Block-V

Project & Operations Management

Design of Facilities and Operations Planning

Block

V

DESIGN OF FACILITIES AND OPERATIONS PLANNING

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BLOCK V: DESIGN OF FACILITIES AND OPERATIONS PLANNING

The fifth block of the course on Project & Operations Management deals with the design of facilities and operations planning. The block contains five units. The first unit explains the importance of facility location and layout. The second unit focuses on the concepts of aggregate planning and capacity planning. The third unit examines the basics of inventory control. The fourth unit examines the purchase management function, while the fifth unit discusses the materials management function.

The first unit, *Facility Location and Layout*, discusses the importance of location and the factors affecting the location decisions. The unit focuses on the general steps in location selection, decision process, and the evaluation methods. The unit also deals with facility layout, the basic layout formats, and how to develop a process layout, a product layout, and a cellular manufacturing layout. The unit also provides an idea of the Japanese approaches and trends in manufacturing layouts, and the service facility layouts.

The second unit, *Aggregate Planning and Capacity Planning*, deals with planning activities and the aggregate planning process. The unit also explains the strategies for developing aggregate plans, and the aggregate planning techniques. It discusses the master production schedule, and the implementation of aggregate plans and master schedules. Finally, the unit examines the concept of capacity planning.

The third unit, *Fundamentals of Inventory Control*, provides an idea about the purpose of inventories and the need for controlling them. The unit explains inventory costs and systems. It discusses the economic order quantity model. It also examines the inventory classification models.

The fourth unit, *Purchase Management*, explains the importance of purchasing, and the ways to organize to purchasing function. The unit discusses the responsibilities of a purchase manager, and the purchasing process. It deals with the duties of buyers, and make-or-buy analysis. The unit also examines the ethical issues involved in buying.

The fifth unit, *Materials Management*, discusses the necessity of materials management. The unit explains the functions of materials management. It discusses the materials management technology. The unit also examines the various techniques used in materials management.

Unit 20

Facility Location and Layout

Structure

20.1 Introduction

In the last unit of the previous block, we have discussed how to design production processes. We have learnt that designing the production processes plays an important part in the structure of operations. In this unit, we will discuss about facility location and layout.

Facility location refers to the place where the firms set up their operations. Manufacturing and service firms evaluate different plant and service locations by conducting a facility location analysis and finally choose an optimum location to start their operations. After deciding on the facility location, firms decide on the internal structure of the firm called the layout. Both facility location and layout play an important role in enhancing the efficiency of the firm. Firms can then revise or redesign the layout in the future depending on its strategies (expansion, etc.). In this unit, we will discuss the role played by facility location and layout in improving the material flow and the overall efficiency of firms.

This unit will introduce you to the importance of location, and explain the factors affecting the location decisions. We will discuss the general steps in location selection, decision process, and the evaluation methods. We shall then move on to discuss facility layout, the basic layout formats, and how to develop a process layout, a product layout, and a cellular manufacturing layout. Finally, we would discuss the Japanese approaches and trends in manufacturing layouts, and the service facility layouts.

20.2 Objectives

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

- Explain the importance of location.
- Identify the factors affecting location decisions.
- Recall the general steps in location selection and the location decision process.
- Define the location evaluation methods.
- Discuss facility layout and the basic layout formats.
- Determine how to develop process and produce layouts.
- Explain the process of developing a cellular manufacturing layout.
- Compare the Japanese approaches and trends in manufacturing layouts.
- Discuss service facility layouts.

20.3 Importance of Location

The selection of a facility location is a strategic decision for any organization and is very important for the following reasons. Facility location will fix the production technology and cost structure, it depends on the size and nature of the business, it affects the company's ability to serve its customers quickly and conveniently. If the facility location is such that it reduces transportation costs of raw materials and goods, lowers labor costs, and has good access to the markets, it helps the firm to score over its competitors. Therefore, facility locations require careful attention of finance, personnel, marketing and operations managers who run the facilities.

20.4 Factors Affecting the Location Decisions

Location decisions are influenced by a number of factors given below:

- *Market Proximity* – Transportation costs can be reduced by locating facilities close to the market, this also helps in providing better service to customers.
- *Integration with other Parts of the Organization* – Organizations that already have plants would want their new facility to be located near the existing ones so that the work can be integrated with other plants.
- *Availability of Labor and Skills* – Firms should locate their operations where labor and skills are more easily available.

- *Site Cost* – The cost of the site should match the benefits that it is going to provide.
- *Availability of Amenities* – Firms generally prefer locations with good external amenities like housing, shops, community services, communications systems, etc.
- *Availability of Transportation Facilities* – Firms prefer locations where they have good modes of transportation — air, rail, road, water.
- *Availability of Inputs* – Apart from good transportation, firms can reduce costs by locating their plant near that of the suppliers.
- *Availability of Services* – While selecting a location, firms should consider availability of services like electricity, water, gas, drainage, and waste disposal.
- *Suitability of Land and Climate* – Firms should consider the climatic conditions such as humidity, temperature, atmosphere, and geology of the location for setting up the facility.
- *Regional Regulations* – Firms should ensure that the proposed location adheres to the local laws and regulations.
- *Room for Expansion* – Firms should ensure that the selected location has enough area for future expansion of the firm's operations.
- *Safety Requirements* – Firms should ensure that units like nuclear power stations and explosive factories are located in remote areas to minimize any damage they may cause.
- *Political, Cultural, and Economic Situation* – Firms should be aware of the political, cultural, and economic environment in the location.
- *Regional Taxes, Special Grants and Import/Export Barriers* – Firms can enjoy the benefits of special grants like tax holidays, infrastructure support, low-interest loans, etc. given by the government for establishing facilities in special export zones, export promotion zones, technology parks, and industrial estates. In addition, companies are provided land at low costs. The land provided is not prime real estate as SEZs are located away from cities or towns.

Activity: Krushi International is a US-based firm set up by an NRI citizen. The company is engaged in manufacturing hardware devices and developing software. The company's management wants to set up a plant in Tamil Nadu in India. The company has sent a team to study the feasibility of setting up the plant in the state. The team has come up with suggestions on a number of locations within the state for setting up the plant. What do you think are the factors to be considered before setting up a plant? Help the management to arrive at a proper decision.

Answer:

Check Your Progress - 1

1. Which of the following reasons persuade companies to set up facilities in export promotion zones, technology parks and industrial estates?

   i. Tax holidays and exemption from import-export barriers

   ii. Availability of infrastructure

   iii. Low loan interest rates

   iv. Low cost of manpower

   a. i and iv

   b. ii, iii, iv

   c. i, ii, iii

   d. ii and iv

2. Cotton yarn manufacturing units are generally concentrated in select areas of the country as yarn production requires certain ideal levels of humidity. What factor influences selection of plant location in this case?

   a. Site cost

   b. Conducive politico-economic situation

   c. Suitability of climate

   d. Availability of amenities

3. In which of the following situations is there **no** need for selecting a facility location?

   a. When a business has just started

   b. When expansion of the existing plant is possible

   c. When a business wants to establish new branches/plants

   d. When government regulations mandate that the business has to shift its location

4. Firms conduct facility location analysis where they evaluate different locations and finally choose an optimum location to start operations. Arrange the following activities related to facility location planning in a logical sequence.

   i. Design layout

   ii. Select location

   iii. Search for a location

   iv. Revise layout

   a. i, ii, iii, iv

   b. ii, iii, i, iv

   c. iii, ii, i, iv

   d. iv, iii, ii, i

5. Rahul wanted to set up a small scale printing press to print books for individuals interested in publishing their work for a small audience. Which is the right location for Rahul to establish a printing press to cater to this kind of market?
   a. Near paper mills
   b. In a town/city
   c. In a village where cost of labor is cheap
   d. Near the manufacturer of printing machines
6. There are many factors affecting the selection of a facility location. Which of the following factors would deter a firm from setting up operations in a particular location?
   a. Low labor costs
   b. High transportation costs
   c. Availability of public utility services
   d. Benefit of tax holidays
7. The basic raw material for a cement manufacturing unit is limestone and the major consumers are the government, real estate and individual consumers. Which is the best possible location to build a cement plant?
   a. Close to sea port
   b. Close to cities where consumption is high
   c. Close to the raw material source
   d. Within special economic zones or export processing zones
8. Many auto-ancillary units have set up facilities close to facilities of auto majors like Hyundai and Ford near Chennai. Which of the following factors would have primarily led to this decision?
   a. Site cost
   b. Proximity to markets
   c. Need for safety requirements
   d. Availability of services like electricity, drainage, and waste disposal
9. Which of the following is **not** considered a benefit derived by companies setting up operations in special export zones (SEZ)?
   a. Good infrastructure support
   b. Tax holidays
   c. Low interest loans
   d. Availability of prime real estate

20.5 General Steps in Location Selection and Decision Process

There are a number of factors that affect location decisions. The following are the steps involved in the location decision process:

- *Define the location objectives and associated constraints* – These are defined on the basis of requirements of the promoters, owners, employees, suppliers, and customers of the firm.

- *Identify the Relevant Decision Criteria* – The criteria should include economic factors like labor and material costs, and non-economic factors like impact of the plant on the surrounding environment.
- *Relate the Objectives to the Criteria Using Appropriate Models* – The decision criteria should be evaluated by using models like break-even analysis, linear programming, and qualitative factor analysis.
- *Do Field Research to Relevant Data and Use the Models to Evaluate the Alternative Locations* – Primary and secondary data should be collected to evaluate the alternative locations using the given decision criteria.
- *Select the Location that Best Satisfies the Criteria* – The location that meets the desired objectives, satisfies the criteria and provides benefits to the society should be selected.

20.6 Location Evaluation Methods

Certain factors should be considered before a location is selected. Each possible decision has advantages as well as disadvantages. The company should select a location that suits the products it offers, the location of its customers and materials, and other criteria that are specific to the company. Several models and techniques are available that help managers take appropriate location decisions.

20.6.1 Cost-Profit-Volume or Break-Even Analysis

- Break-even analysis is a graphical and algebraic representation of the relationships among volume of output, costs, and revenues. In this method, economic comparison is performed between the location alternatives.
- Costs are of two types: fixed costs and variable costs. Fixed costs are those which do not vary with the volume of output. Examples are administration expenses, rents of buildings, lighting, etc. Variable costs are costs which vary with the volume of output. Raw material cost, labor cost, etc. are variable costs.
- The sum of the fixed and variable costs at a specific volume of output would be the total cost at that volume of output.
- Break-even analysis is one of the tools used for selection of a location. As each and every location will have a different cost structure, and sales volume, break-even analysis helps managers to identify the location where profits are high.

The three steps to perform the cost-profit-volume analysis are:

1. Determine the variable cost and fixed cost for each location.
2. Plot the cost of each location where the vertical axis represents the cost and the horizontal axis represents the annual volume.
3. Select the location that has the minimum cost for the expected production volume.

Example: A company wants to expand the capacity of manufacturing facility. The top management chooses three different locations such as A, B, and C for the new manufacturing facility. The goal of the top management is to select an economical location among these three locations where the expected production volume is 2000 units. To find the economic location, they apply cost-profit-volume approach. They find that the fixed cost of these three locations are $30,000, $60,000 and $110,000 respectively, whereas the variable costs are $75, $45, and $25 per unit respectively. The expected selling price for each of the locations is $120.

- Total cost at location A is: $30,000 + $75(2000) = $180,000
- Total Cost at location B is: $ 60,000 + $45(2000) = $150,000
- Total Cost at location C is: $110,000 + $ 25 (2000) = $160,000
- With the expected production volume of 2000 units, location B is considered as the minimum cost location. Thus, the expected profit is = Revenue – total cost = $120(2000) - $150,000 = $90,000 per year. If we plot the total cost vs volume, we can see there is a crossover between total cost of location A and B.
- Thus, $30,000 + $ 75 (x) = $60,000 + $ 45 (x). Solving this equation, we get x = 1000. Similarly, if we can observe another crossover between the total cost of location B and C. Thus, $ 60,000 + $ 45 (x) = $110,000 + $ 25 (x). Solving this equation, we get x = 2500. From this analysis, if the expected volume of less than 1000, then A would be preferable option and if the expected volume is more than 2500, then C is the most preferable option.

Example: Krishna Electricals Ltd. wanted to set up its new plant for manufacturing heaters and the management identified that Hyderabad, Tirupathi, and Vijayawada as potential areas for setting up the plant. The fixed costs per year and the variable costs per unit at each of the three locations are given below.

Location	Fixed cost /Yr	Variable Cost / Unit
Hyderabad	Rs. 3,00,000	425
Tirupathi	Rs. 3,50,000	385
Vijayawada	Rs. 4,00,000	365

The product is expected to be sold at Rs.1200 and the existing demand for heaters in the market is 800 units per year. Calculate the likely profit at each of the locations and determine the location that is the most profitable for the company.

Solution: Let us calculate the total costs (sum of the fixed and variable costs) at each of the three locations when 800 units of goods are sold.

Total cost at Hyderabad = Rs. 300,000 + (425 × 800) = Rs. 640,000

Total cost at Tirupathi = Rs. 350,000 + (385 × 800) = Rs. 658,000

Total cost at Vijayawada = Rs. 400,000 + (365 × 800) = Rs. 692,000

Total revenue of the firm = 1200 × 800 = Rs. 960,000.

Therefore, the profits of the company if they were set up in the given locations would be as follows:

Profit at Hyderabad = Rs. 960,000 – Rs. 640,000 = Rs. 320,000

Profit at Tirupathi = Rs. 960,000 – Rs. 658,000 = Rs. 302,000

Profit at Vijayawada = Rs. 960,000 – Rs. 692,000 = Rs. 268,000

From these calculations it is clear that Hyderabad is the most profitable location to set up the new plant for producing 800 units per year.

Activity: Shruti Refrigerators Ltd. wanted to set up its new plant for manufacturing cold freezers. The management identified that Vijayawada, Cuddapah, and Tirupathi were the potential areas for setting up the plant. The fixed costs per year and the variable costs per unit at each of the three locations are given.

Location	Fixed Cost /Yr	Variable Cost / Unit
Vijayawada	Rs. 4,00,000	625
Cuddapah	Rs. 4,50,000	585
Tirupathi	Rs. 5,00,000	565

The product is expected to be sold at Rs.5000 and the existing demand for cold freezers in the market is 200 units per year. Calculate the likely profit at each of the locations and determine the location that is the most profitable for the company.

Answer:

20.6.2 Point Rating Method or Factor Rating Method

Companies select a site or location based on various objectives which are given certain levels of importance. Weights are attached to these objectives in the form of points. Potential sites are evaluated based on every factor and points are allocated accordingly to each factor. A superior site is the one which adds up to more points.

The disadvantage with this method is that a factor giving a high score would triumph over a factor with a low score. In this method, tangible cost factors are given more importance than intangible cost factors. Points are assigned only to the intangible factors.

However, an evaluation is done to know whether the difference between the intangible factors is worth between tangible factors of the competing locations. For example, A & B are two potential sites being evaluated on the basis of cost. The manufacturer evaluated the sites considering the intangible factors using the point rating method. The following table shows that location A is a more site with more potential than location B.

The factor rating method has six steps:

1. Develop a list of relevant factors (known as key success factors)
2. Assign weight to each factor based on their importance (according to the company's objective).
3. Develop a scale such as 1-10 or 1-100 for each factor.
4. Score each location for each factor based on the scale develop in step 3.
5. Multiply the score by the weights of each factor and then take the summation of weighted score for each location.
6. Select the location which has the maximum weighted score.

For example, a company tries to open an amusement park in either location A or location B. For that, the company identifies few relevant factors and based on the factors, the company is trying to identify the best location for the amusement park (Ex 20.1)

Example 20.1

Factors rated	**Weights**	**Points assigned to (Out of 100)**	
		Location A	**Location B**
Labor availability and attitude	0.25	70	60
People to car ratio	0.05	50	60
Per capita income	0.10	85	80
Tax Structure	0.39	75	70
Education and Health	0.21	60	70
Weighted score		**70.35**	**68.00**

Based on the calculation, we can recommend that location A is most suitable for the amusement park.

Example 20.2

Points Assigned to Alternative Locations			
Factors rated	**Maximum Possible Points**	**Points assigned to**	
		Location A	**Location B**
Availability of fuel in future	700	500	600
Availability of labor	600	540	500
Water supply	300	260	240
Transportation facility	400	350	250
Topography of the site	200	180	190
Living conditions	500	400	410
Total	**2700**	**2230**	**2190**

20.6.3 The Transportation Method of Linear Programming

For a single source of supply, the cost of supply is calculated by adding the production cost at the supply point and the shipping cost from that point to the potential location. However, it becomes difficult to calculate the cost of supply if there is a network of several supply chains supplying to a potential location. In this case, the total cost of supplying to one location should be compared to that of another location. Such a comparison can be made by evaluating the best match of capacity and demand for each potential location and comparing the costs and profits. The transportation method attempts at matching the capacity and demand of a firm and thereby minimizing the total transportation costs of the firm. The plant will be set up at a location which incurs the least total transportation cost.

20.6.4 Center of Gravity Method

The center of gravity method aims at minimizing the total shipping cost, i.e. cost incurred for shipping from the distribution center to the different shipping points. Factors like proximity to markets, cost of goods, transportation costs affect the optimal location of the distribution center.

If the quantities that are to be shipped to the different destinations are equal, the location at which the transportation cost will be minimum can be identified by taking the arithmetic averages of the X and Y coordinates of the destination. If the quantities are not equal, then weighted arithmetic means have to be calculated where the quantities to be shipped act as the weights. The formulae for calculating the coordinates of the optimal location (in case of different quantities being shipped to destination points) are as given under.

$$X_c = \frac{\sum(X_i V_i)}{\sum V_i} \qquad Y_c = \frac{\sum(Y_i V_i)}{\sum V_i}$$

Example 1: Discount departmental store has four different store location in A, B, C, and D. They are currently being supplied out of an inadequate warehouse at location B. The store wants to find some central location in which they can build a new warehouse. The coordinates of these 4 locations are (30,120); (90, 110); (130,130); and (60, 40) respectively. The number of quantities shipped from these locations are 2000, 1000, 1000, and 2000 respectively. Based on center of gravity method,

$$X = \frac{(30 * 2000) + (90 * 1000) + (130 * 1000) + (60 * 2000)}{(2000 + 1000 + 1000 + 2000)} = 66.7$$

And,

$$Y = \frac{(120 * 2000) + (110 * 1000) + (130 * 1000) + (40 * 2000)}{(2000 + 1000 + 1000 + 2000)} = 93.3$$

The result shows that the company can build the new distribution center at location (66.7, 93.3). So that, the distribution cost can be minimized.

Example: The X and Y coordinates of five destination points are given in the table below along with the quantities to be shipped to each point. Use this information to calculate the coordinates of the optimal location for the distribution center such that the total transportation cost is minimum.

Destination Point	X	Y	Volume (in thousand)
A	4	8	80
B	5	12	100
C	3	9	120
D	11	2	130
E	14	6	100

Solution: This is case where quantities shipped to destination points are unequal. Hence weighted arithmetic means have to be calculated where the respective volumes would be used as weights. Hence, the coordinates of each destination point have to be multiplied with the respective volumes. This is as shown in the table below:

Destination Point	X_i	Y_i	Volume (V_i)	V_iX_i	V_iY_i
A	4	8	80	320	640
B	5	12	100	500	1200
C	3	9	120	360	1080
D	11	2	130	1430	260
E	14	6	100	1400	600
			$\sum V_i = 530$	$\Sigma V_iX_i = 4010$	$\Sigma V_iY_i = 3780$

Now the coordinates of the distribution center can be calculated using this data.

X coordinate of distribution center = 4010/530 = 7.57

Y coordinate of distribution center = 3780/530 = 7.13

Hence the coordinates of the optimal location of the distribution center are 7.57/ 7.13)

20.6.5 Analytical Delphi Method

Analytical Delphi method is useful in decisions involving multiple locations with different objectives. This method involves the need of three panels – forecasting panel, strategic panel, and coordinating panel. The function of forecasting panel is to forecast the future trends, in the physical and social environment, that have an impact on the organization. Strategic panel helps develop long-term goals and objectives for the organization, and the coordination panel oversees and manages the entire process.

After formation of the panels, the coordination panel carries out two inquiries with forecasting panel and strategic panel through questionnaires. In the first Delphi inquiry, information on future trends is elicited from the forecasting panel and is given to the strategic panel. In the second Delphi inquiry, the strategic panel uses this information to determine the goals, objectives and future directions of the organization. Various alternatives are developed based on these goals by the strategic panel. The best alternatives among them are selected through group consensus.

Models for Facility Location and Capacity Allocation

The vice president of pharmaceutical firm is considering several options to meet demand. One possibility is to setup facility in each region. This approach will help to minimize the transportation cost. The disadvantage of this approach is that the capacities of manufacturing plants are equivalent to the size of the corresponding market demand where economies of scale may be violated. The alternative approach is to set up manufacturing plant in few areas where they can achieve the economies of scale but transportation cost will increase. The vice president decides to view the overall demand in terms of five domains or regions- A, B, C, D, and E. Annual demand and variable production, inventory, and transportation cost of producing in one region to meet the demand of each individual region are given below.

	Demand Region					Fixed Cost	Low Capacity	Fixed Cost	High Capacity
	Production and transportation per 1 Million units								
Supply	A	B	C	D	E				
A	80	95	100	129	115	6000	10	8500	20
B	120	80	105	95	100	4000	10	6750	20
C	102	104	95	120	110	6500	10	9000	20
D	114	120	95	60	72	4000	10	6200	20
E	140	95	108	105	70	4100	10	6000	20

The capacitated plant location model:

n = number of potential plant locations/Capacity.

m = number of markets or demand points

D_j = Annual demand from market j

K_j = capacity of plant i

F_i = Annual fixed cost from plant i

C_{ij} = cost of production and shipment from source i to destination j

The goal is to minimize the total cost. In this model, we introduce a new variable which is defined as:

$$\begin{cases} y_i = 1, & if\ the\ ith\ plant\ is\ open \\ y_i = 0, & if\ the\ ith\ plant\ is\ closed \end{cases}$$

And $X_{ij} = amount\ of\ quantity\ shipped\ from\ source\ i\ to\ rejion\ j$

With the help of the above information, the objective function of this model is defined as

$$\min Z = \sum_{i=1}^{n} F_i y_i + \sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij} X_{ij}$$

Subject to,

$$\sum_{i=1}^{n} X_{ij} = D_j\ , \forall\ j = 1,2, \dots m$$

$$\sum_{i=1}^{n} X_{ij} \leq K_i y_i,\ \ \forall\ i = 1,2, \dots, n$$

The first constraint represents the demand fulfillment in each region, whereas the second constraint represents each manufacturing plant is either open or closed. For the solution we may use EXCEL solver.

Check Your Progress - 2

10. Which of the following is **not** a location evaluation method?
    a. Point rating method
    b. Center of gravity method
    c. Analytical Delphi method
    d. Historical analogy method
11. Which of the following techniques is **not** associated with taking suitable location decisions?
    a. Cost-profit-volume analysis
    b. Factor analysis
    c. Linear programming
    d. CRAFT analysis

12. Companies can follow certain guidelines when trying to analyze possible locations and identify an optimal one since it is expensive and time-consuming. What is the correct sequence of guidelines a company can follow when evaluating locations?
    a. Define location objectives – relate objectives to criteria – Identify relevant decision criteria – evaluate alternative locations – select the best location
    b. Identify relevant decision criteria – define location objectives – relate objectives to criteria – evaluate alternative locations – select the best location
    c. Define location objectives – identify relevant decision criteria – relate objectives to the criteria – evaluate alternative locations – select the best location
    d. Define location objectives – identify relevant decision criteria – evaluate alternative locations – relate objectives to criteria – select the best location
13. Though there is no standard procedure, certain guidelines can be used for making a location decision. The first guideline is to define location objectives. Whose views and requirements are not considered when defining them?
    a. Owners and promoters
    b. Employees
    c. Customers
    d. Competitors
14. Analytic Delphi Method helps managers take complex multi-location decisions. Give the correct sequence of steps to be taken as part of such location decisions.
    a. Form panels - Identify trends and opportunities - Determine directions and strategic goals of the organization - Develop alternatives - Prioritize alternatives
    b. Identify trends and opportunities - Determine directions and strategic goals of the organization - Form panels - Develop alternatives - Prioritize alternatives
    c. Identify trends and opportunities - Form panels - Determine directions and strategic goals of organization - Prioritize alternatives - Develop alternatives
    d. Form panels - Determine directions and strategic goals of the organization - Prioritize alternatives - Develop alternatives - Identify trends and opportunities

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Exercises

(Questions A to C)

The table below gives details about fixed costs and variable costs for three different locations. Answer the following **three** questions using information given in the table.

Location	Fixed cost /Yr	Variable cost / Unit
Chandigarh	Rs. 4,00,000	300
Gurgaon	Rs. 4,50,000	285
Delhi	Rs. 5,00,000	275

A. Which of the locations would have the highest total cost per year if annual output of a firm located there is 1000 units?

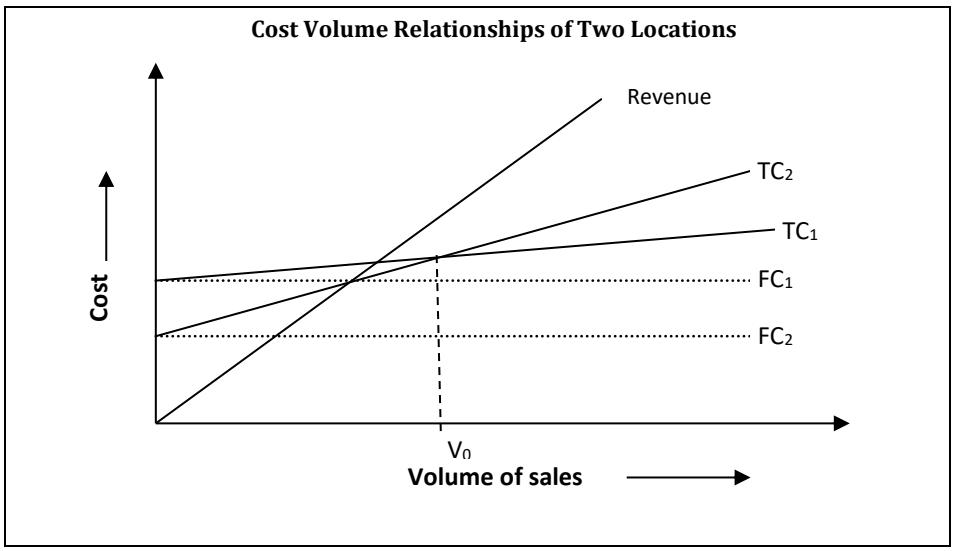
B. Which of the locations would have the highest annual profit if the annual production is 1000 units and selling price per unit is Rs.1000?

C. Which plant location would you select if you were the authority to make the final decision?

D. The following table gives the volume of quantities to be shipped to four markets. The X and Y coordinate values of the location that would help minimize transportation costs are also given. Use the center of gravity method to find out coordinates for the optimal location to set up a warehouse to service the four markets with minimal transportation costs.

