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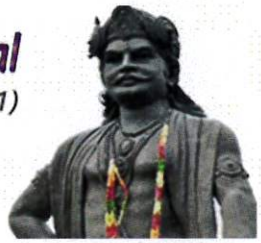
मध्यप्रदेश भोज (मुक्त) विश्वविद्यालय, भोपाल



SELF - LEARNING MATERIAL

MBA, Second Year
Paper – III

PRODUCTION AND OPERATIONS MANAGEMENT

MBA Second Year

Paper - III

PRODUCTION AND OPERATIONS MANAGEMENT

मध्यप्रदेश भोज (मुक्त) विश्वविद्यालय – भोपाल

MADHYA PRADESH BHOJ (OPEN) UNIVERSITY - BHOPAL

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SYLLABI-BOOK MAPPING TABLE

Production and Operations Management

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Unit II 1. Layout Planning and Analysis 2. Materials Handing	**Unit-2:** Layout Planning and Materials Handling **(Pages 21-38)**
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INTRODUCTION

NOTES

Production and Operations Management originated at the time of the Industrial Revolution. However, it gained importance in the late 1950s when scholars realized the need to analyse production operations as a system in its own right. In recent times, production and operations management, popularly referred to as POM, has become an important subject of study. To a layman, POM can be explained as the planning, coordination and control of the resources of an organization in a manner that will facilitate the production process. In simple words, POM is concerned with the transformation of production and operational inputs into outputs that will meet the requirements of consumers, when distributed. It is also an area of business that is concerned with the production of quality goods and services. Among other things, it ensures that all business functions such as production, design and product performance operate smoothly in a manner that is not only efficient but also effective.

Operations management concerns itself with the production of quality goods and services, and ensures that business operations such as production function, design and product performance are executed efficiently. Production and operations management has tremendous potential and is gradually gaining a lot of prominence amongst all functional areas of management, irrespective of the size of the business. Firms gain an edge in numerous ways, for instance in terms of better quality products, reduced wastes, more inventory turns, better product designs, greater flexibility, etc., to name a few.

This book, *Production and Operations Management*, is divided into five units that follow the self-instruction mode with each unit beginning with an Introduction to the unit, followed by an outline of the Objectives. The detailed content is then presented in a simple but structured manner interspersed with Check Your Progress Questions to test the student's understanding of the topic. A Summary along with a list of Key Terms and a set of Self-Assessment Questions and Exercises is also provided at the end of each unit for recapitulation.

UNIT 1 INTRODUCTION TO PRODUCTION/OPERATIONS MANAGEMENT

Structure

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1.1 Objectives
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1.0 INTRODUCTION

The word production immediately conjures up images of large rooms filled with machines, materials and people working to fulfil their targets. The coordination between all these Ms (i.e., man, machine, materials, money and method) is done by the sixth M, i.e., management. This is what production and operations management is all about. It is concerned with the production of goods and services and is responsible for ensuring that these operations are efficient and effective. In other words, production and operations management is to manage the efforts and activities of people, equipment and other resources of the organization in order to change raw material into finished goods and services.

This unit will introduce you to the concept, nature and of production/ operations management. It further deals with facility location which is a process of identifying the best suitable geographic location for a production facility. A suitable facility location ensures effective operations. There are many reasons which lead to search a facility location such as starting a new factory, expansion of the existing plant, re-location of the existing plant, expiry of lease and the non-renewal etc. The unit discusses about the objectives of facility location exercise and importance of facility location. The unit goes on discussing the factors affecting the location decision. You will also study about the centre of gravity model, load distance model along with the suitable examples.

NOTES

1.1 OBJECTIVES

After going through this unit, you will be able to:

- Define production and operations management
- Discuss the fundamental logic behind every production process
- Understand the scope and function of production and operations management
- Describe the different types of management decisions
- Discuss the historical developmental process of operations management
- Explain the different types of plant layout

1.2 NATURE AND SCOPE OF PRODUCTION/ OPERATIONS MANAGEMENT

The Association of Operations Management (APICS) defines operations management as 'The field of study that focuses on the effective planning, scheduling, use and control of manufacturing or service organization through the study of concepts from design engineering, industrial engineering, MIS, quality management, production management, industrial management and other functions as they affect the organization'.

According to Shrin and Joel G. Siegel, 'Production and operation management is the management of all activities directly related to the production of goods and services.' It may be remembered that goods are produced and services are rendered.

Difference between Production and Operations

Production and operations involve the conversion of input into output through a transformation process. In the early days production involved the processes followed for mass production and these produced tangible goods. As the complexities of business grew, managing the systems responsible for production became essential. Later, even services began to be 'produced' or rendered. These were intangible. So, some principles were needed which could encompass the entire system that produced a good or delivered a service. It was found that the same principles could be effectively applied in the management of processes that produced goods as well as those that produced services. This is production and operations management.

P&OM (as it is called) uses the decision-making tools of operations research and the principles of industrial engineering, quantitative techniques, shop floor control, organizational behaviour, safety management and maintenance management, etc. So production and operations management deals with the concepts and principles that are employed by organizations to make them efficient and effective.

1.2.1 Production Process

It has already been stated that production involves conversion of input to output through a transformation process which adds value to the input.

Fig. 1.1 Production Process

(a) **Input:** It includes the six Ms—man, machine, materials, money, method and now management.

(b) **Transformation Process:** This is the process by which the inputs are converted into outputs. It is a value addition process which modifies or adds value to the input and converts it into a form that is more useful and saleable to a customer. This value addition can be in any of the following ways:

(*i*) ***Alteration:*** This includes all activities, such as change in physical state of input, changing dimensions, adding chemicals, heating, rolling, galvanizing, etc. The methods of transformation are numerous and there is one distinct method for every available product in the market.

(*ii*) ***Transportation:*** This refers to the physical movement of goods from one place to another. Some firms, especially traders specialize in buying goods from one place (usually the place of manufacture) and transporting it to a location where it can be sold.

(*iii*) ***Storage:*** This refers to preserving goods, for example, foodgrains, in a protected environment so that it can be made available at a later date. This is also a kind of transformation process.

This list is by no means exhaustive. Value addition can also occur through activities, such as inspection and through services rendered by such companies as book publishers and transport companies, etc. In short, any process that adds value is a transformation process.

(c) **Output:** An output can be a good or a product or a service. The major differences between a product and a service are as follows:

Table 1.1 *Differences between a Product and a Service*

	Goods	Services
1.	Goods are tangible. They have physical parameters.	Services are intangible. They are just ideas, concepts or information.
2.	Goods can be produced, stored and transported according to demand since the value is stored in the product.	Services cannot be produced beforehand, stored or transported. Value of a service is conveyed as used.
3.	It is produced in a factory environment, usually away from the customer.	Services are produced in a market environment in collaboration with the customer.
4.	Goods are often standardized.	Services are often customized.
5.	Quality is inherent to the product.	Quality is inherent to the process since it is a function of people.

As the complexities of an organization grew, it was found that merely converting an input to an output was not enough. Feedback from the output stage was necessary to make the required changes either in the input or in the transformation process. So production control was done to take care of fluctuation if any, in inputs. The quality of the produced output was now constantly compared to the quality of the desired output and feedback mechanisms were put in place to monitor the performance of the transformation process.

At times random disturbances which hamper the transformation process are also noticed. These random disturbances are sometimes unexpected and so not planned for. They occur due to an external environment and can be in the form of strikes, government interference and recession, etc. So in reality the cycle of production and operations management looks like this:

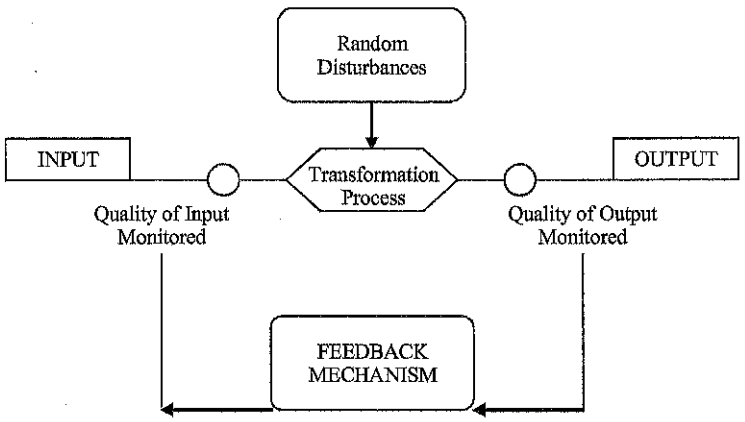

Fig. 1.2 Cycle of Production and Operations Management

1.2.2 Production is the Heart of an Organization

Production is the primary business of an organization. All other wings or activities of an organization exist subject to the existence of production. Without production or anything to sell, there is no organization at all. An organization usually has several departments and each department has a specialized function.

- Marketing establishes the demand for goods and sells what is produced.
- Finance provides the capital for equipment and resources.
- Human resource management provides and manages manpower.
- Purchasing is concerned with procurement of materials needed to run the organization.
- Materials management takes care of inventories.
- Law department safeguards the organization on legal issues.
- Public relations department builds the image of the organization.
- R&D is responsible for research and development.

But it is the production department which produces goods and services. It plays a vital role in achieving a firm's strategic goal.

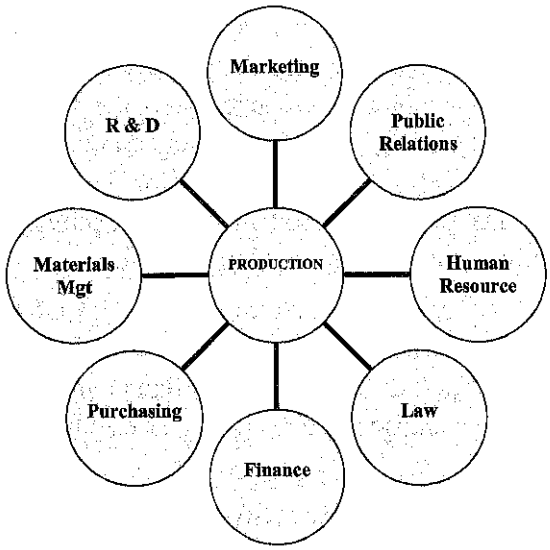

Fig. 1.3 Production and other Departments of an Organization

Production involves the greatest bulk of a company's employees and is responsible for a large portion of its assets. It also has a major impact on the quality and cost of goods and therefore is the visible face of the company. Hence, we say that production is the heart of an organization.

1.2.3 Objectives of Production and Operations Management

Every organization starts with a goal and a mission and then chalks out its activities to achieve these goals. All the activities, primarily those that convert inputs into required outputs, are planned accordingly. The common objectives of any kind of organization are as follows:

(*i*) *Customer satisfaction*

Customer satisfaction is vital for the survival of an organization. An organization studies the expectations of a customer or the service that needs to be rendered and decides on the product. An organization can survive only if its products satisfy the customer on the basis of the following criteria:

- The quality of the product is as per acceptable standards
- The product is reliable and easy to maintain.
- The product's functionality is as promised by the seller.

(*ii*) *Profitability*

To achieve sales, the pricing of the product should be optimum. For this the market price of products should be competitive and commensurate with the features offered by the product. A good organization produces goods and services of the right quality that meet all product specifications and are optimally priced. In order to make good profits an organization should focus on minimizing cost and maximizing revenue.

(iii) Timeliness

The product produced or service rendered may be qualitative and cost-effective but if it does not reach the consumer when required, the organization loses out on the product's market. This is because consumers do not wait for a product or a service; instead they acquire it from a competitor. Therefore, production and operations management plays a vital role in the timely provision of a product or a service by effectively maintaining production schedules.

To summarize, you can say that an effective P&OM needs to produce products or render services of the right quality, in the right quantities, at the right time and at minimal costs. It should also ensure that no matter what, wastages do not occur in the system because these result in cost escalations and cause severe delays.

The above-mentioned factors can also result in the failure of the management in achieving its objectives and targets.

1.2.4 Scope of Production and Operations Management

Production and operations management is concerned with converting inputs into outputs using physical resources in order to offer the required utilities to customers while also satisfying the other organizational objectives of effectiveness, efficiency, and adaptability. It sets itself apart from other operations such as people, marketing, finance, and so on by focusing on 'conversion through the use of physical resources.' The actions described under production and operations management functions are as follows:

1. Location of Facilities
2. Plant Layouts and Material Handling
3. Product Design
4. Process Design
5. Production and Planning Control
6. Quality Control
7. Materials Management
8. Maintenance Management

1. Location of Facilities

The location of operations facilities is a long-term capacity decision that necessitates a long-term commitment to the spatially static factors that effect a company. It is crucial for an organization's strategic decision-making. It addresses issues such as 'where should our major operations be based?'

Because a considerable investment is made in establishing plant and machinery, choosing a location is a critical decision. An incorrect plant site may result in the total loss of all plant and machinery equipment investments. As a result, the site of a factory should be determined by the company's expansion plan and policy, product diversification plans, changing raw material sources, and a variety of other considerations. The goal of a location study is to identify the best site that will provide the most benefit to the company.

2. Plant Layout and Material Handling

The physical organization of facilities is referred to as plant layout. In the conversion process, it is the configuration of departments, work centres, and equipment. The ultimate goal of the plant architecture is to create a physical configuration that meets the desired output quality and quantity in the most cost-effective way possible. 'Plant layout is a plan for an optimal arrangement of facilities including employees, operational equipment, storage space, material handling equipment, and all other supporting services, as well as the design of the best building to accommodate all of these facilities,' according to James Moore.

The moving of materials from the store room to the machine, and from one machine to the next during the manufacturing process is referred to as 'Material Handling.' It's also known as the 'craft and science of moving, packing, and storing products of any kind.' With 50 to 75 per cent of the cost of production, it is a specialised activity for a contemporary manufacturing business. The cost of material handling devices can be decreased by properly sectioning, operating, and maintaining them.

Material handling equipment boosts output, improves quality, speeds up delivery, and lowers manufacturing costs. As a result, material handling is a key concern in the design of both new and existing operations.

3. Product Design

The turning of ideas into reality is the subject of product design. As a survival and growth strategy, any business must design, develop, and offer new products. The most difficult difficulty that organizations confront is developing new items and launching them on the market.

Marketing, product development, and production are all involved in the process of identifying a need and turning it into a real product. Product development transforms marketing's client needs into technical specifications, then designs the product's numerous features to meet those criteria. Manufacturing is in charge of selecting the processes that can be used to make the product. Product design and development connects marketing, customer wants and expectations, and the actions needed to make the product.

4. Process Design

The macroscopic decision-making of an overall process route for turning raw materials into finished items is known as process design. These considerations include process selection, technology selection, process flow analysis, and facility layout. As a result, one of the most significant considerations in process design is to analyse the workflow for turning raw materials into completed products and to choose a workstation for each step in the process.

5. Production Planning and Control

Production planning and control can be defined as the process of planning production ahead of time, determining the exact path of each item, determining the start and finish dates for each item, issuing production orders to shops, and monitoring product progress in accordance with orders.

NOTES

The expression 'First Plan Your Work, Then Work on Your Plan' is the foundation of production planning and control. Planning, routing, scheduling, dispatching, and follow-up are the main functions of production planning and control.

Planning entails determining what to do, how to do it, when to do it, and who will do it ahead of time. Planning is the process of bridging the gap between where we are and where we want to go. It allows things to happen that would not otherwise be feasible.

Routing can be defined as the process of selecting the path that each component of a product will take as it progresses from raw material to final product. Routing identifies the most efficient path to take from one department to the next and from one machine to the next until the raw material is finished.

The operational programme is determined by scheduling. Scheduling can be defined as "the determination of the time and date for each operation" as well as "the order in which the operations will be performed."

Dispatching is responsible for initiating processes. It grants the essential authority to begin a certain task that has already been prepared under the headings of 'Routing' and 'Scheduling.' As a result, dispatching is defined as "the release of orders and instructions for the commencement of production for any item in accordance with the route sheet and schedule charts." The purpose of follow-up is to report on the progress of work in each shop on a daily basis in accordance with a predetermined proforma, as well as to explore the causes of deviations from the anticipated performance.

6. Quality Control

A system for maintaining a desired level of quality in a product or service is known as quality control (QC). It is the systematic monitoring of numerous aspects that influence the product's quality. Quality control focuses on defect avoidance at the source and relies on a good feedback system and corrective action mechanism.

Quality control can alternatively be defined as "the industrial management strategy for producing uniformly acceptable quality products." It is the full set of actions that ensures that the business produces the highest quality products at the lowest possible cost. The following are the main goals of quality control:

- To increase the company's revenue by making the product more appealing to customers, such as by offering longer life, more usability, and maintainability, among other things.
- Reduce the cost of a company by reducing defects-related losses.
- To achieve manufacturing interchangeability in large-scale production.
- To produce high-quality goods at a low cost.
- To ensure customer satisfaction with products or services of a high quality level, and to increase consumer goodwill, confidence, and the manufacturer's reputation.
- To ensure quality control, do inspections as soon as possible.

7. Materials Management

Materials management is a managerial function that is primarily concerned with the procurement, control, and use of materials as well as the flow of goods and services associated with the manufacturing process in order to achieve predefined goals. The following are the primary goals of materials management:

- To save money on materials.
- To efficiently purchase, receive, transport, and store materials while lowering costs.
- Cost savings can be achieved by simplicity, standardisation, value analysis, import substitution, and other methods.
- To find new sources of supply and establish friendly relationships with them in order to assure a steady supply at reasonable prices.
- Developing high inventory turnover ratios and reducing investment related to inventories for use in other profitable objectives.

8. Maintenance Management

Equipment and machinery are an integral element of the entire production effort in modern industry. As a result, their idleness or downtime is quite costly. As a result, it is critical that the plant machinery be well maintained. The following are the primary goals of maintenance management:

- The goal is to keep the plant in good functioning order for the least amount of money possible.
- Maintaining the equipment and other facilities in such a way that they can be used at full capacity without interruption.
- To ensure that other areas of the factory have access to the machines, buildings, and services they need to accomplish their functions while getting the best return on investment.

Functions of Production and Operations Management

The functions of Production Management are determined by the company's size. In small businesses, the production manager may be responsible for all aspects of production planning and management, as well as personnel, marketing, finance, and purchasing. Separate managers for Personnel, Marketing, and Finance may exist in medium-sized businesses. Production management, on the other hand, may be in charge of production planning and control, as well as purchasing and storage. The operations of Production Management are limited to the management of production activities in major companies. As a result, there are no hard and fast rules or guidelines for defining the role of Production Management, but for academic purposes, we can list some of the functions that Production Management department is responsible for. They are as follows:

i. **Materials:** The product's materials are chosen. To select appropriate materials for his product, the production manager must have a thorough understanding of materials and their qualities. Material research is required to develop alternatives to meet the changing needs of the design in the product as well as the availability of materials.

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ii. **Methods:** Some of the activities of Production Management include determining the optimal technique for the process, searching for methods that fit the available resources, and determining the process sequence.

iii. **Machines and Equipment:** The Production Management department is in charge of selecting appropriate machinery for the required process, creating maintenance policies, and planning machine layouts.

iv. **Estimating:** The production management department conducts a detailed calculation of production times and costs in order to set up production targets and delivery dates while keeping production expenses to a minimum. In a competitive setting, this will assist management in determining what should be done to keep costs at the targeted level.

v. **Loading and Scheduling:** The Production Management department must create a timetable for various production activities, indicating when the process should begin and end. It must also arrange personnel activities and sketch the timetables of material transportation. The scheduling must take into account the current loads as well as the capacities of the available facilities.

vi. **Routing:** The Production Management department's most significant duty is routing. Routing entails establishing flow lines for various raw materials, components, and finished products from the stores to the packing of finished goods, so that everyone involved is aware of what is going on the shop floor.

vii. **Despatching:** For each component of the product, the Production Management department must create several documentation such as Job Cards, Route sheets, Move Cards, and Inspection Cards. This is done as a set of five copies. These documents must be released by the Production Management department in order for the production to begin. The shop floor's actions will be guided by the directions in these publications. Dispatching is the process of releasing a document.

viii. **Expediting or Follow-up:** Once the documents have been sent out, the management wants to know if the operations are going according to plan. Expediting engineers walk throughout the factory floor with the blueprints, compare the actual to the plan, and report back to management on the progress of the work. This will aid management in assessing the plans.

ix. **Inspection:** In this case, inspection is often concerned with inspection operations during production, while quality inspection is handled by a distinct quality control department that is not under the supervision of Production Management. This is true because if quality inspection is delegated to production management, there is a likelihood that defective items will be identified.

x. **Evaluation:** The Production department must assess itself and its contribution to the achievement of corporate and departmental goals. This is important in order to establish future standards. Regardless of the company's size, the production management department is responsible for routing, scheduling, loading, dispatching, and expediting. This is due to the

fact that this department is very knowledgeable about materials, methods, and available resources, among other things. If the company is small, the Production Management Department is responsible for all of the above-mentioned responsibilities I to x). In medium-sized businesses, the Production Management Department may be in charge of other functions such as Methods and Machines in addition to Routing, Scheduling, and Loading, Dispatching, and Expediting. There will be separate divisions for Methods, Machines, Materials, and other things in large companies, but Production Management is alone responsible for routing, loading, and scheduling.

1.2.5 Production Management Function

Just like any other field of management, production and operations management can also be viewed as a continuous process of planning, organizing and controlling. The jobs that would fall in each of these categories are given below:

Planning

Planning includes all the activities that precede the actual process of producing. These activities guide future decision-making and involve

a. Product design and product development
b. Production process selection
c. Planning the facility or plant location
d. Planning the facility layout
e. Capacity planning
f. Production planning

Organizing

Organizing includes all those activities that involve structuring of the tasks to be performed and the authority required to perform them. In other words, it determines the activities required to achieve the operations and the subsystem goals and assigns responsibility and authority to carry them out. Organizing includes

a. Work study—motion study and time measurement
b. Materials management
c. Purchasing management

Controlling

Controlling includes all activities that ensure that the actual performance is as per the planned performance. This is done by developing standards and communication networks necessary to ensure that the organizing, staffing and directing functions are pursuing the planned objectives of the organization.

It includes the following:

a. Stores management
b. Value engineering or value analysis
c. Inventory management
d. Quality assurance or quality control
e. Maintenance management

Check Your Progress

1. What are the objectives of production and operations management?
2. List the activities included in the controlling function of production management.

1.3 FACILITIES LOCATION/PLANT LOCATION

Facility location is the selection of an appropriate site for the installation of a facility and it is pertinent to make this decision carefully.

Definition and Objectives

Facility location is the selection of suitable location or site where the factory or facility will be installed, and from where it will function. There are two fundamental objectives to a facility location exercise. They are:

- Minimizing cost
- Maximizing revenue

Whatever may be the nature of the firm these two objectives will govern its location decision exercise. The planning for 'where' to locate should start from 'what' the organization's objectives, priorities, goals, strategies, etc. are, and what the organization does to achieve it in the general socio-economic, technical and legal environment. Unless the objectives and priorities are clear, the location cannot be correct.

Importance of Facility Location

Why is facility location so important? What could happen if the location selection wrong?

(a) The following are the repercussions when a facility is run from an improper and incorrect location.

(i) The company may have to close down the operation and liquidate assets. In that case,

- Locating buyers for used equipment will be difficult.
- Price received for used equipment will be a fraction of the original investment.

(ii) The company may relocate facility to a new location, just like the Tatas have done. But this will involve,

- Large expenditure in shifting machinery, equipment, manpower, etc.
- Taking new land lease/outright purchase, registration, etc., is time taking and added cost

(iii) If the company continues its operation at the wrong location, then,

- It may accumulate losses.
- Competitors with better locations will have an edge.
- The company will lose market share/customer goodwill.

(b) Location facility is an issue for consideration both for

- Starting a new facility
- Starting additional facility

(c) Additional or multiple facilities can be due to the following reasons:

(i) Separate facilities for different products/services – for example. Videocon has different plants for washing machine, TV, refrigerator, microwave oven, etc.

(ii) Separate facilities to serve different geographical areas–for example. LPG filling plants across the country to serve different locations'

(iii) Separate facilities for different processes–for example, a separate facility to make pizza base.

1.3.1 Factors Affecting Location Decision

Proximity to customers and proximity to raw materials are the two factors that play an important role while deciding the location for setting up a production facility.

1. Proximity to Customers (Markets)

When a plant is located near its customers/markets, the cost of transportation will be very less. This will reduce the product cost. Most of the small ancillary units are located near the big automotive factories. The OEMs (original equipment manufacturers) are the institutional customers of small parts, components, or sub-assemblies of these ancillary units. The Maruti Joint Venture Complex at Gurgaon near the Maruti Suzuki Car factory is a good example of how proximity to the customer reduces the transportation cost of auto ancillary units, which supplies parts, components, sub-assemblies, etc., for making the Maruti car.

Proximity to markets also allows companies to meet sudden spurt in demand, thus providing an advantage over competitors located at far-off places. That is why we find hospitals, schools, post offices, banks, insurance companies, etc., located in high-population zones so that they are able to serve a large number of customers.

2. Proximity to Raw Material

Why are the integrated steel plants of SAIL located in Bihar, West Bengal and Orissa? This is because of the large presence of iron ore, coal, dolomite and limestone mines in these regions, which are the basic raw materials for making steel. Proximity to the source of raw materials is an important consideration for facility location, especially if the raw materials are bulky, and huge transportation costs will be incurred in transporting them. Where it becomes absolutely necessary to transport them, it is found that cost of the material is equal to the transportation cost thus making the raw materials very costly at the point they are used.

3. Good Transportation Facilities

Good transportation facilities are necessary for the movement of goods and people. Regions near metro cities have the advantage of good transportation facilities as they have a good network of rail, air, water and road transportation.

4. Availability of Power Supply

Uninterrupted power supply is the basic requirement of most industries. Factories have to set up their own DG sets or captive power plants if located in areas with power problems. This increases the cost of the product, besides additional problems of running the DG sets, captive power plants, etc.

5. Basic Amenities

The area for location of the plant should have certain basic facilities like sewage system, piped water supply and security managed by the local municipality. It is desirable to have roads that lead to the factory. If these basic amenities are present, it will be easier for the workforce of the factory and they will be more willing to work there. Availability of housing facilities, schools, colleges, banks, post office, hospitals, etc. is an added advantage for locating a facility in an area.

6. Government Policies

Relaxed taxation policies, excise duty exemption and various other promotional efforts help to attract industrial activity in a region. Pondicherry and Daman and Diu are declared 'no sales tax regions' and many companies have their offices/ warehouses located there. Many state governments promote industrial activities in their regions by creating Industry Development Zones, Special Economic Zones, etc. The governments of Karnataka, Andhra Pradesh, Tamil Nadu and UP have created Software Development Parks, where facilities such as high-speed Internet, servers, etc., are provided to software companies at subsidized rates. Agriculture gets maximum subsidies from the Central as well as many state governments. Various processing plants of agricultural and horticultural products located in these states can avail these advantages. Before locating a facility in a place, government policies at that place must be considered.

7. Environmental and Community Consideration

Many state governments have strict environmental policies in place, which have to be followed by the industries operating there. States such as Uttaranchal do not give permission to set up in their state, industries that release toxic effluents. Opposition from the community regarding the construction of a plant in their region can disrupt the whole project. The Sardar Sarovar Dam project is an example where opposition from the local people has been disrupting the construction of the dam over the Narmada river. In the Chipko Movement started by S.L. Bahuguna, all the locals embraced a tree each, when the officials came to cut the trees in the forest. After the Union Carbide factory disaster in Bhopal, every new factory is scrutinized closely.

8. Proximity to Sub-Contractors

The presence of ancillary units manufacturing small components/sub-assemblies is important for any new factory. Ancillary units and joint ventures set up their facilities near the OEM. The advantage to the ancillaries is that it will reduce the cost of their components. But the advantage to the OEMs is that if they set up their facility near these ancillaries, they can take advantage of these ancillaries. When Maruti Suzuki wanted to set up their second facility, they set it up at Manesar near Gurgaon (where their first facility is located) so that they can they can take advantage of the suppliers present at the Maruti Joint Venture Complex at Gurgaon.

9. Easy Availability of Cheap Land

Land is the basic necessity for the construction of a new plant. Many big companies set up their facilities in backward areas because of cheap availability of land.

10. Less Construction Costs

Construction costs of a plant may be low at a particular place due to cheap labour available there. The construction material may also be cheaper at another place. Such places are preferred for locating a plant.

Scoring Model

Factor rating is the simplest method for arriving at the best location. The types of rating that constitute this method are given below.

1. Every factor that is relevant to the industry that is going to be set up is given a rating between one and five. These factors are those that are relevant to the industry, irrespective of its location. This is called **Factor Rating.**
2. Every factor that has been listed in (1) above, is given a relative rating between one and five for each of the locations proposed to be selected. This is called **location rating.**

Example 1.0

The following example will help demonstrate how these two ratings are used to arrive at the best location.

