPM, but also a very time consuming and costly process. The mathematical formula is:

OEE=Availability*Performance Rate*Total Yield Rate

The possible benefits -or costs- of TPM are tested by a statistical analyses. OEE is used as a parameter of TPM effectiveness.

Difference between TQM & TPM: Total Quality Management and Total Productive Maintenance are often used interchangeably. However, TQM and TPM share a lot of similarities, but are considered as two different approaches in the official literature. TQM attempts to increase the quality of goods, services and concomitant customer satisfaction by raising awareness of quality concerns across the organization. TQM is based on five cornerstones: The product, the process that allows the product to be produced, the organization that provides the proper environment needed for the process to work, the leadership that guides the organization, and commitment to excellence throughout the organization. In other words, TQM focuses on the quality of the product while TPM focuses on the equipment used, to produce the products. By preventing equipment break down, improving the quality of the equipment and by standardizing the equipment (resulting in less variety, so better quality), the quality of the products increases. TQM and TPM can both result in an increase of quality. However, the way of going there is different. TPM can be seen as a way to help achieve the goal of TQM.

Check Your Progress - 4

21. Which of the following statements **does not** hold correct regarding the economics of maintenance?
    a. Improper maintenance of equipment leads to high maintenance costs.
    b. Process-based organizations and highly automated production units emphasize preventive maintenance and product-based organizations rely on remedial maintenance.

c. Operations managers aim to reduce the total maintenance cost which is the sum of the preventive and remedial maintenance costs.

d. Interruptions due to equipment maintenance can be reduced by emphasizing preventive maintenance, improving the capabilities of maintenance personnel through appropriate training, etc.

22. What is the difference between a JIT manufacturing system and a traditional manufacturing system with respect to simple preventive maintenance?

i. Simple preventive maintenance is done by specialized maintenance staff

ii. Simple preventive maintenance is done by production workers

iii. Simple preventive maintenance is carried out at the beginning of every shift

iv. Shop floor workers should assist repair specialists in case of a major break-down

a. i and ii

b. i, ii, and iii

c. ii, iii, and iv

d. i, iii, and iv

Exercises

(Questions A to D)

A manufacturing plant has 25 machines of the same type. The probability of failure of a machine depending on time lapsed (in months) after the last maintenance is given in the following table. Answer the following **four** questions based on the given information.

Elapsed time after last maintenance (in months)	Probability of failure
1	0.04
2	0.04
3	0.05
4	0.05
5	0.06
6	0.06
7	0.10
8	0.10
9	0.10
10	0.10
11	0.15
12	0.15

i. What is the mean time between failures?

ii. Calculate the probable number of break-downs per year for a machine.

iii. What can be the probable number of break-downs per year for all machines in a plant?

iv. If the yearly cost of servicing a broken down machine is Rs.12000, what is the average cost of repairs per machine per occasion?

(Question E to G)

The probability of failure after maintenance for a machine is given in the table below. Answer the following **three** questions, based on the given information.

Months after maintenance	1	2	3	4	5
Probability of break-down	0.1	0.2	0.3	0.3	0.1

i. If there are 15 identical machines in the plant, what is the expected number of break-downs between maintenance, if the maintenance is performed every two months?

ii. What is the expected number of break-downs between maintenance, if the maintenance is performed every three months?

iii. If the average cost of preventive maintenance is Rs.650 and that of remedial maintenance per machine is 5500, calculate the average total cost of maintenance per month, if the maintenance is performed every 3 months. Assume the number of machines as 15.

30.10 Summary

- Facilities management is taken up by organizations to provide optimum working conditions that support the core operations and improve productivity.
- Facilities management function is either performed in-house or outsourced to external agencies who are specialists in the field. Organizations have to weigh all the possible costs and benefits of outsourcing before making the move.
- Maintenance management ensures that systems are working at their optimum efficiency.
- Poor or improper maintenance of the firm's machines or equipment affects the production capacity, production costs, quality of a product or a service, and the safety of the workers.
- The major areas of maintenance in an organization are mechanical maintenance, civil maintenance, and electrical maintenance.
- All the activities that keep the production facilities and the equipment in operating condition form a part of the maintenance operations.
- Organizations should determine the exact level of preventive maintenance activities required that will minimize the cost of breakdowns and repairs.

- Maintenance activities are being subcontracted by companies to external agencies called original equipment manufacturers (OEMs).
- Computers are also being widely used in maintenance management programs for scheduling the maintenance activities, developing maintenance cost reports, etc.

30.11 Glossary

Civil maintenance: It includes building construction and its maintenance, maintenance of service facilities, drainage systems, fire fighting equipment, security systems, and waste disposal.

Electrical maintenance: It involves maintenance of electrical and electronic equipment such as generators, motors, electrical installations, lighting, telephone systems, etc.

Facilities management: A field/profession, which integrates people, process and technology with the work environment to enable the organization to carryout its core business operations in the most efficient manner.