Distribution Center	X	Y	VOLUME ('000)
A	4	4	60
B	12	6	90
C	10	14	110
D	5	13	100

20.7 Facility Layout



Layout includes the initial layout of machines and other facilities. It also contains improvements or revisions in the existing layout if there is any development in the methods of production. The physical disposition of the facilities of a plant is referred to as the plant layout. A plant layout is a floor plan to determine and arrange the machinery and equipment in the manner that best allows the quick flow of material at minimal cost and the least handling process from the stage of receipt of raw material to the shipment of finished products. It provides a smooth work flow of material through the factory, or a comfortable traffic pattern for both customers and workers in the organization. Like location decisions, layout decisions have long-term consequences in terms of cost and the company's ability to serve its customers. While designing a layout, an organization should identify the objectives of its strategy that have to be supported by the layout and many other factors that affect and are affected by the layout.

20.7.1 Criteria for a Good Layout

Layout can be designed by using work study methods and industrial engineering techniques. For a good layout, some of the criteria that have to be satisfied are:

- *Maximum Flexibility* – A good layout is one which can be modified to suit the changing environment.
- *Maximum Coordination* – The departments and the functions should be arranged in a manner which facilitates proper coordination.
- *Maximum Visibility* – The layout should have no hiding places lest goods can get misled.
- *Maximum Accessibility* – The servicing and maintenance points should be readily accessible.
- *Minimum Distance* – All the movements should be direct and unnecessary and circuitous movements should be avoided.
- *Minimum Handling* – Handling of material and information should be minimized.
- *Minimum Discomfort* – Excessive sunlight, heat, noise, vibrations should be avoided.
- *Inherent Safety* – Safety should be given prime importance in each and every layout.
- *Efficient Process Flow* – Material or information should flow in only one direction.
- *Identification* – A proper work space should be provided to the workers.

20.8 Basic Layout Formats

Layouts are differentiated by the type of work flow they require. The types of layout are:

20.8.1 Process Layout

Process layouts, also known as functional layouts or job-shop layouts, involve grouping of all similar equipment or functions. These are designed to

accommodate variety in product designing and processing. These layouts mostly use general purpose machines that can be changed over rapidly to new operations for different product designs. Workers in process layouts must be highly skilled. These layouts have greater flexibility in production, work can be transferred to another machine in case of breakdown of equipment, they allow expansion of different production line capacities and they also allow proper utilization of the men and machines. However, production requires more time as work-in-progress has to travel from one place to another in search of machines, the layout requires more floor space and work gets accumulated.

20.8.2 Product Layout

Product layouts, also known as flow-shop layouts or straight-line layouts, involve the arrangement of equipment or machines according to the progressive steps by which a product is made. Raw materials are moved to the first machine and the finished products come out from the last machine. These layouts are designed to accommodate only a few, mostly one or two standardized products and process designs. These layouts allow mechanization of materials and reduce material handling costs. These layouts require less floor area per unit of production, and facilitate better production control and help avoid production bottlenecks. However, there are difficulties in expanding the production line and supervising. Breakdown of one piece of equipment leads to disruption in the entire production system

20.8.3 Grouping Technology Layout

Grouping technology layout, also known as cellular manufacturing layout, involves grouping of dissimilar machines into cells where each cell functions like a product layout within a larger job shop or process layout. These layouts help simplify machine changeovers, reduce materials-handling costs, lead to quicker manufacturing and quicker shipping, reduce the in-process inventory required, and automate production easily. However, this layout reduces the flexibility of manufacturing.

20.8.4 Fixed Position Layout

A fixed position layout involves the movement of all machines and men to the product, which remains stationary. In this layout, a major component of the product is fixed in a particular location and all the requirements are brought to the location. It involves low investment, and helps to avoid bulky material being transported.

20.8.5 Hybrid Layouts

Single layouts like process layouts, product layouts, or fixed position layouts, are difficult to practice in their true sense. Therefore, a combination of several types of layouts is used. This is called a hybrid layout or a combined layout.

20.9 Developing a Process Layout

For planning a process layout, managers can use models like mathematical models, computer models, and physical models. Mathematical models help managers to analyze and conceptualize the problem; computer models provide them with a quick approximation of good layouts; and physical models help them visualize the layout.

20.9.1 Graphic and Schematic Analysis

The most common layout-planning tools are templates and two-dimensional cutouts of equipment drawn to a scale. Templates are used for identifying the best layout through trial and error by moving within a scaled model of walls and columns of a facility. These templates are also used for developing product and fixed-position layouts.

20.9.2 Computer Models – CRAFT

Computerized Relative Allocation of Facilities Technique (CRAFT) is a computerized layout program that identifies a layout through the quick evaluation of thousands of alternative layouts. It has the capacity to handle plants with up to 40 work centers of different shapes and sizes, and can account for mobile and immobile process centers.

20.9.3 Load Distance Model

A plant using a process layout produces diversified products in variable work flows. Such a plant handles relatively large amounts of material. Huge movement costs are incurred as there is a lot of movement of material in the process. The load distance model is one of the important models used to minimize the flow of material. This model considers the number of loads (standardized amount of material) moved between each pair of process centers over a period of time and the distances between them. These distances depend on the locations fixed by the initial layout. The initial layout is then modified to reduce costs. This process is repeated until there is no scope for further cost minimization.

Check Your Progress - 3

15. What do you understand by the term ‘facility layout’?
    a. A list of facilities provided by the organization to the consumers
    b. The physical distribution of various departments for ease in production
    c. The location of employees inside the organization
    d. Layout of safety equipment in an organization
16. Identify the statements that **does not hold true** regarding layout.
    a. It contains improvements or revisions in the existing layout if there is any development in the methods of production.

b. Layout decisions have short-term consequences in terms of cost and the company's ability to serve its customers.

c. It determines and arranges the machinery and equipment in the manner that best allows the quick flow of material at minimal cost and the least handling process from the stage of receipt of raw material to the shipment of finished products.

d. It provides a smooth work flow of material through the factory, or a comfortable traffic pattern for both customers and workers in the organization.

17. Which of the following involves the use of layout planning tools like templates and two-dimensional cut-outs of equipment drawn to scale?
    a. Graphic and schematic analysis
    b. Load distance model
    c. Computer models
    d. CRAFT model
18. Layouts are differentiated by the types of workflow they entail. Workflow in turn is dictated by the nature of the product. Which of the following statements is true about product layout?
    a. Equipment is dedicated to the manufacture of a narrow product line
    b. Equipment is flexible to produce a wide range of products
    c. Material handling cost increases significantly
    d. It is used for manufacturing customized products
19. Which of the following types of layout is used when the product manufactured is bulky, heavy or fragile?
    a. Product layout
    b. Process layout
    c. Fixed position layout
    d. Group technology layout
20. Which of the following is **not** a type of facility layout?
    a. Process layout
    b. Product layout
    c. Employee layout
    d. Hybrid layout
21. 'It is also called the cellular manufacturing layout.' Identify the layout from the following.
    a. Process layout
    b. Grouping technology layout
    c. Fixed position layout
    d. Hybrid layout

22. Process layouts are also known as _____.
    a. Functional layouts
    b. Fixed position layout
    c. Flow-shop layouts
    d. Straight-line layouts
23. Under which type of layout are similar machines and equipment grouped to carry out the production process.
    a. Process layout
    b. Product layout
    c. Fixed position layout
    d. Hybrid layout
24. What type of machine is used in a process layout?
    a. Specially designed machines
    b. General purpose machines
    c. Machines that help manufacture standardized products
    d. All of the above
25. Which of the following is an advantage of process layouts?
    a. Increased production time
    b. Increased work-in-progress
    c. Increased accumulation of work
    d. Increased utilization of men and material
26. Which type of layout is designed to produce standardized products?
    a. Process layout
    b. Product layout
    c. Fixed position layout
    d. Hybrid layout
27. Which of the following manufacturing processes requires using a fixed position layout?
    a. Petroleum distillation
    b. Beer manufacturing
    c. Ship-building
    d. Cement manufacturing
28. Managers can use various models like mathematical models, computer models, and physical models to develop a process layout. Which among the following helps find the best process layout by evaluating thousands of alternative layouts very quickly?
    a. Graphic and schematic analysis
    b. CRAFT model

c. Load distance model

d. Line balancing

29. Different types of products are manufactured using a process layout. As workflow differs from product to product, managers focus on minimizing the movement of materials as it can hike material movement costs. Which of the following models aims at minimizing these costs?

a. Graphic and schematic analysis

b. CRAFT model

c. Load distance model

d. Line balancing

20.10 Developing a Product Layout

Design for developing a product layout is partly established when each part of the product is designed and the different steps required to make it are determined. The volume of production determines the most economical process, and the process technology determines the sequence of steps which have to be performed in production. Finally, the equipment and workstations are placed along a line in that sequence. Workstations and equipment for the same product can be arranged in many possible sequences. Line-balancing is a mathematical model used for determining appropriate ways to group the tasks to be performed at each workstation.

20.10.1 Line Balancing

Line balancing is a part of the assembly line study that involves the selection of a suitable combination of work tasks to be performed at each workstation so that the work is performed in a feasible sequence. It ensures that each workstation gets approximately an equal amount of time.

20.10.2 Steps in Assembly Line Balancing

The following steps are needed to balance an assembly line:

i. *The sequential relationship among different tasks is specified by using a precedence diagram.*

The cycle time is determined by using the following formula:

$$\text{Cycle time} = \frac{\text{Production time per day}}{\text{Required output per day}}$$

ii. The theoretical minimum number of workstations required to satisfy the cycle time is determined using the following formula:

$$N_t = \frac{T}{C}$$

Where N_t = Theoretical number of workstations

T = Sum of task times

C = Cycle time

iii. A set of rules is identified to shortlist and select the tasks to be assigned to workstations. A sample set of rules is given below.

a) Identification of feasible (remaining) tasks for the same station:

From the unassigned tasks, identify the task(s) which can be assigned next to the same station, subject to two constraints:

- The precedence rules should not be violated.
- The individual time required for each of these feasible (remaining) tasks should be less than the unassigned time for the station, where Unassigned time for a station = Cycle time – (Sum of the time required for all previous tasks that have been assigned to the station)

Note:

- When there is no feasible (remaining) task for the same station, move on to the next station.
- When there is exactly one feasible remaining task for the same station, assign it as the next task for the same station.
- When there are multiple feasible remaining tasks for the same station, use the following tiebreaker rules to shortlist/select the next task for the same station.

b) Shortlist the tasks with most followers, among the feasible (remaining) tasks for the same station:

Now, shortlist the task(s) which has (have) the most followers from the feasible (remaining) tasks for the same station.

c) Select the task with the longest operation time:

From the short listed tasks with most followers, select the task which has the longest operation time, and assign it as the next task for the same station.

Sometimes, there may be many such tasks. In this case, one of these tasks with the longest operation time can be (arbitrarily) assigned as the next task for the same station.

iv. This set of rules is applied iteratively till all the tasks are assigned. At the end of this process, the actual number of work stations (N_a) required may be greater than or equal to the theoretical number of work stations (N_t).

The efficiency of the balance is calculated by using the following formula.

$$\text{Efficiency} = \frac{T}{N_a \times C}$$

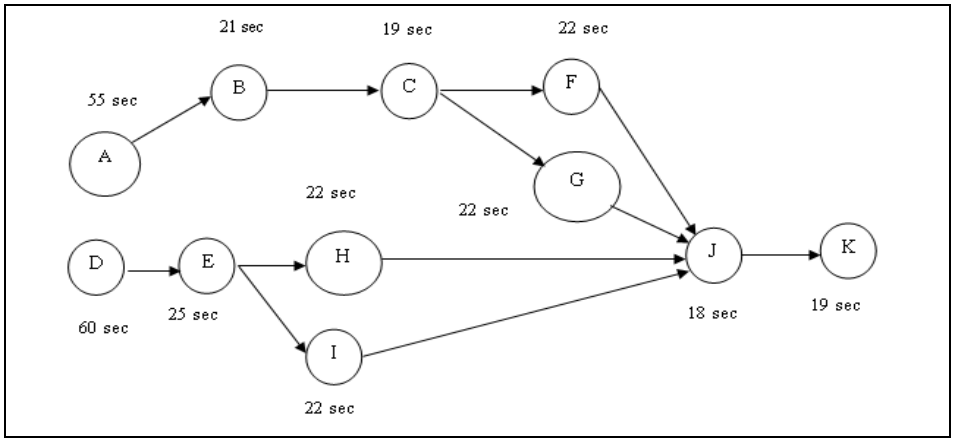
Where, T = Sum of task times

N_a = Actual number of workstations

C = Cycle time

v. The balance is accepted if the efficiency is satisfactory, otherwise balancing is done using a different decision rule.

Example: The desired daily output for an assembly line is 300 units. The assembly line operates for a period of 480 minutes a day. The process involves the tasks A, B, C, D, E, F, G, H, I, J, and K. Balance the assembly line and calculate the cycle time and efficiency of the assembly line.



Task	Task Time (Seconds)	Tasks that Must Precede
A	55	-
B	21	A
C	19	B
D	60	-
E	25	D
F	22	C
G	22	C
H	22	E
I	22	E
J	18	F,G,H,I
K	19	J
Total Time	**305**	

Solution: Following is the precedence diagram of all the tasks. The time required (in seconds) for completion of each of the tasks is given:

Given that the operation time per day is 480 min, i.e. (480×60) sec. The sum of the task times of the process, T = (55 + 21 + 19 +60 + 25 + 22 + 22 +22 + 22 + 18 + 19) = 305 sec.

$$\text{Cycle time} = \frac{\text{Operation time per day}}{\text{Outputper day}}$$

$$= \frac{480 \times 60}{300} = 96 \text{ sec.}$$

The theoretical minimum number of workstations required,

$$N_t = \frac{T}{C} = \frac{305}{96}$$

$= 3.18$

Therefore, a minimum of 3 workstations are required to balance the assembly line.

We arrange tasks in order of the largest number of following tasks.

Task	**Number of Following Tasks**
A	6
B or D	5
C or E	4
F, G, H, I	2
J	1
K	0

Apply the above rules for balancing the assembly line given in the problem:

To begin with, no tasks are assigned to any station. So, the unassigned time for Station 1 is 96 seconds. Subject to the precedence rules and the time constraints, A or D can be considered as the feasible remaining tasks. Since A has the most followers, we assign Task A to Station 1, as shown below.

Station	**Task**	**Time**	**Unassigned Time**	**Feasible Remaining Tasks (for the Same Station)**	**Task with Most Followers**	**Task with Longest Operation Time**
Station 1	-	0	96	A, D	A	A
Station 1	A	55	41	None	None	None

Now, the unassigned time for Station 1 is 41 seconds and neither of the potential next task (B or D) can be assigned next to this station, because of the time constraint. So we move on to Station 2. Following the same rules described above, the entire table can be filled as shown below.

Station	Task	Time	Unassigned Time	Feasible Remaining Tasks (for the Same Station)	Task with Most Followers	Task with Longest Operation Time
Station 1	-	0	96	A, D	A	A
		A	55	41	None	None
Station 2	-	0	50.4	B, D	B, D	D
	D	60	36	None	None	None
Station 3	-	0	96	B, E	B	B
	B	21	75	C,E	C,E	E
	E	25	50	C,H,I	C	C
	C	19	31	F,G,H,I	F,G,H,I	F,G,H,I
	F	22	9	None	None	None
Station 4	-	0	96	G,H,I	G,H,I	G,H,I
	G	22	74	H,I,J	H,I	H,I
	H	22	52	I,J	I	I
	I	22	30	J	J	J
	J	18	12	None	None	None
Station 5	-	0	96	K	K	K
	K	19	77	All tasks have been assigned All tasks have been assigned All tasks have been assigned		

 # The last task (Task K) could not be assigned to Station 4, since the unassigned time (12 seconds) was less than the time required for Task K (19 sec). So, we need a fifth workstation to perform Task K.

Therefore, actual number of workstations, $N_a = 5$

Efficiency of the assembly line $= \frac{T}{N_a C} = \frac{305}{4 \times 96} = 0.79$

20.10.3 Mixed-Model Line Balancing

Mixed-model line balancing is used to meet the demand for a variety of products. It involves multiple lot sizes, lot sequencing, different set-up times for each lot,

differing workstation sizes along the line, and task variations that make it very difficult to design.

Activity: The desired daily output for an assembly line is 800 units. The assembly line operates for a period of 420 minutes a day. The process involves the tasks A, B, C, D, E, F, G, H, I, J, and K. Balance the assembly line and calculate the cycle time and efficiency of the assembly line.

Task	Task Time (Seconds)	Tasks that Must Precede
A	50	-
B	12	A
C	11	B
D	55	-
E	17	D
F	13	C
G	13	C
H	13	E
I	13	E
J	9	F,G,H,I
K	10	J

Answer:

Check Your Progress - 4

30. Match the following models used to develop layouts with their respective features.
    i. CRAFT model
    ii. Load distance model
    iii. Line balancing
    iv. Graphic & schematic analysis
    p. Used for studying workflow in an assembly line
    q. Evaluates thousands of alternative layouts in a short period
    r. Analyses and minimizes material movements costs in a plant
    s. Two dimensional drawings are used to determine the best layout

a. i/p, ii/q, iii/r, iv/s

b. i/q, ii/p, iii/r, iv/s

c. i/r, ii/q, iii/p, iv/s

d. i/q, ii/r, iii/p, iv/s

31. Which of the following is a mathematical model that involves the selection of a suitable combination of work tasks to be performed at each workstation so that the work is performed in a feasible sequence?

    a. Line balancing

    b. Load distance model

    c. Center of Gravity Method

    d. Analytical Delphi Method

32. Given below are the steps required to balance an assembly line.

    i. The set of rules is applied iteratively till all the tasks are assigned.

    ii. The balance is accepted if the efficiency is satisfactory, otherwise balancing is done using a different decision rule.

    iii. The theoretical minimum number of workstations required to satisfy the cycle time is determined.

    iv. The sequential relationship among different tasks is specified by using a precedence diagram.

    v. A set of rules is identified to shortlist and select the tasks to be assigned to workstations.

    a. v-i-ii-iii-iv

    b. iii-v-i-ii-iv

    c. iii-v-i-iv-ii

    d. iv-iii-v-i-ii

33. Which of the following are the rules identified to shortlist and select the tasks to be assigned to the workstations?

    i. Identify the feasible (remaining) tasks for the same station.

    ii. Shortlist the tasks with most followers, among the feasible (remaining) tasks for the same station

    iii. Select the task with the shortest operation time

    a. Only i and ii

    b. Only i and iii

    c. Only ii and iii

    d. i, ii, and iii

34. _____ is used to meet the demand for a variety of products. It involves multiple lot sizes, lot sequencing, different set-up times for each lot, differing

workstation sizes along the line and task variations that make it very difficult to design.

a. CRAFT model

b. Load distance model

c. Mixed-model line balancing

d. Graphic and schematic analysis

20.11 Developing a Cellular Manufacturing Layout

The following are the steps for developing a cellular manufacturing layout:

- The parts that follow a common sequence of steps are grouped into a family.
- The dominant flow patterns of parts-families are identified as a basis for location or relocation.
- The machines and processes are physically grouped into cells. The machinery parts that cannot be grouped with any cell or family are placed in a remainder cell.

Problems involved in developing a cellular manufacturing layout are:

- Developing and classifying a coding scheme for items of different shapes, sizes, materials, etc.
- Grouping parts in families to form cell groups on the basis of processing requirements and routings
- Creating the physical layout for positioning cells relative to each other.

Cellular manufacturing is a train of thought that enables production work stations to operate in a sequential manner. What this will enable is the flow of materials in a seamlessly, effortless flow. With minimal delays, this lean methodology will enable a paradigm shift in activity that will enable better resource management. The key advantage of cellular manufacturing is its ability to increase production velocity, while minimizing the capital requirements of a plant. Exhibit 20.1 presents cellular manufacturing in 2021.

Exhibit 20.1: Cellular Manufacturing: Organized Manufacturing in 2021

2021 operations will experience the sequential movement of parts through a system. With shorter cycle and change over times, more flexible systems can be generated. In high volume environment, a perfect transition will be more flexible smaller systems.

How to Implement Cellular Manufacturing

Moving from operations such as batch and queue and mass production to more pull based operations cellular manufacturing helps disaster recovery plan.

Contd….

Cellular systems don't require as much capital cost in their implementation, and being reliance more on pull, one need not worry about inventory allocation.

Step 1: Apply an A3 approach to your transition to Cellular Manufacturing.

Start with thorough assessment of the current environment and conditions. Plan to convert a work area into a manufacturing cell. Estimate the cost, time current operational flow, current cycle time, takt time and other critical operational parameters. This pooled data helps to calculate averages.

Step 2: Converting to a Process-based Layout.

The understanding of different processes working, will facilitate the planning and implementation process to cellular manufacture. Design the machine configuration, either U or C based on the desired products, needed tools to incorporate, SMED for easy machine configuration, planned Autonomation for the human-machine interaction

Step 3: Continuously Improving the Process.

You are ready with what will work best for the organization. Recommendation is that, in 2021, it cannot be a linear fashion. One has to be able to navigate between various operational modes in order to ensure agility. Keep optimizing it.

https://www.whatissixsigma.net/cellular-manufacturing-organized-manufacturing-in-2021/

20.12 Japanese Approaches and Trends in Manufacturing Layouts

The approach towards business management of Japanese firms is different from that of US firms. These differences are reflected in their facility layout. The Japanese make most use of the little space available as space is available at a premium. Materials travel shorter distances and products go through the factory faster, resulting in high production rates, quick processing of customer orders, and reduction in materials handling and inventory costs. This also makes the factories more flexible to changes in customer orders, production schedules, and production rates. Japanese layouts are designed for flexibility and adaptability to different product models or to different production rates, whereas US layouts are designed for high worker and machine utilization.

Check Your Progress - 5

35. In which of the following countries were compact production layouts developed due to space constraints?
    a. USA
    b. Japan
    c. India
    d. China

36. Given below are the steps involved in the development of a cellular manufacturing layout.
    i. The dominant flow patterns of parts-families are identified as a basis for location or relocation.
    ii. The parts that follow a common sequence of steps are grouped into a family.
    iii. The machines and processes are physically grouped into cells.
    a. i-iii-ii
    b. ii-i-iii
    c. i-ii-iii
    d. iii-i-ii
37. Which of the following are the problems involved in developing a cellular manufacturing layout?
    a. Developing and classifying a coding scheme for items of different shapes, sizes, materials, etc.
    b. Grouping parts in families to form cell groups on the basis of processing requirements and routings
    c. Creating the physical layout for positioning cells relative to each other.
    d. All of the above
38. Which of the following statements is true regarding the Japanese approaches and trends in manufacturing layouts?
    a. The approach of Japanese firms toward business management is similar to that of the US firms.
    b. The Japanese make most use of the little space available as space is available at a premium.
    c. Japanese layouts are designed for high worker and machine utilization, unlike US layouts that are designed for flexibility and adaptability to different product models or to different production rates.
    d. Japanese factors are less flexible to changes in customer orders, production schedules, and production rates.

20.13 Service Facility Layout

A service facility is different from a manufacturing facility as service facilities bring together the customer and the organization's services. Based on the degrees of customer contact, there are two extremely different types of service facility layouts. At one extreme, the layout is designed around the customer receiving service functions like that of banks. At the other extreme, the layout is designed around technology, processing of physical materials, and production efficiency like that of hospitals. Certain service facilities like restaurants strike a balance between these two extremes. In a restaurant, attention is directed both at customer receiving and servicing as well as on processing and preparation of food. In these layouts, the internal work of the employees is given secondary importance.

Check Your Progress - 6

39. Different types of layout of service facilities exist based on degrees of customer contact. In which of the following layouts is internal work of employees given secondary importance?
    a. Layouts focusing on customer receiving and servicing
    b. Layouts focusing on technology
    c. Layouts focusing on physical materials processing
    d. Layouts focusing on production efficiency
40. Which of the following service providers uses both customer focus layouts and process focus layouts as part of its service facility layout?
    a. Banks
    b. Hospitals
    c. Restaurants
    d. Call center
41. All the statements given below are true regarding a service facility layout, except:
    a. It brings together the customer and the services of the organization.
    b. A service facility layout is designed around the customer receiving service functions.
    c. A service facility is designed around technology, processing of physical materials, and production efficiency.
    d. In service facility layouts such as restaurants, attention is directed only at the customer receiving and servicing function, and not at the processing and preparation of food function.

20.14 Summary

- Location decisions are strategic decisions that require huge financial investments and they are irreversible in nature.
- Models and techniques such as break-even analysis, factor rating technique, and the transportation method of linear programming that includes center of gravity method and analytical Delphi method help managers in taking location decisions.
- The physical disposition of the facilities of a plant is referred to as the plant layout. The basic types of layouts are: process layout, product layout, fixed-position layout, cellular manufacturing layout, and hybrid layout.
- In case of designing service layouts, there exist two types based on the degree of customer contact. One is designed around the customer service and the other around the technology.

20.15 Glossary

Analytical Delphi method: It is useful in decisions involving multiple locations with different objectives. This method involves the need of three panels – forecasting panel, strategic panel, and coordinating panel. **Break-even analysis: It** is a graphical and algebraic representation of the relationships among volume of output, costs, and revenues.

Center of gravity method: It aims at minimizing the total shipping cost, i.e., co**st incurred for shi**pping from the distribution center to the different shipping points.

Computerized Relative Allocation of Facilities Technique (CRAFT): A computerized layout program that identifies a layout through the quick evaluation of thousands of alternative layouts. **Facility location: The place where the firms set up their operat**ions.

Fixed costs: These do not vary with the volume of output. Examples are administration expenses, rents of buildings, **lighting, etc.**

Fixed position layout: It involves the movement of all machines and men to the product, which remains stationary. In this layout, a major component of the product is fixed in a particular location and all the requirements are brought to the location.

Grouping technology layouts (cellular manufacturing layouts): These involve grouping of dissimilar machines into cells where each cell functions like a product layout within a larger job shop or process layout.

Hybrid layouts (or combined layouts): A combination of several types of layouts such as process layouts, product layouts, or fixed position layouts is used.

Layout: It includes the initial layout of machines and other facilities. It also contains improvements or revisions in the existing layout if there is any development in the methods of production.

Line balancing: A part of the assembly line study that involves the selection of a suitable combination of work tasks to be performed at each workstation so that the work is performed in a feasible sequence.

Load distance model: It is used to minimize the flow of material. It considers the number of loads (standardized amount of material) moved between each pair of process centers over a period of time and the distances between them.

Mixed-model line balancing: It is used to meet the demand for a variety of products. It involves multiple lot sizes, lot sequencing, different set-up times for each lot, differing workstation sizes along the line, and task variations that make it very difficult to design.

Plant layout: The physical disposition of the facilities of a plant. It is a floor plan to determine and arrange the machinery and equipment in the manner that best allows the quick flow of material at minimal cost and the least handling process from the stage of receipt of raw material to the shipment of finished products.

Process layouts (functional or job-shop layouts): These involve grouping of all similar equipment or functions. These are designed to accommodate variety in product designing and processing.

Product layouts (flow-shop or straight-line layouts): These involve the arrangement of equipment or machines according to the progressive steps by which a product is made.