M/s Indiana Leathers has identified three locations, viz. Kanpur, Noida and Lucknow to set up a new leather goods manufacturing facility. The factor ratings and locations ratings have been given. Arrive at the best location using the factor and location rating method.

Factor				Location Rating	
		Factor rating	Kanpur	Noida	Chennai
1.	Proximity to market	3	4	6	3
2.	Proximity to Raw material	5	10	5	4
3.	Transportation facility	4	9	10	5
4.	Basic amenities	2	6	7	6
5.	Acceptance of leather factory by local	4	8	3	7
6.	Availability of cheap land	3	7	2	8
7.	Low construction costs	1	5	1	6
8.	Easy availability of cheap and skilled labour	3	3	8	4

NOTES

Factory ratings are 1 to 5 5 highest

Location ratings are 1 to 10 10 highest

Solution

For each location find the product of factor and location ratings. Add them up for each location. The location having the highest product will be the best location.

Product of factor and location ratings

Factor	Kanpur	Noida	Chennai
1	12	18	9
2	50	25	20
3	36	40	20
4	12	14	12
5	32	12	28
6	21	6	24
7	5	1	6
8	9	24	12
Total	177	140	131

The highest score is for Kanpur. So it is the best location.

Check Your Progress

3. What do you mean by facility location?
4. Name the two fundamental objectives of facility location.
5. Mention the two factors that affect facility location decision.
6. What do you mean by factor rating?

1.4 ANSWERS TO 'CHECK YOUR PROGRESS'

1. The objectives of production and operations management are:
   a. Customer satisfaction
   b. Profitability
   c. Timeliness
2. The activities included under the controlling function of production management are:
   a. Stores management
   b. Value engineering
   c. Inventory management
   d. Quality assurance
   e. Maintenance management
3. Facility location is the selection of suitable location or site where the factory or facility will be installed, and from where it will function.
4. The two fundamental objectives to a facility location exercise are minimizing cost and maximizing revenue.

5. Proximity to customers and proximity to raw materials are the two factors that play an important role while deciding the location for setting up a production facility.
6. Every factor that is relevant to the industry that is going to be set up is given a rating between one and five. These factors are those that are relevant to the industry, irrespective of its location. This is called factor rating.

1.5 SUMMARY

- Facility location is the selection of suitable location or site where the factory or facility will be installed, and from where it will function.
- The two fundamental objectives to a facility location exercise are minimizing cost and maximizing revenue.
- The planning for 'where' to locate should start from 'what' the organization's objectives, priorities, goals, strategies, etc. are, and what the organization does to achieve it in the general socio-economic, technical and legal environment.
- Proximity to customers and proximity to raw materials are the two factors that play an important role while deciding the location for setting up a production facility.
- Proximity to markets also allows companies to meet sudden spurt in demand, thus providing an advantage over competitors located at far-off places.
- Factor rating is the simplest method for arriving at the best location. Every factor that is relevant to the industry that is going to be set up is given a rating between one and five. These factors are those that are relevant to the industry, irrespective of its location. This is called Factor Rating.
- Centre of gravity method (CGM) is another approach to optimally locate the location of new facility in order to optimize the weighted distance. In this method, the analyst or decision maker has to find the centre of gravity (CG) of the geographic area, where all existing facilities are located, being considered.

1.6 KEY TERMS

- **Operations management:** The field of study that focuses on the effective planning, scheduling, use and control of manufacturing or service organization through the study of concepts from design engineering, industrial engineering, MIS, quality management, production management, industrial management and other functions as they affect the organization.
- **Facility Location:** It refers to the selection of specific site for establishment of the physical unit of production process.
- **Scoring Model:** It is one of the method in which various variables are weighted in varying ways and result in a score.

- **Transformation process:** The process by which inputs are converted into outputs.
- **Transportation**: The physical movement of goods from one place to another.
- **Storage**: Preserving goods in a protected environment so that it can be made available at a later date.
- **Productivity:** A measure of the quantity of output.
- **Planning:** It is the process of thinking about the activities required to achieve a desired goal.
- **Layout:** It means the way in which the parts of something are arranged or laid out.
- **Accident:** It refers to the unplanned, unexpected and uncontrolled event which may result either in injury or in property damage or in both.

1.7 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What are the functions of production and operations management?
2. Differentiate between 'efficiency' and 'effectiveness'.
3. What is the system concept of production?
4. Differentiate between tactical decision and strategic decision.
5. What are the various factors that influence facility location? Discuss.
6. What are the advantages of a good plant layout?

Long-Answer Questions

1. Discuss the importance of facility location.
2. Analyse centre of gravity model of location planning.
3. Prepare a note on load distance model.
4. Explain the four different types of layout.

1.8 FURTHER READING

Aquilano, Chase and Jacobs. 2003. *Operations Management for Competitive Advantage*. New Delhi: Tata McGraw-Hill.

Bedi, Kanishka. 2007. *Production and Operations Management*. New Delhi: Oxford University Press.

Evans, J.R., D.R. Anderson, D.J. Sweeney and T.A. Williams. 1984. *Applied Production and Operations Management*. US: West Publishing Co. St. Paul M.N.

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UNIT 2 LAYOUT PLANNING AND MATERIALS HANDLING

NOTES

Structure

2.0 Introduction
2.1 Objectives
2.2 Layout Planning and Analysis
  2.2.1 Types of Layout
  2.2.2 Layout Planning for Storage and Warehousing
  2.2.3 Methodology of Layout Planning
2.3 Materials Handling
  2.3.1 Principles of Materials Handling
  2.3.2 Materials Handling Equipment
2.4 Answers to 'Check Your Progress'
2.5 Summary
2.6 Key Terms
2.7 Self-assessment Questions and Exercises
2.8 Further Reading

2.0 INTRODUCTION

When the Nano was launched by Ratan Tata, there was widespread jubilation and anticipation of where the factory was going to come up. Various state governments offered attractive concessions to the Tatas urging them to set up the facility in their state. West Bengal was selected to house the Nano plant and work began at Singur. Not only the Tatas, but even their joint venture partners invested crores of rupees to set up their respective facilities.

However, the location option proved to be wrong. Barely months before commercial production was to start, there were agitations by the locals at Singur against the project. The situation got so out of hand that the Tatas were forced to abandon their project at Singur and relocate to Sanand, Gujarat.

So what went wrong? Without going into the reasons vis-à-vis the Tata project, in this unit you will learn about the factors that must be taken into consideration when selecting a location for setting up a factory while learning about layout plans and their various aspects.

This unit will also introduce you to the concepts of material handling, which is associated with moving of goods between incoming transport, storage, processes and outgoing transport. It involves the set of activities that move production inputs and other goods within plants, warehouses and transportation terminals.

2.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand the advantages of a good plant layout
- Describe the different types of plant layouts

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- Understand the layout planning for storage and warehousing
- Discuss the methodology for layout planning
- Discuss the applications and types of material handling
- Understand the characteristics of cross-docking and other logistics techniques

2.2 LAYOUT PLANNING AND ANALYSIS

Once the facility location has been decided and land has been acquired, a sketch or plan is made to decide where each department/section, entrance and exit gates, restrooms, storage areas, etc., will be located. In the following paragraphs, we will see how this type of planning is done.

We can define layout as, 'The physical location of the various departments/ units of a facility within the premises of the facility.'

The departments must be located based on some consideration. The common considerations are as follows:

- Logical sequence of processing operation
- Direction of material flow and material handling
- Aesthetic considerations
- Government regulations
- Special requirements

The entrance and exit gates are usually critical in the layout planning of facilities.

Objectives of a Plant Layout

Plant layout is the method to plan and arrange materials and facilities so that a steady flow of production is ensured at minimum cost. A good plant layout always results in comfort and satisfaction of workmen and this automatically increases the production. A bad plant layout leads to accidents and unnecessary problems.

A good plant layout is designed to achieve the following objectives:

1. Economic handling of materials and finished goods
2. Fast and efficient quality production
3. Enhanced utilization of available space
4. Flexibility in change of plant design and possibility of expansion at a later date
5. Improvement in work condition leading to higher productivity
6. Unidirectional/systematic flow of production operation
7. Reduction in waiting time
8. Reduction in manufacturing cost

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Advantages of a Good Plant Layout

A good plant layout results in better production and lower costs. The advantages of a good plant layout are as follows:

1. **Well-organized workspace:** A good plant layout means a well-organized workspace with adequate facilities provided for the machines as well as for the workmen. Proper arrangement of machineries and tools eliminates congestion. The materials required are stored in their appropriate places so there is no confusion.
2. **Better working conditions:** A good plant layout results in labour satisfaction due to improved and clean working conditions. It has been well documented that motivation level increases when lighting and other aesthetics are improved. Safety of workmen is another important factor. A good plant layout ensures that the machines are properly placed, with adequate space in between so that there is no congestion and no danger of the workmen getting injured. This provides safety to the workmen and creates a good environment for work.
3. **Minimization of material handling costs:** A good plant layout minimizes material handling costs. The machinery and equipment are placed in such a manner that there is no difficulty in transferring materials between workstations. The provision of adequate material handling systems will ensure that there is minimal labour cost, labour fatigue, etc. and labour can be utilized in productive jobs.
4. **Minimization in damage and spoilage of material:** In a good plant layout, materials are handled properly which results in good quality of production. There is minimum damage and spoilage of materials. Minimizing waste also leads to increase in profits for a company.
5. **Flexibility in changing production conditions:** A good layout provides adequate space for future expansions, laying additional workstations, etc. The advantage is that in future if the market conditions change, the firm can easily put up new machinery, etc. without having to dismantle the existing ones and with minimum hindrance to the daily schedule or work.

2.2.1 Types of Layout

There are four basic types of layout.

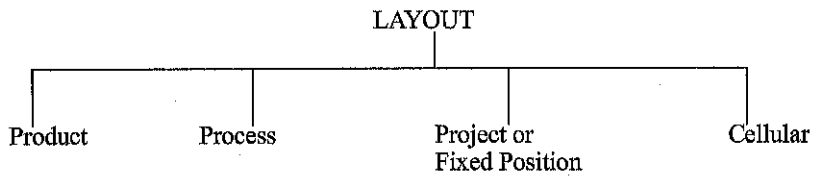

Fig. 2.1 Types of Layout

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(i) Product Layout

The placement of the equipment/machinery and materials in the order in which they are to be used for producing the product is called the product layout or line layout. This type of layout is found in industries where assembling of materials and parts takes place, such as the automobile industry. In such industries, the process starts with feeding in the raw materials and ends with the final product. The flow diagram of a line layout is shown in Figure 2.2.

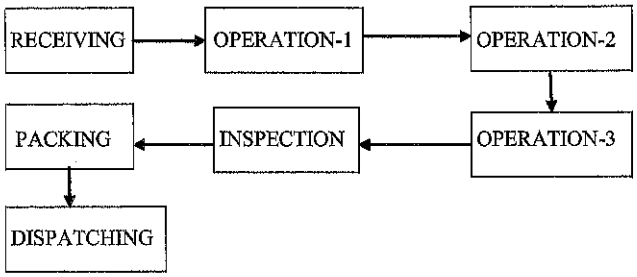

Fig. 2.2 Flow Diagram of a Product/Line Layout

Advantages of product layout

1. There is less work in process since output of one stage is automatically the input of the next stage
2. Material handling is less since the process is automatic.
3. Labour costs are lower, as there is division of labour.
4. Quality control is easier to implement.
5. Easy and accurate scheduling of materials is possible.
6. Production control is simpler due to less product variety.

Disadvantages of product layout

1. It is not easy to change the product. It will involve changes in the layout, which is expensive and time-consuming. So this layout is not very flexible.
2. If even one machine breaks down, the entire line will stop.
3. Expansion of work area or insertion of any machine in between other machines is not possible or is very difficult.

(ii) Process Layout

The layout in which all the equipment/machineries performing similar tasks are grouped together is called the process layout or functional layout; for example, the milling machines can be grouped together to form one department and the grinding machines can be grouped together to form another department. Depending on their processing requirements, parts are moved in different sequences among departments. Dividing the whole workplace into small units helps in faster production and better utilization of the workplace. The process layout can give a higher variety of products; for example, in a garment plant the stitching machines are kept in one place, pressing machines, such as irons in another, knitting machines in another, and so on.

STORES	GRINDING	FOUNDRY
RECEIVING	PLANNING PRODUCTION CONTROL	DESPATCH
MILLING	CASTING	WELDING

Fig. 2.3 Process Layout

Advantages of process layout

1. Flexibility in adapting to changing volumes, changing varieties.
2. Helps workmen learn more skills as job rotation enriches their skills.
3. Problem in one machine does not affect other machines and production need not stop.
4. In case of future expansion or increase in varieties, the existing set-up need not be pulled out.

Disadvantages of process layout

1. Space requirement increases when the work volume increases.
2. Mechanization of material handling is not possible or is very costly.
3. High work in progress inventory as jobs have to queue up for each operation.
4. Difficulty in scheduling work, as different jobs have different operation sequences.
5. High level of supervision is required. Production planning and control is more difficult.

(iii) Project Layout

The layout in which the production operation is performed in a fixed position is called the project layout or fixed position layout; for example, aeroplane and shipbuilding industries use this type of layout. While making a rocket the workmen/ scientists, machines and tools and raw materials are moved to the place of construction of the rocket. Building bridges, roads, the Metro rail, etc. involve project layouts.

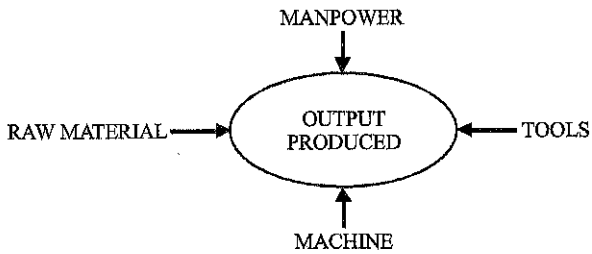

Fig. 2.4 Project Layout

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Advantages of project layout

1. It minimizes the movement of machineries and equipment.
2. Continuity in production allows several activities to take place simultaneously.

Disadvantages of project layout

1. Skilled and versatile workers are required. The necessary combination of skills may be difficult to find. Suitable workers would have to be paid attractive salaries.
2. Once the project is over, the equipment/materials will have to be moved. Not only is this an expensive proposition but equipment utilization is also low since equipment is kept idle during the time that it is being shifted.

(iv) Group Layout

This layout is a combination of the layouts we have studied so far and is more commonly seen in the industry today. Group layout, or cellular manufacturing, has the advantages of both process layout as well as line layout.

In group layout, parts are grouped into families. The layout consists of groups of different machines (called cells) that are necessary for the production of families of parts.

Advantages of group layout

1. The design of new products is good.
2. Production control is simpler than in process layout or project layout, since scheduling of machines is less complex and fewer tools and materials are required.
3. Material-handling costs are fewer than in process layout.
4. There are savings in set-up time which leads to increase in production.

2.2.2 Layout Planning for Storage and Warehousing

The design and layout of a warehouse is slightly different from that of a production unit. A warehouse is used for storing raw materials and supplies, tools and equipment and semi-finished and finished goods. Warehouses are often located at a distance away from actual production or customer locations.

A warehouse should focus on achieving high productivity in day-to-day activities of material management. These productivity objectives are:

1. Maximum utilization of space.
2. Efficient stock location and identification.
3. Conservation of time, labour, and equipment.
4. Rapid and easy transfer to and from storage.

Meeting these goals depends on a variety of factors, such as the size and shape of the physical facility, type of material-handling equipment that is available, placement and arrangement of stock, and the nature and usage of items.

Small firms provide storage space within their own production facilities or in an adjacent warehouse. Larger corporations, particularly multi-plant companies

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and pure distribution systems such as grocery chains or retail department stores, use cubic footage to the maximum. Pallets or portable platforms are used to take advantage of vertical stacking capabilities. They are moved easily by forklift trucks and other handling equipment. Other storage methods are used for small items or those that are used infrequently. Racks, shelves, and bins are used for small items and they are usually picked by hand.

The arrangement of items in storage depends on a variety of factors. These are:

- Items subject to deterioration, such as foodstuffs, medical supplies, iron or paints must be protected from dampness, insects, or extreme temperatures.
- Valuable items need special storage locations with security provisions.
- Hazardous materials require special attention and location.
- The size, weight, and shape of items affect storage and handling. For example, fragile items cannot be stacked very high, and heavy or bulky items are best stored near the shipping area to reduce handling needs.
- Produce turnover also affects storage and handling. Fast-moving items need to be handled quickly, while slow movers can be stored in locations that require slower handling.

2.2.3 Methodology of Layout Planning

In this section, let's discuss the ways in which layout planning can be done.

(i) Line or Product Layout

This is easier to plan since the machines have to be arranged or laid out as per the sequence of operations involved in converting the raw material into finished goods. The problem in line layout is not of how to sequence or relatively position the work areas, but how to group the work elements in such a manner that there is very little idle time between the work centres.

(ii) Process Layout

The problem in process layout is one of arranging the different work areas in such a way that the material movement costs are kept to a minimum. It is assumed that the other relevant costs of layout will also be reduced on account of this optimizing procedure.

The material handling costs between two work areas (departments) = {Distance between the two work areas} × {Load handled between the two departments during a unit period of time}. Here, load means the total number of units of different products any department processes.

The sum of these products, for all the combinations of departments, should be kept to the minimum for an optimal plant layout. This can be expressed as follows:

$$\text{Minimize } \Sigma D_{ij} \times L_{ij} Ij \qquad \ldots 2.1$$

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where, D_{ij} is the distance between departments i and j, and L_{ij} is the number of loads per unit time moved (handled) between departments i and j.

The starting point in such a mathematical optimization procedure for the process layout is gathering data on the number of loads per unit time moved between different combinations of the work areas. This data is called 'load summary' and is presented in matrix fashion.

(iii) Closeness Rating

Closeness ratings indicate the relative degree of desirability of having one department situated near another. These are very effective tools, especially in service facility layout planning; for example, in an MBA institution, it is advantageous to have the library and computer centre as close as possible to the lecture theatres. The boys' and girls' hostel should be as far apart as possible. The girls' hostel is usually located near the teachers' residential premises.

The closeness rating can be indicated as shown below.

Closeness rating	*Importance*
Absolutely necessary	1
Highly important	2
Important	3
Slightly important	4
Unimportant	5
Undesirable	6

Example 2.1

Indiana Hospital has made the following matrix to show the closeness ratings of the various departments for its proposed new building. The matrix shows that the closeness rating between departments D1 and D2 is 2, departments D1 and D3 is 4, D6 and D1 is 5, and so on.

Make a layout for the hospital building keeping in view the closeness ratings.

	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9
D_1									
D_2	2								
D_3	4	6							
D_4	1	5	1						
D_5	4	4	5	4					
D_6	5	4	3	4	6				
D_7	4	5	5	5	2	5			
D_8	5	6	3	1	4	5	3		
D_9	1	4	3	6	5	4	3	1	

Solution:

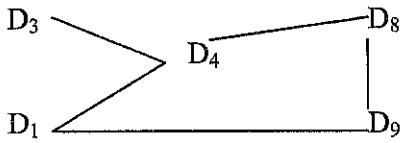
Step-1: Make a list of department pairs with ratings 1. This is necessary.

$D_1 - D_4$
$D_3 - D_4$
$D_1 - D_9$
$D_4 - D_8$
$D_8 - D_9$

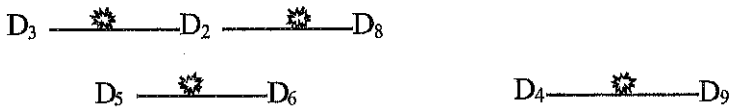
Make a list of department pairs with ratings 6. This is undesirable.

$D_2 - D_3$
$D_5 - D_6$
$D_2 - D_8$
$D_4 - D_9$

Step-2: Now make a network of departments having rating 1, with the department occurring most frequently (D_4) at the centre.



Similarly, make a network of departments having rating 6, with the department occurring most frequently (D_2) at the centre.



Now, keeping in view the above combinations, place the departments in the nine cells as shown below. This placement satisfies all the conditions of not only departments with ratings 1 and 6 but also of those with other ratings. While making the placements, we have to consider only ratings 1 and 6; the other ratings are automatically satisfied.

D_2	D_4	D_3
D_6	D_1	D_8
D_7	D_9	D_5

Closeness ratings require a trial and error method for placement of departments. The Assignment method is more useful and commonly used in industries. Several computer software, such as Automated Layout Design Programs (ALDEP) and Computerized Relationship Layout Planning (CORELAP) are based on the closeness ratings method. Another software, Computerized Relative Allocation of Facilities (CRAFT), is based on the load distance analysis method, which is explained below.

(iv) Load–Distance Analysis

In this method, two or more layouts can be compared to find out which one minimizes the total load–distance value of the product manufactured. Let us understand this technique by means of the following example.

Example 2.2

The figures shown below display two layout options of a facility: Layout A and Layout B. The distance between any two adjacent departments is 10 m. No

diagonal movement is possible, e.g., if a load has to be moved from Department 7 to Department 5 in Layout A, it can be done either through Departments 8, 9, and 6 or through Departments 3, 1 and 2 by travelling a distance of 40 m. The table below shows the department processing sequence of various products and their quantity produced per month. Calculate which layout is better in terms of lower total load–distance value.

LAYOUT A

1	2	5
3	4	6
7	8	9

LAYOUT B

5	3	4
9	6	1
2	7	8

Find the total distance travelled by a product while being processed, according to the given sequence.

Product	*Processing Sequence*	*Qty/Month*
V	5 – 7 – 2 – 9	3000
W	4 – 3 – 8 – 1 – 5	4000
X	3 – 9 – 4 – 1	2000

Solution:

Product	*Processing*	*Distance*	
		Layout A Sequence	*Layout B*
V	5 – 7 – 2 – 9	40 + 30 + 30 = 100	30+10+10=50
W	4 – 3 – 8 – 1 – 5	10 + 20 + 30 + 20 = 80	10+30+10+30=80
X	3 – 9 – 4 – 1	30 + 20 + 20 = 70	20 + 30 + 10 = 60

Now multiply the load, i.e., quantity per month with the distance calculated.

Product	*Qty*	*Qty × Distance*	
		Layout A	*Layout B*
V	3,000	3,00,000	1,50,000
W	4,000	3,20,000	3,20,000
X	2,000	1,40,000	1,20,000
	7,60,000	5,90,000	

The total load distance of Layout B is less than that of Layout A.

Hence, Layout B is a better option.

Check Your Progress

1. What are the advantages of a good plant layout?
2. What are the different types of layout?
3. What does a closeness rating indicate?

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2.3 MATERIALS HANDLING

Material handling is an integral part of an operating solution. Goals of material handling are to promote increased use of facilities, control inventory and reduce tare weight. To ensure efficient loading and unloading, transportation vehicles require an effective material handling mechanism. It is well established fact that individual products are most efficiently handled when packaged together into shipping cartons or other types of containers. Material handling is an important function in the warehouse. The direct labour and the capital invested in material handling equipment constitute a major part of total logistics cost.

Material handling involves moving of goods between incoming transport, storage, processes and outgoing transport. It involves the set of activities that move production inputs and other goods within plants, warehouses and transportation terminals, such as providing the right amount of material in the right condition, at the right place, at the right time, in the right position, in the right sequence, and for the right cost by using the right methods. The materials handling manager aims at finding the methods, the routes, the layouts and the right components to minimize handling. Six main responsibilities of the materials handling manager are packaging – unitizing, internal transport, storage, retrieval, identification and communication.

Unitizing equipment, material transport equipment, storage and retrieval equipment and automatic identification and communication equipment are the material handling equipment. Unitizing equipment include containers, such as cartons, boxes, and bags; carriers or support, such as pallets, skids, and plywood; stretch wrap; and shrink wrap. The design of a material handling system depends upon the type and the characteristics of the materials to be handled.

It may be noted that the need for handling a product should not arise quite frequently. The fewer times a product is handled, the less potential exists for product damage, and the overall efficiency of the warehouse is increased. There are many mechanized and automated devices to assist in material handling. In essence, each warehouse and its material handling capability represent a mini-system within the overall logistical process.

Large-scale material handling projects usually require a team approach. Material handling planning considers every move, every storage need, and any delay in order to minimize production costs. The plan should reflect the strategic objectives of the organization as well as the more immediate needs.

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Objectives of Materials Handling

The major objectives of materials handling are:

- Reduction in wastage of machine and order picking times
- Reduction in overall replenishment cycle time by quick marshalling and movement of goods
- Uninterrupted production and distribution schedules for avoidance of movement bottlenecks, such as loading and unloading problems
- Protection of goods from breakages or damages during movements
- Offering safety to workers and provide safer working conditions
- Ensure better customer service and satisfaction
- Enhance productivity and efficiency by reducing handling cost

2.3.1 Principles of Materials Handling

Certain principles need to be followed by a materials handling system to achieve the objectives (as stated above) of materials handling. Materials handling is defined as a branch of engineering that exclusively deals with the movement of materials between two or more different points. Since a supply chain system is linked together, the major concerns of those involved with logistics is regarding the physical transfer of the product from one party to another. In order to transfer materials from one point to another, the following questions need to be answered:

- How will it be handled?
- In what type of vehicles will it arrive?
- In what form will it reach?
- In what quantities?
- What kind of equipment is needed to handle or store it?

A list of 24 principles has been developed by the College Industry Council on Materials Handling Education. The material handling systems are designed and tested through rigorous engineering analysis. These principles are more significant in terms of laying out the intended design or when there is a need to troubleshoot while learning why a system is not performing well. The 24 principles on materials handling are as follows:

1. The first principle discusses orientation and the importance of orientation. This principle requires that the person in charge should view the entire system and learn how it operates. The designated person should also view the system on the basis of its relationship with other systems including the limitations of the systems.
2. The second principle focuses on the system's functioning. It requires to answer the following question—What is the system expected to do?
3. Integration of systems is very important in materials handling as all storage and handling operations need to be coordinated.

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4. The standardization principle defines the selection of packaging that will be used. It proves beneficial to standardize as small as a number of packages or wraps as possible.
5. Products are not moved until needed or the just-in-time principle.
6. There is a certain amount of conflict between the just-in-time principle and the unit-load principle. This emphasizes the importance of handling materials in large blocks, such as the unit loads.
7. The minimum travel principle states that the systems should be set up in such a manner that the load moves the shortest distance possible.
8. Utilization of space principle requires the optimum use of space. Materials handling equipment is designed to fit into otherwise underutilized space.
9. Ergonomics is the science which deals with the understanding of human interactions among humans and other elements of a system. In materials handling, the ergonomics principle is used to justify manufacturing and materials handling systems which protect the workers from performing complex and repetitive functions which may or may not result in injuries or disabilities.
10. The main objective of the energy principle is to reduce energy consumption by the materials handling activities.
11. The use of environmentally-friendly products in materials handling define the ecology principle. For instance, the choice of materials to use in packaging.
12. The mechanization principle emphasizing the use of machines which may be able to replace human effort.
13. The automation principle involves the development of equipment that is pre-programmed, or self-controlled. Some machines can be programmed to make simple decisions given certain conditions. Some equipment today can respond to radio signals or even voice commands.
14. Systems which require changes on a period basis in the tasks that the system is expected to perform defines the flexibility principle.
15. The simplification principles requires avoiding all overly complicated systems
16. A person should rely on gravity to move materials wherever possible according to the gravity principle.
17. The safety principle stresses on the importance of having equipment that is safe to operate and to be heard.
18. The computerization principle recognizes the widespread use of computers to operate both individual pieces of equipment and massive supply chains spread across several continents. Computers allow better, faster use of information. Material flows are integrated with information flows.
19. The systems flow principle requires an orderly and logical flow of materials

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20. According to the layout principle, the materials handling system should be laid out in such a manner that all these listed principles are accountable.
21. Materials handling requires costs and these costs need to be considered when the materials handling system is devised. The cost principle requires an investment proposal to be presented to the top management for approval.
22. A system needs to be maintained once it moves into the operations phase. The maintenance principle includes taking maintenance alternatives into account.
23. Many existing systems include equipment that has been in service for some time. The obsolescence principle recognizes that this equipment must be phased out, taking into account its usefulness, as well as tax and accounting considerations.
24. The team solution principle means that materials handling challenges are sufficiently large and complex and teams of people are often required to devise the best system.