Irregular preventive maintenance activities: These tasks like repairs, overhauls, and cleaning of spills, which are carried out when the routine inspection of a machine reveals the need for servicing before the next periodic preventive maintenance.

Mechanical maintenance: It involves the maintenance of the firm's machines and equipment, such as boilers, furnaces, compressors, transport vehicles, etc.

Periodic maintenance activities: These are conducted at regular intervals on a weekly or monthly basis or on the basis of machine usage, like, after every 36 hours of operation.

Predictive maintenance: It is a set of irregular preventive maintenance activities, which detect probable future problems before they occur while the equipment is still performing at a satisfactory level. It involves continuous monitoring of the vital attributes of various systems.

Preventive maintenance: It aims at servicing the machines regularly so that the equipment functions satisfactorily under optimum load conditions without breakdown or reduction in efficiency.

Remedial maintenance (or breakdown maintenance or corrective maintenance): It is carried out when a machine or equipment breaks down or is malfunctioning. These activities are reactive as they are performed only after a breakdown has occurred, when equipment malfunctions or operates at a lower speed than desired, produces products of inferior quality.

30.12 Self-Assessment Exercises

1. What is facilities management? Why is it necessary for organizations to focus on facilities management? Discuss the various services that come under facilities management.

2. Many organizations today are showing increasing interest in outsourcing their facilities management function to external agencies. Explain the reasons for this development. Also explain the pros and cons associated with outsourcing the facilities management function.
3. Maintenance management helps in curtailing the effects of factors like wear and tear, aging, misuse in machines and in extending the operational life of the equipment. What is maintenance management? Explain the necessity for maintenance management.
4. Maintenance activities include all the activities that keep the production facilities and the equipment in operating condition. What are the different types of maintenance activities in an organization?
5. Organizations should periodically check whether the level of preventive maintenance activities being carried out is acceptable or not. Explain the method of evaluation of the preventive maintenance policies. Describe briefly the transformations taking place in preventive maintenance.

30.13 Suggested Readings/Reference Material

1. The Facility Management Handbook ebook by Kathy Roper - Rakuten Kobo, Forth Edition, 2017
2. ITIL IT Facilities Management | ITIL Service Operation | ITSM, Last updated on January 22, 2018 by Ayan Brahmachary, https://www.certguidance.com/
3. Dan Lowry, The Complete Guide to Facility Management, Goodreads, August,2017
4. Madhavan KS, Muthukumaran, M, Total Productive Maintenance – TPM, Revised edition, January 2019
5. Prometheus Group, 5 Transformational Trends Reshaping Industrial Maintenance, Prometheus Group University, 25 July, 2019

30.14 Answers to Check Your Progress Questions

Following are the answers to the Check Your Progress Questions given in the Unit.

1. (b) Facilities management

The primary objective of facilities management is to provide a clean and conducive work environment and enable efficient and effective progress of the core functions of an organization, be it manufacturing, distribution or research. Maintenance management is a primary function associated with facilities management.

2. (d) Increases operational costs

Advantages of outsourcing include increase in quality of work and flexibility of operations, reduced operation costs and more focus on core competencies.

3. (d) i, ii, iii, and iv

The common functions of a facilities manager are: (a) conduct and participate in planning activities; (b) recruit the right people to perform facilities management jobs; (c) measure the work performance of the facilities management teams; (d) review the current techniques so as to reduce cost of operations; and (e) develop and maintain a controlling center as a support to facilities management department.

4. (b) Facilities management

Facilities management can be defined as a field/profession, which integrates people, process and technology with the work environment to enable the organization carryout its core business operations in the most efficient manner. The primary objective of facilities management is to provide a clean and conducive work environment and enable efficient and effective progress of the core functions of an organization.

5. (d) i, ii, iii, and iv

The primary objective of facilities management is to provide a clean and conducive work environment and enable efficient and effective progress of the core functions of an organization. Some of the activities under the purview of facilities management include housekeeping & janitorial services, operations and maintenance services, office administration, reprographics & mail services, landscaping and horticulture, pest and rodent control, waste management, energy conservation and management, and communication networks.

6. (d) i, ii, iii, and iv

Through proper maintenance, organizations can retain the productivity of their equipment, increase the operational life of the equipment, reduce the number of breakdowns, minimize losses and maintain safe working conditions by reducing the probability of accidents.

7. (d) Maintenance management

Maintenance helps in developing a reliable and high quality production system. Maintenance management helps in curtailing the effects of factors like wear and tear, aging, and misuse in machines and in extending the operational life of the equipment. It helps in developing a reliable and high quality production system.

8. (a) Minimizing the availability of the firm's assets for production purposes

One of the goals of maintenance management is to maximize (not minimize) the availability of the firm's assets for production.

9. (b) Civil maintenance

Civil maintenance includes building construction and maintenance, maintenance of service facilities like water filters, air conditioning, plumbing, etc. Other activities include maintaining drainage systems, fire fighting equipment, security systems, waste disposal, etc.