Total cost: The sum of the fixed and variable costs at a specific volume of output would be the total cost at that volume of output.

Variable costs: These vary with the volume of output. Raw material cost, labor cost, etc. are variable costs.

20.16 Self-Assessment Exercises

1. Manufacturing and service firms evaluate different locations and finally choose an optimum location to start their operations. What do you understand by facility location? Explain the importance of making location decisions.
2. Location decisions are long-range decisions and are affected by a number of factors. Therefore developing a formal and generic location model is very difficult. What are the factors affecting location decisions? Explain the location decision process.
3. Several models and techniques are available to help managers take appropriate location decisions. Explain the different methods through which an organization can evaluate a location.
4. Facility layout is the physical disposition of the facilities of a plant and its various parts for the purpose of achieving quickest and smoothest production. Explain the criteria for selecting a good layout.
5. Layouts are differentiated by the type of work flow and the nature of the product. What are the various types of layout formats? Describe these layouts and list out the advantages and disadvantages of each.
6. Managers use mathematical models, computer models, and physical models in order to develop layouts. Explain the planning and developing process of the following layouts:
   - Process layout
   - Product layout
   - Cellular manufacturing layout
7. Explain the following:
   - Japanese manufacturing layouts vs. US manufacturing layouts
   - Service facility layouts are different from manufacturing facility layouts.

20.17 Suggested Readings/Reference Material

1. Dr. S. Ramachandran, P.Vijayalakshmi ,D. Jagadish Material Handling And Facilities Planning- Ktu Paperback, Irwalk Publications January 2019
2. Prasanna Chandra, Projects: Planning, Analysis, Selection, Financing, Implementation and Review ,McGraw-Hill; Ninth edition, 15 May 2019
3. Erik Larson, Clifford Gray, Project Management: The Managerial Process | 6th Edition , McGraw Hill Education; Sixth edition, 1 July 2017
4. The Art of Service - Inventory Control Publishing, Inventory Control A Complete Guide - 2021, The Art of Service - Inventory Control Publishing, November 4, 2020
5. P. Gopalakrishnan, Purchasing and Materials Management , McGraw Hill Education; 1 July 2017

20.18 Answers to Check Your Progress Questions

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

1. (c) i, ii, iii

Except alternative 'iv', all others are reasons for companies to set up facilities in select zones. Low cost of manpower is a country-specific factor and does not significantly differ within and outside exclusive zones.

2. (c) Suitability of climate

Cotton yarn manufacturing units require a certain level of humidity in the atmosphere throughout the year which is present in only certain places. This is because cotton is affected by high humidity levels. Hence, many companies are set up in low humidity locations.

3. (b) When expansion of the existing plant is possible

A new location is necessary under all conditions except option 'b'. The need for selection of facility location also arises when there is no possibility of expanding the existing plant and the firm is compelled to search for a new location.

4. (c) iii, ii, i, iv

A firm first looks out for a location and identifies two or more possible locations. It then selects the best location from available choices. After selecting the location, it designs a layout. Firms can then revise or redesign the layout in the future depending on its strategies (expansion etc,).

5. (b) In a town/city

The location of the facility affects the company's ability to serve its customers quickly and conveniently. Rahul must set up the printing press within reach

of target markets. In this case, a town or city is an ideal location as people who wish to publish their work live largely in cities.

6. **(b) High transportation costs**

   If selection of a location leads to high transportation costs, it would reduce profitability of the firm. Low labor costs, availability of public utility services and tax holidays are factors that would encourage firms to choose a particular location.

7. **(c) Close to the raw material source**

   Cement plants are generally located near limestone quarries. This is because raw material required is huge and transportation cost over long distances cannot offset the benefits accrued from other options mentioned in the question.

8. **(b) Proximity to markets**

   The major markets for auto-ancillary units are auto makers like Hyundai and Ford. Proximity to these plants enables them to service clients more effectively.

9. **(d) Availability of real estate**

   Government provides many benefits to industries that set up operations in special export zones. In addition to tax holidays, infrastructure support and low interest loans from banks, etc, companies are provided land at low costs. The land provided is not prime real estate as SEZs are located away from cities or towns.

10. **(d) Historical analogy method**

    The historical analogy method is a forecasting method. The other options – point rating method, center of gravity method, and analytical Delphi method are standard methods to locate the optimal location for a firm.

11. **(d) CRAFT analysis**

    CRAFT analysis is used for developing a process layout and not for determining plant location.

12. **(c) Define location objectives – identify relevant decision criteria – relate objectives to the criteria – evaluate alternative locations – select the best location**

    Though there is no standard procedure, the following steps serve as a guideline for location decisions. The correct sequence includes: define location objectives and associated constraints, identify relevant decision criteria, relate objectives to the criteria using appropriate models, do field research to relevant data and use models to evaluate alternative locations and select the location that best satisfies the criteria.

13. **(d) Competitors**

    Location objectives and associated constraints are defined on the basis of the views and requirements of promoters, owners, employees, suppliers and customers of the firm. Competitor views are not an important factor.

14. **(a) Form panels - Identify trends and opportunities - Determine directions and strategic goals of the organization - Develop alternatives - Prioritize alternatives**

    Analytic Delphi Method helps managers take complex multi-location decisions. This method requires the participation of a coordinating panel, forecasting panel and strategic panel. The coordinating team selects two teams from within the organization, the forecasting and strategic panels. These two panels participate in two Delphi inquiries. In the first, the coordinating panel uses a questionnaire to elicit information from the forecasting panel regarding future trends, threats and opportunities. In most cases, the process is repeated several times till consensus is reached. In the next step, information collected through the first Delphi inquiry is given to the strategic panel. This information is used by the strategic panel in the second Delphi inquiry to identify the organization's direction and goals. After strategic goals have been identified, the strategic panel develops various alternatives. Finally, all alternatives generated in the previous step are presented to members of the strategic panel to obtain their subjective value judgments.

15. **(b) The physical distribution of various departments for ease in production**

    A facility layout represents the physical spread of all the equipment, machinery, parts, etc. in a plant/facility. They are distributed so as to ensure smooth work flow and maximum efficiency.

16. **(b) Layout decisions have short-term consequences in terms of cost and the company’s ability to serve its customers.**

    All the statements are true regarding layout, except statement (b). Layout decisions have long-term consequences in terms of cost and the company’s ability to serve its customers.

17. **(a) Graphic and schematic analysis**

    In Graphic and schematic analysis templates, two-dimensional cutouts of equipment drawn to scale are the most common layout-planning tools. Templates are moved about within a scaled model of the walls and columns of a facility to identify the best layout through trial and error. These templates are also used for developing product and fixed-position layouts. Managers can use various models like load distance and computer models. CRAFT is a type of computer model.

18. (a) Equipment is dedicated to the manufacture of a narrow product line

Product layout is used to produce a narrow product line and all machinery and equipment is dedicated for this. Material handling costs are low as there is less scope for product change over. Product layouts are extensively used to produce standard products and not customized products.

19. (c) Fixed position layout

Fixed position layout involves movement of men, machines and equipment to the product, which remains stationary. The product here may be bulky, large, heavy or fragile. Layout adopted in ship building is an example of fixed position layout.

20. (c) Employee layout

Employee layout is not a type of facility layout. The various types of layouts are process layout, product layout, hybrid layout and fixed position layout.

21. (b) Grouping technology layout

In a grouping technology layout (also called cellular manufacturing layout), dissimilar machines are grouped into cells and each cell functions like a product layout within a larger job shop or process layout.

22. (a) Functional layouts

Process layouts, also known as functional layouts or job-shop layouts, involve grouping of similar equipment or functions (for instance, lathe machines in one section, drilling machines in another section and all activities related to assembling the product in another area, etc.).

23. (a) Process layout

Process layouts, which are also known as functional layouts or job-shop layouts, involve grouping of similar equipment or functions (all lathe machines in one area, all drilling machines in another area and all assembling works in some other area).

24. (b) General purpose machines

Process layouts mostly use general purpose machines that can change rapidly to new operations for different product designs.

25. (d) Increased utilization of men and material

In process layouts, men and machines are utilized most efficiently, owing to use of general purpose equipment. The other options are not advantages. Production requires more time as work-in-progress has to travel from one place to another. This increases accumulation of work at different stages of production.

26. (b) Product layout

Product layouts are designed to accommodate only a few, mostly one or two, standardized products and process designs. Process, hybrid and fixed position layouts allow production of customized products.

27. (c) Ship-building

Ship-building is an example of fixed position layout where all the men, material and equipment are brought to the ship that is stationary.

28. (b) CRAFT model

Except line balancing, all other options are models used in process layout development. CRAFT model finds a layout by evaluating thousands of alternatives quickly. CRAFT has the capacity to handle plants comprising up to 40 work centers of different shapes and sizes. It can account for mobile and immobile process centers. The model considers various types of layouts and different materials-handling methods that a firm can use in its work centers.

29. (c) Load distance model

The load distance model is an important model used to minimize material flow in a layout. In this model, the number of loads (standardized amount of material) moved between each pair of process centers over a period of time and distances between them are considered. Line balancing is used to determine product layouts.

30. (d) i/q, ii/r, iii/p, iv/s

CRAFT is used to analyze and evaluate thousands of alternative layouts very quickly. Load distance model is used to reduce material movement costs in a production plant. Line balancing is used to study workflow in an assembly line. Graphic and schematic analysis is used to study two-dimensional scaled drawings of equipment and machinery to arrive at the best possible layout.

31. (a) Line balancing

Line balancing is a part of the assembly line study that involves the selection of a suitable combination of work tasks to be performed at each workstation so that the work is performed in a feasible sequence. It ensures that each workstation gets approximately an equal amount of time.

32. (d) iv-iii-v-i-ii

The steps required for balancing an assembly line are – (a) The sequential relationship among different tasks is specified by using a precedence diagram; (b) The theoretical minimum number of workstations required to satisfy the cycle time is determined; (c) A set of rules is identified to shortlist and select the tasks to be assigned to workstations; (d) The set of rules is

applied iteratively till all the tasks are assigned; and (e) The balance is accepted if the efficiency is satisfactory, otherwise balancing is done using a different decision rule.

33. (a) Only i and ii

The rules identified to shortlist and select the tasks to be assigned to workstations are – (a) Identification of feasible (remaining) tasks for the same station; (b) Shortlist the tasks with most followers, among the feasible (remaining) tasks for the same station; and (c) Select the task with the longest operation time.

34. (c) Mixed-model line balancing

Mixed-model line balancing is used to meet the demand for a variety of products. It involves multiple lot sizes, lot sequencing, different set-up times for each lot, differing workstation sizes along the line and task variations that make it very difficult to design.

35. (b) Japan

In Japan, space availability is a major constraint as it is a very small nation in terms of geographic area. Hence, layouts were designed to use minimal available space. In contrast, in USA, India and China, as space is not a problem, comparatively larger layouts are designed.

36. (b) ii-i-iii

The steps involved in the development of a cellular manufacturing layout are – (a) The parts that follow a common sequence of steps are grouped into a family; (b) The dominant flow patterns of parts-families are identified as a basis for location or relocation; and (c) The machines and processes are physically grouped into cells. The machinery parts that cannot be grouped with any cell or family are placed in a remainder cell.

37. (d) All of the above

The problems involved in developing a cellular manufacturing layout are: developing and classifying a coding scheme for items of different shapes, sizes, materials, etc.; grouping parts in families to form cell groups on the basis of processing requirements and routings; and creating the physical layout for positioning cells relative to each other.

38. (b) The Japanese make most use of the little space available as space is available at a premium.

All statements are false regarding the Japanese approaches and trends in manufacturing layouts, except statement (b).

39. (a) Layouts focusing on customer receiving and servicing

Two extremely different types of layout of service facilities exist based on degrees of customer contact. At one extreme is the layout totally designed

around customer-receiving service functions. The other is the layout designed around technology, processing of physical materials and production efficiency.

40. (c) Restaurants

In a restaurant, the service layout has to cater to activities of receiving and servicing customers (customer focus) as well as processing and preparation of food items (process layout).

41. (d) In service facility layouts such as restaurants, attention is directed only at the customer receiving and servicing function, and not at the processing and preparation of food function.

All the statements are true regarding a service facility layout, except statement (d). In a restaurant, attention is directed both at customer receiving and servicing as well as on processing and preparation of food. In these layouts, the internal work of the employees is given secondary importance.

Unit 21

Aggregate Planning and Capacity Planning

Structure

21.1 Introduction

In the previous unit, we have discussed service facility layouts. We have learnt that in case of designing service layouts, there exist two types based on the degree of customer contact, one, which is designed around the customer service and the other around the technology. In this unit, we will discuss aggregate planning and capacity planning.

To satisfy market demand for their products, organizations need to estimate resource requirements. This is quite easy for organizations that have a single product in their product portfolio. For organizations that have multiple products, an aggregate output measured in common terms is worked out by grouping individual products or product types together. The aggregate plan defines the best combination of workforce level, inventory on hand, and production rate that will match the company's resources with market demand. Managers can convert aggregate plans into detailed master production schedules by dividing operations. Targets in the plan can be met through sufficient capacity, determined by capacity planning that ensures that there are no inconsistencies between capacity demanded and capacity required. In this unit, we shall discuss the strategies and approaches to aggregate planning, capacity planning, and master production scheduling.

This unit will give you an overview of planning activities, and discuss the aggregate planning process. We will discuss the strategies for developing aggregate plans, and then study the aggregate planning techniques. We shall then move on to discuss the master production schedule, and how to implement aggregate plans and master schedules. Finally, we would discuss the concept of capacity planning.

21.2 Objectives

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

- Identify the different aspects of planning activities.
- Explain the aggregate planning process.
- Assess the strategies for developing aggregate plans.
- Define aggregate planning techniques.
- Discuss the master production schedule.
- Determine the process of implementing aggregate plans and master schedules.
- Define capacity planning.

21.3 Overview of Planning Activities

Operations planning activities can be long-range, medium-range, or short-range in nature, *Long-range planning* focuses on a time period of more than one year. Process planning and strategic capacity planning are examples of long-range planning. *Medium-range planning* focuses on a time period of 6-18 months. Aggregate planning, master production scheduling, and materials requirement planning are examples of medium-range planning. *Short-range planning* focuses on a time period of less than 6 months. Order and workforce scheduling are examples of such planning.

21.3.1 Business Planning

The business planning process coordinates the activities of each function or department such that all the activities and resources are focused on achieving the organization's objectives. This process is used to address concerns like new product development, sales levels to be achieved, new process requirements, capital investments, and new distribution strategies. Decisions regarding these issues are taken with the help of medium-term and long-term plans and are evaluated on the basis of their impact on the profitability of a business. This type of business planning generally involves a committee consisting of various department heads so that all the medium-term plans are focused on achieving the goals established by the long-term business plans of the organization.

Long-term business planning is done on the basis of long-term business forecasts. Planning decisions include setting capital budgets for acquiring new facilities,

expanding plant capacity, and purchasing high cost equipment. These forecasts may not be too accurate as economic and competitive conditions could change in the future. Long-term decisions limit the scope for change during the intervening time period by acting as constraints. Therefore, long-term decisions must be periodically evaluated for their effectiveness and suitability for achieving organizational goals.

21.3.2 Operations Planning

An operations or production plan is a part of the business plan that defines how an organization plans to produce products or services and estimates the cost of production. It contains information regarding the production process, manufacturing facilities, inventory requirements, suppliers, etc. This plan is made on the basis of sales estimates. These plans have to be aligned with business plans and the objectives of marketing, finance, human resources functions, etc.

21.4 The Aggregate Planning Process

The aggregate planning process is complex due to the number of variables that must be considered in the planning process. Following are the basic considerations for developing an aggregate production plan:

a) **Concept of Aggregation –** In this stage, a meaningful measure of output is identified. This is easy for organizations with a single product but difficult for those producing several products. For example, tons of sugar produced can be used as the capacity of a sugar factory while number of patients visited would be a sound measure for a service organization like a hospital.

b) **Aggregation Planning Goals –** An aggregate plan has to simultaneously satisfy a number of goals. Aggregate planning should contain information on the required output level to be produced, inventory levels to be maintained, and the backlogs, based on the business plan.

c) **Forecasts of Aggregate Demand –** Aggregate planning can deliver better results through accurate forecasting.

d) **Inter-relationships among Decisions –** All activities in an organization are interrelated and dependent on each other. Operations managers must therefore consider the consequences of current decisions for the future.

An aggregate planning is a process by which company determines planned levels of capacity, production, subcontracting, inventory, stockouts and even pricing over a specified time horizon. The goal of aggregate planning is to build a plan that satisfies demand while maximizing the profit.

The aggregate planner's main goal is to find out the following operational parameters over a specified time horizon:

i. Production rate: It refers to the number of units to be produced per unit of time such as per week or per month.

ii. Workforce: The number of workers needed for production. Production = production rate * workforce level.

iii. Overtime: The amount of overtime production planned

iv. Machine capacity level: The number of units of machine capacity needed for the production.

v. Subcontracting: The subcontracted capacity required over the specified time horizon.

vi. Backlog: Demand which is not satisfied in the period in which it arises. The unfulfilled demand is carried as backlog to the future periods.

vii. Inventory on hand: The unused inventory carried over the various periods in the planning horizon.

Check Your Progress - 1

1. Operations planning activities can be long-range, medium-range or short-range. Aggregate planning typically fall under which category?
   a. Long range
   b. Medium range
   c. Short range
   d. Both a & b
2. A production plan does **not** contain information about which of the following?
   a. Production process
   b. Inventory requirements
   c. Suppliers
   d. Customers
3. Operations planning activities can be long-range, medium range or short range in nature. Process planning typically falls under which category?
   a. Long-range planning
   b. Medium-range planning
   c. Short-range planning
   d. Both b & c

21.5 Strategies for Developing Aggregate Plans

An aggregate plan is developed taking into consideration the different variables (Capacity, inventory, and backlog) which influence the production plan. These strategies involve trade-off between capacity, inventory and backlog costs. These variables are used in different combinations to enable an organization to satisfy market demands.

21.5.1 Pure Planning Strategies

The production uncertainties and demand fluctuations can be managed effectively by varying the size and utilization of the workforce, and the size of inventory, through back orders and subcontracts, and by varying plant capacity. The strategy is called a pure strategy if only one of these strategies is adopted. However, a combination of these strategies is generally used instead of the focus being on a single strategy. Following are some of the pure planning strategies:

Chase Strategy ***Varying the workforce size in response to the output requirements***

In this strategy, the production rate is synchronized with demand rate by varying the machine capacity or workforce size is changed by hiring and laying-off workers in direct proportion to demand. In real case, achieving this synchronization can creates problem because of varying capacity or workforce on short notice. Based on the productivity of the average worker, the management determines the number of workers required to meet each month's output requirements. When the quantity to be produced is less, the workers are laid off and when there is an increase in orders, workers are hired.

Example: In a textile firm, a worker is capable of customizing three garments per day. Hiring costs are Rs. 4000, lay-off costs are Rs. 5000, and current employee strength is 30. Based on the information given in the table pertaining to aggregate demand, generate a production plan by following the varying workforce strategy. Assume that the time taken for each garment is the same.

	April	May	June	August
Demand	2800	2500	2100	2400
Working Days	24	25	23	24

Solution: At the beginning of the production plan, the workforce level is 30. To satisfy the demand in April, the organization needs 38 workers. So it hires 8 new workers. Refer to Table 21.1 for the production plan with varying workforce levels.

Number of units produced by each worker in April with 24 working days = 24 × 3 = 72

Total output of 30 workers = 72 × 30 = 2160

Demand for April = 2800. Therefore, the deficit is 640 units (2800-2160).

To meet the demand of 2800, the organization needs 8 more workers (2160 is the demand met by 30 workers, how many workers are required to meet the demand for 640 units?).

Cost of hiring in April = 8 × 4000 = Rs. 32000. Similarly, we can calculate the hiring and laying off cost for other months based on number of workers required to satisfy the demand.

Table 21.1: Production Plan with Varying Workforce Level

	April	May	June	July
Working days	24	25	23	24
Units per month/ workers	72	75	69	72
Workers available	30	38	33	30
Demand	2800	2500	2100	2400
Total output	72 × 30 = 2160	75 × 38 = 2850	69 × 33 = 2277	72 × 30 = 2160
Deficit	640	-	-	240
Surplus	-	350	177	
Number of additional workers needed (approx)	8	-	-	3
Hiring costs	32000	0	0	12000
Number of workers to be laid off (approx)	-	5	3	-
Lay-off costs	0	25000	15000	0
Total number of workers	38	33	30	33
Total Costs (hire/lay-off)	32000	25000	15000	12000

Varying the Utilization of the Workforce

Flexibility Strategy In this strategy, the firm maintains a stable workforce and alters their utilization in line with the demand or required output. If the demand is lean, the workforce is scheduled to produce only the output that will meet the demand. This results in idle work hours. If the demand is high, the same workforce works overtime to meet the demand.

Level Strategy ***Varying the Size of inventory***

In this strategy, an organization maintains a constant workforce level and production. If the demand is low, the stable rate of production results in accumulation of inventories. If the demand is more than the capacity, the additional requirement is met by using the already accumulated inventories.

Example: The following table gives the aggregate demand for product X for the next four months:

	August	September	October	November
Demand	9000	8600	11000	9200
Working Days	22	24	23	24

Activity: In a two-wheeler assembling firm, a worker is capable of assembling 5 two-wheelers per day. Assume that the time taken for each vehicle is the same.

Given:

Hiring costs = Rs. 5000

Layoff costs = Rs. 6000

Current employee strength = 50

Aggregate demand for the next four months is given in the following table:

	August	September	October	November
Demand	4900	4170	3000	3660
Working Days	25	24	23	24

Based on the given information, generate a production plan by following the varying workforce strategy.

Answer:

The opening stock of inventory is 800 units, inventory holding cost is Rs. 30/unit, worker productivity is 20 units per day, worker strength is 20, and shortage cost (due to lost sales) is Rs. 20 per unit. Generate a production plan with varying inventory levels.

Solution: The workforce is kept constant in aggregate planning with a varying inventory level. Refer to Table 21.2 for the aggregate production plan with varying inventory levels.

Actual production in a month = (Number of working days) × (Number of workers) × (Worker productivity in units/day)

Closing inventory = Beginning inventory + Actual production – Demand forecast

Shortage cost (due to lost sales) = (Units short) × (Per unit shortage costs)

Inventory carrying costs = (Excess inventory) × (Per unit inventory holding costs)

Excess inventory in one month is taken as the beginning inventory for the next month.

Table 21.2: Production Plan with Varying Inventory Levels

	August	September	October	November
Opening stock of inventory	800	600	1600	0
Working days	22	24	23	24
Actual Production	8800	9600	9200	9600
Demand Forecast	9000	8600	11000	9200
Shortage in Supply (Unmet Demand)	0	0	200	0
Shortage Cost (due to lost sales)	0	0	4000	0
Safety Stock	0	0	0	0
Closing Inventory	600	1600	-200	400
Inventory carrying costs	18000	48000	0	12000

Activity: Aggregate demand for product A for four months is given in the following table:

	April	May	June	August
Demand	6200	5000	6500	5800
Working Days	24	25	23	25

Given:

Opening stock of inventory = 900 units

Inventory holding cost = Rs. 60/unit

Worker productivity = 25 units/day

Worker strength = 20

Shortage cost (due to lost sales) = Rs. 40/unit

Based on the above information, generate a production plan with varying inventory levels.

Answer:

Back Orders, Subcontracting and Plant Capacity

The back order strategy is used to maintain smooth operations. In this strategy, current order commitments are fulfilled in the future assuming that customers are ready to wait for delivery. Though it effectively smoothens out production, it may sometimes result in stock-out costs when customers do not wait till the product is

delivered and switch to a competitor's product. The subcontracting strategy allows level production and sources the additional output required from subcontractors. The adjusting plant capacity strategy allows changing the equipment capacity during the short term and the long term to absorb demand fluctuations.

Check Your Progress - 2

4. Which of the following is **not** a pure planning strategy used for developing aggregate plans?
   a. Varying utilization of the workforce
   b. Varying workforce size in response to output requirements
   c. Varying size of inventory
   d. Varying the compensation method
5. Which of the following is **not** a pure planning strategy used as part of aggregate planning?
   a. Back-order strategy
   b. Maintaining fixed plant capacity
   c. Sub-contracting
   d. Varying workforce utilization

Exercises

(Questions A to D)

The aggregate demand for product X for the next four months is given in the following table:

	Jun	Jul	Aug	Sept
Demand	2600	2700	2800	2750
Working Days	26	25	25	26

In addition, the following information is given:

Opening stock of inventory = 500 units, Inventory holding cost = Rs.20/unit/month, Worker productivity = 4 units/day, Worker strength = 25, Shortage cost (due to lost sales) = Rs.10/unit

Answer the following **four** questions based on the above given information

A. What is the change in inventory on hand after meeting demand for Product X for the month of June?

B. Assume that opening stock for the month of July is 500 units. What is the inventory carrying cost for that month?

C. Calculate the closing inventory for August.

D. What is the shortage cost (due to lost sales) in the month of September if the opening inventory for the month is zero units?

21.6 Aggregate Planning Techniques

Aggregate planning models like the graphical, optimal, and heuristic models help planners formulate the aggregate output plan.

21.6.1 Graphical Method for Aggregate Output Planning

The graphical method is a two-dimensional model linking cumulative demand to cumulative output capacity. Following are the steps involved:

a) A graph is drawn by taking the cumulative productive days for the planning time period on the X or horizontal axis, and cumulative units of output on the Y or vertical axis. The cumulative demand forecast for the entire planning time period is plotted on the graph.

b) A planning strategy is selected based on the aggregate planning goals. Planned output for each period in the planning period is computed and plotted on the same axis used to plot the demand.

c) The planned output is compared with expected demand and periods of excess inventory and shortages are identified.

d) The costs involved in the implementation of the plan are calculated.

e) The plan is modified to meet aggregate planning goals by repeating steps (b) to (d) until a satisfactory plan has been established.

This method is simple to understand and requires minimal computational effort.

21.6.2 Optimal Models for Aggregate Planning

The optimal models are discussed below:

Linear programming – The linear programming model is an optimal model used to formulate aggregate plans. The linear programming procedure identifies the optimal plan for minimizing costs that specifies the number of units to be produced, the total number of shifts for which the plan should operate in the planning time horizon, and the amount of inventory that has to be carried in each time period.

Linear decision rules (LDRs) – LDRs are a set of equations for calculating the optimal workforce, aggregate output rate, and inventory level for each period in the planning period. This method guarantees an optimal solution and eliminates trial-and-error computations. It also overcomes the limitation of linear programming by considering non-linear cost relationships.

Heuristic models – Heuristic models are based on the historical aggregate planning data available with organizations. The management coefficient model is a heuristic model which uses the regression method to identify capacity requirements based on the management's past decisions. The management

coefficient model is used to generate a set of equations that represents the historical patterns of a company's aggregate planning decisions. Heuristic models are easy to construct if the relevant historical data is available. But they should be applied after careful consideration, as past pattern may not always be an accurate indicator of future trends.