2.3.2 Materials Handling Equipment

Different materials handling equipments are used by different industries. The process of materials handling basically depends on the need and requirement of a particular industry. In order to understand materials handling system, they can be categorized into three broad categories:

- Mechanized Handling Systems
- Semi-automated Handling Systems
- Automated Handling Systems

(i) Mechanized Handling Systems: Mechanized handling systems employ a wide range of handling equipments. Some of the major ones are as follows:

- Forklift trucks
- Tow tractors
- Cranes

(ii) Hand-powered equipment: Hand-powered equipment has its own uses in this age of mechanization. Hand-powered equipment is mainly adaptable in situations where weights are small and the available space is limited, or it is not economically feasible to employ mechanically-powered equipment. Hand-powered equipment includes the hand truck, rolling ladders and carts, rolling cages and load buggies, hand pallet trucks or pallet jacks.

(iii) Semi-automated Handling Systems: The semi-automated systems supplement mechanical systems by automating specific handling requirements. Some of the semi-automated handling systems are as follows:

- Automated-guided vehicle systems
- Sortations (devices used in combination with conveyors)

- Robotics (Human-like machine that can be programmed by microprocessors to perform one or a series of activities)
- Automatic Storage/Retrieval (AS/RS) Systems

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Check Your Progress

4. How can an overall efficiency of a warehouse be increased?
5. Which condition are individual products most efficiently handled?

2.4 ANSWERS TO 'CHECK YOUR PROGRESS'

1. The advantages of a good plant layout are:
   a. Well-organized workspace
   b. Better working conditions
   c. Minimization of material handling costs
   d. Minimization in damage and spoilage of material
   e. Flexibility in changing production conditions
2. The types of layouts are:
   a. Product layout
   b. Process layout
   c. Project layout
   d. Group layout
3. A closeness rating indicates the relative degree of desirability of having one department situated near another.
4. The fewer times a product is handled, the less potential exists for product damage, and the overall efficiency of the warehouse is increased.
5. Individual products are most efficiently handled when packaged together into shipping cartons or other types of containers.

2.5 SUMMARY

- Layout may be defined as "the physical positioning of a facility's numerous departments/units inside the facility's premises."
- The departments must be placed according to specified criteria. The following are some of the most typical considerations:
  - o Logical sequence of processing operation
  - o Direction of material flow and material handling
  - o Aesthetic considerations
  - o Government regulations
  - o Special requirements

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- Plant layout is a process for planning and arranging supplies and facilities in order to assure a consistent flow of production at a reasonable cost. A good plant architecture always results in worker comfort and satisfaction, which naturally boosts output.
- A well-designed facility yields more output and reduced costs. The following are some of the benefits of a well-designed plant layout:
  - o Well-organized workspace
  - o Better working conditions
  - o Minimization of material handling costs
  - o Minimization in damage and spoilage of material
  - o Flexibility in changing production conditions
- There are four types of layout:
  - o Product Layout
  - o Process Layout
  - o Project Layout
  - o Cellular Layout
- The process layout or functional layout is the layout in which all the equipment/ machineries that do similar functions are grouped together; for example, milling machines can be gathered together to create one department, while grinding machines can be grouped together to form another department.
- The project layout or fixed position layout is a layout in which the manufacturing activity is done in a fixed location; for example, the aeroplanes and shipbuilding industries utilise this sort of arrangement.
- A warehouse has a somewhat different architecture and layout than a production unit. Raw materials and supplies, tools and equipment, and semi-finished and final items are all stored in warehouses.
- Small businesses can store their goods in their own manufacturing facilities or at a nearby warehouse. Larger organisations, particularly those with several plants and pure distribution networks like grocery chains or retail department stores, make extensive use of cubic feet.
- Because the machines must be grouped or planned out according to the sequence of actions involved in transforming raw materials into final items, line layout is easy to plan.
- The challenge in process layout is to organise the various work areas in such a manner that material mobility costs are minimised. The other relevant layout expenses are expected to be decreased as a result of this optimization method.
- The degree of attractiveness of having one department near another is indicated by closeness ratings.

- Two or more layouts can be compared in load distance analysis to see which one reduces the overall load–distance value of the manufactured product.
- Material handling is an essential component of every operation.
- Material handling aims to maximise facility use, maintain inventory, and minimise tare weight. Transportation vehicles require an efficient material handling device to guarantee efficient loading and unloading.
- Different industries utilise different materials handling equipment. The materials handling process is mostly determined by the needs and requirements of a certain industry.

2.6 KEY TERMS

- **Layout:** It refers to the physical location of the various departments/units of a facility within the premises of the facility.
- **Product Layout:** It refers to the placement of the equipment/machineries and materials in the order in which they are used for making the product.
- **Process Layout:** It refers to the layout in which all the equipment/ machineries performing similar tasks are grouped together.
- **Project Layout**: It refers to the layout in which the production operation is performed in a fixed position.
- **Closeness Rating**: It indicates the relative degree of desirability of having one department situated near another.
- **Load–distance Analysis:** It is a method in which two or more layouts are compared to find out which one minimizes the total load–distance value of the product manufactured.

2.7 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What is layout planning? What is its relevance to an organization?
2. Differentiate between line layout and process layout.
3. What is group layout?
4. Why is facility location important for the success of an organization?

Long-Answer Questions

1. Discuss the steps involved in selecting a location for a facility.
2. Explain the parameters that affect plant location.
3. Describe the factor and location rating methods.
4. Examine the principles of material handling.

NOTES

2.8 FURTHER READING

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UNIT 3 PRODUCTION PLANNING AND CONTROL AND SCHEDULING

Structure

3.0 Introduction
3.1 Objectives
3.2 Production Planning
  3.2.1 Strategies of Production Planning
  3.2.2 Major Functions of Production Planning and Control
  3.2.3 Benefits of Production Planning and Control
  3.2.4 Production Control
3.3 Assembly Line Balancing
3.4 Scheduling
  3.4.1 Scheduling when there are Several Jobs and one Machine
  3.4.2 Sequencing when there are Several Jobs and Several Machines
  3.4.3 Gantt or Bar Charts
3.5 Fundamental Concepts in Modern Manufacturing Techniques
3.6 Answers to 'Check Your Progress'
3.7 Summary
3.8 Key Terms
3.9 Self-Assessment Questions and Exercises
3.10 Further Reading

3.0 INTRODUCTION

In this unit, you will learn about production planning and control. You will learn how raw materials are converted into finished goods through the process of value addition. You will also learn that these activities are not sporadic or spontaneous. It requires a lot of planning and coordination to ensure that these activities are carried out in a systematic manner so that just the right amount of raw materials is purchased, the right number and type of people are employed, the right kind of operations are done on the right types of machines, and so on.

Production activities need to be controlled at every step so that there are no deviations from plans.

Production can be divided into two types of activities:

- Production planning
- Production control

You will study each of these in detail in this unit, including the elements of automation, assembly line balancing and production scheduling.

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3.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the concept of production planning
- Understand the strategy of production planning
- Describe the main functions of production planning and control
- Explain production control
- Understand the elements of automation
- Discuss the concept of assembly line balancing
- Understand what comprises production scheduling

3.2 PRODUCTION PLANNING

Production planning is a complex activity, encompassing various elements. The following figure shows the elements of production planning.

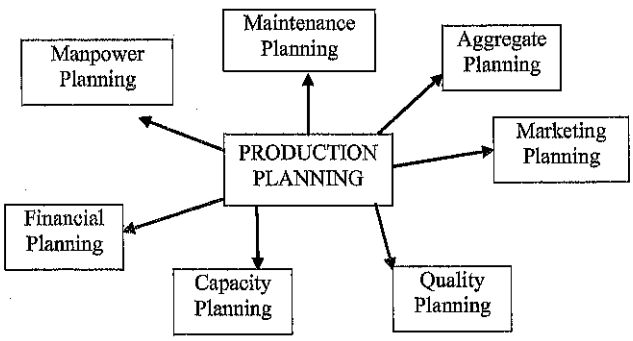

Fig. 3.1 Elements of Production Planning

Types of Plans

You know that the 5 Ms of a business that form the input are man, machine, materials, money and method. Planning their inputs over a specified period of time so as to get the planned output is the job of 'Production Planning'. Depending on the timeframe of planning, it can be

- **Long-term or strategic planning**—focuses on a horizon greater than one year.
- **Medium-term or intermediate range**—usually covers a period of six to eighteen months. If done annually, it is called aggregate planning.
- **Short term planning**—routine planning may be daily, weekly or monthly.

3.2.1 Strategies of Production Planning

The following are the strategies of production planning.

(i) Manpower Planning

There are three parameters that affect the nature of production planning. These are:

- The number of workers
- Utilization of workers
- Size of inventory

The following are the three basic production planning strategies that are based on the above variables. In each of these strategies, one variable is varied and the other two are kept constant.

(a) Level output rate plan

The inventory size is varied keeping the workforce size and utilization of workers constant throughout the time period under consideration. During months of low demand, the excess units produced over demand are accumulated as inventory. This is utilized during periods of high demand. The advantage of this plan is that the cost of hiring and training new workers is zero. Also, the cost of laying off workers is zero, as the workforce size is kept constant. The employee morale is high due to a sense of job security. The disadvantage of this method is that during periods of low demand, there is a high inventory cost due to its large size.

(b) Chase plan

The workforce size is varied according to demand, keeping the utilization of workers and inventory size constant. During periods of low demand, the workforce size is decreased and the extra workers are laid off. Similarly, during periods of high demand, more workers are hired. The hiring and laying off costs are substantial in this plan. Since production is in tune with demand, inventory is almost negligible. During the period of heavy demand, overtime may be required on the part of workers, for which the company incurs overtime cost. The workers' morale could be low due to a sense of insecurity.

(c) Varying utilization plan

The utilization of workers is varied keeping the workforce size and inventory size constant. The number of workers is kept constant in this plan. When demand is low, the workers produce less and have a lot of idle time. On the other hand, when demand is high, the excess units are produced by workers who work overtime. The idle time on the part of workers during months of low demand is a loss to the company, which pays full wages to its employees. On the other hand, the company incurs overtime costs during periods of high demand. Overtime is usually expensive compared to the regular wages given to workers. In addition, excess overtime leads to less efficiency on the part of workers and more accidents due to lack of concentration. Nonetheless , the company saves on inventory costs, which are also negligible, in this plan.

In reality, a combination of these strategies is used in preparing the aggregate production plan. Let us understand how to use a combination of these strategies in the following example.

Example 3.1

M/s Cooperative Textiles is a cooperative society that makes bed sheets. A worker makes 100 bed sheets /month. In the month of October, there are 25 workers on

the roll. The salary per worker is Rs 4,000/month. The cost of hiring a worker is Rs 500 and a worker who is laid off has to be paid 20 per cent of a month's salary. If the forecast for November and December is 2000 and 3000 blankets respectively, prepare a production plan. Take the inventory carrying cost to be Re 1/blanket/month.

Solution:

Case 1: *Chase Plan*

November:

No. of workers required = 2000/100 = 20

Total salary to be paid = Rs 4,000 × 20 = Rs 80,000.

Since there are 25 workers on the roll in October, 5 workers need to be laid off.

Therefore, laying off cost = 20 per cent × 4000 × 5 = Rs 4000

Obviously, no worker is hired.

December:

No. of workers required = 3,000/100 = 30

Total salary = 4,000 × 30 = Rs 1,20,000

Since there are 20 workers on the roll in November, 10 more workers need to be hired.

Hiring cost = 500 × 10 = Rs 5000

Lay off cost = 0

Total additional expenditure = Rs 4,000 + 5,000 + 80,000 + 1,20,000= Rs 2,09,000.

Case 2: *Level Output Rate Plan*

If 25 workers are employed in November,

Number of blankets produced = 25 ×100 = 2,500 blankets

Since demand is 2,000, the number of blankets left in inventory = 500

Inventory carrying cost = 10 × 1 × 500 = Rs 5,000

This will be consumed in December as 2,500 blankets will be produced and the demand is for 3,000.

Salary in November and December = 4,000 × 25 × 2 = Rs 200,000.

Therefore, the grand total cost = 2,00,000 + 5,000 = Rs 2,05,000.

Of the two plans, the Level Output Rate Plan costs less; so, this method should be used.

(ii) Aggregate Planning

Aggregate Plan is the total or aggregate plan of a company for producing a product over a certain period of time, say in the next twelve months. Formulation of an aggregate plan is the starting point for any manufacturing planning and is based on orders expected during the planning period. Various forecasting techniques

are used to determine the approximate aggregate demand for the product family. The plan must be firmed up for a reasonable period of time because the overall production volume cannot be changed abruptly without incurring significant unplanned costs.

Every production volume utilizes a given mix of labour, materials and equipment. When the output volume is changed, a new optimal mix must be achieved by readjusting the usage of various resources. Even though it is possible to change in the long run, in the short run, it is difficult to do it efficiently.

*A **Master Production Schedule** is the disaggregating of an aggregate plan. This means it gives information about the number of various models and sub- models of a product planned to be produced in a given duration.* The master production schedule shows the quantity and timing of each specific product for a time horizon.

A master production schedule (MPS) gives details about the quantities and timing of the planned production of every product of an organization. The MPS provides the sales personnel with information about how many units of a product they can commit to customers in a given time period.

The following table illustrates the difference between an aggregate plan and master production schedule for a toy manufacturing company.

***Table 3.1** Differences between an Aggregate Plan and a Master Production Schedule*

Aggregate Plan *Figures in' 000*

Apr	*May*	*Jun*	*July*	*August*	*Sept*
300	400	350	375	350	290

Master Production Schedule

Apr	*May*	*Jun*	*July*	*August*	*Sept*
Model A 100	120	110	130	125	90
Model B 100	80	125	125	110	100
Model C 100	100	115	120	115	100

The sum total of the master production schedule will be the aggregate plan.

The time interval used in MPS varies from firm to firm. It depends on the type of products used, the volume of production, and the lead times of the materials used. This span of time that the MPS covers is called the **Planning Horizon.** Typically, within the framework of a twelve-month aggregate plan, the MPS is updated weekly to reflect the changing sales demand and also the internal problems which require scheduling.

In manufacturing, the planning process can be stated as follows:

The production control group inputs existing or forecast orders into an aggregate plan. From this, the MPS is derived. The MPS generates the quantities and dates of specific items required for each order. Rough-cut capacity planning then confirms that production and warehouse facilities, equipment, and labour are available and that key vendors have allocated sufficient capacity to provide materials

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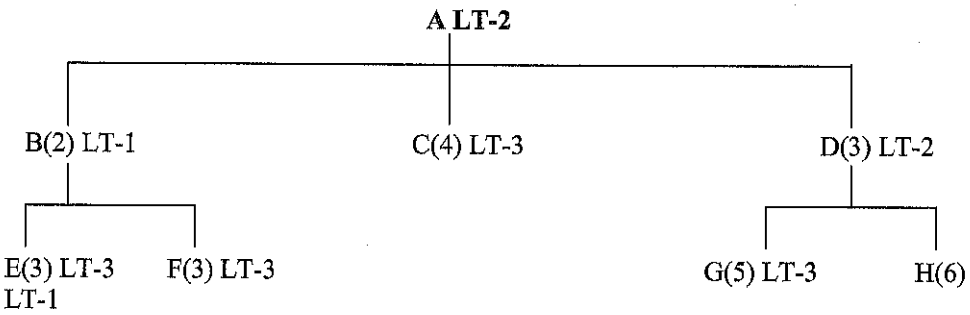
when needed. Then the material requirements plan (MRP) is made. This plan specifies when the products need to be made, what the raw materials are, when and how many are required and when the order should be placed with the vendors. The final planning activity is daily or weekly order scheduling of jobs to specific machines, production lines or work centres.

Example 3.2

Study the following Product Structure Tree. If 100 units of A are to be supplied in eight weeks, prepare the bill of materials and planned order releases.



Solution:

If A is to be ready in 8 weeks, B, C and D should be ready by the sixth week because it takes 2 weeks to make A.

Similarly, if B has to be ready by the sixth week, E and F should be ready by the fifth week (6 – 1).

G and H should be ready by the fourth week (6 – 2).

Therefore, the order should be placed in 2 weeks (E = 5 – 3).

Now, B has to be ready by the sixth week and it takes one week to make it ready or to buy it. So order for B should be placed in the fifth week.

For 1 unit of A, 2 units of B are required. So for 100 units of A, 200 units of B will be required.

For 1 unit of B, 3 units of E are required. So for 2 units of B, 6 units (2x3) of E will be required.

Calculating for all the items and tabulating them, we get,

Item	*No. reqd*	*For 100 units of A*	*Lead time*	*To be ready in in weeks*	*To be ordered in weeks*
A	1	100	2	8	6
B	2	200	1	6	5
C	4	400	3	6	3
D	3	300	2	6	4
E	6	600	3	5	2
F	6	600	3	5	2
G	15	1500	3	4	1
H	18	1800	1	4	3

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3.2.2 Major Functions of Production Planning and Control

The main activities encompassing production planning and control (PPC) are as follows:

(a) Order preparation: The work of PPC begins once an order is received from the sales department. This order is then converted into a 'work order' or 'shop order' and sent to various departments concerned, for planning action at their end.

(b) Materials planning: Once the order is received, the PPC decides on the raw materials required for manufacture, taking into account the capacity of various production shops, the bill of materials, the inventory on hand, and the lead time for procurement.

(c) Routing (or process planning): *Routing means determination of the sequence of operations for manufacturing a product or service.* This path is determined in advance and forms the basis for most of the scheduling and dispatching functions. According to Kimball and Kimball, 'Routing is the selection of a path or route over which each piece is to travel in being transformed from raw material into finished product.'

Routing includes the following activities:

- Deciding the volume of production
- Selecting the men, machines, and materials to be used in its production
- Deciding the type, number, and sequence of production operations
- Deciding the place where production is to be carried out

When routing or process planning is being done, a **Route Sheet** is prepared. This is done in the following manner:

1. The product is analysed with regard to its constituent parts. A decision is then taken as what parts are to be manufactured and which are to be purchased.
2. The specifications, grade, quality and quantity of materials to be used in production are determined.
3. The number of manufacturing operations and their sequence is determined and listed on the route sheet.
4. The process time for each operation and the type and number of machines necessary to produce are determined.
5. The lot size for production is determined keeping in mind the customers' orders and rejections and the spoilage anticipated during the course of manufacturing.

(d) Estimating: This involves establishing the operation times for every process; this also leads to fixation of performance standards for both men and machines.

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(e) Scheduling: According to Spriegal and Lanburgh, *'Scheduling involves establishing the amount of work to be done and the time when each element of work will start or the order of the work.*

Thus, scheduling includes the following activities:

- Determination of quality and rate of output of the plant or department
- Allocation of time for each operation

Scheduling indicates when the work will be released to the plant in a prescribed order and in proper sequence. It fixes the time of start and completion of the operation.

The scheduling function begins when the following information is furnished:

(a) Date of delivery specified by the customer's order

(b) Time required for assembly and sub-assembly process

(c) Time to be taken in the production of component parts

(d) Time required to make purchases

(e) Time required for moving the materials from one station to the other, inspection, etc.

(f) Priority of orders

Necessary provisions for unforeseen contingencies such as power breakdown, strike, and lockout, absence of workers or rush of orders of extreme importance are usually made when the schedule is prepared.

(f) Loading: This involves allocating jobs to machines as per the capacity of machines and priority of jobs to be done, so that the machinery is utilized to the maximum possible extent. It includes the following activities:

- Preparation of machine loads.
- Fixing of actual dates of various operations/sequence of operations to be performed on the jobs.
- Coordination with the sales department to confirm delivery dates and keep them informed about the status of the schedules.

(g) Dispatching: Dispatching means preparation and distribution of work orders and manufacturing instructions to the concerned departments in accordance with the details worked out under routing and scheduling functions. The work order received by the various departments is an authority for them to start the work according to that schedule.

(h) Progressing: This involves controlling the process of production, collection of data from various manufacturing shops, recording the progress of work and comparing the progress against the plan.

(i) Expediting and follow-up: Follow-up means to see whether the work is being carried out according to the plan and orders and instructions issued. It ascertains that the materials, tools and equipment are supplied at the job at the right time and to the right person or job. Follow-up

is the means by which the progress and execution of the plan is evaluated from time to time and divergence from the plan is noted. The reasons for such divergence are then found out and efforts are made to eliminate them from the plan.

(j) **Inspection:** This means comparing the actual with the written or expected specifications and assessing whether they have been met. Inspection can be process inspection or product inspection, in which the process or the product is inspected respectively.

(k) **Cost control:** PPC is responsible for cost control and cost reduction by reducing or eliminating wastes, value analysis, etc.

(l) **Miscellaneous functions**: In addition to the above stated functions of PPC, there are certain miscellaneous functions such as building cost estimates for products, fixing standards with the help of industrial engineering department, capacity planning, making or buying decisions, making specifications of raw materials and process improvement that have to be performed. Another function is taking corrective measures. If the production manager feels that routing is defective or scheduling is rigid and unrealistic, he can rectify the route and lay down realistic and flexible schedules. Workload, machines and men should be determined scientifically, and an effective and optimum utilization of the plant's capacity should be the objective.

Sometimes, abnormal situations like strikes and power or machinery breakdown can upset the work schedules. In such situations, the production manager should adjust the schedules and make up for delays. The production manager is also responsible for appraising the performance of personnel working in the production department.

3.2.3 Benefits of Production Planning and Control

By learning about the functions of production planning and control, you would have realized that it is the nerve centre of any production organization. An effective production planning and control system gives many benefits to an organization. These benefits are as follows:

(a) Better quality of products.

(b) Better utilization of resources.

(c) Reduction in inventories.

(d) Reduction in manufacturing cycle time.

(e) Better customer services due to adherence in delivery dates.

(f) Lower production costs so profits will increase.

(g) Improved market share due to goodwill which is caused by better products at lower costs.

(h) It gives a competitive advantage to the firm when compared to competitors with poorer PPC system.

(i) Dependability on the firm results in earning goodwill in the market.

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3.2.4 Production Control

So far, you have learned what production planning and control is, what its main functions are, its advantages and what production planning is. Now you will learn about production control.

(i) Input-Output Control

One aspect of production control is input–output control. The concept is that the planned work input to a work centre should never exceed the planned work output. When the input exceeds the output, backlogs build up at the work centre, congestion occurs, processing becomes inefficient, and the flow of work to downstream work centres becomes sporadic. The control process would entail finding the cause of upstream problems and adjusting capacity and inputs accordingly.

(ii) Shop-Floor Control

Shop-floor control is also called production activity control. It is the heart of any manufacturing organization. The APICS dictionary defines shop floor control system as, '*A system for utilizing data from the shop floor as well as data processing files to maintain and communicate status information on shop orders and work centres.*'

The major functions of shop-floor control are:

(a) Assigning priority of each shop order
(b) Maintaining work-in-process information
(c) Maintaining shop-order status information
(d) Providing actual output data for capacity control purposes
(e) Providing information for inventory and accounting purposes
(f) Measuring efficiency, utilization and productivity of manpower and machines

3.3 ASSEMBLY LINE BALANCING

In the following sections, you will learn about production planning for continuous production and batch production.

For high volume continuous production, a line layout is preferred. This is also called an assembly line.

The production planning problem in an assembly line is about:

- Establishing production rates of the final product from the line
- Obtaining this production rate with optimal workforce level

This is done so that the costs are reduced and there is smooth and regulated flow of material through a sequence of operations at a uniform rate. The process through which this is accomplished is called 'assembly line balancing.

Suppose, in a line, one operation takes 10 minutes and the next operation takes 2 minutes only. Then, the rate of production in this line will be one unit in 10

minutes, i.e., the rate of production in a line will always be the rate of the slowest operation in the line.

The operator of the second operation will be idle for 10–2 = 8 minutes, every 10 minutes. This is a huge wastage of time.

Assembly line balancing tries to reduce this idle time between operations so that the operations take place at the lowest possible time. This is done by equalizing the output rates of groups of operations, by 'balancing' them; hence, the term assembly line balancing.

However, before you proceed further, you should know what a 'work centres' is. It is an area in a business in which productive resources are organized and work is completed. The work centre may be a single machine, a group of machines, or an area where a particular type of work is done. These work centres are organized according to function in a job-shop configuration; or by product in a flow, assembly line, or group technology (GT) cell configuration.

Consider the following example for learning assembly line balancing.

M/s Caterpillar Inc., a manufacturer of garden equipment, has designed an assembly line for manufacturing belt-driven lawn mowers. Using the information given below, let construct the precedence diagram.

Work element nomenclature	*Description of work element*	*Immediate predecessor of work element*	*Time taken (in seconds)*
A	Bolt leg frame to front wheel	Nil	40
B	Drilling for fixing rear wheels	Nil	40
C	Weld rear wheels	B	30
D	Attach shears	A, C	20
E	Mount the motor	D	20
F	Mount rubber belts	D	30
G	Mount filters	E, F	50
H	Mount tyres	E, F	80
I	Install rubber mountings	G, H	10
J	Mount nameplate	I	10
		Total Time - 330 seconds	

First the **precedence diagram** should be drawn. (Figure 3.2 helps visualize the predecessor relationships better).

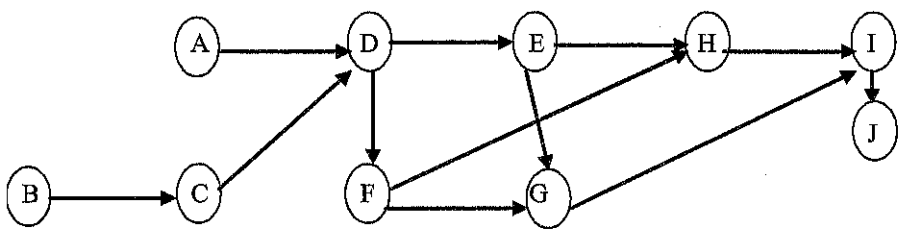

Fig. 3.2 **Precedence Diagram**

The next step is to group the work elements into work centres. You have to group those jobs that are independent of each other, but without violating the precedence requirement.

Jobs A and B are independent of each other. So they can become one work centre. Job C cannot be a part of the same work centre as job B because to begin

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Job C, Job B should be completed. Jobs A and B together will take a total time of 40 + 40 = 80 seconds.

Next, can Jobs C, D and E be clubbed together? Precedence wise, they could be joined. The time taken is, 30 + 20 + 20 = 70 seconds.

Next, Job F cannot be clubbed with Job G or H, since it will violate the precedence requirement.

Next, Job H would be a separate work centre taking 80 seconds.

Jobs G, I and J could be another work centre.

So summarizing,

Work Centre 1: Jobs A and B = 80 seconds

Work Centre 2: Jobs C, D and E = 70 seconds

Work Centre 3: Job F = 30 seconds

Work Centre 4: Job H = 80 seconds

Work Centre 5: Jobs G, I and J = 70 seconds

Cycle time: This is the time required to produce one unit of the finished product or the time available at each work centre.

In this problem, the cycle time is 80 seconds.

Total time of all the elemental tasks = 330 seconds

(If we reduce the number of work centres, we can minimize idle time, maximize efficiency and minimize balance delay. Also, if a worker mans each centre, reducing the number of work centres means maximizing the worker's productivity.

Idle time: It is the total unproductive time for all stations in the assembly of each unit of the product. In this problem, it is $80 \times 5 - 330 = 70$ seconds

Efficiency is the ratio of productive time to total time. In this problem, it is

$$\frac{330}{400} \times 100 = 82.5\%$$

Balance delay: It is the amount by which efficiency falls short of 100 per cent, 100 – 82.5 = 17.5 per cent.

The above example is not the only way to group the work centres. They can be grouped in any manner as long as the technological and other sequential requirements are not violated.

However, this visual method is too simplistic for complex problems involving a large number of elemental tasks; so the heuristic methods are generally used in assembly line balancing.

3.4 SCHEDULING

In the previous section you have learned about assembly line balancing for continuous production systems. Next, you will learn how to do production planning

for job or batch processes, where different products are produced on the same set of machines.

A schedule is a timetable for performing activities, utilizing resources or allocating facilities. It schedules, dispatches, tracks, monitors, and controls production on the factory floor.

In the case of the job shop, jobs need to be routed through a sequence of work centres to complete the work.

Scheduling systems can use either **infinite or finite loading.**

Infinite loading occurs when work is assigned to a work centre simply based on what is needed to be done, without consideration of capacity or resources required to complete the work or the sequence of the work to be done. Infinite loading is beyond the scope of our study.

In **finite loading,** the work is assigned to a work centre only after a careful consideration is done of each resource such as the capacity of machine, the materials available, the manpower available, and so on. If an operation is delayed due to a material shortage, the order will wait for the part to become available from a preceding operation. Theoretically, all schedules are feasible when finite loading is used.

Scheduling systems can also be based on whether the schedule is generated **forward or backward in time. Forward scheduling** refers to the situation where the system takes an order and then schedules each operation that must be completed forward in time. The system will then project the earliest date by which an order can be completed.

Backward scheduling starts from some date in the future (generally the due date) and schedules the required operations in reverse sequence. The backward schedule tells when an order must be started in order to be done by a specific date which has been demanded by the customer.