10. (c) Electrician

As the 5hp motor is an electrical component, it has to be maintained and serviced by a qualified electrician.

11. (c) i/r, ii/p, iii/s, iv/q

A plumber maintains water supply pipes, an electrician takes care of lighting equipment, housekeepers are responsible for cleanliness of buildings and instrumentation personnel maintain and service routers.

12. (c) i, ii, iii

Mr. Kumar can help improve productivity, increase the life of assets and machinery, preserve equipment value and maximize the salvage value of machinery.

13. (a) Improving efficiency of raw materials purchase

Improving the efficiency of raw materials purchase in an organization is not associated with maintenance management. It is more related to materials management.

14. (d) Regular monitoring of vital parameters of a machine

Predictive maintenance is concerned with inspecting vital signs of the machine regularly to identify the health of the system. Some objectives of remedial maintenance are to minimize production losses by getting the equipment back into working condition as quickly as possible, to minimize investments in spare parts and standby machines used when equipment is under repair, and to perform appropriate maintenance based on the extent of problem.

15. (c) Reducing machine vibration

Reduction of machine vibrations does not come under irregular preventive maintenance. It is a form of remedial maintenance.

16. (c) Preventive maintenance involves regular servicing of equipment while predictive maintenance involves monitoring of equipment continuously

The objective of preventive maintenance is to service machines regularly so that equipment functions satisfactorily under optimum load conditions without breakdown or reduction in efficiency. Predictive maintenance involves identification of possible problems before they occur. Options a & b are similar for both types of maintenance operations.

17. (a) i, iii, iv

Any abnormal vibration in equipment indicates that it is not functioning properly in terms of precision cutting. Quality and productivity can come down drastically. The vibration also indicates that the equipment needs maintenance.

18. (a) Preventive maintenance

Periodic maintenance and irregular preventive maintenance fall under preventive maintenance. Periodic maintenance activities are conducted at regular intervals, i.e. weekly, monthly etc.

19. (b) Predictive maintenance

Predictive maintenance is taken up when problems or indications of problems are detected in machinery and equipment. Problems do not mean that the equipment is not functioning properly. But it indicates that such problems or indications can cause breakdown of machinery in future if they are neglected.

20. (a) Remedial maintenance is taken up when machinery breaks down

Remedial maintenance is performed only when there is breakdown or failure of machinery. So, it is reactive in nature. Preventive and predictive maintenance are proactive in nature.

21. (b) Process-based organizations and highly automated production units emphasize preventive maintenance and product-based organizations rely on remedial maintenance.

Improper maintenance of equipment leads to high maintenance costs. Product-based organizations and highly automated production units emphasize preventive maintenance and process-based organizations rely on remedial maintenance.

22. (c) ii, iii and iv

Breakdown in a manufacturing plant adopting JIT system can create a shortage of inputs for all workstations and can hamper the productivity seriously. Hence, production workers are required to do simple preventive maintenance at the beginning of every shift. And in case of major preventive maintenance, they should assist maintenance specialists in the process.

Project & Operations Management

Course Components

BLOCK I	**Project Management – An Overview**
Unit 1	Introduction to Project Management
Unit 2	Project Idea Generation and Screening
Unit 3	Market and Technical Analysis of Projects
Unit 4	Financial Analysis of Projects
Unit 5	Project Selection
BLOCK II	**Project Planning and Control**
Unit 6	Management of Project Scope
Unit 7	Identifying Project Activities
Unit 8	Activities: Sequencing, Estimating Duration, and Scheduling
Unit 9	Project Review
Unit 10	Project Control
BLOCK III	**Project Implementation and Closing**
Unit 11	Project Cost Management
Unit 12	Project Risk Management
Unit 13	Project Quality Management
Unit 14	Project Auditing
Unit 15	Project Closing
BLOCK IV	**Introduction to Operations Management**
Unit 16	Operations Management and Operations Strategy
Unit 17	Forecasting Demand
Unit 18	Allocating Resources to Strategic Alternatives
Unit 19	Design of Production Processes
BLOCK V	**Design of Facilities and Operations Planning**
Unit 20	Facility Location and Layout
Unit 21	Aggregate Planning and Capacity Planning
Unit 22	Fundamentals of Inventory Control
Unit 23	Purchase Management
Unit 24	Materials Management
BLOCK VI	**Operations Control**
Unit 25	Operations Scheduling
Unit 26	Enterprise Resource Planning
Unit 27	Supply Chain Management
Unit 28	Just-In-Time (JIT) Manufacturing System
Unit 29	Productivity and Quality Management
Unit 30	Facilities and Maintenance Management
BLOCK VII	**Current Trends in Operations Management**
Unit 31	Trends in Operations Technology
Unit 32	Globalization and Operations Management
Unit 33	Sustainability and Operations Management