21.6.3 Computer Search Models

These models are used when an organization has a large quantity of information on different production variables. A computer program simulates conditions under all possible combinations of these variables and identifies the most cost-effective one that satisfies the production requirements.

Computer Simulation in Capacity Evaluation – Computer simulation is used for evaluating the performance of a specific plan based on real-world variables and situations.

Aggregate production planning by using linear programming

In this section, we consider an example to illustrate how we use linear programming to formulate the aggregate planning problem. For example, the demand of a company's product from the consumer is highly seasonal. The company can handle this seasonal demand by hiring some workforce during the peak season, subcontracting some activities, storing up inventories during the months when demand is low or building up backlog of orders (late delivery). To determine how to use these options through an aggregate planning, the company considers a planning horizon of 6 months. The company also specifies that the duration of each period within the planning horizon is one month. The company attempts to forecast the demand for each period (shown below).

Month	Demand Forecast
January	1600
February	3000
March	3200
April	3800
May	2200
June	2200

The company sells each of the products through retailers for $ 50. The starting inventory (at the stating of January) of 1000 products. The company has employee strength of 80. Total 25 working days in each month and each employee earns $4/regular hour. In each day, the regular work hour is eight and rest on overtime. The capacity of the production operation is determined primarily by the total labor

hours worked. Employee works more than 10 hours of overtime per month. The various costs are shown below.

Item	Cost
Material Cost	$15/unit
Inventory holding cost	$2/unit/month
Backlog cost	$5/unit/month
Hiring cost	$400/worker
Layoff cost	$500/worker
Labour hours required	4/unit
Overtime cost	$5/hour
Subcontracting cost	$30/unit

The optimal aggregate plan is to maximize the profit over the planning horizon. Here, we assume the company fulfills all the customer demand. So, the revenue earned over the planning horizon is fixed. As a result, minimizing the cost is as same as maximizing the profit.

Based on the above information, we are trying to formulate the linear programming model. The first step in developing the aggregate planning model is to identify the variables which we are trying to find out during the planning horizon. The variables are size of the workforce (W_t), employees hired at the beginning of the month (H_t), number of employee laid off at the beginning of the month (L_t), number of production units in each month (P_t), inventory at the end of month (I_t), stocked out units at the end of each month (S_t), Subcontracted units for each month (C_t) and the overtime hours in each month (O_t).

The objective function is to minimize the total cost during the planning horizon. The total cost has the following components: Regular-time labor cost, overtime cost, employee hiring cost, inventory holding cost, stock-out cost and material cost.

$$Z = \sum_{t=1}^{6} 640W_t + \sum_{t=1}^{6} 5O_t + \sum_{t=1}^{6} 400H_t + \sum_{t=1}^{6} 500L_t + \sum_{t=1}^{6} 2I_t + \sum_{t=1}^{6} 5S_t + \sum_{t=1}^{6} 15P_t + \sum_{t=1}^{6} 30C_t$$

In the above objective function, the first term is related to regular time labor cost per month followed by overtime labor cost per month, cost of hiring and layoff of employee per month, cost of holding and stockout cost, and cost of material and subcontracting.

The decision variables must follow some constraints. They are as follows:

a. The first constraint is related to the workforce size W_t in the period t. The workforce size W_t in a period t depends on number of workers hired in the beginning of period t, the number of workers laid off in period t, and the number of workers in the previous period.

$$W_t = W_{t-1} + H_t - L_t \; \forall \; t = 1,2,..,6$$

b. The second constraint represents the capacity. In each period, the amount produced cannot exceed the current capacity. Each worker can produce 40 units per month on regular time and one unit for every four hours of overtime.

$$P_t \leq 40W_t + \frac{O_t}{4}$$

c. The third constraint is related to inventory. Net demand for period t is equal to the sum of the current demand D_t and the backlog in the previous period. The demand is either fulfilled from current production (in-house or subcontracted) and previous inventory.

$$I_{t-1} + P_t + C_t = D_t + S_{t-1} + I_t - S_t$$

d. The fourth constraint requires no employee can work more than 10 hours of overtime per month.

$$O_t \leq 10W_t$$

All the variables are non-negative. After formulating the aggregate planning problem by using linear programming, we can use EXCEL to solve it and find the values of the decision variables.

Check Your Progress - 3

6. Which of the following is **not** an aggregate planning technique?
   a. Time series analysis
   b. Graphical method
   c. Linear programming
   d. Heuristic methods
7. Which model is based on historical aggregate planning data available with an organization?
   a. Heuristic approach
   b. Computer search
   c. Linear decision rules
   d. Linear programming
8. What is the basic use of the computer simulation method, a type of optimal model used in aggregate planning?
   a. To develop a master production schedule
   b. To identify variables for developing the plan
   c. To evaluate the performance of a specific plan
   d. All of the above

21.7 Master Production Schedule

A Master Production Schedule (MPS) is a detailed plan that states the exact timing for the production of each unit and is also used in scheduling various stages of production, depending on the type of operations. It defines the type and volume of each product that is to be produced within the planning horizon. Following are the functions of an MPS:

Translate aggregate plans: A master schedule is a manufacturing plan, which breaks up the firm's planned total production into groups of products or product lots.

Evaluate alternative schedules*:* To evaluate alternative schedules, planners use computerized production and inventory control systems with simulation capabilities.

Identify material requirement: The master schedule when drawn up, alerts the materials requirement planning system to produce or purchase the components that are needed to meet the requirements of the final assembly schedules.

Generate capacity requirements: The master schedule reflects the most economical usage of labor and equipment capacities.

Effectively utilize capacity: The MPS assigns loads for labor and equipment based on the requirements.

21.7.1 Master Production Scheduling

The master production scheduling process involves planning activities of Material Requirements Planning (MRP) and Capacity Requirements Planning (CRP) to determine whether or not an operation can achieve the production objectives mentioned in the MPS. Following are the steps involved in the process:

- Determining the gross requirements of materials, components, and sub-components (total demand in units of the end-product) for each product in the product line, using MRP.
- Obtaining the net requirements for each unit of materials, components, and sub-components, after considering inventory on hand and inventory on order.
- Revising the preliminary MPS to accommodate the inadequacy of materials in inventory, if any.
- Converting adjusted net requirements into planned order releases (the order quantity for a specific time period) to determine unit or lot-sized production during the planning horizon.
- Developing load reports from the planned order releases.
- The MPS is modified or capacity is added in case of a mismatch between available and required capacities.

Master production scheduling is generally based on the demand forecast results. These results are not always accurate and the actual production output is not always similar to the actual market demand.

21.7.2 Master Schedule Formation

The MPS is based on an estimation of overall demand for the end product. A final assembly schedule is developed only when customer orders are received. It has to be properly implemented for achieving the goals set in aggregate plans. Both the aggregate plan and the MPS are influenced by the market environment and resource availability. Forecasts and customer orders influence the MPS.

Make-to-stock items – Demand forecast is the major input for these items in the MPS. Requirements are based on the need to replenish plant or distributor inventories of end products or service parts. The MPS is generated after considering the end item level.

Make-to-order items – Detailed scheduling of time and materials required is essential for these items as the items and quantities specified are unique for a particular customer order. In this environment, there is no finished goods inventory, customer orders are backlogged, and production begins only after the orders have been placed. For e.g., jet engines. Thus, back orders are common for such items.

Example: Forecasted demand for telephone handsets for the next six weeks is 40, 35, 48, 42, 42, and 40. The number of orders booked at the start of the MPS planning period is 33, 40, 34, 32, 48, and 32. Inventory on hand is 50, lead time is 1 week, production lot size is 90 units, and quantity on hand is 50. Prepare an MPS schedule for the telephone set manufacturer.

Solution: Refer Table 7.3 for the MPS for six weeks.

a) First Week

Forecast for the first week is 40 units. This requirement can be satisfied by using on hand inventory.

Projected inventory on hand at the end of first week = On hand inventory + MPS quantity – Projected requirements for the week = 50 + 0 – 40 = 10 units

b) Second Week

Forecast for the second week is 35 units but the orders received are for 40 units. Inventory on hand at the end of the first week is 10 units, which is not sufficient to satisfy the second week's requirements. So to make up for the deficiency, the organization schedules the MPS quantities. As the lead time is one week, the production should commence in the first week itself to satisfy the requirements of the second week. From Table 7.3, it is seen that the MPS start quantity for the first week is 90 units (production lot size).

Projected inventory on hand at the end of second week = On hand inventory + MPS quantity - Projected requirements for the week = 10 + 90 – 40 = 60 units

Similarly, projected inventory at the end of each week and MPS quantities can be calculated.

Table 21.3: MPS for Six Weeks

	1	2	3	4	5	6
Forecast	40	35	48	42	42	40
Orders	33	40	34	32	48	32
Projected on hand inventory	10	60	12	60	12	62
MPS quantity	0	90	0	90	0	90
MPS start	90	-	90	-	90	-

Activity: The forecasted demand for mobile handsets for the next six weeks is 50, 55, 58, 52, 52, and 50. And the number of orders booked at the start of the MPS planning period is 43, 40, 44, 42, 48, and 42. Prepare an MPS schedule for the mobile handset manufacturer.

Given,

Inventory on hand = 60

Lead time = 1 week

Production lot size = 80 units

Quantity on hand = 60

Answer:

There are numerous production schedule software available for the organizations. Exhibit 21.1 indicates some of them which are popular in 2021.

Exhibit 21.1: Production Scheduling Software, 2021 Shortlist

This exhibit discusses most used production scheduling software tools

Infor Cloud ERP:	Infor enterprise resource planning (ERP) solutions address both enterprise-level and small and medium-sized businesses (SMBs). Infor delivers robust ERP systems such as Infor Infor LN, Infor M3, Infor CloudSuite Financials and Infor CloudSuite Industrial (SyteLine).

NetSuite:	Planning and Scheduling, though are used together, the relationship and interaction between them is critical to the success of the business. NetSuite functionality includes: material purchases, positioning inventory, schedule employees, machines and work centres in production focusing on on-time delivery an achievable priority.
VisiLean:	Visilean organizes scheduling tasks across multiple teams. Facilitates review in real-time for delayed/stopped tasks, and percent planned complete (PPC) tasks, with emphasis on identifying the reasons for any variance. It facilitates planning workflow by the teams or the locations, or both. Every team or worker gets to visualize their tasks.
monday.com:	From ideation to execution, it helps teams to schedule productions with real-time tracking on an infinitely customizable platform.
JobBOSS:	Helps job shops and manufacturers of all kinds to work smarter for improved efficiencies, greater flexibility, and bigger profits.
Odoo:	An open-source suite of integrated apps to manage CRM, PoS, Website, eCommerce, Sales, Accounting, Warehouse, HR, Marketing, and more.
DELMIAworks:	Reliable, real-time extended ERP software with lean and agile functionality focusing more on mid-market manufacturing companies

Source: https://www.capterra.com/production-scheduling-software/

Check Your Progress - 4

9. _____ translates the aggregate plan into a detailed plan that specifies the exact timing for production of each unit.
   a. Master production schedule
   b. Total production schedule
   c. Primary production schedule
   d. Alternative production schedule

10. A Master Production Schedule (MPS) is based on which of the following?
    a. Amount of inventory needed for the end product
    b. Estimation of overall demand for the end product
    c. Confirmed customer orders for the end product
    d. All of the above
11. The two major sources of inputs that influence master production schedule are forecasts and customer orders. Identify the correct combination from the following.
    i. Make-to-stock environment: Takes inputs from forecasts in deciding the MPS
    ii. Make-to-order environment: Takes inputs from customer demand in deciding the MPS
    iii. Make-to-stock environment: Takes inputs from customer demand in deciding the MPS
    iv. Make-to-order environment: Takes inputs from forecasts in deciding the MPS
    a. Only iii
    b. Only i
    c. Both iii & iv
    d. Both i & ii
12. Identify the **false** statement from the following about Master Production Schedule and Master Schedule Formation.
    a. MPS of make-to-order organizations deals only with final products.
    b. MPS for assemble-to-order organizations concentrates on scheduling major components assembled to make a product after orders are received.
    c. Back orders are common in make-to-stock organizations.
    d. There is no finished goods inventory in make-to-order production.

Exercises

(Questions E & F)

The demand forecast for metal rollers used in manufacturing printing machines for the next three months is 60, 55, 65. The number of orders booked at the start of the MPS planning period is 55, 60, 65 respectively. Given, Inventory on hand = 75, Lead time = 1 month, Production lot size = 100 units. Answer the following **two** questions.

E. What is the projected inventory at the end of the second month?

F. What would be the projected inventory at the end of the third month if orders for the month increase to 80 from 65?

21.8 Implementing Aggregate Plans and Master Schedules

Unplanned Events – The effects of unplanned events are contained by continuously updating the aggregate plans. Due to unexpected events, the actual demand for a product would significantly differ from the forecasted demand. While developing aggregate plans, unexpected events which disrupt the plans like not achieving the planned output for the month or the workforce not being able to produce at its average capacity should be considered. In such case, the actual demand is taken as the input rather than the forecasted demand.

Behavioral Considerations – These are vital for planning and implementing aggregate plans. Intricacies in planning are dependent on the time horizon. A plan which is short term and based on judgment and experience would be costly while a drawing up a long-term plan would be a difficult task. Therefore, an optimal time period should be selected for aggregate planning. The implementation of an aggregate plan has an impact on all the functions and departments of an organization.

21.9 Capacity Planning

In general business point of view, capacity is defined as the amount of output that a firm can achieve over a time period. In service, capacity may be defined as how many customers are being served in a particular time window, whereas in manufacturing capacity is defined as number produced in a single shift. Operations managers consider both resource inputs and product outputs to define the capacity. Many industries measure and report capacity in terms of the output, whereas some measure in terms of input such as hospital capacity is expressed in terms of available number of beds.

Capacity is the maximum output that can be produced in a given system. If a factory has a production capacity of 100 units per hour, it means that it can produce 100 units per hour under optimal conditions. It most cases it is not possible to have 100% capacity utilization. Capacity is measured in terms of output, such as units per unit of time (10 units/hour) or available resource hours (5 machine hours/day).

Capacity planning is generally viewed in terms of time horizon. There are three different ways to represent the time dimension of capacity planning such as long range, intermediate range, and short range.

a. **Long range capacity planning:** The time horizon is more than a year. In long term planning, resources take long time to acquire or dispose of. Also, in long term capacity planning requires involvement of top management.

b. **Intermediate capacity planning:** In this case, the time horizon is monthly or quarterly plan for the next 3 to 18 months. Capacity may vary due to hiring or layoffs, new tool, subcontracting.

c. **Short range Capacity planning:** The time horizon is less than one month. This is related to daily or weekly scheduling process and involves making adjustments to eliminate the gap between actual and planned.

Capacity planning involves identification and evaluation of the long term and short-term capacity requirements of an organization, and development of plans to fulfill them. It involves determining adequate production capacity to meet forecast demand levels and determining whether or not sub-contracting and/or overtime has to be used. Overestimation or underestimation of capacity requirements has an adverse impact on an organization's performance. For an effective capacity plan, an organization has to first identify current capacity and forecast the future requirements of the capacity; then identify and evaluate the sources which can be used to meet the capacity requirements; and finally select the most proper alternative.

21.9.1 Measuring Capacity

Capacity of a manufacturing plant is usually measured in terms of input or output of the plant. For instance, the capacity of a cement plant can be measured in terms of millions metric tons of cement produced per annum. In contrast, the capacity of milk processing plant is measured in terms of litres of milk that can be processed per day. In service organizations like hospitals, the capacity can be measured in terms of number of beds available, or number of tables available in a restaurant, etc. Capacity can be measured by using the formula:

Capacity = Available time x utilization x efficiency

Capacity utilization rate is a measure that indicates the capacity level at the production process is operating.

$$\text{Hence, Capacity utilization rate} = \frac{\text{Capacity used}}{\text{Capacity avaialable}} \times 100$$

where, capacity available indicates the designed capacity.

The steps for determining capacity requirements are as follows:

1. Employ forecasting methods and find the individual product demand within the planning horizon.
2. Identify the equipment and human resource requirements to meet the forecasted demand. In case of multiple products or services, identify the time required for switching from one product or service to another.
3. Compare capacity required with available capacity for the required time period and identify the gaps.
4. As determining exact capacity requirements is difficult, organizations in general allocate extra capacity to meet any contingencies in the future. The extra capacity allocated for uncertain future requirements is known as the capacity cushion.

21.9.2 Economies of Scale

As the quantity of output increases, the average cost per unit decreases. This is termed as economies of scale. That is the per unit cost decreases with the increase in the scale of production. This happens due to reduction in fixed costs, adoption of efficient processes and automation technologies. But, as the scale of production is further expanded beyond a point, the cost per unit takes the reverse direction and would increase gradually. This reverse phenomenon is termed as diseconomies of scale. This can be attributed to complexities in operations, high costs of modification, need to replace existing facilities, and increased distribution and storage costs.

Check Your Progress - 5

13. Identify the correct sequence of steps associated with capacity planning.
    i. Identify current capacity
    ii. Forecast future capacity
    iii. Identify and evaluate sources to meet capacity requirements
    iv. Select the most appropriate alternative
    a. i, ii, iii, iv
    b. i, iii, ii, iv
    c. iii, i, ii, iv
    d. iii, ii, i, iv
14. When the scale of production is increased after a certain point, economies of scale can become diseconomies of scale. What can be the possible reasons for diseconomies of scale?
    a. Complexities in operations
    b. High cost of modification & replacement
    c. Distribution and storage costs
    d. All of the above
15. The capacity utilization rate measures capacity level at which a production process is operating. Identify the correct formula for capacity utilization rate.
    a. Capacity utilization rate $= \frac{\text{Capacity available}}{\text{Capacity used}} \times 100$
    b. Capacity utilization rate $= \frac{\text{Capacity used}}{\text{Capacity available}} \times 100$
    c. Capacity utilization rate $= \frac{\text{Available time} \times \text{Utilization}}{\text{Capacity available}} \times 100$
    d. Capacity utilization rate $= \frac{\text{Capacity available}}{\text{Available time} \times \text{Utilization}} \times 100$

16. Which of the following **cannot** be a reason for decrease in per unit cost when volume of production increases?
    a. Decrease in fixed costs
    b. Adoption of efficient processes
    c. Adoption of automation
    d. Increased complexity in operations
17. It is important to determine adequate production capacity to meet forecast demand levels and to determine whether or not sub-contracting and/or overtime has to be used. This activity is associated with which of the following?
    a. Capacity planning
    b. Aggregate planning
    c. Scheduling
    d. Demand forecasting

21.10 Summary

- An aggregate plan defines a company's production rates, workforce levels, and inventory position with respect to market demand and available capacity.
- Aggregate planning balances market demand and the production rate of the organization.
- Proper implementation of the aggregate plan enables an organization to use all its available resources to the fullest extent without overloading the production system.
- The success of an organization is to a large extent dependent on the way potentially productive resources such as equipment and people are utilized over a period of time.
- Aggregate plans can be developed using the graphical method, linear programming, linear decision rules (LDRs), and heuristic models and the computer search method.
- The master production scheduling process disaggregates the aggregate plans into individual products.
- Capacity planning is an important aspect of aggregate planning. Capacity defines the maximum output possible from a system or a process.
- Capacity is measured as the product of available time, efficiency and utilization.
- As the production output increases, the unit cost decreases which is known as economies of scale. A further increase of output beyond a certain point makes the unit cost of the product to increase again and this is termed as diseconomies of scale.

21.11 Glossary

- **Aggregate planning models**: These models such as the graphical, optimal, and heuristic models help planners formulate the aggregate output plan.
- **Back order strategy**: In this strategy, current order commitments are fulfilled in the future assuming that customers are ready to wait for delivery. **Capacity planning:** It involves identification and evaluation of the long term and short-term capacity requirements of an organization, and development **of plans to ful**fill them. It involves determining adequate production capacity to meet forecast demand levels and determining whether or not sub-contracting and/or overtime has to be used.
- **Capacity**: Maximum output that can be produced in a given system. It is measured in terms of output, such as units per unit of time (10 units/hour) or available resource hours (5 machine hours/day).
- **Computer search models**: These models are used when an organization has a large quantity of information on different production variables. **Computer simulation: I**t is used for evaluating the performance of a specific plan based on real-world variables and situations.
- **Graphical method for aggregate output planning**: It is a two-dimensional model linking cumulative demand to cumulative output capacity.
- **Heuristic models**: These are based on the historical aggregate planning data available with organizations.
- **Linear decision rules**: These are a set of equations for calculating the optimal workforce, aggregate output rate, and inventory level for each period in the planning period.
- **Linear programming**: It is an optimal model used to formulate aggregate plans. It identifies the optimal plan for minimizing costs that specifies the number of units to be produced, the total number of shifts for which the plan should operate in the planning time horizon, and the amount of inventory that has to be carried in each time period.
- **Long-range planning**: It focuses on a time period of more than one year. Process planning and strategic capacity planning are examples of long-range planning.
- **Master production schedule**: It is a detailed plan that states the exact timing for the production of each unit and is also used in scheduling various stages of production, depending on the type of operations. It defines the type and volume of each product that is to be produced within the planning horizon.
- **Medium-range planning**: It focuses on a time period of 6-18 months. Aggregate planning, master production scheduling, and materials requirement planning are examples of medium-range planning.

- **Operations plan (or production plan)**: A part of the business plan that defines how an organization plans to produce products or services and estimates the cost of production.
- **Pure planning strategies**: The production uncertainties and demand fluctuations can be managed effectively by varying the size and utilization of the workforce, and the size of inventory, through back orders and subcontracts, and by varying plant capacity. The strategy is called a pure strategy if only one of these strategies is adopted.
- **Short-range planning**: It focuses on a time period of less than 6 months. Order and workforce scheduling are examples of such planning.
- **Subcontracting strategy**: It allows level production and sources the additional output required form subcontracts.

21.12 Self-Assessment Exercises

1. Planning acts as a basis on which organizations can plan their future course of action. Give an overview of planning activities.
2. The aggregate planning process is complex due to the number of variables that must be considered in the planning process. Explain the aggregate planning process in detail.
3. An aggregate plan is developed after considering the different variables which influence the production plan. What are the different strategies used for developing aggregate plans?
4. Aggregate planning models help planners formulate the aggregate output plan. Explain the various techniques used for aggregate planning.
5. A Master Production Schedule (MPS) is a detailed plan that states the exact timing for the production of each unit and is also used in scheduling various stages of production, depending on the type of operations. Explain in detail. Also explain the functions of MPS.
6. The master production scheduling process involves the planning activities of MRP and CRP to determine whether or not an operation can achieve the production objectives mentioned in the MPS. Explain the various steps involved in the master production scheduling process. How can an organization prepare master schedules?
7. Explain the following:
    - Implementation of aggregate plans and master schedules.
    - Capacity planning is vital for determining adequate production capacity to meet forecast demand levels.
    - Economies and diseconomies of scale.

21.13 Suggested Readings/Reference Material

1. Dr. S. Ramachandran, Vijayalakshmi ,D. Jagadhish, Material Handling and Facilities Planning- Ktu Paperback, Irwalk Publications January 2019
2. Prasanna Chandra, Projects: Planning, Analysis, Selection, Financing, Implementation and Review, McGraw-Hill; Ninth edition, 15 May 2019
3. Erik Larson , Clifford Gray , Project Management: The Managerial Process | 6th Edition , McGraw Hill Education; Sixth edition, 1 July 2017
4. The Art of Service - Inventory Control Publishing, Inventory Control A Complete Guide - 2021, The Art of Service - Inventory Control Publishing, November 4, 2020
5. P. Gopalakrishnan, Purchasing and Materials Management, McGraw Hill Education; 1 July 2017

21.14 Answers to Check Your Progress Questions

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

1. (b) Medium range

Medium-range planning focuses on a period of six to 18 months. Examples of medium range planning are aggregate planning, master production scheduling and materials requirement planning.

2. (d) Customers

A production plan contains information about the production process, manufacturing facilities, inventory requirements, suppliers, etc. Such a plan is usually made based on sales estimates.

3. (a) Long range planning

Long-range planning focuses on a period of over one year and is generally carried out annually. Process planning and strategic capacity planning are examples of long-range planning. Medium-range planning focuses on a period of six to 18 months. Examples of medium range planning are aggregate planning, master production scheduling and materials requirement planning. Short-range planning focuses on a period less than six months. Order and workforce scheduling are examples of such planning.

4. (d) Varying the compensation method

Strategies for aggregate planning include varying utilization of the workforce, varying workforce size in response to output requirements, varying size of inventory, back orders, sub-contracting and plant capacity. Varying the compensation method is part of human resource management function.

5. (b) Maintaining fixed plant capacity

Varying workforce utilization is a strategy where the firm maintains a stable workforce and varies workforce utilization in accordance with demand or required output. Other pure planning strategies are back-orders, sub-contracting and varying plant capacity. Adjusting or varying plant capacity by changing equipment capacity over short-term or long-term is a pure strategy to absorb demand fluctuations.

6. (a) Time series analysis

Time series analysis is not an aggregate planning technique. It is associated with forecasting.

7. (a) Heuristic approach

Heuristic models are based on historical aggregate planning data available with organizations.

8. (c) To evaluate the performance of a specific plan

Computer simulation is used to evaluate the performance of a specific plan, based on real-world variables and situations. Simulation provides what-if analysis of different situations, using different variables with alternative values attached, to judge the system performance under different conditions.

9. (a) Master production schedule

Master production schedule translates the aggregate plan into production schedules. The Master Production Schedule (MPS) defines the type and volume of each product to be produced within the planning horizon. The MPS is a detailed plan that specifies the exact timing for production of each unit.

10. (b) Estimation of overall demand for the end product

MPS is based on an estimation of overall demand for the end product. A final assembly schedule is developed only when customer orders are received.

11. (d) Both i & ii

The two major sources of inputs that influence the MPS are forecasts and customer orders. Make-to-stock environment takes inputs from forecasts in deciding the MPS. On the other hand, make-to-order environment takes inputs from customer demand and generates an MPS based on that.

12. (c) Back orders are common in make-to-stock organizations

Back orders are common in make-to-order (not make-to-stock) organizations. This is because actual production does not begin until customer orders are placed.

13. (a) i, ii, iii, iv

The correct sequence of activities in a capacity plan is to identify current capacity, forecast future capacity, identify and evaluate sources to meet capacity requirements and select the most appropriate alternative.

14. (d) All of the above

All the stated options can be reasons for diseconomies of scale. Complexities in operations can lead to high cost due to production bottlenecks. When modifications in machinery or replacements take place frequently, it may prove costly. Further, when scale of production increases, distribution and storage costs also increase.

15. (b) Capital utilization rate = $\frac{\text{Capacity used}}{\text{Capacity available}} \times 100$

Capacity utilization rate measures the rate at which available capacity is used in production. It is obtained by dividing used capacity by available capacity. To measure in terms of percentage, multiply the obtained value with 100.

16. (d) Increased complexity in operations

The complexity in operations can lead to diseconomies of scale or increase in per unit cost. Efficient processes decrease fixed costs, while automation reduces per unit cost considerably.

17. (a) Capacity planning

Capacity planning is important to determine adequate production capacity to meet forecast demand levels. Capacity planning is also used by organizations when deciding on issues like whether or not to use sub-contracting or overtime to achieve production goals.