Objectives of Scheduling

Why is scheduling so important in production planning and control? This is because it enables the organization to:

Meet due dates

Minimize lead time

Minimize set-up time and set-up cost

Minimize work-in process inventory

Maximize machine and labour utilization

There are several methods that are used in industry for work centre scheduling, or simply called job scheduling. You will study the most important ones here.

Job Sequencing (or Scheduling)

The process of determining which job to start first, and in what order other jobs should be processed on the machine or in a work centre, is known as job

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sequencing or priority sequencing. Priority rules are the rules used in obtaining a job sequence. Jobs are generally sequenced according to the processing time, due date or the order of arrival. This method can be used for both finite loading as well as infinite loading and forward as well as backward sequencing.

The following are the common bases on which sequencing is done:

1. Meeting due dates of customers or downstream operations
2. Minimizing the flow time (the time a job spends in the process)
3. Minimizing work-in-process inventory
4. Minimizing idle time of machines and workers

There can be several situations, where there may be a number of jobs and one machine, or there may be 'n' jobs and n machines. For each situation, there are methods for sequencing.

3.4.1 Scheduling when there are Several Jobs and one Machine

In the first case, jobs may be sequenced according to any of the following rules:

1. **Minimum process time method (MINPRT)** This is also known as Shortest Operation Time Method (SOT). Under this rule, job with the shortest process time is first scheduled, followed by the next lowest process time, and so on.
2. **Due date method (DD Method)** In this method, the job with the earliest due date is done first.
3. **First come first served method (FCFS)** In this method, jobs are scheduled in the order in which they are received by the company.
4. **Longest process time method (LPT)** This method is just the reverse of MINPRT method as the job with the longest processing time is attended first.
5. **Dynamic slack/remaining operation (DS/RO) or minimum slack per operation (MINSOP) method** In this method, first dynamic slack (DS) is computed. (This is the difference between due time and processing time). This is divided by the remaining operation (RO) time. RO unless specified will be assumed as one. Final scheduling of the job under this method is done as per the ranking. The job with the lowest DS/RO value is assigned Rank 1 and attended first. The next higher value gets Rank 2, and so on.

Which particular rule is more appropriate for a given situation will depend on the average job lateness and the average number of jobs in the system The lesser the job lateness, the better it is as it will ensure customer satisfaction, optimum utilization of machine, reduced slack time, etc.

You will understand all the above methods by means of the following example.

Example 3.3: Four jobs W, X, Y and Z need to be done on the same work centre. Their process times and due dates are as given below. Sequence the jobs by different methods.

Job (no. of days)	Process Time (days from today)	Due Date
W	5	12
X	6	18
Y	7	21
Z	10	14

Solution:

1. Minimum Process Time Method (MINPRT)

W is done first since it has the least process time.

Next, X is done. (By now, total days required = 5 + 6 = 11. It is less than 18)

Next, Y is done, Total days required = 11 + 7 = 18. It is below 21. Thus, there is no delay.

Next, do Z is done. Total days 5+6+7 + 10 = 28.

It is beyond by 14 days. So delay is 14 days.

Job Z gets delayed by 14 days.

2. Due Date Method (DD Method)

	Process time	Flow time (Cumulative Process time)	Due dates	Job lateness
W	5	5	12	0
Z	10	15	14	1
X	6	21	18	3
Y	7	28	21	7

First the jobs are rearranged in the increasing order of due dates, i.e., W, Z, X, Y.

Calculate the total completion time = 5+10+6+7 = 28 days.

Next, calculate the flow time.

For W=5

Then Z is completed after 5+10=15 days

X=15+6 = 21, Y=21+7 = 28 days

Cumulative or Total = 5+15+21+28 = 69 days

Average Completion time = 69/4 = 17.25 days

Average Job lateness = (0+1+3+7)/4 = 11/4 = 2.75

3. First Come First Served Method (FCFS)

Irrespective of the process times or due dates, the job received first is done first.

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4. Longest Process Time Method (LPT)

	Process time	*Flow time*	*Due dates (Cumulative Process time)*	*Job lateness*
Z	10	10	14	0
Y	7	17	21	0
X	6	23	18	5
W	5	28	12	16
	28	78		21

In this case, the jobs are rearranged in the decreasing order of process times, i.e., Z, Y, X, W.

Total completion time =28 days.

Average completion time = 78/4 = 9.5

Average job lateness = 21/4 =5.25

5. Dynamic Slack/Remaining operation (DS/RO) or Minimum Slack Per Operation (MINSOP) Method

Assume that the number of operations for each job are W = 2, X = 3, Y = 2, Z = 4. (Number of operations means the number of activities which need to be done to make W).

$$DS/RD\ ratio = \frac{\text{Delivery date} - \text{Process time}}{\text{No. of operation}}$$

DS/RD ratio is W = (12–5)/2 = 7/2 = 3.5

Similarly, X = 4, Y = 7, Z = 1.

Rank them with Z being the lowest at 1. W = 2, X = 3, Y = 4

Rearranging them in the increasing order of their rank, we get

	Process time	*Flow time*	*Due dates (Cumulative process time)*	*Job lateness*
Z	10	10	14	0
W	5	15	12	3
X	6	21	18	3
Y	7	28	21	7
				13

Total completion time = 28 days

Average completion time = 74/4 = 18.5

Average job lateness = 13/4 = 3.25 days

Tabulating all the results:

Sequencing rule	*Total completion time*	*Av. completion time*	*Av. job lateness*
MINPRT	28	15.5	4.25
FCFS	28	15.5	2.21
LPT	28	19.5	5.25
DD	28	17.25	2.75
DS/RD	28	18.5	3.25

You can select the rule depending on your requirements.

3.4.2 Sequencing when there are Several Jobs and Several Machines

This method was developed by S.M. Johnson to minimize the idle time by prudent job allocation.

Example 3.4

In a job shop, Jobs A,B,C,D,E,F and G have to be performed on two machines M1 and M2 in the same sequence, i.e, M1 first, followed by M2. The time taken by each job on each machine is given as follows. Determine the sequence of the jobs.

JOB	*M1*	*M2*
A	9	2
B	5	4
C	8	10
D	3	5
E	4	6
F	1	11
G	7	6

Solution:

(a) The lowest time taken on M1 is Job F. So F is first.

(b) Next '2' is taken by Job A on M2. So A will be last.

(c) Next '3' is Job D on M_1. So D is the second job.

(d) Next '4' is Job E on M_1 . So E is third.

(e) Also '4' is Job B on M_2. So B is before A.

(f) Next '5' is Job D on M_2. But D is already scheduled. So ignore.

(g) Next '6' is Job E on M_2. Ignore since E is already scheduled.

(h) '6' is also Job G on M_2. So G is before B.

(i) C is left over. So place it after E.

So the sequence decided is F,D,E,C,G,B,A.

The situation becomes difficult when we have to assign several jobs to several machines. The index method and assignment method are used for this purpose. The following examples illustrate both these methods.

(i) Index Method

This is a method of finite job loading and backward scheduling. The least time or cost required by a particular job–machine combination is considered as the base and the indices for the other combinations are made based on the base index. While allocating, the capacity of the respective machines and the time available are considered, which under no circumstances should be exceeded.

Example 3.5

In a job shop, five products, A, B, C, D and E, need to be produced on four machines 1, 2, 3 and 4. The number of days it will take if A is made on Machine 1

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is 10; if A is made on 2 is 9 days; and so on. Allocate the five jobs to the four machines so that all the jobs are completed within the total time available of 20 days.

WORK CENTRE (NO. OF DAYS)

JOB	*1*	*2*	*3*	*4*
A	10	9	8	12
B	3	4	5	2
C	25	20	14	16
D	7	9	10	9
E	18	14	16	25
No. of days Available	20	20	20	20

Solution:

Assign an index number first. For every job, assign number 1 to the job–machine combination having the lowest number of days. In this example, for Job A, 8 is assigned index 1, for B, 2 is assigned 1, for C, 14 is assigned 1, for D 7 is assigned 1 and for E 14 is assigned 1.

Then calculate the ratios for the other numbers and tabulate as follows:

WORK CENTRE

JOB	*1*	*Index*	*2*	*Index*	*3*	*Index*	*4*	*Index*
A	10	1.25	9	1.13	8	1.0	4	1.5
B	3	1.5	4	2.0	5	2.5	2	1.0
C	25	1.78	20	1.42	14	1.0	16	1.14
D	7	1.0	9	1.28	10	1.47	9	1.28
E	18	1.28	14	1.0	16	1.14	25	1.78
Days available	20		20		20		20	
Days assigned	7	14	8	2 + 16 = 18				

In the table, A has the lowest index for Work Centre 3. So A is allocated Work Centre 3.

Similarly, D is assigned line 1.

E = line 2

B = line 4

For C, the lowest index is at Work Centre 3. But if it is allotted, it will take 8 + 14 = 22 days, which will exceed the available 20 days. So if C goes to 1.14 index, that is line 4. Then line 4 will be booked for 2 + 16 = 18 days.

(ii) Assignment or Job Loading

In most job shops, there may be more than one work station available to perform a job. It then becomes necessary to choose between alternatives and jobs are allocated to the most time and cost effective job–machine combination. Assignment or job loading technique is a quantitative method which optimizes–our decision on job scheduling.

The Hungarian Method is a combinatorial optimization algorithm that helps in solving the assignment problem. This method was first invented by Harold Kuhn

in 1955 and then modified by James Munkres in 1957. The study of this method is beyond the scope of this course.

3.4.3 Gantt or Bar Charts

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This method was introduced by Henry Gantt in 1917 for use in production planning, scheduling and control. It is a type of bar chart that plots tasks against time. It is used for project planning as well as for coordinating a number of scheduled activities. In a Gantt chart, the time frame, which may be in terms of hours, days, weeks or months, is on the 'X' axis. The activities are plotted on the vertical or 'Y' axis.

Gantt Charts are used as:

- Scheduling or progress charts, to show the sequence of job progress
- Load charts, to illustrate the work assigned to work group or allocated to machines
- Record charts, to keep a track of the actual time spent and delays, if any

Gantt charts require updating at regular intervals, like when starting of work is delayed, when work continues beyond the time schedule, or when progress of work is not in accordance with actual plan. For unforeseen eventualities, it may be essential to initiate corrective actions, which will require corresponding changes in Gantt charts.

Advantages of Gantt charts

1. They are simple and inexpensive and can be developed even by a supervisory staff with some amount of training.
2. The decided time and work schedules for every job can be clearly shown.
3. Updating and changes can be made quickly and with less cost involvement.
5. These types of chart boards are available in standard sizes in the market, which substantially saves the cost of developing customized Gantt chart boards.

Disadvantages of Gantt charts

1. Interrelationships and interdependencies between jobs cannot be shown.
2. Cost aspect of jobs cannot be indicated.
3. Alternatives for project completion cannot be shown.

Depending on the nature of requirement, the shape and form of Gantt charts may be different.

Smaller job shops and individual departments of large shops employ the Gantt chart to help plan and track jobs. You will learn how to draw and interpret a Gantt chart through the following example.

Example 3.6

Two jobs, J1 and J2, need to be performed on two machines in that sequence, that is M1 first and then M2. The time taken by each job on each machine is given below. Draw a Gantt chart and use it to allocate the jobs to the machines.

	M_1	M_2
J_1	3	9
J_2	5	11

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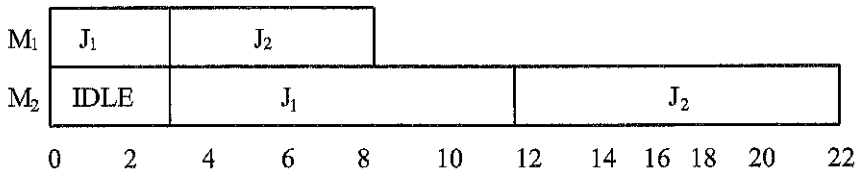
Solution:

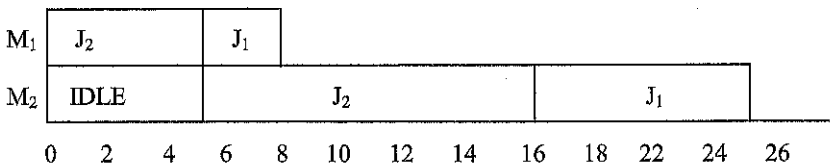
Suppose we follow sequence J_1, J_2.



When J1 is on M_1, M_2 is idle. After 3 hours, when J_1 goes to M_2, J_2 starts on M_1.

The total time required in this sequence = 3+9+11 = 23 hours.

Suppose we follow the sequence J2, J1.



When J_2 is on M_1, M_2 is idle. After five hours, when J_2 goes to M_2, J_1 starts in M_1.

The total time required in this sequence = 5+9+11 = 25 hours.

So, J_1, J_2 is a better sequence since time taken in lesser.

Check Your Progress

1. What is routing?
2. How does production control benefit an organization?
3. What is scheduling?
4. What is dispatching?
5. What do you understand by follow-up?

3.5 FUNDAMENTAL CONCEPTS IN MODERN MANUFACTURING TECHNIQUES

Automation means replacing human labour with machines. Automation and advanced technology began in the 1950s with the development of numerically controlled (N/C) machine tools. N/C machining enabled the machinist's skills to be duplicated by a computer program that was stored on a computer medium such as punched paper tape. The computer program controlled the movements of a tool when making complex shapes. Over time, N/C computer hardware has become smaller and cheaper, computer controlled software has become more

sophisticated, and machine tools have become more complex. This has led to the development of industrial robots and flexible manufacturing systems (FMS). Advances in computer software and communications systems have led to improvements in manufacturing equipment and vice versa. Similarly, the knowledge base on which production planning and control decisions are made has significantly improved. By combining knowledge bases with physical process control, computer assisted manufacturing (CAM) was born.

The union of Computer aided design (CAD), CAM, and FMS represents the latest development in manufacturing, which is referred to as computer integrated manufacturing (CIM).

N/C was probably the first true CAM system. Early N/C systems had manufacturing instructions on punched paper tapes. These instructions controlled the operations of a machine tool — for example, movement, drilling, and cutting and tool changes.

Computers are also used to create N/C tapes automatically. An interesting system has been developed by Structural Dynamics Research Corporation (SDRC), which specializes in computer-aided engineering. The SDRC HI – PRO system is an integrated N/C tape-preparation system for punching, shearing, and other sheet metal operations. Typically, a supplier receives orders for sheet metal parts of different sizes — for instance, 100 pieces of 1.5" × 8", 300 pieces of 6" × 10", and so on. These parts are cut from larger sizes of sheet metal on N/C shearing machines. The different parts must be laid out in a manner that will minimize the waste from the larger sheets. Computer programs are used to generate optimal cutting patterns, to plot graphically the patterns for visual verification, and to create automatically an N/C tape for manufacturing. The user needs to enter only the various stock sizes, part dimensions and requirements. The cutting patterns and manufacturing is computer-controlled.

You will learn in brief the various technologies of automation.

Computer-Aided Design (CAD)

Early CAD systems were basically computer-controlled plotting systems; today's systems revolve around graphics terminals. CAD allows engineers and designers to work in two and three dimensions and utilize colour to simplify complex designs. Designers can carry out geometric transformations at high speeds and can obtain the top, side and front views of design, rotations about any axis and cross sections. In addition, CAD systems allow the storage and retrieval of designs for easy updating and automatic creation of bills of materials and process information for production planning and scheduling systems.

Computer-Aided Manufacturing (CAM)

CAM involves computer control of the manufacturing process, such as determining tool movements and cutting speeds. N/C machines is an old form of CAM, robotics is a modern example. CAM offers advantages over conventional manufacturing methods. It can be used when several different parts with variable or cyclic demands are produced, when frequent design changes are made, when the manufacturing

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process is complex, when there are multiple machining operations on one part, or when expert operator skills and close control are required. Each machine in a CAM system has the ability to select and manipulate a number of tools according to programmed instructions. Thus, CAM provides a high degree of flexibility in performing and controlling manufacturing processes.

Caterpillar Corporation, for instance, uses CAM to make components for tractor engine drive assemblies. A transfer device shuttles parts among the work stations on both sides of a track, where some thirty to forty machining operations are performed. Operators at entry and exit points clamp the parts on and off the transfer mechanism; the rest of the process is computer-driven.

When a CAD system and a CAM system share a common database, the term CAD/CAM is used. The integration of CAD and CAM allows for important coordination between design and manufacturing; through such integration the lead time for process planning can be reduced, quality assurance is improved and cost savings in tool design and other capital investments can be realized.

Flexible Manufacturing System (FMS)

A flexible manufacturing system (FMS) is a logical extension of CAM. An FMS consists of two or more computer-controlled machines linked by handling devices such as robots and transport systems. Computers direct the overall sequence of operations and route the work piece to the appropriate machine, select and load the proper tools, and control the operations performed by the machine. More than one different work piece may be machined simultaneously, and many different parts can be processed in a random order.

General Electric modernized its locomotive plant in Pennsylvania using an FMS. The machining time for engine-frame parts was reduced from sixteen days to sixteen hours; the overall productivity was increased by 240 per cent; capacity was increased by 38 per cent; and design flexibility was increased as well.

Advantages of FMS

- It reduces work-in-process inventory.
- It provides increased capacity due to reduction in set-up times.
- It provides better predictability and control of operations and scheduling.
- It offers reduction in material-handling costs.
- It provides greater sensitivity to market requirements.

All these advantages increase profitability and competitive position of the company.

Computer-Integrated Manufacturing System (CIMS)

The complete integration of CAD, CAM and FMS has led to a system called **computer–integrated manufacturing systems** or **CIMS.** This system represents the union of hardware, software, database management and communications, to plan and control production activities from planning and design to manufacturing and distribution. CIMS allows for much smaller and economically viable batch production capabilities. A firm can then match its production efforts to a much wider range of demand and create a competitive advantage through rapid response

to market changes and new products. CIMS also provides all the advantages discussed for CAD, CAM, and FMS.

The cost of developing and implementing a fully operational CIM system is exorbitant and requires a high degree of management commitment and effort. Many companies are beginning to reap the rewards of carefully planned systems. The development of CIMS will be a focus of manufacturing throughout this century.

Robotics

A robot is a programmable machine designed to handle materials or tools in the performance of a variety of tasks. Industrial robots were first introduced in 1954 when George Devol filed a design with the US Patent Office for a simple pick and place robot. Unimation, founded in 1962, was the first industrial robot manufacturing company. In 1986, approximately 16,000 industrial robots were in use in the United States and Japan had approximately 60,000 in use. Robots have been relatively slow to be used in the United States because of management resistance to change, the fact that the United States has a plentiful labour supply, human fears associated with being replaced by robots, and lack of technical knowledge about their uses.

By using computer control, the robot can be 'taught' a large number of sequences of motions and operations and can even make logical decisions. A principal advantage of a robot is that it can be reprogrammed and transported from one application to another. Some of the typical applications of industrial robots include spot welding of automobiles, spray painting, machining operations such as drilling and assembly, inspection and material handling. Robots are especially useful for working with hazardous materials or heavy objects, labour, improvement in quality, increased capacity, and more flexibility of low- volume production equipment. In addition, they never complain!

Vision Systems

Vision systems consist of a camera and video analyser, a microcomputer, and a display screen. Computer vision systems can read symbols, identify objects, measure dimensions, and inspect parts for flaws. Thus, they are beginning to find extensive use in quality control.

In automotive applications, vision systems are used in conjunction with robots to weld body seams of varying widths, tighten imprecisely located bolts, mark identification numbers on engines and transmissions using lasers, and arrange car hoods on racks that have unevenly spaced slots. At a General Motors plant in Lansing, Michigan, for example, a vision-equipped robot system finds the exact location of a dozen lower-suspension rail bolts and then uses a pneumatic nut runner attachment to tighten the bolts to precise torque specifications. The system has resulted in more accurate bolt torquing and in less manual rework required downstream on the assembly line.

Automatic Identification Systems

At the operational level of manufacturing, a large amount of data from the shop floor is required in order to provide the information necessary for effective production control. The conventional method of capturing data involves manual

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recording by supervisors in a register. This data is then keyed into a computer system for processing. This method is slow and subject to errors. An alternative approach to the conventional method of capturing data involves the use of **automatic identification systems**. These systems read source data and convert it into a form readable by computers for controlling equipment and generating reports. Error rates for automatic identification systems are as low as 1 in 3 million, and speeds are hundreds of times faster than conventional methods. Automatic identification systems reduce paperwork, improve accuracy, and provide more timely and useful information than previous methods of data collection.

Examples of automatic identification systems are bar code scanners and voice recognition systems. Bar code scanners read symbols by measuring the width of the bars and spaces and differentiating between symbols by the amount of light reflected. Bar code scanners are probably the most popular method of automatic identification, and are the fastest and most accurate. Voice recognition systems are useful in operations that require a worker to use both eyes and hands for accomplishing a task; for instance, in a receiving and inspection application, in which handling, sorting and recording of data must all be done simultaneously.

Automation in Materials Handling

Automation plays an important role in materials handling applications. Two major applications here are automated sorting and automated storage and retrieval. Automated sorting equipment is often found in such places as post offices, air cargo terminals, mail order distribution centres, airline baggage handling, truck terminals and publishing houses.

Automated storage and retrieval systems (AS/RS) are designed to provide high material flow rates through warehouses, particularly for high volume, unit load storage. Incoming pallets arrive via a conveyor and are transferred to a loader at one of the storage aisles. The storage/retrieval (S/R) vehicle then moves both horizontally and vertically to deposit the load in an empty storage location. On the way back, S/R vehicles usually retrieve a required item to be sent to shipping. S/R vehicles may be manually controlled or fully automated. Computer control is needed to maintain an up -to-date list of storage locations for efficient retrieval. Capital investment in AS/RS is high, although the increased productivity and reduction of direct labour are the primary benefits.

Cellular Manufacturing (CM)

Cellular Manufacturing (CM) is characterized by a production system where the machine components and workstations are aligned in such a way as to derive maximum benefits. This means that these types of manufacturing ensure that there will be a continuous and unhindered movement of raw materials and inventories (single process flow) through all stages of production. Moreover, this process also ensures minimal waiting period, thereby ruling out delays of any nature. These days cellular manufacturing plays a significant role in lean manufacturing.

A small, well-defined unit of production is often referred to as a cell. A cell supports within itself all the necessary raw materials, equipment and manpower required for manufacturing a product. Since this process involves manufacturing

families of components within a single line or unit, this process is known as cellular manufacturing. Thus, cellular manufacturing differs from the customary 'batch and queue' process, where in the production area only those machines which are identical or complementary are placed together. This results in much loss of time as various components which are in intermediary level of production need to be transported to the next stage for further processing. Such situations do not arise in cellular manufacturing, where the product of one process or machine is directly transferred to the adjacent process or machine.

Advantages of Cellular Manufacturing

1. Firms that supported cellular manufacturing saw reductions in work-in-process, finished goods, lead time, late orders, scrap, direct labour and workspace.
2. Improvement in the quality of production and control. This is because the segmentation of the manufacturing plant in to small self-combatable units makes the job of production and control easier. Cells or units which do not meet the expected targets can be removed as it is easier to detect the cell producing the defective component or part.
3. It enables just-in-time production, because there is no break in the production process, thereby resulting in improved production efficiency.
4. It requires only the required inventory, thereby minimizes wastage.
5. It enables optimal utilization of floor space.
6. It finds good support from customers because of shorter production cycle times.

Disadvantages of Cellular Manufacturing

One major limitation of cellular manufacturing is bottlenecks. Bottlenecks can be taken care of by balancing equipment capacities. This means that only the correct-sized equipment that complements each other in the production line must be chosen. Another way of combating bottlenecks is by joining together two or more smaller capacity machines to match one larger-capacity equipment. All workers employed in cellular manufacturing units must have wide range of multiple skills as they need to work with different equipments in the individuals cells allotted to them.

Check Your Progress

6. What is FMS?
7. What is CIMS?
8. When does infinite loading occur?

3.6 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Routing means determination of the sequence of operations for manufacturing a product or service. This path is determined in advance and forms the basis for most of the scheduling and dispatching functions.

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2. Production control offers the following benefits to an organization:
   (a) As production control aims to make the right quality and quantity of products accessible to the customers at the right time at minimum cost, the management can align the production activities with its sales programme.
   (b) Investment in inventories and finished stock can be kept to the minimum.
   (c) The firm can capture and increase its market share by producing the goods at the lowest cost.
   (d) Profits will improve as increased sales will increase profit.
   (e) Production control function guides the management to direct the production along the lines planned. It evaluates the actual performance consistently and locates deviations. It also suggests corrective measures to eliminate the deficiency in planning and operations.
3. Scheduling: According to Spriegal and Lanburgh, 'Scheduling involves establishing the amount of work to be done and the time when each element of work will start or order of the work.'

   Thus scheduling includes the following activities:
   - Determination of quality and rate of output of the plant or department.
   - Allocation of time for each operation.

   Scheduling indicates when a work will be released to the plant in a prescribed order and in proper sequence. It fixes the time of start and completion of the operation.
4. Dispatching means preparation and distribution of work orders and manufacturing instructions to the concerned departments in accordance with the details worked out under routing and scheduling functions. The work orders received by the various departments serve as an authority to start the work according to that schedule.
5. Follow-up means seeing whether the work is being carried out according to the planning and orders and instructions issued. It ascertains that the materials, tools and equipment are supplied for the job at the right time and to the right person or job. Follow-up is the means by which the progress and execution of the plan is evaluated from time to time and divergence from the plan is noted. The reasons for such divergence are then found out and efforts are made to eliminate them from the plan.
6. A flexible manufacturing system is a logical extension of CAM. A FMS consists of two or more computer-controlled machines linked by handling devices such as robots and transport systems. Computers direct the overall sequence of operations and route the work piece to the appropriate machine, select and load the proper tools, and control the operations performed by the machine.
7. It stands for computer-integrated manufacturing system. The complete integration of CAD, CAM and FMS has led to systems called or CIMS. CIMS represents the union of hardware, software, database management

and communications, to plan and control production activities from planning and design to manufacturing and distribution.

8. It occurs when work is assigned to a work centre simply based on what is needed to be done, without consideration of the capacity or resources required to complete the work or the sequence of the work to be done.

3.7 SUMMARY

- Production planning is a complex activity, encompassing various elements. The elements of production planning include maintenance planning, aggregate planning, marketing planning, quality planning, capacity planning, financial planning and manpower planning.
- Planning can be of various types long-term planning, medium-term planning, and short-term planning.
- There are many different strategies of production planning including manpower planning and aggregate planning.
- The main activities encompassing production planning and control (PPC) are as follows: order preparation, materials planning, routing, estimating, scheduling, loading, dispatching, progressing, inspection, etc.
- For high volume continuous production, a line layout is preferred. This is also called an assembly line.
- The production planning problem in an assembly line is about: establishing production rates of the final product from the line and obtaining this production rate with optimal workforce level.
- In case of production planning for job or batch processes, where different products are produced on the same set of machines, scheduling is followed.
- A schedule is a timetable for performing activities, utilizing resources or allocating facilities. It schedules, dispatches, tracks, monitors, and controls production on the factory floor.
- Scheduling systems can use either infinite or finite loading.
- Scheduling systems can also be based on whether the schedule is generated forward or backward in time.
- Different methods are used for cases where scheduling when there are several jobs and one machine, and where sequencing when there are several jobs and several machines. In case of several machines, index method or job loading is used.
- Gantt or Bar charts method was introduced by Henry Gantt in 1917 for use in production planning, scheduling and control. It is a type of bar chart that plots tasks against time. It is used for project planning as well for coordinating a number of scheduled activities.
- Automation means replacing human labour with machines. Automation and advanced technology began in the 1950s with the development of numerically controlled machine tools.

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- The various technologies of automation include computer-aided design, computer-aided manufacturing, flexible manufacturing system, computer-integrated manufacturing system, robotics, vision systems, automatic identification systems, automation in materials handling.
- Cellular manufacturing is characterized by a production system where the machine components and workstations are aligned in such a way as to derive maximum benefits.

3.8 KEY TERMS

- **Aggregate plan:** It refers to the total or aggregate plan of a company for producing a product over a certain period of time, say in the next twelve months.
- **Master production schedule**: This gives information about the number of various models and sub-models of a product planned to be produced in a given duration.
- **Planning horizon:** It is the time interval used in MPS varies from firm to firm. It depends on the type of products used, the volume of production, and the lead times of the materials used. This span of time that the MPS covers is called the planning horizon.
- **Material requirements plan (MRP)**: It specifies when the products need to be made, what the raw materials are, when and how many are required and when the order should be placed with the vendors.
- **Routing (or process planning)**: It refers to the determination of the sequence of operations for manufacturing a product or service.
- **Dispatching:** It means the preparation and distribution of work orders and manufacturing instructions to the concerned departments in accordance with the details worked out under routing and scheduling functions.
- **Progressing:** This involves controlling the process of production, collection of data from various manufacturing shops, recording the progress of work and comparing the progress against the plan.
- **Shop floor control system**: It is a system for utilizing data from the shop floor as well as data processing files to maintain and communicate status information on shop orders and work centres.
- **CAM:** It stands for computer-aided manufacturing. Involves computer control of the manufacturing process, such as determining tool movements and cutting speeds.
- **Work centre:** It is an area in a business in which productive resources are organized and work is completed.
- **Forward scheduling:** It refers to the situation where the system takes an order and then schedules each operation that must be completed forward in time.