Unit 22

Fundamentals of Inventory Control

Structure

22.1 Introduction

In the previous unit, we have discussed the concept of capacity planning. We have learnt that capacity planning is a vital aspect of aggregate planning. In this unit, we will discuss inventory control.

Inventory is a stock of goods held by a firm at a particular time for future use in the production process or for meeting future demands. Effective inventory management and control help in reducing inventory costs without compromising on the firm's ability to meet customer demand on time. These involve ordering the right quantity at the right time without disrupting the production process. Inventories can be direct or indirect. Direct inventories such as raw materials, work-in-progress goods, etc., play a vital role in the production process and form a part of the finished product. Indirect inventories are items that are necessary to run the production process but do not become part of the end product. Examples are lubricants, grease, oils, stationery, etc. Raw materials are the items to be used in the production process. Work-in-progress goods are semi-finished goods that are stored temporarily during the production process. Finished goods are items stored for delivery to the end consumer. Inventory also includes machinery, furniture, components, etc. Organizations should carefully decide on the level of inventory they need to maintain. Stocking large inventory leads to high inventory costs and stocking too little leads to disruptions in the production process.

This unit will discuss the purpose of inventories. We will discuss inventory costs and systems. We shall then move on to discuss economic order quantity model. Finally, we would discuss inventory classification models.

22.2 Objectives

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

- Explain the purpose of inventories.
- Analyze inventory costs and inventory systems.
- Discuss the economic order quantity model.
- Identify the various inventory classification models.

22.3 Purpose of Inventories

Firms maintain inventory at various stages of the production process. The following are the benefits of maintaining an inventory:

- **Smooth Production –** In certain cases, the demand for the item fluctuates widely, but the production capacity of the firm remains fixed. For example, the demand for air conditioners is high during summer and it is difficult for an organization to manufacture the required quantity at that time. In such cases, the organization maintains a constant production rate and a finished goods inventory. This inventory helps in meeting the high demand during the period of deficiency in manufacturing capacity.
- **Better Service to Customers –** By maintaining an inventory, firms can provide quicker and better service to their customers. A finished goods inventory helps firms to continuously supply finished goods to their customers even at times when there is a temporary stoppage of production or a sudden rise in demand. A machinery spare parts inventory allows firms to repair facilities in case of a machine breakdown.
- **Protection against Business Uncertainties –** Firms maintain an inventory to operate in an uncertain environment. By maintaining inventories, they can take advantage of the speculative and unexpected opportunities in the market. For example, by maintaining an inventory of finished goods, the firm can meet any unexpected rise in demand. By maintaining a raw materials inventory, the firms can tide over an expected increase in prices or an anticipated scarcity in the future.
- **To take Advantage of Quantity Discounts –** A firm incurs ordering costs each time it places an order. Therefore, firms try to order a larger quantity than needed so as to minimize ordering costs. Large orders also attract bigger quantity discounts from the suppliers, thereby reducing the per unit cost.

Check Your Progress - 1

1. Semi-finished items stored temporarily and used to finish production are termed _____.
   a. Raw material inventory
   b. Work-in-progress inventory
   c. Finished products inventory
   d. None of the above
2. Manufacturers maintain an inventory of _____to meet unprecedented increase in demand.
   a. Raw materials
   b. Work-in-progress
   c. Finished products
   d. None of the above
3. From the following, identify the benefits of maintaining an inventory.
   i. To meet high demand during the period of deficiency in manufacturing capacity
   ii. To provide quicker and better service to their customers
   iii. To operate in an uncertain environment to take advantage of the speculative and unexpected opportunities in the market
   iv. To attract bigger quantity discounts from the suppliers
   a. i, ii, and iii
   b. i, iii, and iv
   c. ii, iii, and iv
   d. i, ii, iii, and iv

22.4 Inventory Costs

The operations managers decide on the order quantity (quantity to be ordered) and the inventory levels to be maintained after considering the following costs:

Purchase Costs: The cost of purchasing a unit of item is called its purchase cost. The purchase cost of an item is 'nx', where 'x' is the unit price of the item and 'n' is the number of items that the firm wants to purchase. Suppliers provide discounts based on the purchase costs.

Carrying Costs: Carrying costs (or holding costs or storage costs) are incurred on inventories stored in warehouses or stores. Carrying costs include opportunity costs, storage costs, staffing costs, equipment maintenance costs, insurance costs, and interest charges for financing the inventories, taxes, security, and other expenses associated with holding materials in stores. They also include loss of

inventory due to pilferage, spoilage, or breakage in stores, and the cost of obsolescence. These costs are expressed as a percentage of the material cost (generally between 25-35%) or as the actual amount incurred on storage of inventory in a warehouse for a year.

Ordering Costs: Ordering costs are those costs incurred each time an order is placed with the supplier. These costs are considered fixed and so decrease with increase in order size. Costs associated with preparing the purchase order, postage, telephone calls to the vendors, set-up costs if produced in-house, record-keeping and accounting costs, and material-receiving costs come under ordering costs. These costs are also known as acquisition costs

Stock-out Costs: Stock-out costs or shortage costs are penalty costs associated with delays in meeting demand or stoppage in production due to shortage of stock. These costs include loss of sales to the company caused by shortage of stocks and are avoided by holding inventory. Shortage of stocks lead to loss of customer goodwill, thus, leading to the loss of future sales as customers could shift to competitor's products due to the company failing to meet their demand.

Activity: Shakthi India Pvt. Ltd is an Indian company engaged in textile manufacturing. Realizing that it was incurring huge costs relating to inventories, the company's management has asked the purchase department to find ways to reduce the inventory costs. The purchase manager, after going through the inventory details has found that the inventory carrying costs and the stock-out costs are huge. The purchase manager has therefore to decide on ways to reduce these costs. Suggest how the purchase manager can reduce these costs. Do you think that the company is facing problems regarding shortage of inventory at the time of production? Suggest ways in which the company can solve these issues.

Answer:

Check Your Progress - 2

4. Carrying costs represent cost incurred while inventories are stored in warehouses or stores. Which of the following is **not** associated with carrying costs?
   a. Insurance costs
   b. Maintenance costs
   c. Cost of obsolescence
   d. Material receiving costs

5. Opportunity cost is associated with which basic category of inventory cost?
   a. Carrying costs
   b. Ordering costs
   c. Purchase costs
   d. Stock-out costs
6. Which of the following costs are considered by a firm as part of calculating inventory costs?
   i. Holding costs
   ii. Acquisition costs
   iii. Ordering costs
   iv. Stock out costs
   a. i, ii and iii
   b. ii, iii and iv
   c. i, iii and iv
   d. i, ii, iii, iv
7. _____ are penalty costs associated with delays in meeting demand or stoppage in production due to shortage of stock.
   a. Carrying costs
   b. Ordering costs
   c. Stock-out costs
   d. Purchase costs
8. A firm decides on quantity of material ordered to maintain various inventory costs. Which of the following costs **does not** influence quantities ordered by the firm?
   a. Purchase cost
   b. Carrying cost
   c. Ordering cost
   d. Hiring cost
9. Suppliers offer discounts to manufacturers based on which of the following type of costs?
   a. Purchase costs
   b. Carrying costs
   c. Ordering costs
   d. Stock-out costs
10. Which of the following does **not** come under carrying costs?
    a. Pilferage
    b. Spoilage
    c. Maintenance costs
    d. Material-receiving costs

11. Match the following inventory costs with their related descriptions.

    i. Purchasing costs
    ii. Carrying costs
    iii. Ordering costs
    iv Stock-out costs
    p. These costs arise when inventory is damaged
    q. Loss of customer goodwill is a consequence of these costs
    r. Discounts are given by suppliers on these costs
    s. These costs are fixed and come down with increase in size of purchase

    a. i/r, ii/q, iii/p, iv/s
    b. i/p, ii/q, iii/r, iv/s
    c. i/r, ii/p, iii/q, iv/s
    d. i/r, ii/p, iii/s, iv/q

22.5 Inventory Systems

The Inventory Cycle is a series of activities involved in maintaining adequate levels of inventory. These activities include ordering of inventory, and receiving, storing, and using them in the production process. Firms place orders on the basis of any of the following inventory systems: Fixed Order Quantity System or Fixed Order Period System. Operations managers face questions of when to order (time) and how much to order (quantity). The time at which the inventory is reordered is called the reorder point and the quantity of materials reordered is called the reorder quantity.

22.5.1 Fixed Order Quantity System (Q-System)

- In this system, the inventory is continuously checked and a new order is placed when the inventory level reaches a certain point called the reorder point. The system is also called the reorder point system. The order quantity (Q) is always constant and is determined by demand and cost factors.
- The assumptions made by this system are that the demand for inventories remains constant over a period of time and that the lead time (time lag between the point of order and receiving the material) for replenishment is zero. As time passes, the stock level gradually depletes and reaches the reorder point, R. The stock is replenished by ordering Q units at that point.
- Since the assumptions made by the system are not practically applicable, firms try to enhance the system applicability by using a more practical approach wherein the time between two successive orders is altered to facilitate the changes in demand.

- For example, assume that the order quantity is 50 units and the order period is 10 days in the fixed order quantity system. If the demand for the period becomes 100 units, then instead of changing the order quantity, the next order period is reduced to 5 days.
- The reorder point is determined by estimating the expected usage of inventory during the lead time plus the safety stock required. An order is placed as soon as the inventory level falls below the predetermined reorder level. (Reorder level is the quantity of inventory where a new order is placed for replenishment.)

22.5.2 Fixed Order Period System (P-System)

- In this system, the order period is fixed, but the order quantity differs with the requirement. The order quantity depends on the current inventory level and the future inventory requirements.
- The inventory level is measured during the review period and the order size is estimated based on the available and required inventory level.
- The costs involved in conducting constant reviews are saved as the system involves a periodic review of the inventory level. However, the system requires higher levels of safety stocks to meet sudden variations in demand.

Operations managers, in general, use a combination of these systems. For example, firms make use of reorder levels to estimate the order quantity (like in the fixed order quantity system) and do not order the same quantity of material every time (like in the fixed order period system). Decisions pertaining to the quantity of materials are taken based on various costs associated with the inventory.

Check Your Progress - 3

12. Which of the following terms refers to the time lag between the point of order and receiving the material?
    a. Lead-time
    b. Slack time
    c. Reorder time
    d. Order time
13. According to which inventory system inventory is continuously checked and a new order placed when the level of inventory reaches the reorder point?
    a. Q system
    b. P system
    c. EOQ system
    d. Fixed order period system

14. Which inventory model is also referred to as the reorder point system?
    a. P system
    b. Q system
    c. EOQ
    d. None of the above
15. The quantity at which an order is placed for inventory replenishment is _____.
    a. Safety stock
    b. Reorder level
    c. Buffer stock
    d. Cycle stock

22.6 Economic Order Quantity Model

The Economic Order Quantity (EOQ) model was developed in 1913 by F.W. Harris to determine the optimum order quantity that would minimize the total inventory cost. The following are the assumptions made by the model:

- The price of the inventory item (p) is independent of the order quantity. This means that the benefits of economies of scale are not taken into consideration while purchasing.
- The ordering cost (C_0) is fixed and is independent of the quantity ordered (Q).
- The total holding cost of inventories is proportional to the number of inventory items stored.
- The demand for a product or its usage rate is constant over time.
- Materials are always issued in equal quantities to the indenting departments and the inventory supply rate is always greater than or equal to the usage rate (i.e. there is no scope for shortage of inventory).
- The lead-time for material delivery is known with certainty and it remains constant.
- The quantity of inventory ordered is delivered in a single lot and there is no scope for splitting of deliveries.
- Stock-outs are not allowed. It implies that inventory is replenished just before the time when it becomes zero. Hence, the total cost of maintaining inventory can be assumed to have only three components: ordering costs, holding costs, and variable item costs.

22.6.1 Reorder Point

- The calculation of the reorder point should ensure that the inventory level reaches zero at the end of each reordering cycle as a positive inventory level at the end of the cycle would increase the average inventory and related costs.

- Therefore, the reorder level is equal to the number of units that are estimated as being used during the lead time. It is equal to the product of demand per unit time and lead time, where unit time and lead time are expressed in same units.

Reorder Point = d × LT, Where d = Average Daily Demand, LT = Lead time

22.6.2 Optimal Order Quantity

- The total cost of maintaining inventory (TC) includes ordering costs, holding costs, and variable item costs.
- Stock-out costs are not included while computing the EOQ as shortage of materials is not allowed.
- The ordering costs are equal to the fixed cost per order (C_o) times the number of orders placed per unit time as they are assumed to be independent of the order quantity.
- The number of orders placed per unit time is equal to the demand per unit time divided by the order quantity. Operations managers plan and procure materials to control inventory levels in order to minimize the related costs.

For example, if a firm uses 200,000 units per year and orders 40,000 units per order, then the number of orders placed per year is five.

Therefore,

ordering cost per unit time = $C_o\left[\frac{D}{Q}\right]$,

Where D = Demand per unit time, Q = Quantity ordered.

While the demand rate D is assumed to be constant, the average inventory level is equal to the arithmetic mean of the maximum and minimum inventory levels. The reorder point is set in such a way that the inventory level is zero when the inventory is replenished and the average inventory level is half the order quantity. The holding cost per unit time is the product of the holding cost per unit time (C_h) and the average inventory level.

i.e., holding cost per unit time = $C_h\left[\frac{Q}{2}\right]$, Variable item cost per unit time is equal to the cost per unit (C_p) times the quantity purchased per unit time, D.

Therefore, Total cost (TC) = $C_o\left(\frac{D}{Q}\right) + C_h\left(\frac{Q}{2}\right) + C_pD$

The total cost will be the least when the ordering cost is equal to the holding cost.

i.e, $\frac{C_oD}{Q} = \frac{C_hQ}{2}$

Solving the relation we get,

$$\frac{C_o D}{Q^2} = \frac{C_h}{2}$$

$$Q^2 = \frac{2C_o D}{C_h} \text{ Or, } Q = \sqrt{\frac{2C_o D}{C_h}} = EOQ$$

Example: Choco Ltd., a company that specializes in making different types of chocolates and chocolate cakes, uses 6000 tins of cocoa per year at a purchase price of Rs. 25 per tin. The cost associated with placing an order is Rs. 150 and carrying cost is Rs. 5 per unit; the lead time is 4 days. Based on the given information, calculate the EOQ and the reorder point.

Solution:

Given Annual Usage or Demand D = 6000 units

Unit Price = Rs. 25

Ordering cost per unit (C_o) = 150

Holding or Carrying cost (C_h) = Rs 5

Using the equation,

$$EOQ = \sqrt{\frac{2C_o D}{C_h}}$$

We get,

$$EOQ = \sqrt{\frac{2C_o D}{C_h}} = \sqrt{\frac{2 \times 150 \times 6000}{5}} = \sqrt{360000} = 600$$

Optimal Order Quantity = 600 units. At this quantity level, the firm will be able to minimize total cost i.e. the carrying and ordering cost.

Reorder point = Lead time × Demand per day

Assuming 275 working days annually,

Demand Per Day = Total Annual Demand /275

= 6000/275=21.82

We can round off demand per day to 22,

So the Reorder point = 22 × 4 = 88

Therefore, whenever the inventory level drops to 88, the firm should orders 600 more units.

Activity: ABC Ltd estimates that the demand for an item would be 200 units per month. The ordering cost is Rs. 500 per order and the carrying cost is 15% per unit cost of the item. The price of each individual item is Rs. 80. Assuming the lead time to be 5 days, calculate the EOQ and the reorder point.

Answer:

Check Your Progress - 4

16. On what basis do organizations fix reorder level for raw material under the EOQ model?
    a. Recommendations of finance managers
    b. Estimated demand during lead-time
    c. Recommendations of suppliers
    d. Estimated sales for a financial year
17. What does the EOQ inventory model primarily attempt to minimize?
    a. The number of items ordered
    b. The number of orders placed
    c. Total inventory costs
    d. The safety stock
18. Which of the following is **not** an assumption of the EOQ model?
    a. Demand for a product or its usage rate is constant over a period of time
    b. Supply rate is always greater than or equal to usage rate
    c. The lead-time for material delivery is known with certainty and it remains constant
    d. The purchase price per unit varies depending upon quantity ordered
19. Lead time is assumed to remain constant. This is a condition associated with which of the following inventory systems?
    a. Q-System
    b. P-System
    c. EOQ
    d. Fixed Order Quantity system
20. Which of the following costs are **not** considered part of EOQ?
    a. Purchasing costs
    b. Carrying costs
    c. Ordering costs
    d. Stock-out costs

21. Which of the following is the basic objective of economic order quantity purchasing?
    a. Minimizing total inventory cost
    b. Minimizing transport cost
    c. Minimizing storage cost
    d. Minimizing ordering costs

Exercises

A. Suppose a company consumes a particular product at an average of 50 units /week. It costs Rs.200 to order and Rs.0.50 per unit per week to hold the item in inventory. Compute the EOQ.

B. If the lead time for replenishing inventory in a production facility is 7 days and daily demand is 25 units, calculate the reorder point at which the firm should order inventory replenishment.

(Questions C to F)

A production facility uses a certain type of raw material in its production process for which details are given below. Annual Demand = 300000 units, Quantity per order = 75000 units, Fixed cost per order = Rs.2000, Holding cost per unit = Rs.5, Item cost per unit = Rs.10. Using the EOQ model, answer the following **four** questions.

C. Calculate total ordering costs incurred in a year.

D. Calculate holding costs per order.

E. Calculate total variable cost.

F. Calculate total cost of maintaining inventory.

22.7 Inventory Classification Models

Inventory classification models are used to classify and categorize inventory items. They help operations managers devise effective control plans. The following are the classification models that are discussed in this section.

22.7.1 ABC Classification

In "Always Better Control" (ABC) classification model, items are classified based on their consumption or usage value into A, B, C categories. Annual consumption or usage value is given by the following relationship - Annual usage value = (annual requirement) x (per unit cost)

- Category A includes those items with high proportion of investment (around 75% of inventory investment) and accounting for nearly 10% of the total inventory volume. Category A items need highest level of control.

- Category B items take up around 15% of the inventory investment and account for around 15% of the total inventory volume. They require comparatively lower levels of control.
- Category C items have the least investment and hence least importance. They account for around 75% of the total inventory volume.

22.7.2 VED Classification

Vital, Essential, Desirable (VED) classification is based on importance of an item in the production process.

- The most important items are termed as 'vital' and are classified as 'V'.
- Items which are important but not critical in the production process are classified as 'E'.
- The non important items in the inventory that does not affect the production process are classified as 'D'.

The level of control required is maximum for V items, and minimum for D items.

22.7.3 FSND Classification

This classification is based on the frequency of usage of items in the inventory.

- Some items have faster turnover than others. Such fast moving items are classified as 'F'.
- Slow moving items are classified as 'S'.
- 'N' stands for non-moving items and
- 'D' for dead items (items which have not been issued in recent years).

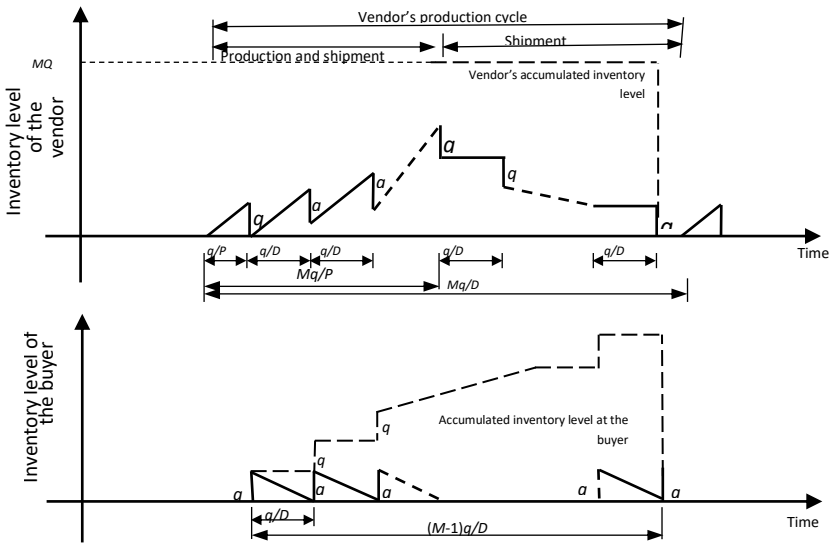
Calculation of inventory for a two-echelon supply chain

- In this chapter, we have already discussed about some classical inventory models. These models are mostly used to calculate inventory levels for single buyers. In this section we are going to calculate average inventory level of a two echelon vendor-buyer supply chain.
- In today's competitive business world the concept of standalone business houses are getting eroded in real sense. All the big business houses are parts of one or more supply chains. In general, a supply chain is a network of manufacturers, suppliers, transporters, warehouses, retailers and customers. It facilitates supply of goods at right place at right time at right price. Managing and calculating the inventory level across a supply chain is quite a big challenge for mangers. We have tried to explain how one can calculate the inventory level in a simple two echelon supply chain. This model is an extension of basic EOQ model. This type of model was first conceptualized by Joglekar (1989) considering infinite planning horizon. Later, many researchers considered similar models for their research works. A basic model with one buyer, one vendor, their activities, assumptions are discussed

in following paragraph and then the average inventory is calculated. Here we have elaborately shown the solution procedure.

- Description and Assumptions: Assume, there is a buyer and the average demand on the buyer is *D* per unit time. To satisfy the demand the buyer places orders on a vendor. Suppose, the buyer places orders of lot size *q*. That means whenever the buyer places an order, it asks vendor to send *q* quantity. After getting an order, the vendor starts production with a production rate *P*. The production rate *P* is constant, and always more than or equal to demand *D* (*P*≥*D*). Whenever the vendor receives an order of size *q*, it produces the *Mq* units in each production cycle of length *mq*/*D*; i.e. *T*= *mq*/*D*. The vendor sends the produced items to the buyer in *m* shipments of size *q*, where *m* is an integer variable. Initially, both the production and the shipments take place simultaneously for *Mq/P* units of time, then the vendor stops the production and only continues shipments until it's inventory level falls to zero. The buyer receives the goods in *m* lots each of lot size *q*. The first lot of size *q* is ready at the vendor for shipment after *q*/*P* units of time from the starting of the production, and then the vendor continues the delivery of subsequent lots after every *q*/*D* units of time. The inventory at the buyer reduces with a constant rate *D* per unit time. We, further assume that the demand is deterministic and constant, and there is no lead time. Figure 22.1 depicts the production, and inventory variation patterns at the vendor and the buyer, respectively.
- The maximum inventory level at the buyer in any order cycle *q*, and the minimum inventory level is 0. So the, average inventory level at the buyer is *q*/2. To calculate the average inventory level at the vendor we need to diagram 1. The average inventory level at the vendor per unit time can be calculated as following.(Fig 22..1)

Figure 22.1: Inventory pattern at the buyer and the vendor



The average inventory of vendor per unit time= (Total inventory at the vendor-Total inventory at the buyer)/ Production Cycle

$$=> \frac{\left[\left\{Mq\left(\frac{q}{P}+(M-1)\frac{q}{D}\right)-\frac{M^2q^2}{2P}\right\}-\left\{\frac{q^2}{D}\left(1+2+.....+(M-1)\right)\right\}\right]}{\frac{Mq}{D}}$$

$$=> \frac{\left[\left\{Mq\left(\frac{q}{P}+(M-1)\frac{q}{D}\right)-\frac{M^2q^2}{2P}\right\}-\left\{\frac{q^2}{D}\left(1+2+.....+(M-1)\right)\right\}\right]D}{Mq}$$

$$=> \left[\frac{Mq^2}{P}+\frac{M^2q^2}{D}-\frac{Mq^2}{D}-\frac{M^2q^2}{2P}-\frac{M^2q^2}{2D}-\frac{Mq^2}{2D}\right]\frac{D}{Mq}$$

$$=> \frac{qD}{P}+Mq-q-\frac{MqD}{2P}-\frac{Mq}{2}-\frac{q}{2}$$

$$=> \frac{Mq}{2}-\frac{MqD}{2P}+\frac{qD}{P}-q-\frac{q}{2}$$

$$=> \frac{q}{2}\left[M\left(1-\frac{D}{P}\right)-1+\frac{2D}{P}\right]$$

So, per unit time the average inventory level at the vendor $= \frac{q}{2}\left[M\left(1-\frac{D}{P}\right)-1+\frac{2D}{P}\right]$

The average inventory level per unit time in the supply chain=

Average inventory at the buyer+ Average inventory at the vendor

$$= \frac{q}{2}+\frac{q}{2}\left[M\left(1-\frac{D}{P}\right)-1+\frac{2D}{P}\right]$$

Inventory management is all about having the right items on hand at the right time to meet customer demand while controlling costs and minimizing waste and loss. Companies with best-in-class inventory management practices don't guess how much stock to buy, and they keep a steady flow of raw materials, work-in-progress items and finished goods moving from manufacturing to consumer, over a variety of distribution channels. Exhibit 22.1 discusses different inventory management trends in 2021

Exhibit 22.1: Top Inventory Management Trends to Know in 2021

We learn about some inventory management trends of 2021.

Top Inventory Management Trends

1. AGVs and AMRs:

- Automated guided vehicles (AGVs) and automated mobile robots (AMRs) are tools to help warehouse operators collect products from decks and pallets.

2. Artificial intelligence:

- Systems with artificial intelligence (AI) and machine learning (ML) capabilities work with those IIoT initiatives.
- Machine learning could be employed to spot out defective products or packaging so that customers only get quality items.

3. Cloud-based solutions:

- Cloud-based solutions allow company's data to be stored securely and centrally and accessed from anywhere, leading to quick solutions to inventory issues.
- Centralization enables a GPS location project to track on-the-move pallets, containers or delivery vehicles in real time to predict when items will arrive at their destinations.

4. Distributed inventory management:

- Distributing inventory across multiple warehouses can reduce transportation costs and speed up delivery times, by putting the right products in the right places to dispatch closest to the customer.

5. Predictive picking:

- Unstructured data is used to predict the behavior by recognizing interdependencies and patterns.
- Success depends on compiling data, such as planned marketing campaigns, weather and seasonality to predict customer orders with a high degree of accuracy.

6. Personalization:

- Companies can tap into personalization data, with a robust inventory management system, to boost sales.
- Sources of personalization data are: Demographic/persona data for individuals, Company data points, Behavioral data from website or a customer's order history, Contextual data.

7. Creative financing:

- For new manufacturers, using creative financing to pay for inventory delivers a competitive edge.
- Larger manufacturers might look beyond inventory loan, reduce invoice carrying costs.
- Companies with stock that's not moving may convert stale inventory to cash by offering discounts or by bundling items.

8. Automation:

- Warehouse automation is a focused on moving inventory into/ around /out of warehouses, with minimal human involvement.

- More advanced warehouse automation could use AI, cameras and sensors to help an AMR navigate a warehouse and compile an order without human help.

9 3PL:

- Third-party logistics, or 3PL, is where distribution and warehousing or other activity is outsourced to a third party.

10 Hybrid warehousing & shipping:

- Hybrid warehouse combines multiple activities like storage, picking, shipping, and
- Drop shipping, where a retailer never takes possession of stock but pays a manufacturer to send items direct to customers.

11 Omni-channel inventory control

- Align channels for customer to look online about the availability of an item in a nearby physical location
- Make the purchase to walk into the store to pick up the item. .

12. Blockchain

- A number of companies use blockchain for inventory management and control.
- The top industry using blockchain is life sciences and healthcare, from clinical trials to digitize health records.
- In the supply chain, Walmart and Nestle are among the food retailers that use the IBM Food Trust blockchain.

13. Reporting & analytics

- Use of real-time data analytics to make decisions, create a more customer-centric business model and minimize costs while boosting efficiency.
- Allows businesses to make better demand forecasts, move toward just-in-time inventory replenishment and get and provide near-real-time updates on where supplies or shipments are and when they'll arrive at their destinations.

https://www.netsuite.com/portal/resource/articles/inventory-management/inventory-management-trends.shtml April 2021

Check Your Progress - 5

22. In which of the following types of classification of inventory are items classified based on annual consumption value?
    a. ABC
    b. VED
    c. FSND
    d. Both b & c

23. Which of the following inventory classification models is based on importance of an item in the production process?
    a. ABC
    b. VED
    c. FSND
    d. None of the above
24. In the _____ inventory classification model, the classification is based on the frequency of usage of items in the inventory.
    a. ABC
    b. VED
    c. FSND
    d. None of the above
25. In the ABC inventory classification model, items are classified based on their consumption or usage value. In this, annual consumption or usage value is given by:
    a. Lead time × Demand per annum
    b. Annual requirement x Per unit cost
    c. Cost per annum x Quantity per annum
    d. None of the above

22.8 Summary

- Inventory is a stock of goods, commodities, or other resources held by a firm at a particular time for future use in the production process or for meeting future demands.
- Inventories can be direct or indirect.
- Effective inventory management and control help in reducing inventory costs without compromising on the firm's ability to meet customer demand on time.
- Firms maintain an inventory to ensure smooth production, to provide better service to customers, to take advantage of quantity discounts, and to operate during times of business uncertainty.
- Operations managers decide on the order quantity (quantity to be ordered) and the inventory levels to be maintained after considering the purchase costs, carrying costs, ordering costs, and stock-out costs.
- Orders can be placed by firms based on the fixed order quantity system or the fixed order period system.
- Operations Managers use the EOQ model to find out the optimal order quantity, which minimizes the inventory ordering and holding costs.
- Inventory classification models are used by operations managers for easy recognition and to provide effect control.

22.9 Glossary

ABC classification: In Always Better Control (ABC) classification model, items are classified based on their consumption or usage value into A, B, C categories.

Carrying cost (holding or storage cost): Cost incurred on inventories stored in warehouses or stores.

Direct inventories: These play a vital role in the production process and form a part of the finished product.

Economic order quantity: It is used to determine the optimum order quantity that would minimize the total inventory cost.

Finished goods: These are items stored for delivery to the end consumer.

Fixed order period system (P-System): The order period is fixed, but the order quantity differs with the requirement. The order quantity depends on the current inventory level and the future inventory requirements.

Fixed order quantity system (Q-System or reorder point system): Inventory is continuously checked and a new order is placed when the inventory level reaches a certain point called the reorder point.

FSND classification: This classification is based on the frequency of usage of items, whether they are fast moving, slow moving, non-moving, or dead, in the inventory.

Indirect inventories: These items are necessary to run the production process but do not become a part of the end product.

Inventory: A stock of goods held by a firm at a particular time for future use in the production process or for meeting future demands.

Ordering cost: Cost incurred each time an order is placed with the supplier.

Purchase cost: Cost of purchasing a unit of item.

Stock-out cost (shortage cost): Penalty costs associated with delays in meeting demand or stoppage in production due to shortage of stock.

VED classification: Vital, Essential, Desirable (VED) classification is based on importance of an item, whether they are vital, essential, or desirable in the production process.

Work-in-progress: These are semi-finished goods that are stored temporarily during the production process.

22.10 Self-Assessment Exercises

1. Firms maintain inventory at various stages of the production process. What are inventories? Mention the different types of inventories.
2. Effective inventory management and control help in reducing inventory costs without compromising on the firm's ability to meet customer demand on time. Explain the significance of maintaining inventory in an organization.

3. Operations managers decide on the order quantity (quantity to be ordered) and the inventory levels to be maintained after considering various costs. What are the different inventory costs and inventory systems? Explain briefly.
4. The Economic Order Quantity (EOQ) model is used to determine the optimum order quantity that would minimize the total cost. Explain the EOQ model in detail. How can one decide on the optimal quantity to be ordered based on this model? Explain with an example.
5. Explain the following:
   - VED classification
   - ABC classification
   - FSND classification

22.11 Suggested Readings/Reference Material

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22.12 Answers to Check Your Progress Questions

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

1. (b) Work-in-progress inventory

Work-in-progress goods are semi-finished items stored temporarily during the production process.

2. (c) Finished products

Firms maintain adequate levels of inventory to successfully operate in an uncertain environment. Inventories help firms take advantage of unexpected opportunities. For instance, a sudden and unexpected increase in demand can be met with larger finished goods inventory.

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

Firms maintain inventory at various stages of the production process. The following are the benefits of maintaining an inventory: to ensure smooth production, to provide better service to customers, to protect against business uncertainties, and to take advantage of quantity discounts.

4. (d) Material receiving costs

Carrying costs include opportunity costs besides storage costs, staffing costs, equipment and maintenance costs, insurance costs, loss of inventory due to pilferage, spoilage or breakage in warehouses and the cost of obsolescence.

5. (a) Carrying costs

Carrying costs include opportunity costs, storage costs, staffing costs, equipment and maintenance costs, insurance costs, interest charges for financing inventories, taxes, security and other expenses associated with holding materials in warehouses.

6. (d) i, ii, iii, iv

Acquisition (purchase) costs, holding costs, ordering costs and stock-out costs are considered in calculating inventory costs.

7. (c) Stock-out costs

Stock-out costs or shortage costs are penalty costs associated with delays in meeting demand or stoppage in production due to shortage of stock. These costs include loss of sales to the company caused by shortage of stocks and are avoided by holding inventory. Shortage of stocks lead to loss of customer goodwill, thus, leading to the loss of future sales as customers could shift to competitor's products due to the company failing to meet their demand.

8. (d) Hiring cost

Hiring costs are those incurred by an organization as part of recruitment. It is not a factor that influences the quantity of material ordered. Purchase, carrying, and ordering costs influence the quantity ordered.

9. (a) Purchase costs

The cost of purchasing a unit of a particular item is its purchase cost. Suppliers sometimes provide discounts to customers (manufacturers) based on purchase costs (quantity of purchase). Discounts are usually given while purchasing quantities in bulk.

10. (d) Material-receiving costs

While pilferage, spillage and maintenance costs come under carrying costs, material-receiving costs fall under ordering costs.

11. (d) i/r, ii/p, iii/s, iv/q

Discounts are given by suppliers on the basis of total cost of purchase when material is purchased in bulk. Damage to inventory either in the warehouse or in production facilities can increase carrying costs. Ordering costs are considered fixed and so decrease with increase in order size. Marketers may lose customer goodwill if they cannot supply goods on time due to non-availability of finished goods in the inventory.

12. (a) Lead-time

Lead time refers to the time between placing the order for the material and receiving it.

13. (a) Q system

Under the Q system (also called Fixed Order Quantity System), inventory is continuously checked and a new order is placed when the inventory level reaches the reorder point.

14. (b) Q system

In Q system, order quantity (Q) is always constant and the order is placed when the level of inventory reaches the reorder point. This system is also referred to as the reorder point system.

15. (b) Reorder level

Reorder level is the quantity of inventory where a new order is placed for replenishment. In the Q system, the reorder level is equal to quantity used in lead time plus safety stock. But in EOQ model, it is equal only to the quantity used in the lead time.

16. (b) Estimated demand during lead-time

The calculation of the reorder point should ensure that inventory level reaches zero at the end of each reordering cycle. This is because a positive inventory level at the end of the cycle raises average inventory and associated costs. To ensure this condition is satisfied, reorder level is set equal to the number of units estimated to be used during lead-time.

17. (c) Total inventory costs

EOQ model always aims to reduce total inventory costs, which include ordering costs, purchasing costs, carrying costs and stock-out costs.

18. (d) The purchase price per unit varies depending upon quantity ordered

One of the assumptions of the EOQ model is that purchase price per unit is fixed and is independent of order quantity. It means that benefits of economies of scale, if any, are not taken into consideration.

19. (c) EOQ

In the EOQ system, lead time is known and is assumed to remain constant.

20. (d) Stock-out costs

One of the assumptions of EOQ concept is that stock-outs are not allowed. It implies that inventory is replenished just before the time when it becomes zero. Hence, the total cost of maintaining inventory can be assumed to have only three components: ordering costs, holding costs and variable item costs.

21. (a) Minimizing total inventory cost

EOQ method is used to identify order quantity to minimize the total inventory cost.

22. (a) ABC

ABC is one of the most widely used inventory classification models. It is also known as 'Always Better Control' model. As per ABC classification, items are classified on the basis of their annual consumption value. Items with highest value are classified as A, next lower value items are classified as B and the lowest value items are classified as C.

23. (b) VED

Vital, Essential, Desirable (VED) classification is based on importance of an item in the production process. The most important items are termed as 'vital' and are classified as 'V'. Items which are important but not critical in the production process are classified as 'E', and the non important items in the inventory that does not affect the production process are classified as 'D'. The level of control required is maximum for V items, and minimum for D items.

24. (c) FSND

FSND inventory classification model is based on the frequency of usage of items in the inventory. Some items have faster turnover than others. Such fast moving items are classified as 'F' while slow moving items are classified as 'S'. 'N' stands for non-moving items and 'D' for dead items (items which have not been issued in recent years).

25. (b) Annual requirement x Per unit cost

In "Always Better Control" (ABC) classification model, items are classified based on their consumption or usage value into A, B, C categories. Annual consumption or usage value is given by the following relationship: Annual usage value = (annual requirement) x (per unit cost).

Unit 23

Purchase Management

Structure

23.1 Introduction

In the previous unit, we have discussed the inventory classification models. We have learnt that inventory classification models like ABC, VED, and FSND are used by operations managers for easy recognition and to provide effective control. In this unit, we will discuss purchase management.

Organizations purchase materials from external sources as they do not have the capability to manufacture them internally or because they are cheaper to purchase than to make. Until recently, the purchasing process involved placing an order with the supplier who offered materials at a low price. However, of late, the growing competition, market demand, and scarcity of resources have forced organizations to expand their purchasing function. Purchasing department ensures that the right materials, equipment, and services are procured in the right quantity, from the right source, at the right time, and at a competitive price. Factors like low price, high quality, and goods after-sales service are considered by the purchase department while buying material and supplies from a supplier.

This unit will give you the importance of purchasing, and explain the ways to organize the purchasing function. We will discuss the responsibilities of a purchase manager, and then study the purchasing process. We shall then move on to discuss the duties of buyers, and make-or-buy analysis. Finally, we would discuss the ethical issues involved in buying.

23.2 Objectives

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

- Recognize the importance of purchasing.
- Explain how to organize purchasing.
- Identify the responsibilities of a purchase manager.
- Discuss the purchasing process.
- State the duties of buyers.
- Analyze the make-or-buy decisions.
- Recall the importance of ethics in buying.

Method of Purchasing

Purchasing department is the internal department which provides all the production of goods and material that are required by a company. Any department can request for materials and goods. The request may be received for direct or indirect materials, seasonal items, production items and low price items. For procuring any materials, different kind method is required.

Contract purchasing

It is the process of buying items based on special contract which provides delivery of items over the time period of contract. Spriegal defined "Contract purchasing is the purchase made under contract, usually formal of needed materials, the delivery of which is frequently spread over a period of time". Material always purchased based on occasion with small quantities. The interval time between two consecutive receipts may be a week, or a month, or a quarter or any period based on value of requirement, how much distance covered and finally the mode of transport. Purchasing department has to create purchase requisition about material requirement based on contract. This method is most suitable for procuring materials on regular exercise. There are three different types of contract purchasing: rate, running and services.

Rate: the price is fixed but quantity is flexible.

Running: the price and quantity are fixed during contract period.

Service: service is required by buyer on period basis.

Merits

- The buyers will get benefit when fluctuations in the market.
- It helps to provide positive terms of contract with the suppliers.
- It reduces the risk of investment due to maintaining minimum safety stock.
- There is flexibility to pay payment to supplier such as credit based.

Hand to mouth purchasing

It is also known as Zero Stock Buying or buying according to the requirements. In this method, when demand arises then purchase requirement takes place based

on required quantity. It includes features such as when items are purchased then immediate requirement may be fulfilled, Item is purchased in small quantity but can be purchased in large quantity when it required, items are purchased based on demand and finally contract should be negotiated. This method is useful when the items are purchased from a vendor based on quality and reliability. The vendor can fulfil the buyer's request with any condition. It also matched for items such as no shelf life and requires more space for storage etc.

Merits

- Aid lower inventory investment
- Aid to reduce worsening and obsolescence of materials.
- Aid to reduce losses due to price declines
- Aid to low shipping charges

Demerits

- Higher accounting cost due to regular purchase
- Due to upward movement in price leads to possible losses
- Cost of material increase due to urgency

Scheduled Purchasing

It is the process of buying an item in staggered delivery according to the delivery schedule provided by buyer to supplier/seller. In this method, annual requirement comes from buyer side in form of purchase order. There is a mutual agreement between buyer and seller to complete the task within the specific time period such as confirmation and tentative schedule. Before the completion of previous schedule, fresh delivery schedules are provided to supplier. These fresh delivery schedules keep the confirmed schedules and tentative schedule for the next coming periods. This method is most suitable for regularly used items (eg. Lubricants, cutting tools etc.)

Merits

- This method helps both parties i.e. buyer and seller.
- Buyer gets security of supply of goods where seller gets security of business.
- Buyer can plan his requirements of finance where supplier may plan for different factor of production.
- Buyer and supplier save the time and money due to regular production and small inventories.

Market Purchasing

It is the process of procuring items in advance when the price of the items is low. Low price helps the organization to buy the items in large quantity because price can be negotiated. This purchase process takes place for a significant period because buyer gets discount on large purchase. This approach focuses on stable

and usual consumption items, seasonal items, non-perishable items and less susceptible items.

Merits

- Helps to get low price in the market.
- Helps to get more discounts due to large quantity.
- Profit may be more on finished goods
- Helps to save more purchasing expenses.
- Helps to get security that item is available within the firm.

Demerits

- Purchasing of items does not provide the needs of production department.
- Company may suffer losses if price expectations are not met.

Purchasing department has to take the responsibility to track the market condition (demand and supply). It also focuses on different factors for predicting the requirement and high inventory carrying cost.

Group Purchasing

Group purchasing refers to the process of buying of items of irrelevant value in a single purchase order. In this method, small quantity of item is required and these items are grouped together according to source of purchase. Example, hardware items in one group, nuts and bolts in another group etc. each classified group has fixed number of inventory levels and creates only one purchase order. On hand inventory (Safety stock) checks on regular basis and if any requirements then reorder level take place. The main benefit of this method is to save delivery cost because single order has multiple items.

Tender Purchasing

Tender purchasing is followed by government department and public sector (Municipalities) undertaking in India. If private sector organizations want to adopt tender buying process then they have to fulfill the condition (the value of the purchase exceeds the prescribed limits). Tender process of government and private sector is totally different. In this method, purchasing department invites application from the suppliers to create bidder's list. This bid can be quotation or tender which is written document offer from supplier to render. Different bids obtained from different suppliers are compared based on specific criteria to select the right supplier. The selection of bid focused on lowest price quotation from different suppliers. Using this method, firm can identify qualified supplier based on certain criteria and select the best supplier among them. The disadvantage of this method is time-consuming and expensive. Tender purchasing has four types:

Single: All requirements are communicated only to one or single firm. In this type, price is fixed and there is no competition.

Limited or closed: first, enquiry is sent to the limited or fixed number of suppliers based on bids received from supplier. Then firm selects the best supplier.

Open: firm requires information/enquiry using advertisement in print media or electronic media. Bids are received in open market so many firms can apply. It's very difficult to select the right tender.

Global: firm gets required information/enquiry using advertisement in print media or electronic media of not only in home country but also of the foreign country.

23.3 Importance of Purchasing

Purchasing refers to buying of a material or an item from a company or division that supplies materials. The purchase department has to purchase the right materials at low cost, develop a network of vendors, and provide the necessary information about the new products, materials, and services to other departments. A firm purchases an item only, when the cost of purchasing the item is less than the cost of making it, when it does not have the requisite manpower to make the item, when the expected returns on the investment in manufacturing the item in-house are not attractive and the demand for the item (to be manufactured) is seasonal and there is a risk in storing and maintaining it.

Management of purchasing activities is very important for a firm for the following reasons:

- As the costs of procuring raw materials have an impact on the profitability of the firm.
- Automated manufacturing facilities have resulted in low labor costs making the purchase department's role more significant.
- Competition globally has forced companies to globalize their purchasing activities.

23.4 Organizing Purchasing

Purchasing systems are of two types: Centralized purchasing systems and decentralized purchasing systems.

- In *centralized purchasing system,* all the purchasing activities are carried out by a separate department called the purchasing department. This system is effective for organizations which have a number of production sites or many autonomous production units within the same site which require raw materials with the same or similar specifications.
- In d*ecentralized purchasing system*, particular department heads purchase the raw materials according to their requirements. The method gives departments the flexibility to alter their production policy based on their specific requirements. Most organizations generally use a combination of both types of purchasing systems.

Check Your Progress - 1

1. Which of the following factors should a purchase department consider while purchasing materials and supplies from a supplier?
   i. Low price
   ii. High quality
   iii. Good after sales service
   a. i and ii
   b. i and iii
   c. ii and iii
   d. i, ii, and iii
2. If the material requirement in the various production facilities of India Metallics Company differs significantly, which type of purchasing system is most suitable for the company?
   a. Centralized purchasing
   b. Decentralized purchasing
   c. A combination system
   d. Outsource the purchasing function
3. In a centralized purchase system, which department is responsible to the user department for proper delivery of components?
   a. Supplier
   b. Purchase department
   c. Top management
   d. Quality control department
4. Identify the statements that hold **true** regarding centralized purchasing system.
   i. In this system, particular department heads purchase the raw materials according to their requirements.
   ii. All the purchasing activities are carried out by a separate department called the purchasing department.
   iii. It gives departments the flexibility to alter their production policy based on their specific requirements.
   iv. It is effective for organizations which have a number of production sites or many autonomous production units within the same site which require raw materials with the same or similar specifications.
   a. Only i and ii
   b. Only i and iii
   c. Only ii and iv
   d. Only iii and iv

23.5 Responsibilities of a Purchase Manager

A purchasing manger should undertake the following activities:

Vendor Development: The purchase manager should search for and evaluate suppliers and should judge them on their quantitative and qualitative ability to meet the firm's requirements.

Selection of Suppliers: The purchase manager should select the prospective suppliers from the list of vendors and asks them for a quotation for materials. After obtaining the quotations, the purchase manager examines the cost of items, delivery charges, discount charges, and supplementary charges like taxes payable. The selection is made after analyzing the vendor's ability to deliver on time items of the required quality and in the required quantity (based on the past experience with vendors). Vendor rating is a method used for selecting suppliers. It is a scientific ranking technique in which the purchasing managers rate the vendors according to their performance. The purchasing manager identifies the factors that are important for evaluating the vendors and assigns weights to each of them. Based on the factors considered, each of the vendors is rated on a scale of 0 to 10. The score of each factor is multiplied with the appropriate weight to obtain the weighted score. The vendor score is then obtained after summing up the weighted score of each factor. The vendor score for all the vendors is calculated and the vendor who obtains the highest score is selected.

Contract Negotiation and Communication Interface: After selecting a vendor, the purchasing manager negotiates with the vendor and specifies the terms and conditions that the vendor must stick to while supplying the items. These include the price of the items, quality and other performance standards, technical specifications, delivery schedule, freight payment, payment terms, etc. The communication between the various departments and the suppliers flows through the purchase manager.

Value Analysis: The purchase manager conducts a value analysis to assess the value of the material. Value analysis mainly aims at controlling costs of purchasing material. It evaluates the materials by analyzing the functionality of the item, checking whether it is possible to run the system without the item, checking if the item can be substituted with a standard part, evaluating the cost of the item, and checking if the functions performed by two or three materials be clubbed together and replaced by any other material.

Value analysis involves the combined efforts of various departmental units, and helps in reviewing purchase activities to ensure that the amount is expended to get an appropriate value. The following is the procedure for value analysis:

- Examining all the products/materials that are being reordered and identify each product/material that needs an improvement.

- Gathering all possible information about the designs, costs, scrap rates, etc. of the product.
- Forming a team that includes experts from various functional areas related to the material.
- Generating alternatives by generating new ideas and ways of accomplishing the tasks.
- Evaluating the alternatives on criteria like cost and feasibility.
- Refining the feasible alternatives and selecting the optimal alternative.

Activity: Ram has been appointed as the purchase manager of a new plastic manufacturing plant at Hyderabad. It is his first job and he has been given the responsibility of finding suppliers of raw materials for the plant. How should Ram go about it? Assist him in the process.

Answer:

23.6 Purchasing Process

During the purchasing process, the purchase department interacts with the production department, the finance department, and the sellers. The purchasing department deals with purchasing instruments like purchase indents (or requisitions), requests for quotations, and purchase orders.

- *Purchase requisitions* are made by departmental representatives stating the quantity of material they need and the date of requirement.
- After receiving the requisition from the indenting department, the purchase department sends *requests for quotations* to the prospective suppliers.
- Based on these requests, the suppliers give quotations comprising the price, delivery schedule, the mode of transportation, and special conditions, if any.
- The purchase department selects the supplier who offers the best quotation and negotiates the terms and conditions in order to enter into a deal.
- The purchase department subsequently issues a purchase order to the supplier.

A *Purchase Order* is a legal document that authorizes the supplier to supply the goods and represents the buyer's obligation to buy the materials against the specified terms. Once the supplier delivers the materials the finance department releases the payment. There are some variations in the purchasing procedures of different firms depending on the material required. Nowadays, many organizations use the Internet for purchasing.

Manual purchase process inefficiencies cost organizations, long purchase cycles, missed discounts, and transaction disputes and thus cash losses. Modern procurement tools can transform a painfully slow procurement strategy to rapid delivery mechanism. Exhibit 23.1 presents procurement management process for 2021.

Exhibit 23.1: Procurement Management Process – The 2021 Guide

Discussed below are 7 steps which one needs to know to power up the procurement process.

1. Needs Recognition: Accurate plan for procuring goods and services in a timely manner and at a reasonable cost.
2. Purchase Requisition comprises key information that is required to procure the right goods, services, or works
3. Requisition review: Approved and cross-check for budget availability. Approved purchase requests become POs, while rejected requests are sent back to the requisitioner with the reason for rejection.
4. Solicitation process: Once a requisition is approved and PO is generated, the procurement team will develop an individual procurement plan and sketch out a corresponding solicitation process. Once the budget is approved, the procurement team forwards several requests for quotation (RFQ) to vendors with the intention to receive and compare bids to shortlist the perfect vendor.
5. Evaluation and contract: Solicitation process is officially closed - review and evaluate supplier quotations- vendor is selected - contract negotiation and signing are completed, PO delivered-Vendor accepts – acknowledges – legal binding document
6. Order management: The vendor delivers the promised goods/services within the stipulated timeline - purchaser examines the order- notifies any issues
7. Invoice approvals and disputes:This is a crucial step in the procurement process and having procurement software gives a competitive edge-perform three-way matching between GRN, Supplier Invoice and PO-check for discrepancies- else the invoice is approved and forwarded to payment processing
8. Record Keeping: Make a record- bookkeeping and auditing-store all appropriate documents right from purchase requests to approved invoices

Source: https://kissflow.com/procurement/procurement-process/ sept 2021

Check Your Progress - 2

5. Value analysis is an organized effort to control cost of _____.
   a. Materials purchased
   b. Materials exported
   c. New product development
   d. Marketing efforts
6. Which of the following is **not** a primary responsibility of the purchase department?
   a. Vendor development
   b. Selection of suppliers
   c. Contract negotiation
   d. Quality control
7. What are the tasks of a purchase department in an organization?
   a. Processing requisition for materials and supplies
   b. Locating suppliers or vendors
   c. Negotiating purchasing contracts
   d. All of the above
8. Identify the logical sequence that best represents a simple purchase process.
   a. Purchase indent - Purchase order - Quotation
   b. Purchase indent - Quotation - Purchase order
   c. Quotation - Purchase indent - Purchase order
   d. Purchase order - Quotation - Purchase indent
9. Which of the following is **not** an activity performed by the purchase manager?
   a. Vendor analysis and development
   b. Supplier selection
   c. Value analysis
   d. ABC analysis
10. Purchase indents are also called _____.
    a. Purchase requisitions
    b. Purchase quotations
    c. Purchase orders
    d. Purchase information
11. Who generally issues a purchase indent?
    a. User department
    b. Purchase department
    c. Vendor
    d. Top management

12. Which of the following authorizes suppliers to supply materials/goods?
    a. Purchase indent
    b. Quotation
    c. Purchase order
    d. All of the above
13. From the list of questions given below, identify the one **not** considered under value analysis.
    a. Is it possible to run the system without the item?
    b. Can the item be substituted with a standard part?
    c. Can the vendor supply the material at the right time?
    d. How much does the item cost?

23.7 Duties of Buyers

Organizations employ qualified and experienced people in teams for carrying out the purchasing activities. Each buyer is assigned the task of procuring a particular input, say, raw materials, tools, electrical components, etc. With this specialization, buyers become competent and have a complete understanding of the manufacturing processes of the organization and the vendors. Buyers should be cost and value conscious, should be aware of the legalities of purchasing, should have good negotiating skills, and should be able to build good relations with suppliers.

23.8 Make-or-Buy Analysis

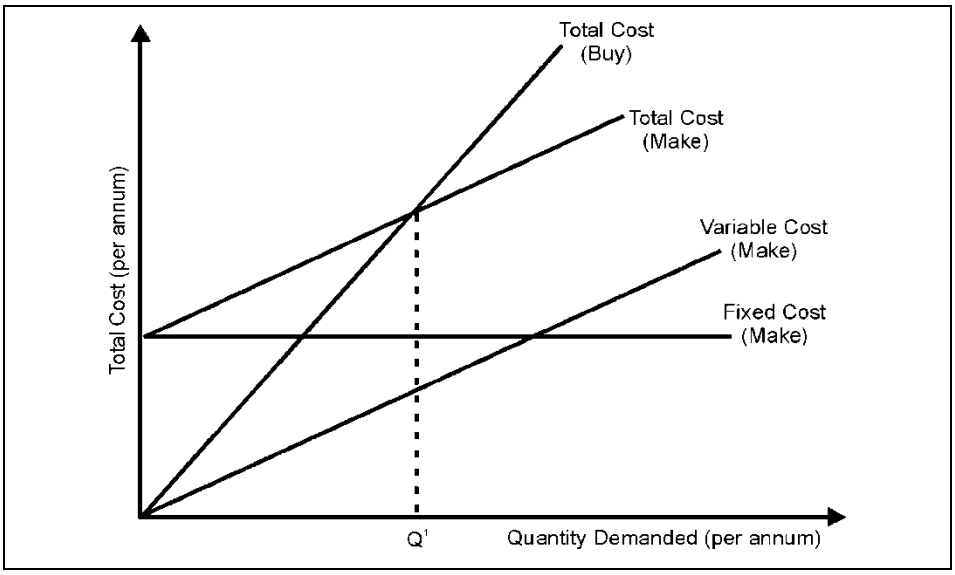
Before including an item in the purchase order, managers conduct a make-or-buy analysis. This analysis helps them to find out whether it is more feasible to manufacture the item in-house or to purchase it from external vendors. Usually, make-or-buy analysis is based on the break-even analysis. For the make-or-buy analysis, organizations consider factors like cost, availability of raw materials in the long run, and the ability to monitor and control quality.