3.9 SELF-ASSESSMENT QUESTIONS AND EXERCISES

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Short-Answer Questions

1. What is FMS?
2. What are the advantages and disadvantages of automation?
3. What are the main functions of PPC in an organization?
4. Write short notes on:
   (i) Automation in material handling
   (ii) Finite and infinite loading
   (iii) Gantt charts
   (iv) Prioritization
   (v) Hungarian Method

Long-Answer Questions

1. 'A good production planning and control system adds to the profit of an organization'. Explain.
2. What are aggregate plan and master production schedule? Explain their relevance.
3. What are the different methods of manpower planning?
4. What do you understand by production planning? Explain in detail.

3.10 FURTHER READING

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UNIT 4 WORK STUDY AND MATERIAL MANAGEMENT

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Structure

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4.0 INTRODUCTION

Although a significant level of automation has been implemented in many factories, human beings still control a large part of the manufacturing process. Clearly, personnel also need to be 'managed'. The workplace comprises people of diverse cultural and educational backgrounds. This, coupled with the organization's objectives, warrant a clear definition of jobs for the workforce so that maximum productivity is possible, in addition to the highest levels of quality, service and responsiveness. Also, the job should be safe, satisfying and motivating to the worker.

Material Management is the planning and control of the functions supporting the complete cycle (flow) of materials, and the associated flow of information. The scope of Materials Management varies greatly from company to company and may include material planning and control, production planning, purchasing, inventory control, in-plant materials movement, and waste management. It is a business function for planning, purchasing, moving, storing material in an optimum way which helps organizations to minimize the various costs like inventory, purchasing, material handling and distribution costs.

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This unit will introduce you to the concept of work study materials management. You will learn about the objectives of materials management the cost involved in materials management.

4.1 OBJECTIVES

After going through this unit, you will be able to:

- Define work study and its objectives
- Understand the method study procedure
- Learn the techniques of measuring work or output
- Understand the concept of materials management
- Describe the scope and importance of materials management
- Discuss the concept of purchasing in the materials context
- Explain the methods of purchasing

4.2 WORK STUDY

Work study means the study of human work. The British Students Instiution, in its *British Standard 3138: 1969*, defined work study as, 'A management service based on those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts and which lead to the systematic investigation of all the resources and factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement.' This means that it is a procedure for understanding and determining the activities of the people, plant and machineries, identifying the factors which affect their efficiency and achieving economy through their optimum utilization. Work study is a generic term for two inter-dependent techniques, i.e., method study and work measurement.

In the same *British Standard*, method study has been defined as '... the systematic recording and critical examination of the factors and resources involved in existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs'. Method study, therefore, is concerned with the way in which the work is done.

Work measurement is defined by the same 'British Standard' as 'The application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance'.

The difference between work study and other productivity improvement techniques is that the latter involve major capital expenditure in plant or equipment. But work study ensures productivity by using the existing resources. In work study, the human element is emphasized and importance is given to the operation rather than to the technical process.

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Objectives of Work Study

The primary objectives of work study are:

- Effective use of plant and equipment
- Effective use of human effort
- Evaluation of human work

If the techniques of work study are not properly applied, they are likely to encounter resistance at all levels. Even trade unions acknowledge that work study provides the following benefits to workers:

(a) Eliminates drudgery, frustration and unhealthy working environment

(b) Provides opportunity to workers to increase their earnings (by achieving increased rate of output)

(c) Strengthens the health of the organization at the micro level and the nation as a whole at the macro level

In 1952, the International Labour Organization, in its 35th session held at Geneva, emphasized the importance of work study and consultation and cooperation between employers and workers.

In the following sections you will learn the two techniques, i.e., method study and work measurement.

4.2.1 Method Study

Method study is a method for examining, recording and analysing the existing way of doing work and proposing a method for improving the efficiency of a system. Unnecessary costs may be incurred in the existing methods. In method study, the reasons for these costs are identified. A critical examination of the proposed methods prevents unnecessary costs in the new jobs.

Objectives of Method Study

The main objectives of method study are as follows:

- To identify the proper sequence of production operations
- To optimize the utilization of machineries
- To reduce the manufacturing cycle time by reducing idle time of machinery
- To choose the right kind and amount of materials and reduce the raw material consumption per unit of production
- To reduce wastages and production of defective products
- To enhance tool life and therefore reduce tool cost per unit of production
- To allocate workforce optimally and reduce idle time by optimal utilization of human resources
- To improve the processes and procedures involved in production
- To improve the working environment in the workplace

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The Method Study Procedure

Method study is a scientific and systematic method by which an organization can determine the most appropriate method to manufacture a product. An organization it should study a process to identify delays, reduce transport distances for both materials and labour, economize processes, reduce requirements of processing time, and thereby make the total operation simple. By doing a method study, the organization aims to eliminate any stage or step in the process that does not add any value to it.

We begin the method study by first making a flowchart for the process.

The basic procedures involved in method study are as follows:

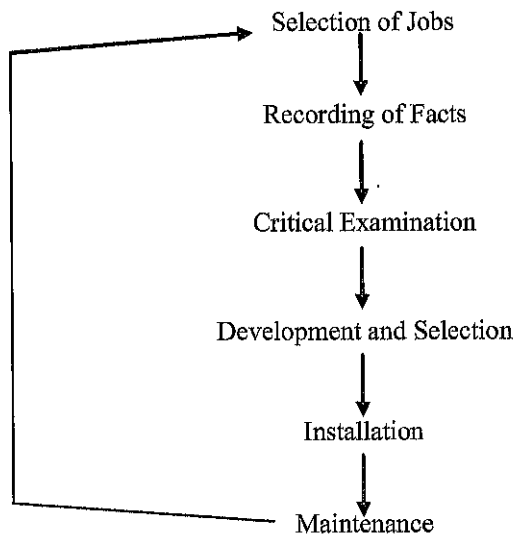

Fig. 4.1 Flowchart of the Method Study Procedure

a) Selection of jobs

Selection of a job for which method study is to be done is a managerial responsibility. The considerations for selecting a job could be economic, technical or human.

i) Economic considerations

These include operations which could be holding up other production operations, such as:

- Needless movement of workmen and materials over long distances
- Operations that involve great deal of manpower
- Operations that involve poor utilization of men and machines
- Sections or departments from which too many suggestions for improvement are received

ii) Technical considerations

- Operations that produce a great deal of waste or defectives
- Operations that involve repetitive work
- Complaints that performance standards cannot be achieved

- Operations requiring frequent supervision
- Jobs with incompatible quality
- Operations involving discrepancies in materials and tool performance
- Jobs involving greater number of man hours for checking and rechecking work

iii) Human considerations

- Workers complain about being overworked
- Poor worker morale
- Frequent accidents and health hazards
- Inconsistency in the earnings of the employees due to overtime

b) Recording of facts

Accurate and precise recording of facts related to a method determines the success of the method study which generally uses the graphical method to record facts, such as completion time and labour required in a method. The graphical method uses five symbols to record the facts related to a method. They are:

○ **Operation:** This symbol indicates that an activity is being done. Generally an operation is any activity that is adding some value to a product. It is a transformation process.

⇨ **Transportation:** This symbol indicates that the product, service or worker is moving from one location to another.

□ **Inspection:** This symbol stands for checking/observing for quality/ correctness/adherence to specifications, etc.

D **Delay:** This symbol indicates that the subject of study (product, service or worker) has to wait before starting the next process.

▽ **Storage:** This symbol indicates storage. Sometimes, T or P is written inside the triangle to indicate temporary storage or permanent storage respectively.

The advantages of graphical method over the descriptive method are as follows:

- It takes less effort and time.
- It helps isolate the valuable areas of a method from the useless areas.
- Critical examination becomes easier and more effective because it is visually clear.

c) Critical examination

Critical examination means analysing the facts related to a method. In critical examination, the facts related to a method should be examined as they are and not as they should be. Each step should be analysed in a logical sequence and hasty decisions should be avoided.

A systematic and methodical questioning process is used to conduct the critical examination. In the questioning process, all the activities, whether related

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to processing, inspection, material handling or any other aspect of a method, are recorded in a chart. After recording all the activities involved in a method, each activity is then examined carefully. There are five major factors related to an activity that need to be considered during the questioning process. These factors include:

Purpose: Analyses whether the selected activity is necessary for completing a method or not. The kinds of questions asked are – What activity is being done? Why is that activity being done? What will happen if that activity is not done? What else can be done? What should be done?

Place: Analyses whether the selected activity occurs at a specified place or not. Questions asked are – Where is that activity done? Why is it done there? What will happen if it is not done at that location and done elsewhere? Where else can it be done?

Sequence: Analyses whether the selected activity occurs at specified time and in a specific sequence or not. Questions asked are – When is the activity done? Is the performance of the activity at that time critical or can it be done at any time or in any sequence? Could it be combined with some other activity in the process?

Person: Analyses whether or not the right person performs the selected activity. Questions asked are – Who does the activity? Why should that person do that activity? Can it be done by someone else? Should the worker possess a high level of skill or will a lower skill level do?

Means: Analyses whether or not the selected activity is done using proper materials, tools, jigs and fixtures, measuring instruments and gauges. Questions asked are – How is the activity done? Why is it done that way? Is there a better way to do the activity?

d) Development and selection

Development involves an analyses of all the ideas generated during critical examination and implementation of these ideas practically. All the ideas generated during critical examination may not be practical. So the organization first needs to isolate the practical ideas from the conceptual ones. The selected ideas are then refined and developed during the development and selection process. The development process comprises three functions–evaluation, investigation and selection.

i) *Evaluation phase:* All the ideas generated during critical examination are evaluated to assess their true value and determine whether they should be pursued or discarded. To isolate the practical ideas from the useless ones, they are first categorized as–

- Useful ideas
- Ideas with technical flaws
- Ideas that cannot be used immediately because of insufficient data or lack of requisite knowledge
- Ideas with more disadvantages than advantages

Ideas which are similar are clubbed. The cost of testing and implementation is estimated.

ii) *Investigation phase:* The ideas generated in the evaluation phase are investigated to determine how a suitable idea can be taken up for practical implementation. The investigation phase includes preparing layouts, organizing discussion with personnel from various departments, such as design and quality control, making prototypes, conducting trial runs, getting work measurement studies redone from industrial engineering and preparing fresh cost estimates. Every idea is investigated to check its economic and technical feasibility.

iii) *Selection:* The selection stage involves choosing the best possible alternative from the available options. Various factors are taken into consideration, such as investment required, production rate expressed in terms of cycle time per unit of product, manufacturing cost per unit of production and physical effort required for performing the method. Every factor is assigned some points. The points acquired by every factor are added and the alternative that acquires maximum points is selected.

e) Installation

Implementation of the proposed method is known as installation. The proposal for change in method is presented to the management indicating the sequential steps that must be taken to implement the changed proposal. On receipt of the formal approval, the implementation plan is prepared. A demonstration of the proposed method can be held to clear misconceptions and apprehensions. Training of the employees who will use the new methods can also be carried out.

f) Maintenance

After implementing a method, it is important to monitor its performance. A feedback mechanism is needed to inform the concerned authorities about the results of the monitoring process. The savings accrued by using the new method should be audited to determine whether or not the implementation work is complete. The audit will also reveal additional factors that can enhance profits and then the whole cycle will start again.

The approach followed by the practitioner is also reviewed at this stage.

- Did he follow the effective approach? Does it need any correction?
- Was the implementation process efficient and favourable? If not, what changes are required in the approach so that the implementation of future projects is smooth?
- Which methods were used for efficient data collection? Can these methods be used in similar projects in the future?

Performance appraisal: The last step in the maintenance stage involves performance appraisal. This helps to determine the productivity gains of the proposed method that are evaluated at regular intervals.

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As human reactions play an important role in a method study, human consideration forms an important part in selecting a job. Workers should accept changes proposed by the method study. A change which is not fully accepted by the workers is not considered a good change. It is human nature to resist change. Opposition by the workers can be avoided by taking them into confidence. The following points should be considered in order to avoid resistance by the workers:

- Proposed changes should be intimated to the workers in advance because any surprise change is likely to be opposed.
- Approved methods must be properly introduced into the organization.
- Changes should be made slowly so that the organization can easily absorb them. This helps the workers to gradually adapt themselves to the changed methodology.
- Methods should be implemented in such a way that the entire human resource of the organization is won over.

4.2.2 Work Measurement

Work measurement is a technique to find out the time required to do any activity, at a predetermined level of performance, by a qualified worker. In other words, it is a technique to develop time standards for the performance of jobs.

To establish usable standards, the workers must first be trained to do a particular job. The method's analysis and study should provide work measurement.

Objectives of Work Measurement

The primary objectives of work measurement are:

- To establish the standard time for completing a job.
- To fix the salary of employees and to determine and calculate incentives based on their performance.
- To estimate the machine and labour requirements for planning and scheduling of production, the time required for jobs and when deliveries are possible, etc.
- To distribute workload.
- To calculate the number of employees needed for various tasks of the organization.
- To determine the number and nature of machines that a worker can run.
- To help the management accurately determine the costs incurred in the production.
- To compare the efficiency of various alternative methods and determining the best alternative among them.
- To establish standards for the performance of employees and utilization of machinery. This way, substandard workers can be identified.
- To control costs by uncovering wastages of both machine and labour and thus help to increase the operating efficiency.
- To track the performance of workers, their training needs, etc.

Techniques of Work Measurement

There are several techniques for measuring work. The most common are:

(i) Time study

(ii) Work sampling

(iii) Standard data

(iv) Predetermined motion time studies (PMTS)

We will now study these techniques in greater detail.

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(i) Time study

This method of work measurement is generally used when the work is repetitive. It is a sampling process in which a few observations of a sample are taken. The inferences drawn from the study of the sample are used to determine the time required for the performance of the subsequent cycles by the worker.

First, the job or task selected for time studies is split or broken down into activities. Then each activity is timed separately using devices, such as stopwatch.

Some principles are followed in breaking down the job into activities. These are:

1. Each activity should be of short duration, but at the same time long enough for it to be timed with a stopwatch.
2. The activities of the operator and activities of the machinery should be distinguished. Both should be timed separately.
3. Delays of the operator and the equipment should also be indicated separately.

Several readings need to be taken for each activity. The average of these readings will give the average time for an activity. The average time for each activity of a job is added to get the average time for a job.

The time thus obtained must be 'normalized' to make it usable for all the workers. So a rating factor is used to give the normal time. To take an example, if an operator completes a task in two minutes and it is estimated that he is performing 20 per cent faster than normal, then the performance rating of the operator is said to be 1.2 times or 120 per cent of the normal.

The normal time for the task will be 2 minutes × 1.2 = 2.4 minutes.

So, Normal time (NT) = Observed performance time per unit × Performance rating

When an operator is observed for a period of time during which he produces a number of units, then the normal time is given as

$$NT = \frac{\text{Time worked}}{\text{No. of units produced}} \times \text{Performance rating} \quad \ldots 4.1$$

Standard time is calculated by adding allowances for personal needs (such as breaks for freshening up or for drinking tea), inevitable work delays (such as lack of material or breakdown of machinery), and worker fatigue (physical or mental), to the normal time.

Standard time (ST) = Normal time (NT) + (Allowances × Normal time) ... 4.2

Note: Allowances may be given in minutes or as a percentage of the normal time

$$ST = NT(1 + \text{Allowances}) \quad \ldots 4.3$$

This equation is most often used in practice.

(ii) Work sampling

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This is another technique for measuring an activity. This method is similar to time study in that here also we observe a portion or sample of the work activity. Inferences are drawn based on the findings in this sample and this is applied for the activity in general.

For example, if a blacksmith is observed 100 random times during a week and it is found that he is making a hammer 30 out of the 100 times, it can be inferred that the blacksmith spends 30 per cent of his time in making hammers.

Note: The time required to make an observation is dependant on the object or activity that is being observed. Many times, only a glance is required to determine the activity, and most of the studies require only few seconds' of observation.

In work sampling, the size of the sample is a major issue. The level of statistical confidence desired in the results is considered before deciding the sample size. The account of observations needed in a work sampling study can be fairly large, ranging from several hundred to several thousand, depending on the activity and level of accuracy required.

The three primary applications of work sampling are:

(i) To determine the average time that the machine and labour are idle or running. This is also called 'activity time' for personnel and machinery.

(ii) To develop a performance index for workers. These performance measures help in performance evaluation of the workers, fixing of pay, bonus, penalties, etc.

(iii) To fix time standards, that is, the standard time required for a task.

The following is the sequence of activities in doing a work sampling study:

1. Identify the activity for which the study is to be done.
2. Estimate the percentage of time the selected activity takes, to the total time (e.g., the machine is working 80 per cent of the time). These estimates are made by analysts from existing data, guesswork or a pilot work sampling study.
3. State the degree of accuracy desired in the study results.
4. Determine the particular times when each observation is to be made.
5. Two or three times during the study period, the data collected are examined and if necessary, the required sample size and number of observations to be made are altered.

In a work sampling study the number of observations to be taken is equally divided over the study period. Thus, if 500 observations are to be made over a period of 10 days, observations are usually scheduled at 500/10, or 50 per day. A specific time may also be assigned for each day's observations.

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Work sampling compared to time study

Work sampling has advantages over time study:

- One observer can simultaneously conduct several work sampling studies.
- Generally, the observer is not highly skilled. Only the analysts need to be highly trained.
- Timing devices are not required in work sampling.
- Work of a long cycle time may be studied with fewer observer hours.
- Since the duration of the study is longer the effect of short-term variations is negligible.
- The study can be temporarily delayed without affecting the results.
- Since work sampling involves observations made over a longer period, the worker has less chance of influencing the findings by changing his or her work method.

The disadvantages of work sampling over time study are:

- Work study is not economical in case of a short cycle time. In such cases time study is more appropriate.
- Observers in work sampling tend to develop repetitive time of taking observations and route of travel. This can make the observations predictable and the inferences may be erroneous. So the observer should adopt a random sequence of observations to lessen these errors.
- Work sampling is more accurate when the system is stable. In a dynamic situation, work sampling may give erroneous results.

(iii) Standard data

For jobs in which there are a large number of repetitive operations with similar characteristics, companies often develop standard data through time studies or predetermined data. The advantage of having standard data is that each job need not undergo a time study. Standard data is applied in a similar manner as predetermined motion time data, except on a less detailed level.

For instance, an income tax service may develop standard data on the time required to fill out different tax forms. From this data, it is easy to provide an estimate of the cost for a client based on information about the forms required for the client. Standard data are also useful in estimating times for jobs with different characteristics through regression type equations.

Standard data is used in the following manner.

Example 4.1: In a warehouse the standard time required to unload 10 Kg boxes from a truck is 2 minutes per box. Due to increasing allowances for fatigue, suppose this goes up by 0.10 minutes for each additional 2 kgs. The standard time for a box of weight 'b' is $2 + 0.10/2\ (b - 10)$ minutes.

Therefore, if 50 boxes, each weighing 18kgs are to be unloaded, the standard time required is $50\ \{2 + .05\ (18 - 10)\} = 50 \times 2.4 = 120$ minutes, or 2 hours.

Having an adequate data base of standard data makes such calculations easy to compute.

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(iv) Predetermined motion time studies (PMTS)

An alternative to time study is the use of standard times for work elements that have been predetermined from long periods of observation and analysis. The major advantage of this method is that only motion patterns must be known; alternatives may be evaluated prior to actually trying them out. In order for such a system to be universally applied, it is necessary to define a basic set of motions into which any task can be split into.

However, these motions must be refined to account for various degrees of difficulty; for example, lifting a bag of 5 kg is easier than lifting 5 kg of cotton wool, and thus should be expected to take lesser time.

Since it is necessary to apply micro-motion analysis to such systems, these systems are often costly to use. There are a number of different motion time systems. One of the best known and most widely used is methods time measurement (MTM). This system was developed in 1948 from studies of motion picture films of assembly operations. The basic elements used in MTM are:

1. Reach
2. Move
3. Turn and apply pressure
4. Grasp
5. Position
6. Release
7. Disengage
8. Eye travel time and eye focus
9. Body, leg, and foot motions
10. Simultaneous motions

Each of these has several subcategories. For example, there are five types of reach:

1. Reach to an object in a fixed location or in the other hand
2. Reach to an object in a general location
3. Reach to objects jumbled together
4. Reach to very small objects
5. Reach to an indefinite location, such as moving the hand out of the way

Element times are measured in time measurement units (TMUs), where one TMU is .00001 hour, or .0006 minutes. Tables of times have been developed for each activity, so that employees can take an active role in increasing productivity and quality and in reducing costs.

Check Your Progress

1. Define work study.
2. List four objectives of method study.
3. What are the various techniques of work measurement?
4. What is the sequence of activities to be followed in work sampling?

4.3 MATERIAL MANAGEMENT

NOTES

'Material management is a term used to connote controlling the kind, amount, location, movement and timing of the various commodities used in and produced by the industrial enterprise.'

Materials are the most important resources for any company because no goods can be produced without them. Materials management controls the procurement, storage, amount, movement and consumption of materials that can be used by a company for its production process. It covers various aspects of materials and supplies the necessary materials when required for converting them into finished products.

An Integrated Approach to Materials Management

The basic task of materials management is to improve the productivity of materials. For this, materials management follows a systematic and an integrated approach that involves various activities. These activities are as follows:

- **Materials planning:** Determines the needs of the consumers in advance, translates sales projection into production requirements and makes accurate estimation of materials that are required for production.
- **Make-or-buy decisions:** Decides which items can be produced at the home plant and which should be obtained from the outside sources based on the total cost available for production.
- **Purchasing:** Provides constant supply of raw materials, parts, components and consumables to meet the target of the production.
- **Receiving and inspection:** Collects materials and inspects them to ensure their quality. This helps to decide whether the materials should be accepted or not for further production.
- **Storage:** Provides the right place to store materials, uses proper methods of preservation and also provides proper security against theft and malpractices. This activity also takes certain steps to ensure that the wastage of materials while storing them is minimum.
- **Inventory control:** Maintains optimum investment in inventories and also ensures supplying materials that are required for the production at the right time.
- **Distribution of materials:** Ensures the fastest and efficient supply of materials to the customers
- **Transportation:** Ensures efficient transportation of incoming and outgoing materials.
- **Disposal of surplus, obsolete and scrap materials:** Analyses the requirement of materials and selects the most economical channel to dispose the materials that are surplus and not required.
- **Developing new sources of supply:** Locates, selects sand develops new sources to supply materials for improving the product quality and reducing the total cost of production.

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- **Import substitution:** Reduces purchasing cost by developing domestic sources of supply for imported materials and therefore, saves foreign exchange.
- **Materials research:** It involves analysis of all the factors, such as economic analysis, market analysis, price analysis, transportation analysis, lead-time analysis that affect the functions of materials management.
- **Waste management:** Minimizes the wastage of materials by determining the causes for rejection and scrap of materials.

All the above activities must be properly coordinated to maximize the effectiveness of materials management.

Objectives of Materials Management

The main objectives of materials management are as follows:

- The first and foremost objective of materials management is to minimize the materials cost thus paving the way for reducing the cost of the product manufactured. The company is able to maintain the price at a reasonable level.
- It also aims at procuring and providing materials of desired quality at the lowest possible overall cost.
- It also aims at reducing investment tied-up in inventories for use in other productive purposes and to develop high inventory turnover ratios.
- The next objective of materials management is to purchase, receive, transport and store materials efficiently and to reduce related costs.
- Continuous supply of materials is an essential pre-requisite for uninterrupted production. Materials management aims at finding out new sources of supply and develops cordial relations with the suppliers.
- The next objective of the materials management is to cut down costs through simplification, standardization, value analysis and import substitution.
- Materials management aims at minimizing procedural delays in procuring materials.

In a nutshell, various important objects of materials management can be summed up as follows:

- To reduce material cost
- To ensure efficient control of inventories which helps in releasing the working capital for productive purposes
- To ensure uniform flow of material for production
- To ensure right quality of products at the right price
- To establish and maintain cordial relationship with customers

The primary objective of the organization is to reduce the cost that occurs while buying, storing, handling, insuring, transporting and packaging materials. In addition, materials management fulfils the following objectives:

- Maintains steady flow of materials to ensure that the production of the products does not get interrupted
- Adopts cost reduction techniques like MRP and value analysis to manage the total cost required for proper management of materials
- Provides the right materials, of the right quality, in the right quantity and at the right time to ensure the production of high-quality products
- Implements scientific inventory control techniques to reduce inventory investment
- Maintains records of purchase, stores
- Preserves stocks so that any loss of materials caused due to deterioration, pilferage can be kept at minimum
- Improves producer–consumer relationship by producing high-quality products
- Improves the firm's strength in the market by producing the best-quality products at the lowest possible cost
- Minimizes wastage of materials and therefore reduces operating cost
- Dumps surplus materials that are not required for the production process

Figure 4.2 shows the objectives of materials management.

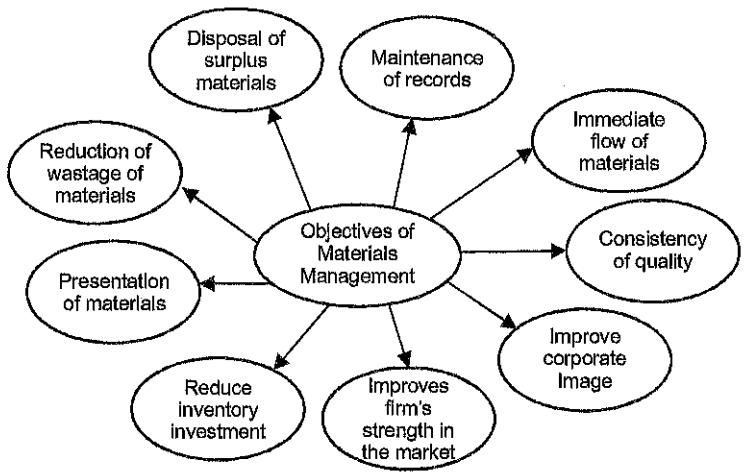

Fig. 4.2 The Objectives of Materials Management

4.3.1 Scope and Importance of Materials Management

Materials management covers all aspects of materials and material supply which are very important for converting raw materials and other inputs into the desired finished products. The various functions of materials management are as follows:

- Materials planning
- Purchasing of materials
- Reducing store-keeping and warehousing
- Inventory control
- Standardization, simplification and value analysis

- Transportation and material handling
- Disposal of scrap surplus and obsolete materials

Let us discuss the importance of materials management.

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Importance of Materials Management

A survey conducted by the Directorate of Industrials Statistics during 1954–57 showed that the average material cost is 64 per cent of the sales value. In some industries, it goes up to 70 per cent. These figures show the importance of materials management. Materials have their tentacles spread to all areas of production, such as men, machines and marketing. The concept of materials management has recently been gaining importance. Avoidance of wastage is very important for efficient utilization of materials. Materials management helps to avoid wastage to a great extent. As emphasized earlier, materials management is a service function and is of great importance to other sections like manufacturing, marketing, engineering and finance, by way of providing assistance to these sections in their operations. Also, materials management is of great help in efficient and judicious purchasing, minimizing wastages in handling, storing and transporting the materials and the utilization of materials very efficiently. It is worth mentioning here that materials management contributes to the success or failure of a concern. From the national point of view, materials management plays a pivotal role for the success of national plans because efficient materials management can exploit the national resources. In addition to reducing material costs, efficient materials management is useful for the following purposes—(a) for reducing foreign exchange by utilizing the imported items to their maximum value and thus help in reducing the imports; (b) by reducing the cost of finished goods and maintaining the quality. As such, it is possible for Indian manufacturers to compete better in the foreign market and earn more foreign exchange.

Functions of Materials Management

The main function of materials management is to obtain and control all the materials and items required by the organization. Following are the functions of materials management:

- **Planning and programming of materials:** It determines the needs of the consumers in advance and makes exact estimation of various materials that are required and the time when they are required for the production process.
- **Purchasing of materials:** It ensures the uninterrupted supply of materials to achieve the goal of production. Purchasing of materials should be always done after market research.
- **Inventory control:** It maintains the sufficient inventory level of materials to meet customer needs. It also enables the organization to determine an appropriate inventory level by keeping in mind the carrying inventory cost.
- **Store keeping:** It manages the physical storage of materials, because the materials are required to be stored until they are consumed or sold. It is the responsibility of materials management to receive, store, move, and issue materials until they are consumed.