The total cost of purchasing material is the product of the price per unit (P) and the number of units procured (Q). The organization does not incur any fixed cost during purchase of a product.

Total Cost $_{Buy} = P \times Q$

If the item is produced in-house, the organization incurs a fixed cost (F) for installation of equipment and facilities. It also incurs variable production cost, which is the product of the variable cost per unit (V) and the number of units demanded (Q).

Figure 23.1: Make or Buy Analysis



Total Cost $_{Make}$ = (VQ) + F

From Figure, we can see that the total cost of buying is equal to the total cost of making the item in-house at the break-even point. Assume that Q^1 is the demand to reach the break-even point.

$P \times Q^1 = (VQ^1) + F$, where, $Q^1 = \frac{F}{P-V}$

If the annual demand for the product is less than Q^1, the total cost of purchasing the product from an external vendor will be less than the total cost of making the product in-house and vice-versa, if the annual demand for the product is more than Q^1. This analysis is useful in determining whether the purchase cost of a product is less than the cost of producing it in-house. For the make-or-buy analysis, organizations consider factors like cost, availability of raw materials in the long run, and the ability to monitor and control quality.

Most organizations opt for external suppliers as they specialize in producing the products, maintain high quality standards, and ensure timely delivery for fear of losing the contract. Organizations usually opt for in-house production when they want to retain control over all the value chain activities, put excess plant capacity to productive use, and ensure that the design of a product is kept a secret.

23.9 Ethics in Buying

Ethics is the science of morals, moral principles, and recognized rules of conduct. It also implies systematizing, defending, and recommending concepts of right and wrong behavior. A purchasing department might sometimes get involved in unethical and illegal activities like manipulating quotations, fixing prices, favoring a specific supplier while placing an order, altering a product sample with

the intention of getting approval for a substandard item, etc. Vendors also give personnel gifts like free lunches, stays at holiday resorts, etc. as part of relationship building. Though it is a normal practice, organizations should state the type of gifts that the purchasing personnel are permitted to accept and should clearly draw the line beyond which accepting gifts would be considered unethical.

Check Your Progress - 3

14. Which of the following is **not** a reason for organizations to opt for in-house production?
    a. To gain control over all value chain activities
    b. To put excess plant capacity to productive use
    c. To ensure that the design of a product is kept secret
    d. To take advantage of knowledge and expertise of suppliers
15. Which of the following statements is **incorrect** regarding make-or-buy analysis?
    a. It is based on break-even analysis.
    b. It is conducted by managers after they include an item in the purchase order.
    c. It helps them to find out whether it is more feasible to manufacture the item in-house or to purchase it from external vendors.
    d. Organizations consider factors like cost, availability of raw materials in the long run and the ability to monitor and control quality.
16. India Rubber Ltd. requires on a continuous basis a certain rubber component for their product. When should the firm opt for buying the component rather than producing it in-house?
    a. When the quantity of the part required is huge
    b. When the fixed cost to make the product is less than buying costs
    c. When the total cost to make the product is less than buying costs
    d. When the quantity of the part required is small
17. Buyers should:
    i. be cost and value conscious.
    ii. be aware of the legalities of purchasing.
    iii. have good negotiating skills.
    iv. be able to build good relations with suppliers.
    a. Only i, ii, and iii
    b. Only i, iii, and iv
    c. Only ii, iii, and iv
    d. i, ii, iii, and iv

Activity: Krushi Incorporation is a company that has been engaged in manufacturing agricultural tools and equipment for almost 20 years. Recently, there has been a change in the management of the company. The new management is verifying the various practices of the company in the past years. During the process, the management has come to know that the company had been purchasing raw materials from only two suppliers. On investigation, they have found that though these suppliers supply the materials at a higher price than the others in the market, the purchasing department had been favoring them. Inquiry revealed that the favors that the purchasing personnel had received from the suppliers had prompted them to place orders consistently with the same suppliers. The management has decided to lay down rules regarding the ethical practices to be followed in the organization with respect to purchasing. Assist the management in this process.

Answer:

23.10 Integrity Pact and its implementation:

Global scams in the past few decades shook the confidence of the governments, business community and the customers alike. A necessity was felt for creating an institutional mechanism to ensure openness and transparency in all procurement functions.

What is Integrity Pact?

The Integrity Pact (IP) is a tool developed in the 1990s by Transparency International to help governments, businesses and civil society to fight corruption in the field of public contracting. IP establishes mutual contractual rights and obligations to reduce the high cost and distortionary effects of corruption in public contracting.

Source: Transparency International

The Mechanism: IP is intended to make public procurement transparent by binding both parties to ethical conduct. It also envisages a monitoring role for civil society who is the ultimate beneficiaries of government action. IP covers all activities related to the contract from pre-selection of bidders, bidding and contracting, implementation, completion and operation.

Terms of contract: The Public Authority commits that:

- No official will demand or accept any illicit gratification to give any of the parties an advantage at any stage of the project.

- All necessary and appropriate technical, legal and administrative information related to the contract will be made public.
- None of the officials will make available confidential information to a bidder/ contractor to give unfair advantage in the contract.
- Declaration by all concerned officials on any conflict of interest and disclosure of own and family assets is compulsory.
- Officials will report to appropriate government authority about any breach/attempt to breach a commitment.

The Bidder commits that:

- They will not offer any illicit gratification to obtain unfair advantage.
- They will not collude with other parties to impair transparency and fairness.
- They will not accept any advantage in exchange for unprofessional behavior.
- They will disclose all payments made to agents and intermediaries.
- It will demonstrate existence of organization-wide code of conduct forbidding unethical practices.

Penalties: For failure to implement IP, officials will be subject to penal action and bidders will face cancellation of contract, forfeiture of bond, liquidated damages and blacklisting. Action will not require criminal conviction but be based on "no-contest" after the evidence is made available or there can be no material doubts. Disputes in IP implementation would be resolved by arbitration detailed in IP.

Implementation: Monitoring is a key aspect of IP implementation. Public access of all relevant information is a necessity. It calls for a forum in which representatives of civil society can discuss the contract itself. The concept of IP includes the existence of Private Sector Inspector General (IPSIG) who is called the Independent External Monitor (IEM), delegated with the rights of civil society to monitor the contract. The monitoring and supervising procedures are to be specified and at the conclusion of the contract a certificate of corruption-free will be issued.

As a concept it is undeniably a model for transparency in public procurement. While it is an ideal, its implementation will require will on the part of both vendor and purchaser. Without effective implementation, it will remain merely an additional part of the tender files. Propensity to seek legal intervention and an assumption that terms of contract are not particularly sacrosanct is a part of the procurement process in the country. In these circumstances, arbitration will have limited value in the event of breach of IP. Level of evidence for pointing out breach is also liable to be disputed.

Therefore, its implementation will suffer. India's stand in the latest WTO round against transparency in public procurement may render this concept a non-starter.

The identification of a monitoring agency also will pose problems. TI India may not have the level of acceptability that TI has in other countries. NGOs could be hijacked by vested interests.

MNCs have problems in participating in third world bids without indulging in bribery – IP is intended to provide a level playing field so that non-OECD country-based bidders are also subject to the same limitations. However, it is certainly worth pursuing as a model for future public procurement. The need for a debate on the adoption of IP, with appropriate modifications, can be initiated by the Commission.

In India, many Public and Private sector companies signed and adopted IP as a part of Corporate Governance.

23.11 Summary

- Purchasing refers to buying a material or an item from a company or division that supplies materials.
- A purchasing department ensures that the right materials are procured at competitive price.
- Purchasing systems are centralized and decentralized.
- A purchasing manager should undertake activities of vendor development, selection of suppliers, contract negotiation, communication interface, and value analysis.
- During the purchasing process, the purchase department interacts with the production department, finance department, and the sellers. It deals with purchasing instruments like purchase requisitions, requests for quotations, and purchase orders.
- The purchase managers conduct a make-or-buy analysis to find out whether it is feasible to manufacture the item in-house or purchase it from external vendors.
- Organizations should follow ethical practices while purchasing.

23.12 Glossary

Centralized purchasing system: In this system, all the purchasing activities are carried out by a separate department called the purchasing department.

Decentralized purchasing system: In this system, particular department heads purchase the raw materials according to their requirements. The method gives departments the flexibility to alter their production policy based on their specific requirements.

Make-or-buy analysis: This helps firms find out whether it is more feasible to manufacture the item in-house or to purchase it from external vendors.

Purchase order: A legal document that authorizes the supplier to supply the goods and represents the buyer's obligation to buy the materials against the specified terms.

Purchase requisitions: These are made by departmental representatives stating the quantity of material they need and the date of requirement.

Purchasing: It refers to buying of a material or an item from a company or division that supplies materials.

Requests for quotations: The purchase department sends requests for quotations to the prospective suppliers, based on which the suppliers give quotations comprising the price, delivery schedule, the mode of transportation, and special conditions, if any.

23.13 Self-Assessment Exercises

1. Purchasing refers to buying of a material or an item from a company or division that supplies materials. Why is purchasing important for an organization? Explain the different types of purchasing systems.
2. The purchase department is one of the key players in achieving the strategic objectives of a firm. What is the role of a purchase manager in the purchasing process?
3. During the purchasing process, the purchase department interacts with all the departments of the firm. Explain the purchasing process. Also explain the duties of the buyers in brief.
4. A make-or-buy analysis helps in finding out whether it is more feasible to manufacture the item in-house or to purchase it from external vendors. How can a purchase manager conduct this analysis?
5. Organizations develop a set of rules and guidelines to ensure that the purchasing conduct of its personnel is ethical. Why should organizations follow purchasing conduct that is ethical? Mention a few important rules of ethics.

23.14 Suggested Readings/Reference Material

1. Dr. S. Ramachandran, Vijayalakshmi,D. Jagadhish, Material Handling And Facilities Planning- Ktu Paperback, Irwalk Publications January 2019
2. Prasanna Chandra , Projects: Planning, Analysis, Selection, Financing, Implementation And Review ,Mcgraw-Hill; Ninth Edition, 15 May 2019
3. Erik Larson , Clifford Gray , Project Management: The Managerial Process | 6th Edition , Mcgraw Hill Education; Sixth Edition, 1 July 2017
4. The Art Of Service - Inventory Control Publishing, Inventory Control A Complete Guide - 2021, The Art Of Service - Inventory Control Publishing, November 4, 2020
5. P. Gopalakrishnan, Purchasing And Materials Management , Mcgraw Hill Education; 1 July 2017

23.15 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**

   All the above factors must be taken into consideration by the purchase department while buying material and supplies from a supplier.

2. **(b) Decentralized purchasing**

   When specific material requirements vary between production facilities, a firm must adopt a decentralized purchasing system. Centralized purchasing reduces flexibility and outsourcing reduces control of the firm over the purchasing function.

3. **(b) Purchase department**

   The purchase department is responsible for proper delivery of goods purchased. As this department acts as an interface between the user department and suppliers, it is answerable to the user department for delays in delivery of material.

4. **(c) Only ii and iv**

   Purchasing systems are of two types: Centralized purchasing systems and decentralized purchasing systems. Statements ii and iv refer to a centralized purchasing system, while statements i and iii refer to a decentralized purchasing system. Most organizations generally use a combination of both types of purchasing systems.

5. **(a) Materials purchased**

   Value analysis aims at reviewing design of materials to be procured and attempts to modify the design to replace high cost and obsolete parts with cost effective parts and designs. Value analysis mainly aims at controlling costs of purchasing material.

6. **(d) Quality control**

   Quality control is part of raw material purchase. It is an activity taken up by the production/ quality control department, sometimes in conjunction with the purchase department.

7. **(d) All of the above**

   Processing requisition for materials and supplies, locating suppliers or vendors, and negotiating purchasing contracts are tasks carried out by the purchase department.

8. (b) Purchase indent - Quotation - Purchase order

A purchase indent from a department within the firm initiates the purchase process. This is followed by request for quotations from suppliers by the purchase department. After selecting a supplier, the purchase order is placed by the purchase department.

9. (d) ABC analysis

ABC analysis is used in materials management and is not performed by the purchase manager.

10. (a) Purchase requisitions

Purchase indents are also called requisitions, which include a clear specification of materials required.

11. (a) User department

The user department that utilizes material or goods issues purchase indents. They are issued to the purchase department, which requests for quotations from vendors for the materials.

12. (c) Purchase order

The purchase order is the legal document authorizing the supplier to supply goods. It represents the buyer's obligation to buy materials against specified terms.

13. (c) Can the vendor supply the material at the right time?

Value analysis is concerned about increasing product value by reviewing design and modifying the product without affecting its usability. Option (d) relates to vendor supply and does not come under value analysis.

14. (d) To take advantage of knowledge and expertise of suppliers

Organizations opt for in-house production when they want to control all value chain activities, to use excess plant capacity productively, or when they do not want competitors to get to know the product design. Suppliers' knowledge and expertise is a factor when the organization decides to outsource rather than produce in-house.

15. (b) It is conducted by the managers once they include an item in the purchase order.

All the statements are true regarding make-or-buy analysis, except statement (b). Before including an item in the purchase order, managers conduct a make-or-buy analysis.

16. (d) When the quantity of the part required is small

India Rubber can buy the part when the quantity required is small or when the total costs to make it are more than buying costs.

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

Each buyer is assigned the task of procuring a particular input. With this specialization, buyers become competent and have a complete understanding of the manufacturing processes of the organization and the vendors. Buyers should be cost and value conscious, should be aware of the legalities of purchasing, should have good negotiating skills, and should be able to build good relations with suppliers.

Unit 24

Materials Management

Structure

24.1 Introduction

In the last section of the previous unit, we have discussed the ethical issues involved in buying. We have learnt that organizations should develop a set of rules and guidelines to ensure that the purchasing conduct of its personnel is ethical. In this unit, we will discuss materials management.

Materials management is the study of flow of materials through various operations in a production facility. The American Production and Inventory Control Society (APICS) has defined materials management as, "*the grouping of management functions supporting the complete cycle of material flow, from the purchase and internal control of production materials to the planning and control of work-in-process to the warehousing, shipping, and distribution of finished products*." Materials management helps in assessing material requirements at various stages of the production process and in maintaining a control over the firm's production and distribution functions.

This unit will introduce you to the necessity of materials management. We will discuss the functions of materials management. We shall then move on to discuss materials management technology. Finally, we would discuss the various techniques used in materials management.

24.2 Objectives

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

- Explain the necessity of materials management.
- Discuss the functions of materials management.
- Identify the various technologies used in materials management.
- Evaluate the various techniques used in materials management.

24.3 Necessity of Materials Management

A major portion of investment is made in materials. Though the range of investments made varies from industry to industry, about 50% of the total capital is invested in materials. Therefore, they need to be effectively and efficiently managed. For example, if a hospital runs out of a single item like a syringe, a seemingly insignificant item in its inventory, it brings most operations to a standstill. Such shortages also delay service delivery and increase the expenses for the firm. Materials management is very important for the following reasons:

- Due to scarcity and increasing demand of materials firm should minimize wastage.
- Material is the only major area for cost reduction therefore should be effectively managed.
- The quality of the end product or service is dependent on the materials management.
- Materials management helps in preserving important and scarce resources.
- Materials management helps in obtaining the lowest possible prices for materials purchased.

24.4 Functions of Materials Management

The materials management process is explained by three inter-related functions: production control, inventory control, and materials handling.

24.4.1 Production Control

The production control function involves directing and regulating the movement of goods through the entire manufacturing cycle from the process of purchasing materials to producing the finished product. The purchasing, receiving, raw materials inventory, and production departments perform this function by providing an adequate supply of materials for production.

Purchasing department: The purchasing department acquires the required materials in the right quantity, of the right quality, from the right source, at the right time, and at the least possible cost.

Receiving department: The receiving department processes the incoming shipments of materials. In most firms, the purchasing department itself acts as the receiving department. The receiving department performs tasks like unpacking incoming materials, checking their quantity and quality, and generating receiving reports.

Raw materials inventory department: The raw materials inventory department manages the raw materials inventory, which is the collection of inputs used in the production process. The department performs tasks like storing and protecting raw materials, auditing existing raw materials, and repackaging and labeling raw materials to make them ready for use in the production process. Most firms use Materials Requirement Planning (MRP) to manage raw material inventory.

Production department: The production department allows the continuous flow of goods during the production process without any stoppages. Some of the functions of the production department include monitoring the flow of raw materials, determining and adjusting inventory storage capacity, and identifying material flow bottlenecks.

24.4.2 Inventory Control

The inventory control function involves the maintenance of stock in various stages of production in the desired quantities so that the overall cost of production is minimized. This function is performed by the raw material inventory, production, and finished goods departments. Production control focuses only on materials availability whereas inventory control also emphasizes cost minimization.

Finished goods inventory department: The finished goods inventory department checks the quantity and quality of the products in the production process, stores the products to protect them from pilferage and other damage, audits the finished goods inventory, and retrieves the finished goods from the stocks.

Materials Handling

The materials handling function manages the physical movement of materials into, through, and out of the firm to the required location in a timely and cost-effective manner without affecting the primary objectives of the other two materials management functions.

The primary objective of materials management is to move materials to the required location in a timely and cost-effective way without affecting the primary objective of production control and inventory control functions.

Factors like the type of plant layout, type of production process used, the nature of materials, and the material handling equipment influence the materials handling function.

Materials handling equipment are of two types – fixed path equipment and variable path equipment.

- Fixed path equipment like conveyors, monorail devices, and pulley-drive equipment, move on a fixed path. Overhead cranes also belong to this category with a slight variation.
- Variable path equipment does not restrict the direction of movement of materials. However, the size of the equipment, as in the case of trucks, forklifts, mobile cranes, and industrial tractors, affects their movement.

The materials handling function is performed by the purchasing, receiving, raw material inventory, production, finished goods, and shipping departments, and distribution centers and warehouses.

Shipping department: The shipping department delivers goods from the finished goods inventory department to customers. Some of the tasks carried out by this department include staging or organizing orders to be shipped; weighing, labeling, and packing orders to be shipped; and physically checking orders to make sure their content is consistent with the order.

Distribution centers and warehouses: Distribution centers and warehouses are physical facilities used to store and ship inventory. Distribution centers are located near markets to provide better customer services.

Activity: Suketu has been appointed as the head of the materials handling department in a manufacturing company. He has to manage the movement of the materials into, through, and out of the company. He has identified that the materials handling function is not being properly done in the organization. What are the departments in an organization that carry out the materials handling function? Assist Suketu in the process of developing a materials handling function in the organization.

Answer:

Check Your Progress - 1

1. Which of the following is **not** a function of materials management?
   a. Vendor analysis
   b. Production control
   c. Materials handling
   d. Inventory control

2. The departments involved in production control are purchasing, receiving, raw materials, and production department. Which of the following tasks does the raw material inventory department carry out?

   i. Repackaging and labeling incoming stock

   ii. Storing and protecting raw materials

   iii. Auditing existing raw materials

   iv. Unpacking incoming materials

   a. i and ii

   b. ii and iv

   c. i, ii, and iii

   d. i, ii, and iv

3. The shipping department is associated with the materials handling function. Which of the following tasks are carried out by this department?

   i. Staging or organizing orders to be shipped

   ii. Weighing, labeling, and packing orders to be shipped

   iii. Physically checking orders to make sure their content is consistent with the order

   iv. Storing raw materials safely

   a. i and iii

   b. ii and iii

   c. i and ii

   d. i, ii, and iii

4. What is the basic objective of materials handling function under materials management?

   a. To maintain stock of materials in various stages of production and in desired quantities

   b. To direct and regulate movement of goods through the entire manufacturing cycle from the process of purchasing materials to making the finished product

   c. To move materials to the required location in a timely and cost-effective way without affecting the primary objective of production control and inventory control

   d. All of the above

5. Materials management comprises production control, inventory control and materials handling. Which department is **not** associated with inventory control function?

   a. Purchase department

   b. Raw materials inventory department

c. Production department

d. Finished goods inventory department

6. Production control is one of the functions of materials management. Which of the following is **not** a function of the production department associated with production control function?
   a. Monitoring flow of raw materials
   b. Determining and adjusting inventory storage capacity
   c. Locating and receiving raw materials
   d. Identifying material flow bottlenecks

7. Which of the following tasks are **not** performed by the receiving department under the production control function of materials management?
   a. Unpacking incoming orders
   b. Processing requisitions for material
   c. Inspecting the quality of incoming material
   d. Preparing receiving reports

8. The detailed study of complete material flow process in a firm is termed _____.
   a. Operations management
   b. Inventory management
   c. Materials management
   d. Purchase management

9. How does shortage in materials affect a firm's functioning?
   i. It breaks the flow of operations
   ii. It delays delivery
   iii. It increases operational efficiency
   iv. It increases operational expenses
   a. i and ii
   b. i, ii, and iii
   c. i, ii, and iv
   d. i, ii, iii, iv

10. Materials management comprises production control, inventory control and materials handling. Which of the following departments is **not** associated with production control function?
    a. Purchase department
    b. Raw material inventory department
    c. Finished goods inventory department
    d. Production department

24.5 Materials Management Technology

The latest technologies like Robots and Automated Storage and Retrieval Systems (AS/RS) have made the execution of materials management functions convenient, easy, and economical.

24.5.1 Robots

Robots are computer-controlled, re-programmable, multi-functional manipulators designed to move materials, parts, tools, and other specialized devices through variable programmed motions to perform various tasks independently. Several robots are fixed and installed on the floor, with an arm that can reach different locations. Robots are used for processing and pick-and-place applications.

Physical capabilities of a robot: A robot's capability can be determined by its work envelope and grippers (hands). The work envelope is the physical movement capability of the robot's arms and hands. The grippers of a robot consist of the jaw hand which is used to pick up materials, turn them, and keep them on a nearby conveyor (or location) within its work envelope, while the claw hand has teeth for grasping the materials.

Robots can be broadly classified into:

Physically operated robots – These robots have a mechanical arm and hand and are used by workers to pick up materials.

***Fixed sequence robots* –** These robots perform a sequence of operations based on a predetermined set of procedures. Electronic sensors are used to activate these robots.

Variable-sequence robots – The sequence of actions performed by these robots can be easily changed depending on the nature of operations to be performed, while their functioning is similar to that of fixed sequence robots.

***Numerical control robots (NC robots)* --** These robots perform a set of operations based on numerical data fed into them through punched tapes, data cards, and digital switches. They are used to perform manufacturing operations which require high precision.

***Playback robots* –** These robots store a sequence of operations in memory. An operator initially performs these operations using a robot.

***Intelligent robots* –** These robots perceive the environmental conditions of the workplace through tactile or visual perception or both and can make necessary and suitable decisions by using on-board computers.

24.5.2 Automated Storage and Retrieval System (AS/AR)

AS/AR systems are computer-controlled and mechanically-operated materials handling systems. These systems function like physically operated robots. The

system executes inventory stocking and picking functions and automated material handling functions, which are integrated and controlled by a computer.

Automated guided vehicles (AGVs) **–**These systems are used to store and retrieve inventory items from stock. Semi-automatic AGVs, which are a combination of computer and human control, can move independently on their guided paths to a specific workstation and then signal to the operator to perform the required operation.

Conveyance systems **–** In conveyance systems, the inventory items are stored in standardized boxes. These boxes have a trip control device that prevents the inventory items from spilling out. The systems are controlled by a Computer Integrated Manufacturing System. To pick up a particular inventory item, the computer releases the control device at the place where that item is located and the box automatically falls onto the conveyor. The conveyor then sends the boxed items to the order-processing area where a robot or a human being collects them. To store the items, the computer directs the AGVs to locate and replenish inventory boxes (which the AGV carries from the receiving areas) to the desired locations.

Activity: The management of a company Khaled Ltd. wants to know about the various technologies that can be used in carrying out the materials management function. It has appointed Kevin to identify and report to it on the various technologies. Assist Kevin in the process.

Answer:

Check Your Progress - 2

11. Which of the following category of robots, based on the nature of their operations, can change their sequence of tasks to suit the operational process?
    a. Playback robot
    b. NC robot
    c. Variable-sequence robot
    d. Intelligent robot
12. _____ robots carry out a sequence of operations based on a predetermined set of procedures.
    a. Fixed-sequence
    b. Variable-sequence
    c. Physically-operated
    d. Numerical control

13. Which of the following types of robots perceive the environmental conditions of the workplace through tactile or visual perception or both, and can make necessary and suitable decisions by using on-board computers?
    a. Playback robots
    b. Intelligent robots
    c. Physically operated robots
    d. None of the above
14. Identify the statement that **does not** hold true regarding automated storage and retrieval systems.
    a. These systems function like physically operated robots.
    b. These systems store a sequence of operations in memory.
    c. These are computer-controlled and mechanically-operated materials handling systems.
    d. These systems execute inventory stocking and picking functions and automated material handling functions that are integrated and controlled by a computer.
15. In which of the following systems are the inventory items stored in standardized boxes with a trip control device that prevents the inventory items from spilling out?
    a. Robots
    b. Kanban systems
    c. Conveyance systems
    d. Automated guided vehicles

24.6 Materials Management Techniques

The most widely used materials management techniques are the Kanban card systems, ABC classification systems, and Just-In-Time (JIT) purchasing. The transportation method of linear programming is also useful for minimizing the materials transportation distance.

24.6.1 JIT Purchasing

According to this concept, the size of the purchased quantities is reduced to such an extent that the materials directly reach the production point. This results in a reduction in wastage, storage, and maintenance costs.

The method advocates reduction in size of purchased quantities to the extent that materials reach the production point directly. Hence, safety stocks need not be maintained.

In JIT purchasing, flexibility is higher in terms of ability to change materials required at the last minute depending on changes in customer/client preferences, etc. Apart from reduction in carrying costs, the other advantages of JIT purchasing are improved quality and enhanced responsiveness.

The following are the basic features of JIT purchasing:

- Buyers and sellers can reach the stage of zero defects through the proper use of JIT systems.
- JIT involves frequent shipments in small lot sizes.
- A firm following the JIT system ensures that the high value components and materials arrive only when they are required. This reduces maintenance costs.
- Delivery delays are avoided by using a good transportation system for transporting materials.
- Standard shipping methods are used to ensure the safe transportation of materials.
- Stable production schedules are developed and communicated to the suppliers.
- Electronic data exchanges are used to provide information about the current status of the production process and the inventory level.
- Buyers and sellers enter into long-term agreements and develop lasting relationships.