- **Stores accounting:** It maintains the records of materials to determine the reorder level. This helps a storekeeper to order the materials when the stock reaches the reorder level.
- **Transportation:** It manages the proper handling and transportation of incoming and outgoing materials.
- **Materials economics:** It helps reduce the cost incurred while purchasing, tendering, packaging, handling, moving, storing and inspecting materials. Utilizing various cost reduction techniques such as value analysis, variety reduction, critical path analysis and MRP help in reduction of materials cost.
- **Waste management:** It minimizes the wastage of materials by determining the causes for the rejection of materials.

Figure 4.3 shows the functions of materials management.

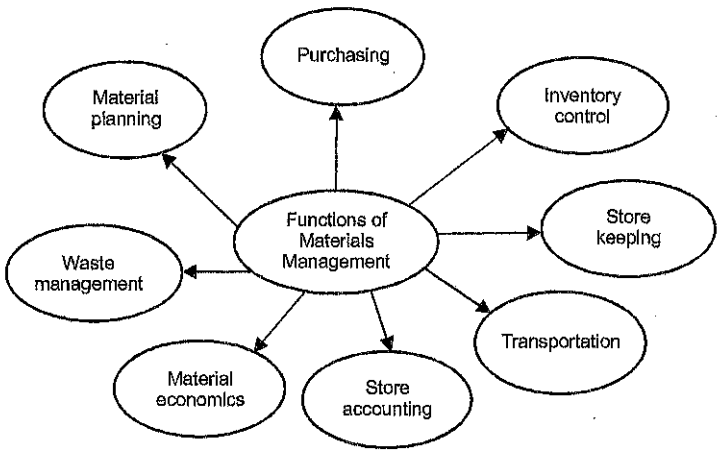

Fig. 4.3 Functions of Materials Management

Material Planning and Budgeting

Managing materials involves various costs that are:

- **Basic:** Cost of materials paid by the company to a supplier
- **Government levies and taxes:** Cost paid to the government such as excise duty, and sales tax by the company
- **Ordering:** Costs such as tendering, stationery, postage, receiving, inspection and bill payment that are incurred while purchasing materials
- **Inventory carrying:** Costs such as losses due to deterioration of materials, insurance premium and storage and preservation expenditure that are incurred for maintaining inventory of materials
- **Packaging:** Cost that is incurred while packaging the products
- **Materials handling:** Cost that is incurred while moving and storing materials
- **Shipment:** Cost that is incurred while transporting materials from suppliers to buyers
- **Insurance:** Premium cost that is incurred for insuring materials

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In addition to these costs, there are certain costs that occur due to the defects in designing of the product, poor quality of material, rework and rejection of the product during inspection.

Benefits of Materials Management

Because all the activities regarding materials management are placed under one department—materials management department, the coordination between them is much better and therefore all the data related to materials is collected and analysed at one place. This helps to take optimal decisions and maintains right balance among various conflicting issues. It can also lead to the reduction of the cost of materials. Not only this, it also improves the relationship with other departments as the staffs from other departments are not required to solve materials-related problems.

Check Your Progress

5. What is the basic task of materials management?
6. State any two objectives of materials management.
7. List any two functions of materials management.
8. State the benefits of materials management.

4.4 MANAGING PURCHASE

A study by McKinsey (Management consulting firm) found that after pricing, reducing purchasing costs is the most powerful way to improve shareholder returns. A 10 per cent decrease in material cost improves the returns by 22 per cent, while the same reduction in labour costs or increase in market share, increases returns by 16 and 17 per cent respectively. The McKinsey results are shown in Figure 4.4.

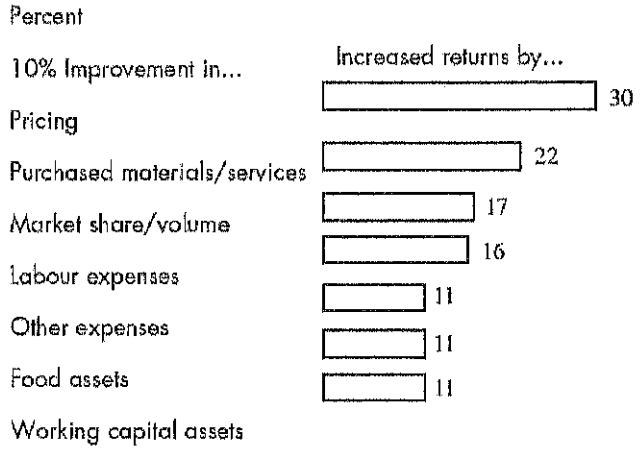

***Fig. 4.4** Purchasing as a Performance Leveler*

Source: McKinsey

What are the implications of the McKinsey study? The message is very clear, though purchasing has strategic importance under all circumstances, when the market is highly competitive, purchasing becomes a critical function. It provides the highest leverage to the profitability of the firm.

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Materials management views the purchasing/supply organization as the integrating mechanism in the internal and external exchanges of the firm.

Marketing strategies of suppliers shape purchasing strategies of buyers and vice- versa. Within the context of interactive buyer-seller relationship, purchasing exceeds buying as marketing exceeds selling.

From systems theory and total quality viewpoints, every purchase is also a sale and a part of the value-creation process. Suppliers have the ability to enhance this value, because they can deliver technology, knowledge, products or service quality that will beat competitors.

These argument lead us to the conclusion that purchasing can be seen linking the internal and external exchange functions of the organization. Simply put, it means:

- **Every purchase is a sale as well:** The focus is on internal exchange, you are supplying an internal customer and purchasing decisions also contribute to marketing and organizational goals.
- **Purchasing is more than buying:** The focus is on external exchange, i.e., there are complex exchange relationships with suppliers in markets. The core idea is that profits are best achieved through provision of competitive products that give customers satisfaction, and purchasing has a major role in this.

Purchasing activities involve management and combination of internal/external and upstream/downstream supply chain integrated into the customer-employer-supplier chain. The contemporary concept of purchasing is shown in Figure 4.5. As will be apparent from the Figure, there are three primary functions of modern material management:

- Strategic procurement, i.e., aligning procurement tasks and suppliers' performance with the corporate and business strategies of the firm
- Supplier-base management, i.e., managing the structure and culture of supplier relationship that is denominated in strategic purchasing
- Develop a lean supply organization by energizing organizational teams through flexible structures and responsive information systems

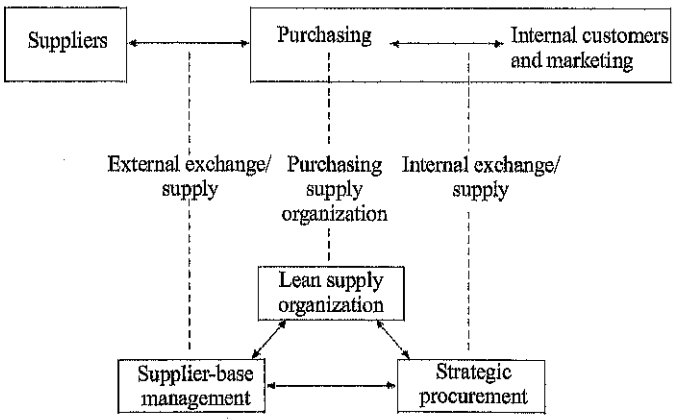

Fig. 4.5 Purchasing in the Modern Materials Management Context

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The contemporary concept of purchasing means modifying the association with suppliers besides another kind of internal relationship between supply and the other functional areas. In order to accomplish this successfully, companies have to bring in five major concepts into the functioning of the purchase department, which reflect the basic characteristics of purchasing in the materials context:

- **Horizontal integrated perspective:** The first requirement is that purchasing has to transform from a traditional vertical, stand-alone process to a horizontal, *integrated* one. A purchasing department that functions as a separate unit, restricted to cutting purchase orders, expediting parts, and trying to wring price concessions from suppliers, fails to give the best results. The concept of purchasing in the supply chain is that of a horizontal, integrated process. As purchasing controls and/or influences nearly three-quarters of the costs, it has to mange both internal and external relationships effectively. This is a change that has to be led and supported by the top management.

  Internally, it needs to function upfront as equal associates with sales, engineering, and manufacturing in product design. With the cooperation of user groups, purchasing is better qualified to evaluate the non-price elements of total cost; for example, in the case of a well-known automobile purchasing found that engineers were specifying different types of fasteners for different products, when one common fastener would have been sufficient. By standardizing the part, the company was able to make saving in excess of rupees one crore.

  Externally, it needs to work with suppliers in the supply chain. Companies, as diverse as Toyota, Honda, Ford, Harley-Davidson, Detroit Diesel, Black & Decker, Yamazaki Mazak, Motorola, Bose, and Xerox; the identified strategic significance of maximizing their supply management processes. They are developing effective new ways for their internal functions to work together with suppliers in optimizing product design, development, manufacture, and distribution. Such improvements have enabled some to slash their development times by as much as 40 per cent, increase inventory turns from six to over 50 a year, and reduce the cost of purchased materials by 15 to 35 per cent.

- **Total cost of ownership:** Purchasing has to move from a price focus to a total cost focus. Best-practice companies comprehend and quantify the total cost of ownership (TCO). TCO is the actual price of any purchase which includes hidden extras. Traditional purchasing focused exclusively on price reductions. The result was that costs popped up elsewhere, e.g. by using lower quality raw materials or by buying in bulk. In the first case, it often results in increased product failure. In the second case, goods can become obsolete. Both eventualities affect overall expenditure.

  The best approach is to work across functions to quantify important elements such as warehousing expenses, field failure, freight and the cost of poor forecasting, and to include these in the TCO. Only nations clear of the TCO can enable a company to take reasonable decisions, certain that price reductions in one area will not simply appear as increases somewhere else.

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Companies that do not track the TCO, moreover, risk leaving as much as half of the potential cost savings—those unrelated to price—on the table.

- **Improved skills:** Given the complexities and challenges the supply chain faces, purchasing has to convert itself from low-skilled to best-skilled people. Purchasing needs the company's best and brightest people, especially as its contribution to the improvement of shareholder returns is significant.

  Efforts made by organizations to generate strategic alliances, preferred suppliers, single source and partnering types of arrangement with suppliers to release benefits and create synergies, are not achievable in the standard, competitive, and non-trusting mode.

  Cooperative agreements with suppliers require far greater top management and inter-functional contact within the purchasing organization as well as across the peer functions in the supplier's organization. Getting more from suppliers will require an internally different approach and skill set.

- **Use of innovative tools:** Purchasing needs to change its traditional approach. It has to abandon standard approaches in favour of using innovative tools. Many progressive firms have discovered traditional bidding and administrative tools to be insufficient to generate and manage supplier networks, and have had to develop new ones.

Some examples of the use of innovative tools by companies that have extracted the most from reconfiguring the supply chain are as follows:

- Linear performance pricing helps manufacturers and suppliers quantify the link between function and cost for large capital items or for unique and infrequently purchased items.
- Partnership performance contracts are used to identify and quantify value-creation opportunities and to ensure they are fairly distributed between partners.
- Lean production diagnostics help suppliers identify where and how they can improve performance.
- Electronic market making and online bidding are applied to obtain the lowest possible cost.

  A new study of leading European businesses by benchmarking specialist PIMS Associates and the Chartered Institute of Purchasing and Supply (CIPS) reveals that an effective purchasing strategy can add up to 4 per cent of sales value or 30 per cent to profitability. With such possibilities, it is not surprising that many companies are now training their purchasing personnel in the use of different analytical tools, reflecting the degree of skill needed to set up and run a supplier network.

- **Information and insight:** Finally, purchasing has to have the ability to covert data into insight. Good decisions are made with the right information. Often, purchasing departments depend on data—much of it incomplete—about what their company buys. Their actual requirement is established facts and insight in three primary domains—TCO, supply markets, and supplier economics.

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Understanding supply markets helps a company determine, among other things, how much leverage it has over suppliers. TCO ensures new business is awarded to suppliers at the right total cost. Comprehending supply markets enables a company to decide how much leverage it has over suppliers and analysing supplier economics helps determine where a supplier might be extracting disproportionate profits, or running losses. With this knowledge, purchasing helps achieve continuous improvement and a competitive advantage.

Information technology has made it feasible to create a computer network for handling purchasing, billing and payment. The development of Electronic Data Interchange (EDI) provides links beyond organizational boundaries between buyers, sellers, and between companies performing similar functions, through automated computer-to-computer exchange of standard commercial documents. The economics of EDI are so inducing continuced to grow that it has at a fixed rate all over the world while it is being utilized by both manufacturing and service industries. It is estimated that more than 1,50,000 companies worldwide were involved with EDI by 2000.

With a knowledge base the firm can establish yardsticks by which to judge purchasing performance. Purchasing departments frequently make independent savings estimates that have little trustworthiness with other departments. However, improvements in purchasing can quickly boost productivity and profits.

- Effective purchasing is not just about price (short-term) but about total cost of acquisition (long-term value).
- Professional procurement teams that base their expertise on negotiation and transaction skills alone are not sufficient to implement an effective procurement approach.
- Applying a strategic approach to a poorly purchased good or service generates a saving of between 20 per cent and 40 per cent in expenditure.
- There is a clear correlation between purchasing effectiveness and relative market prices paid. Transactional purchasing leads to 102 per cent of market price while advanced techniques achieve 98.5 per cent, a saving of 3.5 per cent.
- Close relationships with suppliers restrict price rises to below market norms.
- An effective purchasing strategy improves the quality of the supplier's service in terms of product, delivery, response times and customer service as well as price

4.4.1 Methods of Purchasing

Before we learn about the methods of purchasing, lets take a step back and first define the term 'purchase' then learn about the objectives of purchasing and the functions of the purchase department.

According to Alford and Beauty author of Principles of Industrial Management, 'Purchasing is the procuring of materials, supplies, machine tools

and services required for the equipment, maintenance and operation of a manufacturing pant.'

Purchasing is the process of obtaining the materials, tools and supplies that are required for the manufacturing of a product. About 50 to 60 per cent of the total expenditure of the production organization is expenditure on raw materials, components and services. Therefore, purchasing should be done in such a manner so that the total savings of the company increases. Purchase department handles all the activities related to the purchasing of items for the organization.

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Purchase management is the process that includes various responsibilities, such as buying quality goods in the right quantity, from the appropriate place, at the right time and at the right price.

Objectives of Purchasing

Purchase management is responsible for purchasing raw materials and other items, keeping in mind the following objectives:

- To obtain the required materials, tools and services at a competitive price for production
- To ensure that the supply of material is according to the production requirement at minimum inventory investment
- To guarantee the production of better-quality goods at a competitive price
- To suggest better-alternative materials for production that help in decreasing the cost of production and maintaining the quality of the products
- To encourage standardization, variety reduction, value analysis and cost reduction programmes
- To advise the various departments on feasible prices, timely deliveries and improved performance of items, keeping in mind the design, development and estimated cost of each department
- To maintain the goodwill of the company by fair dealing with the customers and suppliers

Functions of a Purchase Department

The following are the functions performed by the purchase department:

- Provides sources for the supply of capital goods and equipments, raw materials, components, spares
- Studies the market and keeps track of new developments in production materials and processes that are of interest to the company
- Supports engineering and user departments for developing correct and healthy descriptions and standards of materials
- Scrutinizes purchase indents and decides on appropriate method of buying
- Conducts discussions and releases purchase orders
- Helps in pre-delivery transcription and shortage chasing of purchased items
- Coordinates with inward inspection that includes timely return of defective materials back to suppliers

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- Sanctions suppliers' statements for payment
- Processes suppliers' requests for increase in price of production materials
- Attends to suppliers' representatives and travelling salesmen
- Arranges discussions and meetings between suppliers' representatives and the company's officials
- Disposes excess, outdated and leftover materials
- Handles management of new materials and new products in the market
- Researches and studies the possibility of substituting native materials for imported ones
- Acts as a link between the company's finance department and suppliers for timely payments and settlement of suppliers' bills
- Attends to journal activities like applying for import licence, and quota

The purchase department provides all the production goods and materials that are required by the company. The stores department or any functional department can request for goods and materials. Their requests may be received for direct materials, indirect materials, production items, seasonal items, low-price items, etc. As there are ample variations in practices that are followed for the purchase of items, there is a need to select suitable purchasing methods. In the following section, we will discuss various methods of purchasing.

1. Hand to Mouth Purchasing

Hand to mouth purchasing is also known as 'buying according to the requirements'. According to this method, items are often purchased in small quantities. The important characteristics of hand to mouth purchasing are:

- Items are purchased only when there is demand for those items.
- Items are purchased so that the immediate requirements can be met.
- Items are generally purchased in small quantities, but can be purchased in large quantities when required.
- Competitive bids cannot be obtained due to lack of time. Therefore, the terms of contract are negotiated.

Advantages

There are various advantages of hand-to-mouth purchasing, which are:

- Helps in lowering the inventory investment
- Helps in lowering the carrying charges
- Helps in reducing the worsening and obsolescence of materials
- Helps in reducing losses that occur from price declines

Disadvantages

There are many disadvantages of hand-to-mouth purchasing, which are:

- Leads to high cost of materials due to the loss of quantity discounts and urgencies

- Frequent occurrence of losses at different times due to the upward movement in prices
- Interruptions in production schedules at the time of shortage of materials in the market
- Higher accounting costs due to frequent purchases
- Needs to accept the substandard goods in case of emergency

Suitability

This method is effective only when items are purchased from a vendor that is known for quality, reliability and integrity. Such vendors meet the buyer's order without taking advantage of the situation. Therefore, a long list of vendors is generally necessary for buying items. This method is best suited for:

- Sample items and products that are under development
- Items that are used rarely and not required to be stocked. For example, machine tools, special building materials, office furniture
- Items that have a limited shelf life and are not stocked for fear of perishability
- Items that are bulky and need a lot of space for storage

2. Scheduled Purchasing

The process of buying the items that are in the form of distributed deliveries according to the delivery schedule provided by the buyer to the supplier is termed as scheduled purchasing. Following are the prominent characteristics of scheduled purchasing:

- Purchase order that covers annual requirements of the company is placed with the supplier.
- The estimation of the procurement needs is provided to the supplier. Generally, confirmed and tentative schedules, both of 2-3 months, are provided to the supplier.
- Fresh delivery schedules are provided to the supplier before the completion of the previous schedule. These fresh schedules retain the confirmed schedules and the tentative schedules of the next few periods. Also, they specify the confirmed as well as tentative schedule for the next few periods.
- Monthly deliveries are generally specified excluding perishable materials, bulky items and other items that are required in large quantities or where the supplier has set up production facilities especially for the company. In all these cases, monthly schedules are further split into weekly schedules.

Advantages

There are various advantages of scheduled purchasing, which are:

- Regularity in production and smaller inventories results in saving time and money of both the buyer and the seller.
- This method provides security of the supply of goods to the buyer and security of business to the supplier.

- The supplier can easily plan the various factors of production while the company can plan its requirements of finance.

3. Market Purchasing

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The purchasing of sufficient quantity of items in advance when the prices of these items are low is termed as market purchasing. This method of purchasing is also known as forward purchasing.

Characteristics of market purchasing

Following are the significant characteristics of forward purchasing:

- Purchases are made to cover production requirements for a considerable period
- Quantity of items purchased is generally large
- Atmosphere is usually favourable for negotiation
- Purchases are made when the prices are low.
- Buyer also gets discount on large purchases.

Advantages

There are various advantages of the market purchasing, which are:

- Helps in lowering the purchase price
- Greater margin of profit on finished goods
- As purchases are usually consolidated, it leads to saving in procurement expenses
- Provides security against shortage of required items

Disadvantages

There are many disadvantages of market purchasing, which are:

- Buying of items in this manner does not serve the needs of the production department completely.
- The firm may suffer from financial loss if price expectations are not realized.
- Higher inventory holding charges.
- Change in the design of the product can result in large-scale obsolescence of the goods purchased from the market.
- In order to prevent these disadvantages, it is the responsibility of the purchasing department to keep regular track of the market condition. It must frequently study the statistics and factors that influence the availability of an item or its price balances so that it can forecast the changing trends. Purchasing management should balance the high inventory carrying charges and deterioration against price advantage. This method of purchasing is applicable to:
  - Non-perishable items
  - Items that have stable and usual consumption
  - Materials that are less susceptible to radical changes in specifications, for example, basic materials such as coal, steel, and coke

- o Seasonal items such as fruits and vegetables
- o Proprietary items that are required to be purchased in advance of the supplier's agreement period
- o Pre-budget purchases

4. Speculative Purchasing

The process of buying large quantities of an item when its price is low so that tentative profits can be earned by selling them later at a higher price is called speculative purchasing. Following are the main characteristics of speculative purchasing:

- Purchase of items is not related to the company's production programme
- Purchasing decisions in this method are not based on quantity
- Main aim of this method is to earn speculative profits
- Large quantities are purchased depending on the financial situation of the company

Advantages and disadvantages

The main advantage of this method is the probability of earning large speculative profits. There are disadvantages, such as tying up a large amount of capital, storage problem, the risk of obsolescence and downfall of the company, if its predictions go wrong.

Speculative purchasing is not really a function of the purchasing department. It should generally be discouraged.

5. Contract purchasing

The process of buying items based on a special contract, which call for deferred delivery of items over the period of contract is termed as contract purchasing. 'Contract purchasing has been defined as 'the purchase made under contract, usually formal, of needed materials, the delivery of which is frequently spread over a period of time.' Following are the important characteristics of contract purchasing:

- Contracts are provided to suppliers for large amount of future requirements or for a definite period.
- Materials are generally purchased per occasion in small quantities. The interval of time between two consecutive receipts may be a week, fortnight or month or any period considering the value of requirements, distance and the mode of transport.
- There is sufficient time for the purchasing department to secure competitive proposals and to discuss the terms of contract.

Advantages

There are various advantages of contract purchasing, which are:

- This method saves the procurement expenses by protecting the company from the trouble of inviting quotations, preparing comparative statements, placing of orders.

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- This method assures the reliability of the buyer's company to supply the products despite fluctuations in the market.
- It reduces the risk of investment and the cost of carrying inventory to the minimum, as the buyer needs to keep very little working stock and safety stock.
- Provides favourable terms of contract to the involved parties.
- It provides the buyer the flexibility of planning his requirement of finance as he has an advance idea about the amount he has to pay to the vendor.

There are three types of contract purchasing:

- **Rate**: In this contract, the rate is fixed and not the quantity. It also indicates some probable requirements.
- **Running**: In this contract, both rate and quantity are fixed for the contract period. The contract comes to an end as soon as the vendor supplies the specified quantity.
- **Service**: In this contract, services from the supplier are obtained periodically.

Suitability

This type of purchasing is suitable for the procurement of materials and production items that are of regular use. Service contract may be signed to obtain periodical services such as servicing of typewriters, punching clocks, air conditioners, repair or calibration of measuring instruments and gauges, filtering of oils.

6. Blanket Order Purchasing

The process of buying a variety of items from a single source is termed as blanket order purchasing. Following are the important characteristics of blanket order purchasing:

- It determines the item categories specified by the order.
- It generally covers low unit value items.
- Hold-ups in case of non-availability of an item are avoided by selecting more than one middleman.
- Market price is generally specified in the order, which may include a specified method of determining price variations.
- The buyer can contact the seller on phone to get the necessary information. For example, the buyer can inquire about price from many sellers and buy from the one who quotes the lowest.

Responsibility of the purchase department

The responsibility of the purchase department with regard to blanket order purchasing is:

- A large stockist is known for sincerity and consistency is selected as the middleman. Generally, the stockist in the vicinity of the factory should be given preference over others.

- The purchasing department should check up whether the demand for an item has risen considerably so that it can be removed from the group and is purchased as an individual item.

7. Tender Purchasing

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Tender purchasing is generally followed by government departments and public sector undertakings in India. This method is applied by the private sector organizations if the value of the purchase exceeds the prescribed limit fixed by the management as policy decision. Following are the important characteristics of tender purchasing:

- The purchasing department, to invite suppliers to submit their bids, creates a bidders' list. A bid can be a tender or quotation, which is a written offer from a supplier to render a specified service or supply materials of the specified quality at the specified price and within the specified item.
- Bids obtained from different suppliers are compared to select the right supplier. Generally, the lowest-price criterion is used to compare different bids, except when the supplier quoting the lowest price has questionable delivery time, quality, reliability or financial stability.

Advantages

The advantages of tender purchasing are:

- Using this method of buying, we can select the qualified supplier on the basis of competitive prices.
- This method eliminates the possibility of discrimination and personal preferences.

Disadvantage

The disadvantage of tender purchasing is that it is expensive and time-consuming.

Responsibility of the purchase department

- A buyer should obtain quotations from at least three potential suppliers for every new product, material or service.
- Contract of a new item is decided by taking the past performance of old suppliers in account.
- The capabilities of the competing firm must be considered for evaluating the quotations. The proposal should be high enough to yield a reasonable margin of profit to the potential vendor.

The four types of tender are:

- **Single:** The tender system in which the details of the requirements are communicated only to a single firm is known as the single tender. In this type of tender, there is no competition and the price is fixed. This type of tender is generally used when there is a single supplier for an item.
- **Limited or closed:** The tender system in which enquiry is sent to a limited number of suppliers who are on the approved list of suppliers, and bids are

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received in response to the suppliers is known as closed tender. Management makes the buying policies to decide the number of suppliers to whom enquiry is being sent. Generally, in case of private sector firms, enquiry is sent to three to eight suppliers, depending upon the rupee value of the order. On the other hand, public sector undertakings restrict the number of tenders to eight.

- **Open**: The tender system in which the required enquiry is advertised in the newspapers or journals of the home country and bids are received in response is termed as open tender. This tender system is also known as advertised tender or unlimited tender. This system of tendering is generally used for those items that are required in large value and are difficult to obtain.
- **Global**: The tender system in which the enquiry is advertised in the newspapers and trade journals of not only the home country but also of the foreign country and bids are received in response is termed as global tender. This system of tendering is used for purchase, which involves huge investments such as procurement of plant and machinery.

8. Seasonal Purchasing

The process of buying an item as per its annual requirements during its season is termed as seasonal buying. This method of buying is used for items that are available in a particular season only. These items are required for food processing and other similar industries. Following are the important characteristics of seasonal purchasing:

- As the items can be purchased in a particular season only, they must be purchased and stocked in sufficient quantity till the next season, for example, mangoes, sugarcane, apples.
- Items that are purchased are of small size but they are required in large quantity.
- These items are purchased at the cheapest rates because the market price is lowest during the season.
- These items are generally purchased directly from the producers of the goods.

Responsibility of the purchase department

It is the responsibility of the purchase department to achieve the maximum advantage by locating the producers of these items and discussing the price and other terms mentioned in the contract.

Suitability

Seasonal method of purchasing is applicable for the items that are either purely seasonal or items that have decreased market price during off-season.

9. Group purchasing

The process of buying items of insignificant value in a single purchase order is termed as group purchasing. Following are the important characteristics of group purchasing:

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- In this method of buying, items that are required in small quantities are divided into some basic groups according to the source of purchase:for example, drills and taps are placed in one group, plug gauges in another group, hardware in a third group, and so on.
- Items of every classified group have fixed inventory levels.
- For every group, there is a purchase order that covers various items that are present within the group.
- Stocks-on-hand are reviewed at regular intervals, say once a month or once in two months.
- If the stocks of some items have degraded to the reorder level, then replenishment action is taken for these items.

Advantages

This method helps in saving accounting and delivery cost because only one order is placed for multiple small items.

10. Subcontract Purchasing

The process of employing another firm to perform some of the manufacturing operations or to provide certain parts and sub-assemblies that are required to be incorporated into the buyer's end product is termed as subcontract purchasing. These are of three types:

- When a company receives a big order, it may be possible that it produces some quantity of the final product and buys the remaining from other vendors. A company buys from other vendors because it may not be possible for it to complete the order within the defined time of contract.
- In some cases, the company ponders on certain items of the assembly and buys other items from others.
- In some cases, when a company does not have the required manufacturing facilities, it gets certain operations done by other firms.

Suitability

Subcontracting is desirable when:

- Different types of machines are required for production
- Certain operations are required to be performed by a special expertise
- Lack of facility at the home plant that cannot be removed instantly
- Procurement of particular manufacturing facilities is economically non-viable

Responsibilities of the purchasing department

The responsibilities of the purchasing department with respect to subcontract purchasing are:

- It is the responsibility of the purchasing department to establish and choose subcontractors that can supply parts of good quality, in the right quantities, in the required time schedule and at the right price.

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- The subcontractors should be within close propinquity to the firm. This closeness provides many advantages such as less transportation cost, easy and cheap follow-up and better control on the supplier's quality.
- For every required component, the purchasing department should select more than one subcontractor.
- The buyer should keep a detailed quality assurance system with the subcontractor that is in conformity with the complete manufacturing process and inspection criteria.
- This department should ensure that its own quality control staff have fully understood the production specifications and inspection standards related to the component that is subcontracted.
- Subcontractors should be selected after thorough discussion with them regarding the capacity requirement of the buyer and the capacity available with the subcontractors.
- The purchasing department should make the subcontracting decisions on the basis of cost–benefit analysis.

A central purchase organization

A central purchase organization is a large firm in the public or private sector that may have section-wise stores at different places. Examples of such organizations are State Road Transport Corporations (MSRTC, GSRTC), nationalized banks, and cooperative banks.

Following are the two methods that can satisfy the requirements of the central purchase organization:

- Every store should make its own purchase
- Central stores should make purchases and in turn, supply material to the section-wise stores

Advantages

There are many advantages of the central purchase organization, which are:

- Helps in obtaining quantity discounts, lower rate and better contract terms due to the large purchases made in the organization
- Helps in reducing the risk of mismanagement by implementing strict control on consumption
- Suitable to obtain the required items according to the specifications by directly contracting with the manufacturers
- Avoids purchase at higher price

The central purchasing organization that enters into contract with various firms for the supply of certain materials to the government departments during a year at a settled rate is known as the Directorate General of Supplies and Disposal.

4.4.2 Purchasing Procedure

Purchasing procedure comprises of several steps. The following section describes the major steps that constitute the purchasing procedure:

1. **Indenting a purchase requirement:** The first step in the purchasing procedure is to indent the purchase requirements that are issued by the purchase department. This purchase indent can be received from the supplier for the stock items or the production control department for non-stock items or the maintenance department for machinery spares or from the head of department for special items such as filing cabinets, almirahs, other furniture. Generally, three copies of the purchase indent are issued. The original copy is issued to the purchase department and the other two copies are issued to the stores and originating departments.
2. **Inspecting purchase indents:** The second step is to inspect the purchase indents. Every purchase indent received in the purchase department is inspected to see whether:
   - The indent contains the sign of the authorized signatories so that irresponsible purchase can be avoided.
   - The indent is circulated through the stores department informing that the stock is not available in the store.
   - The indent contains clear and correct description of the required items.
   - The indent contains correct and clear description of the last supply of the stated items.
   - The indent contains clear information about the quantity of every item.
   - After checking the security of the purchase indent, it is logged into the purchase indent register and then given to the concerned buyer. The second copy is initiated, dated and given to the indenter.
3. **Market study and selection of sources of supply:** The third step is to survey the market for the selection of sources of supply. This stage involves separating items into groups, checking the available information from the source register and the previously received catalogues and quotations. Also in this step, we select a source that can supply goods of the right quality at the right price and are able to meet the quantity requirements of buyers. The supplier is selected on the basis of the buyer's previous experience with the supplier, catalogues, price lists and quotations submitted by him in the past. The following section describes the process involved in the market research and source selection:
   - Telephonic quotations are obtained from the seller and a verbal order is specified to the supplier for the items to be purchased. An official purchase order is sent later to confirm the transaction.
   - Delivery schedules are released to the suppliers as call-offs against the contract orders raised earlier for the items of regular use. Also enquiry is sent to probable sources, and quotations are received from the suppliers. A relative statement is prepared from the quotations received from the suppliers that are followed by provisional selection of one or two sources.
   - Vendors are called for discussions and exact terms of contract are finalized with one or two vendors.

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- Enquiry is sent to the manufacturer or dealer about the replacement and insurance of spares. After receiving the quotation from the dealer or manufacturer, a purchase order is raised to authorize him to supply the spares.
- Enquiries are either mailed to the machine tool manufacturer or advertised for procurement of capital equipment. Potential sources are selected on the basis of the quotations received in response to the tender. Detailed negotiations are held and finally sources are selected.
- The buyer may choose for petty cash purchase if the amount involved is less and the item is easily available.
- The purchasing department may have to disclose information on the desired sources, float enquiries, prepare a comparative statement and select suppliers for new items.
- The purchasing department may have to establish, choose and expand suppliers for new items.

4. **Order preparation:** The fourth step is the order preparation. It means approval of the selected supplier for supplying materials by placing a purchase order. A purchase order is the legal official document that is used to approve the supply of goods in the required quantities and the services at the time and price specified in the document.

5. **Follow-up with suppliers:** The fifth step is follow-up with the suppliers. Purchase follow-up is the function of observing that the suppliers are sending the deliveries on time. Purchase follow-up is required in two stages, pre-delivery follow-up and shortage chasing.

   Pre-delivery follow-up

   Pre-delivery follow-up is intended to remind the suppliers about the due date. Also they are used to make alternate arrangements if the supplier does not fulfil the delivery commitment.

   Shortage chasing

   It is the universally accepted and most vital part of purchase follow-up. The main functions that are performed by this follow-up are:

   - It orders the materials that are in shortage as soon as possible.
   - It also generates a feeling at the supplier's works that it is easy to have an effective delivery on time by doing shortage chasing.
   - The short chasing follow-up starts when the due date is over. The criticality of items, availability of alternative sources, quantity in hand and coverage for future period are used to determine the nature of follow-up and the level at which follow-up is done.

6. **Receiving materials:** After the goods are received, they are first sent to the receiving stores. These goods are then unpacked from the packets to verify the contents according to the details provided in the purchase order. The Goods Receipt Report (GRR) register is used to store the entries of all the incoming supplies from the suppliers at the receipt store. For every consignment, a goods receipt report or goods inward note is raised. Another

note known as discrepancy note is notified to the vendor in case of any inconsistency.

7. **Inspection of goods:** All the items that are purchased from the buyers are subjected to inspection and testing. Some items that are required to be purchased are inspected at the vendor's plant prior to affecting the deliveries by the vendor. These are generally the items that require use of specific and complicated measuring instruments whose cost is not justified in lieu of limited purchase. Other items excluding the above-mentioned ones are inspected by the inward inspection at the buyer's plant for one or more of the following checks:
   - **Conformity to dimensions**: Component drawings are generally checked for conformity to dimensions. The component is subjected to both visual as well as dimensional checks using gauges and measuring instruments.
   - **Conformity to material specifications**: Material specification of any component is checked with the help of chemical and metallurgical tests. Various tests are performed for checking hardness, material composition, microstructure and other properties by sending the sample pieces of components to laboratories.
   - **Conformity to performance**: Performance of items is decided on the basis of tests and trial runs: for example, machinability test for raw materials, life test for bearings, r. p.m. test for motors.
8. **Storage and record keeping:** Next step that comes after the inspection and testing is to separate the goods into accepted/rejected or rework categories. The fully accepted quantity is forwarded to the main store. These quantities are checked and entered into the ledger or bin cards.
9. **Invoicing and payment:** The supplier immediately prepares the invoices after supplying the goods. However, sometimes both the buyer and the supplier have discussions and after the receipt of the goods receipt report, the buyer agrees to raise the invoice. This system has a number of benefits such as:
   - After the receipt of GRRs, invoices are raised. This helps in avoiding the delay of materials because the buyer links up necessary papers with invoices.
   - Helps in avoiding the need to raise credit or debit notes for discrepancies in quantities or rejection
   - Helps in avoiding disputes in quantities to be supplied and rejection etc, as the paperwork is clear, faster and payment-wise
   - Settlement statements are very easy to be prepared
10. **Scrutiny of invoices:** Invoices of suppliers are sorted out according to the suppliers and temporarily filed until the GRRs are received. The accounts department performs this process of sorting. After receiving the GRRs from the receiving store, these are entered into the control register, which is maintained by the accounts department. The same procedure is followed for the linked invoices.

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Check Your Progress

9. What does purchasing activities involve?
10. State the five basic characteristics of purchasing in the materials context.
11. Define purchasing.
12. What is purchase management?
13. What is speculative purchasing?
14. Name the four types of tender.
15. What is the first step in the purchasing procedure?
16. State any two benefits of invoicing and payment.

4.5 STORE MANAGEMENT

Store keeping is the process of storing raw materials or goods under the supervision of a person called storekeeper or store controller. The raw materials are called stores and the finished goods are called stocks. The place where these materials are stored is called a storeroom.

Additionally, stores management includes various responsibilities such as receiving the raw materials, protecting the materials from damage and spoilage and keep the finished goods until the goods are dispatched. Stores management also includes distribution of materials in the right quantity, at the right time and at the right place. It also ensures that the services are provided by stores management at a low cost. It also manages the different types of stores such as warehouse and scrap yard.

Functions of Stores Management

Raw materials as well as finished goods are one of the most essential parts of any production process. So, the raw materials should be available all the time and should be of the best quality in order to produce a good quality product.

The following functions ensure that goods in the stores are properly organized:

- Requesting the purchasing department for adequate quantity of materials so that deliveries can be made in the appropriate time
- Controlling on quantity of materials received from excess use
- Protecting the materials from conditions such as bad weather, damage and stealing
- Issuing materials only to authorized people or requisitions
- Maintaining proper records of receipts, issues and balances
- Maintaining the exact records of expenditures and dispatches
- Maintaining proper records of stores so that they can be provided at right time
- Keeping record of inventory investment

Types of Stores

The requirement of stores depends on the nature of the industry and the work performed in that industry. The various types of stores available are:

- Receiving
- Main
- Warehouse
- Special

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1. Receiving Store

A receiving store performs activities that control the quality and quantity of purchased materials before the materials are accepted for production. This type of store is also called the goods inward store. The receiving store is further divided into the following types:

- **Inward:** It is used to store the incoming materials until they are accepted and taken into stock.
- **Quarantine:** It is used to store the stock materials temporarily that are under dispute or need certification from the supplier.
- **Rejection:** This is used to store materials that are defective and rejected by a company until the materials are sent back to the respective suppliers.

2. Main Store

A main store performs activities that are concerned with storage and issuance of accepted materials. The main store also deals with the maintenance of records of materials. The main store can be maintained either in the company as a godown or can be located near the company from where goods can be easily transferred. The main store is further divided into the following types:

- **Crib:** It is used to store stocks, such as cutting and hand tools, gauges, etc., that are to be issued to the workmen at the beginning of their shift and to be received at the end of their shift.
- **Finished part:** This store is used to store stock components and parts that are produced in economic sizes in the plant itself.
- **Plant store:** It is used to store spare parts of tools and machineries that are used in a plant for production.
- **Sub:** This is used to store bar stocks, casting and forgings that require a lot of space and need to be stored in open spaces. This type of store is also called the raw material store.

3. Warehouse

A warehouse performs activities that are concerned with receipt, packing and dispatch of the finished goods to various destinations. A warehouse also involves handling of papers and documents related to goods. This type of store is also called the finished product store.

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4. Special Store

A special store performs activities that are related to receipt, storage and issuance of special materials such as bank papers, petroleum products, etc. The special store is further divided into the following types:

- **Bonded:** This type of store is used to store materials that are related to banks and stocks that are excisable.
- **Statutory:** It is used to store petroleum products such as kerosene and diesel that require safety precautions.
- **Temperature-controlled:** This store is used to store materials such as meat, fish and vegetables or goods such as rubber or ingredients such as vitamins and calcium that require temperature-controlled storerooms.

Check Your Progress

17. Define store keeping.
18. List the various types of stores available.
19. Define warehouse.

4.6 INVENTORY CONTROL AND CLASSIFICATION OF INVENTORY

To begin a study of the inventories, it is first necessary to classify or group them on the basis of some parameters. Several methods of classification are practiced in the industry.

Depending on the nature of materials, they can be classified into four broad groups which are:

- Production inventory
- MRO inventory
- In-process inventory
- Finished goods inventory

1. **Production inventory:** This includes raw materials, parts and components that are directly used in the production process and go into making the final product. They may either consist of standard items sourced 'off the shelf' or special tailor made items. All raw materials obtained from mother earth fall in this category. Some organizations such as the FMCG and engineering goods, buy their components/sub-assemblies from other vendors. They concentrate more on producing and assembling the critical parts only. Many of the companies are going towards this route these days, including Volkswagen, Dell Computers and General Motors.
2. **MRO inventory:** This stands for maintenance, repair and operating supplies. These items are required in the production process although they do not go into making the final product. They include:

- Consumables which are usually available off the shelf and are used by more than one usage departments. Their inventory levels are fixed based on past consumption. They include lubricating oils, safety items, electrical items such as lights, and fans.
- Spare parts which are the parts of machines used in the production process. Their requirement is determined by the nature of the spare and may often lead to a huge loss to the organization if not present.
- Packing material is used to give a face lift to the product, to protect it during transportation and storage. In the pharmaceutical industry, packing cost is substantial and is considered a part of raw materials. In some cases, packing materials are a part of consumables, e.g., industries where the finished product is in a liquid form such as juices, and syrups.

3. **In-process inventory:** In-process inventory is also called work in process (WIP) inventory. It comprises of the semi-finished products formed at various stages of the production process. Typically, the output of one stage in an assembly line is the input for the next stage.
4. **Finished goods inventory:** This comprises all the final products made by the company, ready for shipment and sale.

In most of the companies, the production and MRO inventories represent the biggest segment of the total inventory investment.

Inventory Catalogue

Before beginning any kind of classification of inventories, it is necessary to have a list of all the items in the inventory. This list should ideally contain:

- An identifiable individual number or a code for each item; various methods of codification are in use in the industry, take numeric, and alpha numeric.
- Description of the item, should include the dimensions, weight, identity of the mother equipment, drawing numbers, and part number.
- Annual consumption of at least the last three years
- Names of suppliers who have supplied the item in the last three years
- Average life of the item
- Stock of the item

Such a list of items in the inventory is called the *inventory catalogue*. It helps to identify the items in the inventory and helps in standardization and variety reduction. Cataloguing is mandatory for computerization of the inventory records. By logging in the catalogue number, the history of an item can be known. The catalogue number serves the same purpose as a PAN number or a passport number.

Classification of Inventory

Irrespective of the nature and size of the industry, there are items varying from the smallest to the largest in terms of value, size, complexity and criticality. It is not possible and also feasible to exercise strict management control over all these items. It will only be too much effort with too little benefit. Hence, the principle of

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management by exception is applied here. The items are classified based on a certain criteria to facilitate selective control. Such control minimizes waste of efforts as well as confusions.

The various ways in which inventory can be classified are:

1. **ABC analysis:** This is the most commonly used method of classification. It is based on the annual consumption value of the items and goes by the principle of 'vital few, trivial many.' This means that a small number of items account for a major portion of the total expenditure, and there are several items which together are many in number but account for a small portion of the annual expenditure.

   The actual percentages vary from one firm to another, but it can be taken as a general rule that ten per cent of the items account for seventy per cent of the cost. They are called the class A items and require maximum attention. Similarly, around seventy per cent of the items account for only ten per cent of the cost. They are called the class C items and should not be given too much attention. The remaining items are called class B items.

   The ABC analysis is also called the Pareto analysis, developed by the Italian economist Vilfredo Pareto. It can be represented as:

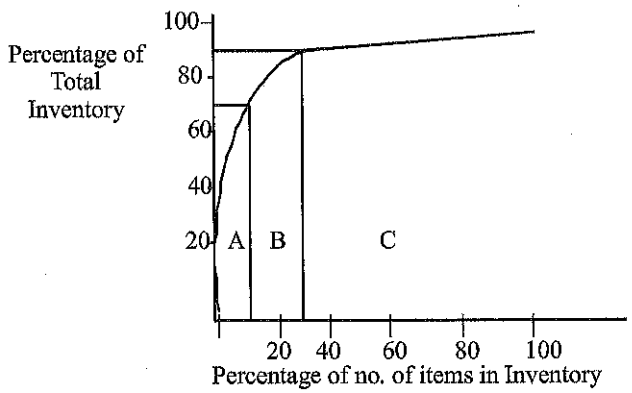

Fig. 4.6 ABC Analysis

This analysis is usually carried out annually. Once the items in the inventory have been identified, their usage record for the year is built. Then the items are sorted and ranked in the decreasing order of their consumption value. The value of each item is next expressed as a percentage of the total. By going down the list and successively cumulating the individual percentages for each item, one can determine which items make up the first seventy per cent of inventory investment, the next twenty per cent and the balance ten per cent. The groups are called A, B and C respectively and the items within the group are called item A, B or C. Separate policies are usually adopted for class A items and class C items. Class C items need to be monitored on a daily basis, decision is taken on class C items based on the objectives of minimizing acquisition cost, maximizing service and reliability, minimizing inventory investment, minimizing indirect costs associated with inventory and utilizing personnel and their time effectively.

2. **XYZ analysis:** This classification is based on the stock value of the items. Items having a very high stock value are classified as 'X'. Items with least stock value are classified as 'Z'. The method of arriving at the classification is the same as for ABC classification described above. Only, instead of taking the annual consumption value into account, the annual stock value for each item should be taken into account. The rest of the procedure remains the same.
3. **VED analysis:** This classification is based on the relative importance of the item in the production process. Certain unavailable holdup production and result in high costs of shut down. These items may or may not be priced high but their stock-out costs are very high. These items are called *vital items*. The 'E' stands for 'essential.' Although these items are not very critical to production their stock-outs are expensive. The 'D' stands for 'desirable.' It is better to avoid stock-outs for these items although a stock out for a short period will not affect production.
4. **FSN analysis:** Items can also be classified as fast moving, slow moving or non-moving based on their pattern of issue from the stores. This denotes how soon a material is consumed after it has been purchased and taken into stock. This classification helps in controlling obsolescence.

   Items which are very fast moving and are used once every week or, every month are classified as 'F.' Items which are not consumed even once in say two or three years are classified as non-moving or 'N.' Keeping non-moving items in the inventory is dangerous. These block useful working capital and eat into the profitability of the company. The company should declare them as surplus or obsolete and find alternate uses of the material or else dispose them off, so that it leads to money realization as well as space saving. All items which are neither 'fast' nor 'non-moving' are termed as 'slow moving' items. This classification is again of great importance to companies who need to keep a check on where their money is spent.
5. **PQR classification:** Besides value and criticality of the items, another commonly used method to classify items is based on the shelf life of the item. Shelf life is defined as the useful life of an item that is the time period within which the item can display the complete characteristics, for which it is meant. Items having a low shelf life and thus requiring frequent attention are classified as 'P.' Items having the longest shelf life and thus requiring the least attention are classified as 'R.' All the other items which are not 'P' or 'R' fall within 'Q.' The time period in which to define 'P,' 'Q' and 'R' varies from industry to industry. This classification is more relevant in industries producing perishable goods such as confectionaries, etc.
6. **SDE classification:** This classification is based on the ease of obtaining an item. 'S' stands for scarce. Such items are not easily available in the market and might require source development or else it might be an item which is difficult to manufacture or there are only one or two known manufacturers who have to be given orders several months in advance and so on. All these

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require special efforts for procurement. 'D' stands for difficult to obtain and 'E' for easy to obtain. An organization need to concertedly focus on items that are both A as well as S.

7. **GOLF classification:** This classification is based on the nature of the source for an item. 'G' stands for government, 'O' for open market, 'L' for local and 'F' for foreign sources of supply. Items which are channeled through the State Trading Corporations, Minerals and Metals Trading Corporation, come under the 'G' category. They require special procedures for procurement and as such common procedures for inventory management may not be fully applicable to them. The transactions require more paperwork and lead times are longer. For 'O' items, there are a number of suppliers. Quality and availability is good. Most big organizations depend on the local market only for emergency supplies and low value procurement. For 'F' the source of supply is abroad, this involves considerable paperwork and lead time is high.
8. **SOS classification:** This classification is based on the nature of the time of availability for an item. 'S' stands for seasonal and 'OS' for off-seasonal. This is more relevant in case of items which are derived from nature, such as jute, cotton, etc., which are available more during their harvest time and less available during the monsoons when it rains. They require separate purchasing and stocking strategies. The inventory management system will have to balance out between the stocking cost and lower prices at which it will be available. 'OS' items are ordinary items which are not seasonal and can be subject to any other classification for selective control.
9. **HML classification:** This classification is based on the unit price of material. 'H' stands for high, i.e., high price per unit of the item, 'M' stands for medium and 'L' for low unit price of the item. This classification is particularly relevant when it comes to deciding the procedure to be followed for procurement.

Inventory control includes tasks and activities that help maintain the inventory levels of the organization. The most important decisions involved with inventory control are as follows:

- How much of an item is to be ordered during inventory replenishment?
- When to replenish the inventory of that item?

4.6.1 Objectives and Benefits of Inventory Control

Inventory control is used to maintain the safety stock of raw materials that can be used during the delay in the delivery of raw materials. Other objectives of inventory control are as follows:

- **Minimizing blocked capital in inventories:** Inventory control in the organization aims at reducing the capital, blocked in the inventories, which help increase liquidity. This is because the capital required to carry out inventories costs decreases liquidity.
- **Reducing surplus stock:** Reduction of surplus stock is one of the essential requirements of effective inventory control. Inventory control helps analyse

the causes of excessive stocking and also helps take appropriate measures for reducing the excessive stocks to an optimum level.

- **Ensuring proper control over inventory:** To achieve this objective, the material should be properly checked before being stocked and when used in production. The following are the tasks involved in inventory control:
    - o Maintaining timely records of inventories
    - o Maintaining stocks within the desired limits
    - o Providing a scientific base for short-term and long-term planning of inventory requirements
    - o Providing timely action for replenishment
    - o Safeguarding the stock of inventories from pilferage, theft, waste, loss, damage and unauthorized usage
    - o Standardizing and centralizing information on stock levels and progress of stock issues
    - o Meeting demand fluctuations

Benefits of Inventory Control

Inventory control helps utilize the available capital efficiently and thereby avoiding unnecessary expenditure on huge inventories in theorganization. In addition, various benefits of inventory control are:

- Provide adequate supply of materials to consumers and thereby avoiding shortages
- Minimize the risk of loss caused due to the change in prices of items stocked at the time of making the stock
- Ensure regular supplies of stocked items to industries, thereby resulting in smooth and efficient running of the organization
- Acquire quantity discounts on bulk purchases
- Provide buffer stock in case of delayed deliveries by the suppliers
- Minimize the loss caused due to deterioration, obsolescence, damage or pilferage
- Maintain economy by absorbing some of the fluctuations when the demand for an item fluctuates or is seasonal
- Control the accumulation and build-up of surplus stock
- Utilize the benefits of price fluctuations

4.6.2 Components of Inventory Control

Inventory control has various components such as cost and demand, which are essential in the organization for inventory controlling. The various components of inventory control are as follows:

(i) **Inventory Costs:** Inventory control costs aims at the minimization of various costs related to inventory. The various types of costs are as follows:

(a) Production costs refer to the cost of producing or purchasing one unit of item.

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(b) Ordering costs is also called acquisition cost or set-up cost. It refers to the cost incurred in transferring purchased items into the organization's warehouse. These costs are also incurred when the order for each item is placed with the supplier.

(c) Holding costs are also termed as inventory carrying costs. It refers to the cost incurred on keeping and maintaining a stock of items in storage. It also includes different costs, which are:

- Opportunity cost refers to the investment made in inventory.
- Storage space cost refers to the cost incurred on rent, lighting, heating and refrigeration.
- Handling cost refers to the cost incurred on the movement of cost of labour, overhead cranes and other machinery.
- Storage operations refer to the cost incurred on the record keeping and protection of inventory.

(d) Shortage cost is also called stock out cost. It refers to the penalty costs incurred due to the delay in meeting the demand or inability to meet the demand due to the shortage of stock. In order to avoid this cost, the stocks are kept in advance. These costs include the following disadvantages:

- Loss of sales due to change in consumer preferences
- Loss of consumer goodwill
- Extra cost associated with urgent replenishment purchases

(ii) Demand refers to the total number of items required over a specified period of time. The demand can be deterministic or probabilistic. The demand is deterministic when the items demanded in future are known in advance. The known demand can be either fixed or variable, which is called static or dynamic, respectively. However, the demand is probabilistic if the requirements for items over a period of time is not known but can be calculated through probability distribution.

(iii) Order cycle refers to the time period between two continuous orders. The order is placed on the basis of the inventory review system.

4.6.3 Different Systems of Inventory Control

The different systems of inventory control are discussed below:

1. Perpetual System

Under this system, inventory levels are checked continuously until the reorder point is reached. This system is also called as the reorder-point system or two-bin system. According to the two-bin system, the inventory is divided into two bins. The first bin is used to draw items and when it becomes empty, a new order is placed. Demand is then satisfied from the second bin until the new order is executed.

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2. Periodic Review System

Under this system inventory, levels are checked at fixed intervals and orders are placed at such intervals. The available inventory level at the time of review determines the quantity to be ordered. In contrast to the previous system, here the time after which the supplies are ordered is fixed but the quantity to be ordered can vary.

- Lead time refers to the time gap between the placing of an order and actually receiving it. Lead time can be constant, variable, deterministic or probabilistic. It can be zero when there is an instant delivery of products. If lead time is not zero and demand is known then order must be placed in advance.
- Stock replenishment refers to the addition of items to existing inventory level. It may occur instantaneously or at a uniform rate. Instant replenishment occurs when the items are purchased from outside sources whereas uniform replenishment occurs when items produced within the organization are added to the existing inventory level.
- Time horizon refers to the time period over which inventory levels are controlled. The nature of demand determines whether they will be finite or infinite.
- Number of items refers to various items such as different raw materials. These items compete with each other for the limited floor space. In order to provide solution to the above situation, inventory models are developed.
- Maximum stock refers to the stock level that indicates which stocks have risen very high.
- Minimum stock refers to the buffer or additional stocks maintained in order to avoid delay in the delivery of products or for any unexpected demand that may arise during lead time.
- Reorder level refers to the level between maximum and minimum stocks at which manufacturing activities must start for replenishment.
- Reorder quantity refers to the quantity of the replacement order. In some types of inventory control system, it is called economic order quantity.

4.6.4 Types of Inventory

The term inventory means any stock of direct or indirect material (raw materials or finished items or both) stocked in order to meet the expected and unexpected demand in the future. A basic purpose of inventory management is to control inventory by managing the flows of materials. It sets policies and controls to monitor levels of inventory and determine what levels should be maintained, when stock should be replenished, and how large orders should be.

Inventory is a stock of materials used to satisfy customer demand or support production of goods or services. The study of inventories is necessary because it is an organizational asset; it needs to be acquired, allocated and controlled. All organizations have an inventory and it can be a sizable asset. Inventories influence sales and revenue generation. They impact customer relations and influence production and operations costs. Large amounts of inventory reduce ROI as

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inventory constitutes a cost and is frequently the largest single expenditure of the firm. Excesses of inventories can result in bankruptcy.

By convention, inventory generally refers to items that contribute to or become part of an enterprise's output. The most commonly identified types of inventory are:

1. **Raw materials inventory**: Parts and raw materials obtained from suppliers that are used in the production process. Examples of this type of inventory are steel sections and sheet metal used in fabrication shops, and raw materials such as rayon, acetate, cotton gin and dyes used in the textile industry.
2. **Work-in-process (WIP) inventory**:This constitutes partly finished parts, components, sub-assemblies or modules that have been started into the production process but not yet finished. For example in a fabrication shop these may be cut steel sections or pressed parts, and in a textile unit these may be plied yarn or raw woven fabric.
3. **Finished goods inventory**: Finished product or end-items: These are the products that are ready for delivery to the customer. Examples of finished goods are the common items you find in your retail store like packaged soaps, tea, shirts, pants.
4. **Replacement parts inventory**: This constitutes maintenance parts meant to replace other parts in machinery or equipment, either the company's own or its customers'.
5. **Supplies inventory**: Parts or materials used to support the production process, but not usually a component of the product: These could be stationery used by the company and lubricants and coolants used to run the machines.
6. **Transportation (pipeline) inventory**: Items that are in the distribution system but are in the process of being shipped from suppliers or to customers.

Though the description above focuses on manufacturing inventory, wholesalers and retailers have corresponding inventory types.

These exhibit different risks depending upon a firm's position in the distribution channel. If an individual enterprise plans to operate at more than one level of the distri-bution channel, it must be prepared to assume additional inventory risk:

Manufacturing: Manufacturing inventory is typically classified into raw materials, finished products, component parts, supplies and work-in-process. Independence of workstations is desirable in intermittent processes and on assembly lines as well. As the time that it takes to do identical operations varies from one unit to the next, inventory allows management to reduce the number of setups. This results in better performance.

In case of seasonal items, any fluctuation in demand can be met, if possible, by either changing the rate of production or with inventories. If the fluctuation in demand is met by changing the rate of production, one has to take into account the different costs. The cost of increasing production and employment level involves

employment and training; additional staff and service activities; added shifts; and overtime costs. On the other hand, the cost of decreasing production and employment level involves unemployment compensation costs; other employee costs; staff, clerical and services activities; and idle time costs. By maintaining inventories the average output can be made fairly stable. The use of seasonal inventories can often give a better balance of these costs.