24.6.2 Kanban Systems

The Kanban system was developed by the Toyota Motor Company, Japan.

- To use this system, firms have to store their materials and other inventory items in a single-use container like trays or boxes.
- A card called the Kanban is attached to each container that holds a specific amount of materials or other inventory parts used to manufacture the product. These cards are used for initiating the transactions. For example, when the material in a container is depleted, a Kanban is kept in the container which defines the requirement of inventory items to continue the production process.
- A Kanban system uses three types of cards to initiate material transactions: the production authorization card, the vendor authorization card, and the conveyance authorization card.
- The production authorization card authorizes the production department to start the production process. It specifies the product's name, identification number and description, and the list of materials needed for continuing the production process.
- A vendor authorization card authorizes a vendor to supply the required materials in the specified quantity. It specifies the product's name, vendor's name, and the quantity ordered.
- A conveyance authorization card authorizes a materials handling agent to move the tray to a specified destination. It specifies the product's name, its identification number, and the delivery destination.

The following are the benefits derived from the Kanban systems:

- Reduces work-in-process and raw materials stores
- Eliminates stock-out situations
- Improves customer service by minimizing the lead time
- Ensures effective supply chain management

A Single-card Kanban System

A single-card Kanban system uses the conveyance card. Following are the steps involved in the functioning of the system:

- An assembly line worker needs some inventory items to manufacture a product.
- He/she puts an empty tray at point A and issues a conveyance Kanban specifying the materials or the other inventory parts required.
- The materials handling agent takes the tray from a point A to a point B in the inventory department.
- The tray is filled with the desired inventory and the materials handling agent collects the filled tray at point C. Here, the materials manager should ensure that the required amount of inventory is ready to be picked up; otherwise the production process gets delayed.
- The agent moves the tray to point D in the assembly area where it is required for processing, and then it again goes to point A.

This cycle is repeated whenever there is a materials requirement in the assembly line.

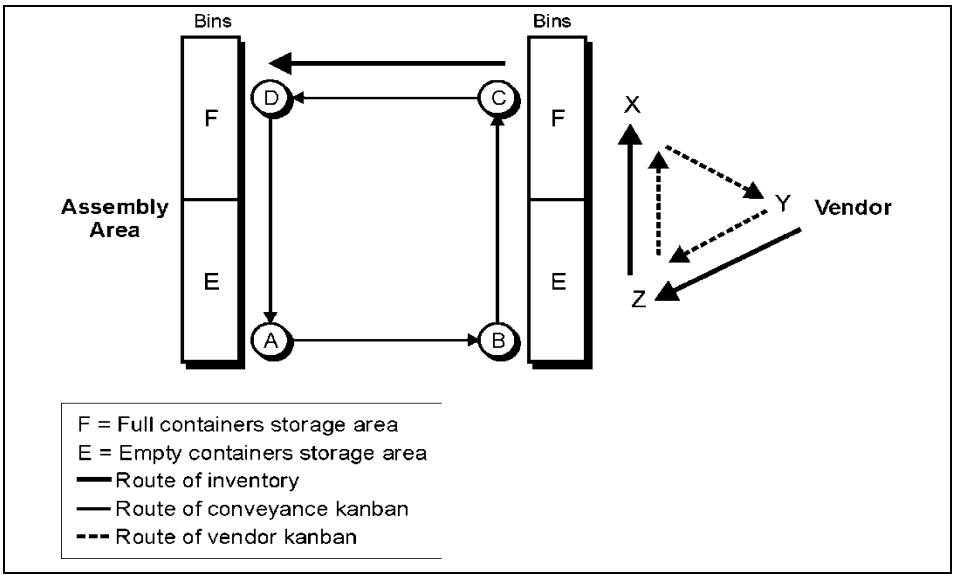
A Dual-card Kanban System

A dual-card Kanban system uses the conveyance card and the vendor card. In this system, the required quantity is obtained from the vendor and a vendor authorization card is used in the process. Following are the steps involved in the functioning of the system:

- A conveyance card is put in an empty tray at point A and the materials handling agent moves it to point B in the inventory department. The tray is collected at point C and is sent to point D in the assembling area just as in the single card system.
- The vendor card is introduced at point X, authorizing a vendor (at point Y) to deliver the materials that are specified in the card.
- After receiving the card, the vendor delivers the materials into the empty trays that are available at point Z.
- The filled container is placed in the bins at the position X. It remains at this position till a conveyance card arrives from Point B to Point C, authorizing the movement of material from Point C to Point D.
- Once the container is authorized to move, the vendor card is removed and sent to the vendor and the cycle repeats itself.

Kanbans operate in closed loops and they continue to operate until the materials manager withdraws them. However, the disadvantage is that the system is highly dependent on the people.

Figure 24.1: Dual-Card Kanban System



24.6.3 ABC Classification Systems

Firms use different varieties of material in the production process. As materials vary in prices, usage, and lead-time, it is difficult for the materials managers to control all of them. Therefore, in ABC classification systems, attention is paid more to those items whose usage value or consumption value is high and less to those whose usage value is low. Usage value is the product of the number of units of a material used per year and the cost per unit. Based on the usage value, materials are classified into three categories: A, B, and C. Category A represents materials of high usage value per annum accounting for 60-70% of the total cost. Category B represents materials of moderate usage value per annum accounting for 10-30% of the total cost. Category C represents materials of low usage value accounting for 5-15% of the total cost. However, these percentages vary from industry to industry and also from one firm to another within the industry. One limitation is that ABC analysis does not consider the aspect of availability of materials. The ABC classification system is also referred to as ABC (Always Better Control) analysis, which is done to change the expenses associated with material control based on their usage value. Following is the procedure:

- List all the materials that the firm holds.
- List the unit cost and the annual demand (in units) of each material.
- Calculate the usage value of each material.
- Tabulate the materials in the descending order of their usage value.
- Classify the items into categories: A, B, and C based on their usage values.

Example: The following table lists the number of items used per year and the cost per unit of the materials. Classify them on the basis of ABC analysis.

Type of Material	Number of Materials Used per Year	Cost per Unit
1000	5000	20
1001	400	150
1002	1200	30
1003	500	50
1004	700	15
1005	200	25
1006	400	7.5
1007	50	35
1008	60	12
1009	20	9

Solution: Calculate the usage values of the items and arrange them in descending order based on the values.

Type of Material	Usage Value	% of Usage Value	Cumulative Value
1000	100,000	41.30	41.30
1001	60,000	24.78	66.08
1002	36,000	14.87	80.95
1003	25,000	10.32	91.27
1004	10,500	4.34	95.61
1005	5000	2.06	97.67
1006	3000	1.24	98.91
1007	1750	0.72	99.63
1008	720	0.30	99.93
1009	180	0.07	100
Total	**242,150**	**100.00**	

The items which can be classified under Category A are 1000 and 1001. They use about 66% of the total expenditure on inventory. The items which can be classified under Category B are 1002, 1003, and 1004. They use about 29.53% of the total expenditure on inventory. The remaining items: 1005, 1006, 1007, 1008, and 1009 are classified under Category C. They use around 4.39% of the total expenditure on inventory.

With nano-technology, 3D printing, bamboo floors, smart windows, eco friendly insulation, material management has evolved as a very prominent science for both manufacturing as well service organizations. Exhibit 24.1 presents material handling trends in 2021.

Exhibit 24.1: Material Handling Mega Trends for 2021 and Beyond

Presented below are 5 Material Handling "Mega Trends".

Trend #1: Explosion of SKUs (stock-keeping-units): With "flexible warehouse" becoming the new standard, highly expandable, modular systems with quick changeover will become as important as system throughput.

Trend #2: Scarcity of Talent:

- Skilled labor is narrowing and traditional skill sets are not easily transferred to current technology needs. Remote support will become more critical to end users, creating after market opportunities.
- Automation systems will start being enabled with workflows to give the operator just enough information to get the job done, and put it timely training element in the maintenance process.
- Augmented Reality (AG) and Virtual Reality (VR) solutions could become an effective training method.

Trend #3: Digitization:

- The promise of Industry 4.0 is yet to be realized. What's needed is a combination of end users understanding about their need, OEMs with direct involvement of optimizing those processes, and partners in the automation space to help enable it with the right tools – "domain expertise" – to make it all happen.
- An accelerating trend is: Virtual tools, such as a simulation and emulation, virtual commissioning, etc. which is used well ahead of production or implementation to mitigate risk and reduce cost.

Trend #4: Increased Automation:

- New automation technologies are becoming needed tools, and the flexibility of a proposed system is becoming a major buying influence for many end users.
- Automation's flexibility for new "configurations of workflow" — how parcels, packages and items move through the warehousing system is the exciting actvitiy.

Trend #5: Personnel Safety:

- Classic safety systems need to be replaced by more automated systems, enabling the increased flexibility and cohabitation of machinery and people.

One of the main concerns of material handling companies is retention of employees, and ensuring safety at the workplace.

Source: https://matthewsautomation.com/material-handling-mega-trends/

Check Your Progress - 3

16. Materials managers should pay more attention to items whose usage value or consumption value is high and less attention to items whose usage value is low. Which inventory classification model seeks to alter the expenses associated with controlling materials according to their usage value?
    a. ABC
    b. VED
    c. FSND
    d. FIFO
17. A Kanban system uses different types of cards to initiate material transactions. Which of the following type of Kanban card authorizes a materials handling agent to move the tray to a specified destination?
    a. Conveyance authorization card
    b. Production authorization card
    c. Vendor authorization card
    d. Dual-card Kanban system
18. Which of the following is **not** a characteristic of the ABC inventory classification system?
    a. It classifies inventory items based on the size of resources required to control usage value.
    b. The greater the usage value, the greater the resources to be allocated to control usage of an item.
    c. The system considers availability of materials.
    d. Extent of allocation of resources is based on value of the inventory.
19. On what principle is ABC analysis based upon?
    a. An item is critical if its usage is high.
    b. There are usually a few critical items and several items that are less critical.
    c. The safety stock (in terms of volume) should be higher for A items than for C items.
    d. An item is critical if its unit price is high.
20. JIT purchasing has many advantages over traditional purchasing. Which among these is **not** an advantage?
    a. Reduction in carrying costs
    b. Improved quality
    c. Increased responsiveness
    d. Reduced flexibility

21. A Kanban system uses different types of cards to initiate material transactions. Which of the following type of Kanban card authorizes the production department to commence the production process?
    a. Conveyance authorization card
    b. Production authorization card
    c. Vendor authorization card
    d. Dual-card Kanban system
22. What does the concept of just-in-time purchasing highlight?
    a. Maintain bulky inventory
    b. Maintain safety stock in case of adversity
    c. Maintain minimum inventory till the next replenishment
    d. None of the above

Exercises

A. The following table gives the unit cost and annual usage rates for different items. Classify items based on their rupee volume using ABC classification and identify them under A-classification.

Type of Item	Cost per Unit (Rs)	Annual Usage
1	400	50
2	510	40
3	10	600
4	11	500
5	0.50	1,000
6	0.25	1,500

(Questions B to E)

Assume that JKL Industries uses 5 types of materials in its production process. The quantity of each type of material used per year and the cost per unit is given in the table below. Use this data to answer the following **four** questions.

Material Type	Quantity Used per Year	Cost per unit
1	2000	20
2	4500	10
3	1500	35
4	3000	20
5	2500	25

B. Use ABC analysis to identify the type of material that has the most usage value.

C. What is the least usage value of a material that requires lowest allocation of resources?

D. Which type of material can be classified under 'A' category?

E. Which material falls under the C category of ABC analysis?

Activity: A company uses a variety of raw materials in the manufacture of three-wheelers. The following is the list of those materials based on their bin card numbers and the cost of those materials. Classify them on the basis of ABC analysis.

Answer:

24.7 ERP in Materials Management

ERP by virtue of its scope and coverage encompasses the entire organization, integrating all functions. Materials Management being the most crucial function utilizing most of the working capital to procure, stock and consume materials, needs to be very efficient. Organizations which opted for progressive implementation of ERP usually start with Materials Management in anticipation of smooth supply chain, efficiency and effectiveness of operations. Generally, ERP package for Materials Management addresses the following activities:

- Material Master Data
- Vendor Master Data
- Purchasing Information Data
- Release Strategy for Purchasing
- Split Valuation
- Material Master Records
- Purchase Requisitions
- Requests for Quotations
- External Services Management
- Inventory Management
- Goods Issue
- Taxes in MM

However, the selection and use of sub-modules is organization specific and are chosen accordingly.

ERP System and Materials Management Module

Business consists of several processes that create and deliver value to the customers. The core business processes are procurement, production, supply chain, services, finance, human resource, and others. Enterprise Resource Planning (ERP) that integrate these processes into a system, often known as ERP system. In the ERP market, there are several key players developing and offering enterprise solutions to the companies. For example, SAP, Oracle, Microsoft Dynamics, and Sage are widely considered by both large and mid-size companies that depend on their scale, scope, and budget. Today, the ERP systems available in the market provide more than the basic requirements of integrating various business processes. They use latest technologies such as advanced optimization, analytics, machine learning, and artificial technology applications to the companies which improve efficiency, visibility, and intelligence on every function of the business processes. The new-generation of ERP systems provide digital assistants, like chatbots, to users, machine learning and artificial intelligence (ML/AI) to automate business processes, and analytics capability to real-time visibility and decision-making. The benefits of ERP systems are higher productivity, better insights, accelerated reporting, lower risk, simple information technology, and improved agility.

An ERP System, also known as ERP Suite, consists of many ERP applications for different business processes that interact and communicate with each other and share a common database. Each ERP application, also known as ERP Module, focuses on one business area. For example, ERP applications are focused on sales, logistics, finance, human resources, etc. However, different modules can be combined to meet the companies' requirements. Moreover, there are several modules available to different industries from manufacturing, retail, banking, airlines to education. Now-a-days, ERP can be implemented in three ways depending on the companies' requirements – Cloud, On-Premise, and Hybrid ERP. Most often, companies manage their business processes with some standalone products, like Spreadsheets, and then they realize importance of integrating business processes and benefits of implementing ERP. Companies can identify the need for implementing ERP system by recognizing either one or more signs. Companies spending more to complete their daily or routine activities and/or working with multiple data sets manually can easily sense the need for an ERP system to efficiently manage and integrate the business processes.

Materials management (MM) module primarily focuses on the functionalities like inventory management, purchasing, material requirements planning (MRP), physical inventory, valuation, service master, invoice verification, and product catalogs. Materials management system, also known as MM Module, is an ERP

application that mainly focuses on managing the flow of materials within the company. MM module is organized by three types or levels of data – organizational, master, and transaction data. Organizational data defines the organizational structure of the module that includes client, company code, plant, storage location, purchasing organization, and purchasing group data. Purchasing organization is an organization unit which is responsible for buying materials and services from vendors (also known as business partners). Master data defines the main data relevant for the module that includes vendor, material, purchasing information record, condition, and output master data. Vendor master data contains all information needed to do business with suppliers. It has general, company code specific, and purchasing organization specific information. It is primarily maintained by accounting and purchasing department. Material master data contains all information relevant to manage the flow of materials within the company. It has several information (also known as views) such as basic, sales, purchasing, material planning, forecasting, storage, quality, accounting, and controlling data. It is maintained by various departments from sales and distribution, materials management, production, plant maintenance, accounting, controlling, and quality management. The views that relevant to materials management are basic, purchasing, storage, and accounting information. The transaction data contains all information involved while executing the process namely, documents, document numbers, date, time, person, etc.

The standard materials management process in any ERP systems, also known as procure-to-pay process, triggered by the need for the materials in the form of purchase requisitions from other departments or processes and completed by making payment to vendors by accounting department. It can be executed by the following steps: purchase requisition, vendor selection, purchase order, notify vendor, vendor shipment, goods receipt, invoice receipt, and payment to vendor. The process would be initiated as when the need for the materials are raised in the form of purchase requisitions. It can be initiated either by manually or automatically. The output of this step would in turn decide whether to make internally or buy externally the requested materials. In case the request is for procuring the materials externally from potential vendors from the market then it would trigger the vendor selection step that in turn identify the vendor to whom the purchase order would be submitted. Once, the vendor is notified either by manually or automatically, the vendor initiates the shipping and delivery process. After receiving the materials requested as physical goods, the process further initiates the accounting process to complete the vendor payment against goods and invoice receipt with purchase order placed. As and when the process moves from one step to another step, it generates several documents and automatically updates several master data information. For example, while processing the invoice receipt, purchase order status gets updated, material master updates, and accounting document is created for the transaction. There are variety of forms

generated from the purchasing order that supports the procure-to-pay process such as purchase order output, order acknowledgement forms, reminders, and schedule agreements.

24.8 Summary

- Materials management encompasses all operations management functions from purchasing to the final delivery of the end items.
- An organization can achieve significant cost savings, reduction in lead time, improvement in production efficiency, and reduction in wastage by properly managing materials.
- Materials management covers purchase of raw materials, management and control of work-in-process items, stores and warehouse management, and distribution of finished products.
- The flow of materials is divided into three overlapping functions of production control, inventory control, and materials handling.
- The inventory control function involves maintaining stock in various stages of production in the desired quantities so that the overall cost of production is minimized.
- The materials handling function involves the physical movement of materials into, through, and out of the firm.
- Techniques like the Kanban system, ABC classification system, and JIT purchasing are used in the management and control of material in an organization.

24.9 Glossary

ABC classification system: Based on the usage value, materials are classified into three categories: A (materials of high usage value per annum accounting for 60-70% of the total cost), B (materials of moderate usage value per annum accounting for 10-30% of the total cost), and C (materials of low usage value accounting for 5-15% of the total cost).

Automated and semi-automated guided vehicles: These are used to store and retrieve inventory items from stock. Semi-automated guided vehicles, which are a combination of computer and human control, can move independently on their guided paths to a specific workstation and then signal to the operator to perform the required operation.

Automated storage and retrieval systems: These are computer-controlled and mechanically-operated materials handling systems. These systems function like physically operated robots.

Conveyance systems: The inventory items are stored in standardized boxes, which have a trip control device that prevents the inventory items from spilling out. To pick up a particular inventory item, the computer releases the control device at the place

where that item is located and the box automatically falls onto the conveyor. The conveyor then sends the boxed items to the order-processing area where a robot or a human being collects them.

Distribution centers and warehouses: These are physical facilities used to store and ship inventory.

Finished goods inventory department: It checks the quantity and quality of the products in the production process, stores the products to protect them from pilferage and other damage, audits the finished goods inventory, and retrieves the finished goods from the stocks.

Fixed sequence robots: These perform a sequence of operations based on a predetermined set of procedures.

Intelligent robots: These robots perceive the environmental conditions of the workplace through tactile or visual perception or both and can make necessary and suitable decisions by using on-board computers.

Inventory control: It involves the maintenance of stock in various stages of production in the desired quantities so that the overall cost of production is minimized. This function is performed by the raw material inventory, production, and finished goods departments.

JIT Purchasing: The size of the purchased quantities is reduced to such an extent that the materials directly reach the production point.

Kanban system: Firms store their materials and other inventory items in a single-use container like trays or boxes. A card called the Kanban is attached to each container that holds a specific amount of materials or other inventory parts used to manufacture the product. These cards are used for initiating the transactions.

Materials handling: It manages the physical movement of materials into, through, and out of the firm to the required location in a timely and cost-effective manner without affecting the primary objectives of the other two materials management functions.

Materials management: The study of flow of materials through various operations in a production facility. It helps in assessing material requirements at various stages of the production process and in maintaining a control over the firm's production and distribution functions.

Numerical control robots: These perform a set of operations based on numerical data fed into them through punched tapes, data cards, and digital switches.

Physically operated robots: These have a mechanical arm and hand and are used by workers to pick up materials.

Playback robots: These robots store a sequence of operations in memory. An operator initially performs these operations using a robot.

Production control: It involves directing and regulating the movement of goods through the entire manufacturing cycle from the process of purchasing materials to producing the finished product.

Production department: It allows the continuous flow of goods during the production process without any stoppages.

Purchasing department: It acquires the required materials in the right quantity, of the right quality, from the right source, at the right time, and at the least possible cost.

Raw materials inventory department: It manages the raw materials inventory, which is the collection of inputs used in the production process.

Receiving department: It processes the incoming shipments of materials.

Robots: These are computer-controlled, re-programmable, multi-functional manipulators designed to move materials, parts, tools, and other specialized devices through variable programmed motions to perform various tasks independently.

Shipping department: It delivers goods from the finished goods inventory department to customers.

Single-card and dual-card Kanban system: In a single-card Kanban system, a conveyance card is used, while in a dual-card Kanban system, the conveyance card and the vendor card is used. In this system, the required quantity is obtained from the vendor and a vendor authorization card is used in the process.

Usage value: The product of the number of units of a material used per year and the cost per unit.

Variable-sequence robots: The sequence of actions performed by these robots can be easily changed depending on the nature of operations to be performed, while their functioning is similar to that of fixed sequence robots.

24.10 Self-Assessment Exercises

1. Materials management is viewed as a trouble avoidance and opportunistic tool to improve a firm's profits. Define materials management and explain the need for it.
2. The materials management process is explained by three inter-related functions of an organization. Explain in detail the different functions of materials management.
3. The use of the latest technology has enhanced the efficiency of materials management. What are the various technologies available for material managers for managing materials?
4. Various techniques are being used by organizations to manage and control materials. What are the different materials management techniques being used? Explain in detail.

24.11 Suggested Reading/Reference Material

1. Dr. S. Ramachandran, Vijayalakshmi,D. Jagadhish, Material Handling And Facilities Planning- Ktu Paperback, Irwalk Publications January 2019
2. Prasanna Chandra, Projects: Planning, Analysis, Selection, Financing, Implementation And Review ,Mcgraw-Hill; Ninth Edition, 15 May 2019

3. Erik Larson, Clifford Gray , Project Management: The Managerial Process | 6th Edition , Mcgraw Hill Education; Sixth Edition, 1 July 2017
4. The Art Of Service - Inventory Control Publishing, Inventory Control A Complete Guide - 2021, The Art Of Service - Inventory Control Publishing, November 4, 2020
5. P. Gopalakrishnan, Purchasing And Materials Management, Mcgraw Hill Education; 1 July 2017

24.12 Answers to Check Your Progress Questions

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

1. (a) Vendor analysis

The functions of materials management are production control, materials handling and inventory control. Vendor analysis is associated with purchase management (purchase department).

2. (c) i, ii and iii

Alternatives i, ii and iii are tasks carried out by the raw material inventory department. Alternative 'iv' is associated with the receiving department. The tasks of the receiving department include unpacking incoming materials, checking quantity and inspecting quality and then generating receiving reports.

3. (d) i, ii and iii

Storing raw materials safely is a task of the raw material department. All other tasks are carried out by the shipping department.

4. (c) To move materials to the required location in a timely and cost-effective way without affecting the primary objective of production control and inventory control

Materials handling refers to managing the physical movement of materials into, through, and out of the firm. The primary objective of materials management is to move materials to the required location in a timely and cost-effective way without affecting the primary objective of production control and inventory control functions.

5. (a) Purchase department

The inventory control function is represented in three departments - Raw materials inventory department, production department and finished goods inventory department. Purchase department is associated with the inventory control function of materials management.

6. (c) Locating and receiving raw materials

Locating and receiving raw materials is the function of the raw materials inventory department. All the other options are functions of the production department. The function of production control aims at directing and regulating goods movement through the entire manufacturing cycle from the process of purchasing materials to making the finished product. The departments involved in this function are purchasing department, receiving department, raw materials inventory department and production department.

7. (b) Processing requisitions for materials

Processing requisitions for material is done by the purchase department and not by the receiving department. The main task of the former is to acquire the required materials in the right quantity, of the right quality, from the right source, at the right time and at the least possible cost. The primary responsibility of the receiving department is to process incoming shipments of materials.

8. (c) Materials management

Materials management is the study of flow of materials through various operations in a production facility. Inventory management deals with managing inventory and maintaining it at optimum levels. Operations management encompasses both materials management and inventory management. Purchase management is a separate sub-function under materials management.

9. (b) i, ii and iv

Shortage in materials supply affects the firm in many ways. They include stoppage or breakage in production, delay in delivery to customers, increase in operational expenses, etc. On the other hand, the efficiency of the production process actually decreases rather than rising.

10. (c) Finished goods inventory department

Purchase department, raw material inventory department, receiving department and production department are associated with production control. The finished goods inventory department is associated with inventory control function.

11. (c) Variable-sequence robot

The function of variable-sequence robots is similar to that of fixed-sequence robots, but the sequence of tasks can be changed depending on the nature of operations to be performed.

12. (a) Fixed-sequence

Fixed-sequence robots perform a sequence of operations based on a predetermined set of procedures. Electronic sensors are used to activate these robots.

13. (b) Intelligent robots

Intelligent robots perceive the environmental conditions of the workplace through tactile or visual perception or both and can make necessary and suitable decisions by using on-board computers.

14. (b) These systems store a sequence of operations in memory.

All the statements are true regarding automated storage and retrieval systems, except statement (b). Playback robots store a sequence of operations in memory.

15. (c) Conveyance systems

In conveyance systems, the inventory items are stored in standardized boxes. These boxes have a trip control device that prevents the inventory items from spilling out. The systems are controlled by a Computer Integrated Manufacturing System.

16. (a) ABC

The ABC classification system is also referred to as ABC (Always Better Control) analysis. The purpose is to alter expenses associated with controlling materials according to their usage value.

17. (a) Conveyance authorization card

A Kanban system uses three types of cards to initiate material transactions: production authorization card, vendor authorization card and conveyance authorization card. A conveyance authorization card authorizes a materials handling agent to move the tray to a specified destination. This specifies the product's name, its identification number and delivery destination. The dual-card Kanban system makes use of two Kanban cards, a conveyance card and a vendor card.

18. (c) The system considers availability of materials.

Resource allocation is made based on value of the inventory. The more valuable the inventory is, the more the resources allocated. Even though the method facilitates selective control of materials, the method suffers from several limitations. One limitation is that ABC analysis does not consider the aspect of availability of materials.

19. (a) An item is critical if its usage is high

In ABC analysis, an item is said to be critical if its usage is high. The purpose of this analysis is to alter expenses associated with controlling materials according to their usage value.

20. (d) Reduced flexibility

In JIT purchasing, flexibility is higher in terms of ability to change materials required at the last minute depending on changes in customer/client preferences, etc. Thus, flexibility is not reduced. It rather increases.

21. (b) Production authorization card

A Kanban system uses three types of cards to initiate material transactions: production authorization card, vendor authorization card and conveyance authorization card. The production authorization card authorizes the production department to start the production process. This card describes the product's name, identification number and description and the list of materials needed for continuing the production process.

22. (c) Maintain minimum inventory till the next replenishment

JIT purchasing implies that inventory can be replenished just-in-time for manufacture. The method advocates reduction in size of purchased quantities to the extent that materials reach the production point directly. Hence, safety stocks need not be maintained.

Project & Operations Management

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