In addition, the firm also has to have in-services inventory. This generally refers to finished goods, tangible goods that must often be transferred to warehouses in close proximity to wholesalers and retailers to be sold, and the supplies necessary to administer the service.

For a manufacturer, inventory risk has a long-term dimension. Although retailers or wholesalers have a wider product line than a manufacturer, the manufacturer's inventory commitment is relatively deep and of long duration.

Wholesale: The wholesaler purchases large quantities from manufacturers and sells small quantities to retailers. He provides the capability to provide retail customers with assorted merchandise from different manufacturers in smaller quantities. Expansion of product lines has increased the width and inventory risk. Where products are seasonal, the wholesaler has to take an inventory position far in advance of selling.

Wholesaler risk exposure is narrower but deeper and of longer duration than that of retailers.

Retail: For a retailer, inventory management is fundamentally a matter of buying and selling. The retailer purchases a wide variety of products and markets them. The prime emphasis in retailing is on inventory turnover and direct product profitability. Turnover measures inventory velocity and is calculated as the ratio of annual sales divided by average inventory.

Although retailers take risks on a variety of products, the position on any single product is not deep. This does not mean that their risk is lesser; due to the variety of merchandise the risk is wider. A typical supermarket, for example, carries more than 10,000 SKUs. The variety of merchandise reflects the risk of the retailer.

4.6.5 Inventory Control Techniques

An inventory is made up of a large number of items in varying quantities. Good management of an inventory means that it is to be maintained at optimum levels to synchronize with the demand and supply requirements. The various methods by which inventory can be reduced are:

- Reducing the number of items
- Reducing the quantities of the items
- Reducing the lead time of procurement

1. Item Reducing Techniques

Several techniques help in reducing the number of items in the inventory. The most important amongst them are:

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- Preferred number series
- Value Analysis/Value Engineering
- Standardization
- Codification
- Analysis of frequency distribution of demand/ use

The following section contains detailed discussions of these techniques.

(i) **Preferred number series:** If the pattern of consumption of items is analyzed, it found that the demand is often concentrated around a few types or sizes. In such cases, a series of standard sizes in suitable steps would be required. These are generally determined by preferred numbers which are numbers derived from five series in geometric progression.

Preferred numbers owe their origin to Charles Renard, a French balloonist and the five series he formulated are known as R-5, R-10, R-20, R-40 and R-80. The basic series for R-5 provides a geometric increment of approximately sixty percent between steps to reach from any size to the next standard size. When mathematically derived, the steps for a five step increase would be 1, 1.58, 2.51, 3.98, 6.31 and 10. This has been simplified to 1, 1.6, 2.5, 4.6 and 10. (This is stated in IS 1970-1957). That is why one finds electric bulbs of wattages of 10, 15, 25, 40, 60 and 100, which are the standard wattages. All these are commonly available in the market. To obtain finer incremental steps other sister series could be adopted, like R-10, with increment of 26 per cent between steps, like R-10 with increment of twenty-six per cent between steps, R-20 with increment of twelve per cent between steps, R-40 with increment of 6 per cent between steps and so on.

(ii) **Value analysis/Value engineering:** The concept of value engineering that was discussed in the context of new product development can be applied for reducing the number of items in inventory as well. The principles and methodology are the same and the methods are very effective.

(iii) **Standardization:** The dictionary meaning of standardization states that it is an activity that gives solutions for repetitive applications, to problems essentially in the spheres of science, technology and economics, aimed at the achievement of the optimum degree of order in a given context. Generally, the activity consists of the process of formulating, issuing and implementing standards.

As per the International Standards Organization (ISO), 'Standardization is the process of formulating and applying rules for an orderly approach to a specific activity for the benefit and with the cooperation of all concerned and in particular for the promotion of optimum overall economy taking due account of functional conditions and safety requirements.'

Standardization is a tool to promote the use of minimum number of parts to serve the maximum number of purposes, in order to achieve economy in manufacture, minimize whole life costs and maintain the quality and reliability necessary to ensure operational effectiveness and efficiency. Standardization is achieved through the process of variety reduction, i.e., reducing the numbers, sizes and categories of a given product or item and still meeting

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almost the entire range of demands of the customers. Simplification, on the other hand, is the process of making the design simple but standardization is the process where the same standard part is fixed in many varieties of the product.

Some of the benefits of standardization are:

- It helps in easy understanding of requirement.
- It improves the quality of the end product.
- It lowers the cost of production, as non-standard parts would be costlier.
- Smaller range of machinery required results in a smaller range of spares being carried for after-sales-service to customers.
- It enables the reduction of varieties.

There are four types of standards.

- **International standards:** International standards such as (ASTM) American Society of Testing and Materials, (ASME) American Society of Mechanical Engineers, (BS) British Standards, (JIS) Japanese Industry Standards
- **National standards:** National standards, for example, (BIS) Bureau of Indian Standards
- **Industry standards:** (IPSS) Interplant Standards Sub-Committee for Steel Industry
- **Company standards:** They are applicable company-wide which may include some of the earlier three types of standards and go beyond.

(iv) **Codification:** The inventory of any company has several items which will only keep increasing if steps are not taken to reduce them. To begin the process of consolidation, the first step required is to uniquely and unambiguously identify each and every one of the items. This is done by allotting a number to each item called a code and this process is called codification. The logic is similar to allotting a PAN number to every income tax payee in India or a passport number to every citizen of India. Through this number, it is possible to locate the history of every citizen in India. The code would consist of digits or alphabets or both. It should be allotted to every item on the basis of some standards or system of codification; say, the intrinsic characteristics of the item, how or where they are used or who is using it, its composition, sizes. The system should ensure a unique code to each item and enable easy identification of the item.

The advantages of codification are:

- Duplicate stocks under different descriptions for the same item are avoided
- Accurate identification of items by all consumer departments and customers/ users
- Posting of receipts, issues, accounting records, etc., in a systematic and accurate manner since they will be posted only once
- Codification is the fundamental requirement for computerization of materials management activities

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- It helps in standardization and variety reduction.

The British system and the Kodak system are two examples of codification systems. They are a seven digit and ten digit systems respectively. Each organization develops its own system of codification based on its number of items and characteristics of items. Care must be taken to ensure that there are no unnecessary items or duplicate/ multiple identifications and the number of different unique items are absolutely necessary.

The simplest form of codification can be seen in the system of 'tiffin-carriers' or *dabbawallahs* of Mumbai. Each *dabbawallah* handles over thirty-five lunchboxes a day and together they deliver over 2,00,000 lunchboxes daily, over a radius of 60–70 kilomtres in Mumbai. Initially, the 'box identification system' was a unique coding system wherein the *dabbawallahs* would tie coloured threads, cloth swathes or cutting to identify and separate the boxes, along with symbols such as +, = and #, various versions of Hindu swastika, or triangles, circles and squares. However, as the number of boxes grew exponentially, this system was found to be inadequate; so a system was devised in the early 1970s which involved colour coding of alphabets, with a maximum of seven basic VIBGYOR colours signifying the group handling the boxes and signifying the point of origin and point of destination. 10-9/M/16 would translate to 10 being the destination, i.e., Nariman Point in South Mumbai, 9 is the specific area in Nariman Point, M for Mittal Towers and 16 for the 16th floor. This simple system has won the *dabbawallahs* the coveted Forbes' Six Sigma certification.

(v) **Barcoding:** Barcoding is one of the IT tools used today for automatic data capture. It enables data capture with 100 per cent accuracy. It helps in making the apparently long meaningless string of number, i.e., codes into user friendly readable labels. It is a step towards automation of physical handling. Barcoders translate the digital/ alphanumeric codes into groups of thick and thin bars or vertical lines, which can be printed on to items or labels easily and reconverted into decipherable digital/alphanumeric codes by the barcode readers. Barcodes are extensively used worldwide, across industry sectors and trade for a wide number of applications. Some applications of barcoding are:

- **In manufacturing:** For inventory management of finished goods / raw materials, work-in-progress and product tracking during manufacturing process
- **In retail:** At point-of-sale, stock management, demand forecasting, automated stock ordering and track and trace of products
- **In transport:** For consignment track and trace, consolidation and container stuffing, ensuring correct dispatches and correlation

between transport documents and consignments, facilitating trans-shipments and loading/unloading operations

Today, bar coding companies can be found all over India. They supply labels/tags as per supplier's/buyer's designs. Label cost is low—from 50 paise/label upwards. They can also be printed on product package itself. EAN India, a non-profit organization and Government-industry initiative, responsible for allocation of international numbering standards used in bar coding has been extending technical advice to the Indian industry.

(vi) **Analysis of frequency distribution of demand/use:** The starting point of any program for variety reduction of stores is purchase order analysis or analysis of stores issued over a period. This will reveal the situation prevailing in the stores and indicate areas where action for variety reduction can be profitably started. The relevant information to be collected is:

- Frequency of demand for each type, size, material, etc., of an item in terms of quantity or numbers purchased
- Proportion of standard items in all stores purchased
- Proportion of standardizable items

The collected data should then be plotted as a graph with sizes/types on the X-axis and frequency on the Y-axis. This would give a normal frequency distribution curve. In this curve, the sizes/types at the peaks could be retained. For the other sizes, study would be needed whether they are to be retained or eliminated or reduced, using several other techniques such as preferred number series, value analysis/value engineering, standardization or codification.

2. Quantity Reducing Techniques

The following are the techniques that can be used to reduce the quantities of items. The process begins by asking the following questions:

- Should this particular item be stocked at all?
- If so, when should it be ordered?
- How much should we order at one time?

Each and every item in the inventory, however cheap or low in value it may be, should be subjected to these three questions. A careful review based on examination of the advantages of stocking, costs, consumption, sources of supplies, availability and the associated various costs should be done and a decision taken regarding quantities. This analysis should not be a one time activity. It should ideally be an annual activity wherein all the items in the inventory are reviewed.

The quantity reducing techniques commonly used in the industry today are:

(i) Ad hoc approach to inventory management

(ii) Inventory control through stock levels

(i) Ad hoc approach to inventory management: Decisions in this method are taken on an ad hoc basis, often based on past practices or what has always been done'. This method is unscientific and useful only in case of very small companies,

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where the cost of inventory does not justify the time and money spent in analyzing the same. Some examples of the ad hoc approach are,

- A company buys twenty pairs of gloves at a time (its monthly requirement) for ₹ 20 each. The drawback is that every month, the company incurs expenditure on purchasing costs, transportation, packing, forwarding, receiving, inspection, etc. when the total monthly consumption of the item is only ₹ 400 and the item is also not perishable.

  A company buys 1800 helmets at a time for ₹ 1500 each. Monthly requirement is 300 pieces. Helmets are available off the shelf, they do not cause direct loss of production, they are non-perishable, storage space is occupied and leads to unnecessary handling and inventory carrying costs are incurred.

- In a company the machine setup costs in production are high and take several hours to several days. Yet short production runs are scheduled. This will cause a rise in production costs. This adds up to the cost of the finished goods, which will rise.

- In a company the machine setup costs in production are low. Yet long production runs are scheduled. This will result in the requirement of large inventories of raw materials to support the long production runs. Also, finished goods stock gets built up which apart from leading to high inventory carrying costs, might lead to problems of shortage of space and sometimes deterioration of the products if they have low shelf life.

- In a company the stock level of finished goods is maintained at previous levels irrespective of whether the demand of the goods is rising or falling. This could either result in loss of sales and revenue, and act as a welcome to competition, or result in huge losses due to accumulation of stock.

The above-mentioned situations illustrate how unscientific inventory decisions can spell disaster to a company's profitability. Hence the need for a scientific approach based on quantitative tools plus judgement of the inventory manager to carry the optimum inventory for the organization.

(ii) Inventory control through stock levels: Every company fixes certain 'levels' for holding inventory. These are called stock levels. The important ones are given below.

Stock levels

Every company fixes certain 'levels' for holding inventory. These are called stock levels. The important ones are given below.

- **Maximum stock level:** This is the maximum stock, which a company can hold for a particular item. This will depend on the storage space, sunk costs. The company should order only that much quantity so that the sum of the delivered quantity plus the safety stock/ existing stock do not cross the maximum stock level.

- **Minimum stock level:** This is the quantity that should be carried by the company so that the production is not affected before the next delivery arrives. It is often same as the safety stock. The next delivery should ideally arrive when the stock reaches the minimum stock level.

- **Reorder level:** This is the point when the stocks are just sufficient to meet demands during one normal lead time without dipping below the minimum level or into safety stocks. At this level, the orders should be placed so that stocks arrive just when the stock reaches the minimum stock level.
- **Danger warning level:** This is the level at which stocks are just sufficient to meet the demands during one normal lead time without getting totally exhausted and resulting in stockouts. This would be lower than the reorder level by the quantum of planned and provided safety stocks. It is the point after which stockout is inevitable if any delay occurs. In this time the purchase department should put extra pressure on the supplier and see that the delivery is received without any delay. Good supplier relationships will be of help here.
- **Safety/buffer stock level:** This is also called an amber zone. This is the stock that is required to take care of fluctuations in supply. Any fluctuations beyond this will result in stockout. At this stage, the purchase department, in addition to putting extra pressure on the supplier and ensuring that the delivery is received without any delay, should also try for supplies from an alternate source and inform production to revise their production plan and plan to manufacture items for which materials are available in plenty.
- **Stockout level:** Stockout level is also called a red zone. It is a situation in which no material is left in stock. The purchase department should take emergency measures, such as borrowing from other similar organizations, buying from stockists at listed price. It always extracts a price from the organization, hence should be absolutely avoided.

By exercising continuous vigilance, the purchase manager can operate in the green zone without having to enter into the amber zone or red zone.

Safety stock

To meet the uncertainties arising from fluctuating demands, fluctuating lead times, unforeseen situations, an extra stock is invariably maintained for each item in the inventory. This extra stock is termed as buffer stock or safety stock. Safety stocks arise due to variations in consumption rates and variations in lead times.

There are various factors which influence the determination of safety stock. They are:

- **Nature of the item:** Items which are tailor-made, i.e., needed for a particular equipment or machinery, which are made based on drawings or specifications require a safety stock to be maintained to take care of the lead time required to manufacture those items. Standard items, i.e., those available off the shelf, such as motors, batteries, tyres, may not require a safety stock to be maintained as they can be procured immediately.
- **Annual usage:** Class A items having high consumption would be more prone to fluctuations than class B or class C items and require more safety stock.

- **Lead time of manufacture:** Items having longer lead times for manufacture and/ or supply are more prone to fluctuations and therefore require a safety stock to be maintained, e.g., imports, mechanical spares.
- **Stockout cost:** If the stockout cost of an item is high, i.e., non-availability of the item would result in high loss of production, such items should have a considerable safety stock.
- **Seasonality:** For items which are manufactured only during a particular season, it may be sensible to stock till the next season arrives. Even though the item may be available throughout the year, the factor of price comes into play.
- **Risk of obsolescence/ deterioration:** For items which have low shelf life, e.g., medicines, vulcanizing solution, certain electronic items, it may not be prudent to carry a large stock. A small safety stock would be sufficient.
- **Macro/environmental issues:** Uncertainty in supplies, such as impending war, change in policies, government restrictions, may cause a larger safety stock to be maintained.

Then, how much safety stock should be maintained? It should neither be so high as to lock scarce working capital nor so low as to result in stockouts.

Safety stock is a function of two parameters, which are:

- Consumption rate
- Lead time

Four combinations of the two factors are possible. These are:

(a) Both consumption rates and lead times are constant

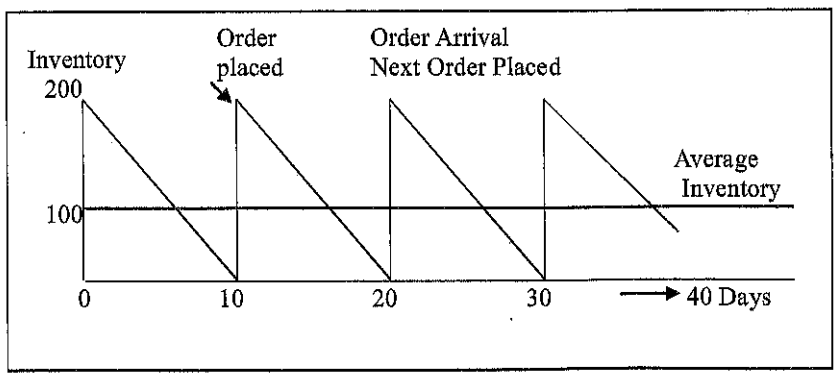
(b) Consumption rate varies but lead time is constant

(c) Consumption rate is constant but lead time varies

(d) Both consumption rate and lead time varies

We will now learn each of these in detail.

(a) Both consumption rates and lead times are constant: This is an ideal situation. Supply against fresh order arrives just when the quantity against the previous order has exhausted. No safety stock is required.



Most homes buy a set amount of milk every day. This system is too simplistic and is not usable in industry. It should be learnt for theoretical purposes.

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(b) Consumption rate varies but lead time is constant: In the previous example, consumption rate (CR) is 200/10 = 20 units/day.

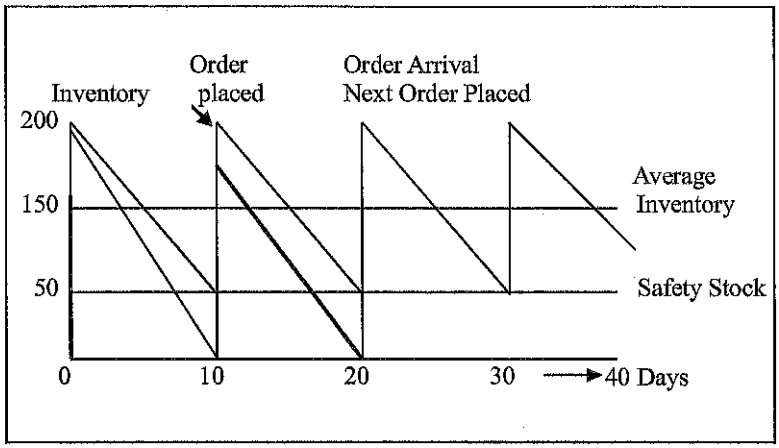
Let the CR increase to 25 units/day, while lead time remains at 10 days.

The inventory would become zero on day 8 (200/25). So there would be a stockout for 2 days, i.e., stockout of 50 units in total.

Hence, if the variation in demand is + or – 5 units, it is necessary to maintain a safety stock of 50 units to take care of variations in demand.

The average inventory would therefore be 200/2 + 50 = 150 units.

This can be represented diagrammatically as follows:



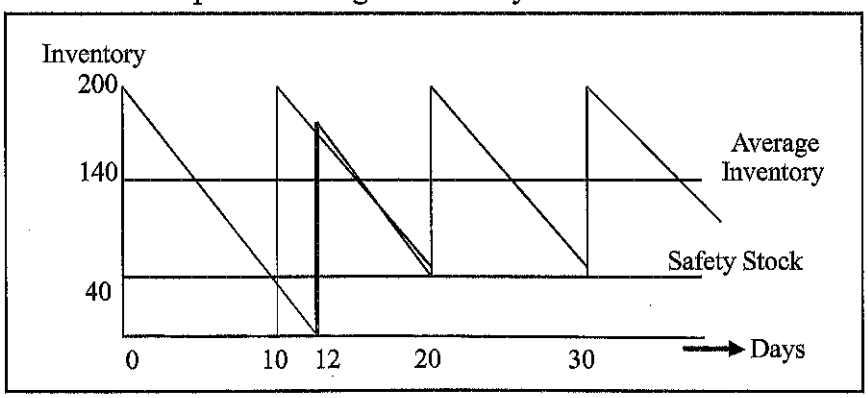
(c) Consumption rate is constant but lead time varies: The previous example is continued here.

Let the CR remain at 20 units/day, while lead time varies by 2 days. If it arrives 2 days early, there is no problem. But if it arrives 2 days late, there would be a stockout for 2 days. So the stockout quantity will be 20 × 2 = 40 units.

Hence, one can say that if the variation in lead time is + or – 2 days and never more, a safety stock of 40 units would be required to be maintained, to take care of variations in lead time.

The average inventory would therefore be 200/2 + 40 = 140 units.

This can be represented diagrammatically as follows:



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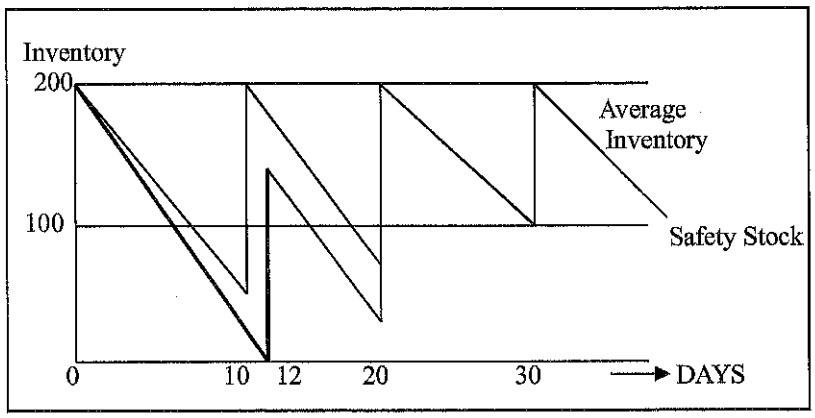
(d) Both consumption rate lead time varies: As in the previous examples, let the consumption rate (CR) increase to 25 units/day, and lead time increase to 12 days.

The inventory would become zero on day 6, i.e., there would be a stockout for 4 days at 25 units per day, i.e., stockout of 100 units in total.

Therefore, a safety stock of 100 units would be required to be maintained, to take care of variations in demand.

The average inventory would therefore be 200/2 + 100 = 200 units.

This can be represented diagrammatically as follows:



Based on these four situations, one decides when to order an item. By the same logic, there are two parameters which decide when to place an order. They are,

- Quantity
- Interval between orders

A combination of these two parameters could lead to four situations.

- Both quantity and interval between orders are fixed
- Order quantity is fixed but interval between orders is variable
- Order quantity is variable but interval between orders is fixed
- Both order quantity and interval between orders are variable

4.6.6 Inventory Management Systems

Inventory management systems based on the above situations are discussed below.

There are primarily four types of inventory management systems:

(i) Fixed quantity fixed interval order system

(ii) Fixed order quantity system

(iii) Fixed interval order system

(iv) Variable order variable interval system

Let's discuss each of these in detail.

(i) Fixed quantity fixed interval order system: This is the most simplistic system in which a fixed quantity, usually the EOQ, is ordered at fixed, regular

intervals. It can be adopted in small activity organizations such as bakeries, etc. A small safety stock may also be added for safety (even milk procurement at homes).

(ii) Fixed order quantity system: Fixed order quantity system is also known as fixed order system, Q-system or reorder point system, perpetual review system, etc., and is based on the fact that the order quantity for each item is fixed but the timing of order is variable. This system works on the following assumptions:

- Annual requirement of the item is predetermined and there will be no deviations
- Consumption rate is constant
- Price charged per unit will be constant throughout the year.

The stock level is continuously monitored and whenever it reaches the ROL (Re-Order Level), an order for the fixed quantity is released. This fixed quantity is usually the EOQ or the closest convenient suppliable quantity. The ROL is fixed as the quantity likely to be consumed during normal lead time plus the safety stock.

Example 4.1

A Company A has a purchasing lead time of 1 week for a consumable. The consumption rate for the consumable is 50 units/week, with +/– 10% variation over the long run. At what inventory level should the new order be placed?

Solution:

CR = 50 units/week.

This means, maximum usage during lead time – 50 + 10% of 50 = 55 units

Average usage during lead time – 50 units

Minimum usage during lead time – 50 – 10% of 50 = 45 units

Since the lead time is 1 week and the maximum usage is 55 units, the new order should be placed when the stock level falls to 55 units. Under these conditions, the new order will arrive just when the stock reaches zero.

What happens when the usage is 50 units in a week? The new order will arrive when there is a stock of 5 units (55 – 50). This is the safety stock.

Therefore, in a fixed order system, the safety stock can be defined as maximum lead time usage minus average lead time usage.

The advantage of this system is that it is simple, reliable, and cheap to operate, is possible by visual or documentary control and is ideal for low consumption items such as B and C items. However, it is not possible to operate this system where the number of items is very large; they have long and variable lead times, the ROL for the different items are reached at different times and the consumption rates are not constant. The most serious drawback is that it works on the basis of historical rather than actual demand data. Therefore, the order point is often incorrect and results in inventories much higher than a comparable MRP system. This system is often used in schools, hospitals, banks.

Two examples of the fixed order system are the Two-Bin and the Three Bin system.

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- **Two bin system:** The two bin system physically keeps its stocks in two separate bins. The lower bin contains stock equal to the reorder point level. The upper bin contains the stock equal to the difference between the maximum stock level and the reorder point level. As soon as the upper bin gets empty, the next order is placed. The stock of the lower bin is now being used and just when it reaches zero, the new order arrives. Upon receipt of the new order, the proper quantities are again placed in the two bins.

  The biggest advantage of this method is its simplicity and reduction in clerical work. Issues do not have to be posted to determine the reorder time. However it is too simple for complex industrial operations.

- **Three bin system:** The three bin system is a slight modification of the two bin system in that the lower bin is split into two bins. One bin contains the reorder level while the other bin contains the safety stock. While the next order is placed upon reaching the reorder level, when this bin also becomes empty the safety stock starts getting used and the purchase department is warned of depleting stocks and requested to hasten the order. When supplies are received, all the bins are topped to the requisite levels.

Example 4.2

Find the economic order quantity and reorder point, given that,

Annual Demand (D) = 1000 units

Ordering Cost (U) = ₹ 500/order

Holding Cost (Inv. Carrying Cost) = ₹ 125 per unit per year

Lead Time (L) = 5 days

Cost/unit @ = ₹ 1250.00

Define the Inventory Policy for the item and find the total cost incurred for the item.

Solution:

$$EOQ = \sqrt{\frac{2A \times U}{C \times I}}$$

Substituting,

$$EOQ = \sqrt{\frac{2 \times 1000 \times 500}{125}} = 89.4 \text{ units or say } 89 \text{ units}$$

$$\text{Reorder level} = \frac{100 \times 5}{365} = 13.7 \text{ units say } 14 \text{ units}$$

The inventory policy would therefore be as follows:

'When the inventory position drops to 14 units, place an order for 89 more units'

The total annual cost would be:

TC = Item Cost + Ordering Cost + Inv Carrying Cost

$$TC = 1000 \times 1250 + \frac{1000 \times 500}{89} + \frac{89 \times 125}{2}$$

TC = 250000 + 5618 + 5563

TC = ₹ 1261181.00

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(iii) Fixed interval order system: Fixed interval order system is also known as fixed time ordering system, P-system or periodic reorder system, cyclic order system, etc., and is a time based operation. It involves scheduled periodic reviews of the stock level of the items. When the stock level of a given item is not sufficient to sustain the production operation until the next scheduled review, an order is placed to replenish the supply. The quantity or 'how much to order,' will vary according to the fluctuations in consumption rate, and can even be zero. The frequency of review is determined by the management. It is often set as the EOQ divided by the consumption rate, to that the order quantity is as close to the EOQ quantity as possible. It may also be fixed as quarterly/monthly/yearly for administrative convenience.

In order to calculate how much to order after each review period, the consumption during the review period is taken into account. The stock in hand and on order immediately after a review date must be enough to last till the next review date.

Thus,

Q = MSL – (Stock in hand + Stock on Order)

Where,

Q = Quantity to be ordered

MSL = Maximum stock level which is fixed by the management and should at least be equal to the consumption during review period plus consumption during lead time plus safety stock.

It may be noted that in this system, the safety stock has to provide protection not only during the whole of the review period but also the lead time following it for receipt of supplies. Hence, it will be slightly higher than the fixed order quantity system.

The advantages of this system are:

- Consolidation is possible since review can be possible according to nature of items/ same or similar suppliers, etc.
- It permits even distribution of workload throughout the year
- It is possible to vary the order quantity at every review, thus stricter inventory control is possible

The disadvantages of this system are:

- It leads to higher inventory levels due to higher safety stock
- It may cause problem to suppliers since order quantity is not fixed
- Review is possible only by the higher levels of management

One example of the fixed interval system is the flow control system.

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Flow control system

Flow control system is applicable in continuous manufacturing operations that produce the same basic product in large quantities day after day. The materials used are often purchased on term contracts with deliveries on daily or weekly basis and materials flow through the plant on a continuous basis. Inventory can therefore be kept low.

In such an operation, an open stores system is used and the material is stored near the production line, i.e., near the point of use. Stores personnel visually review the level of all material stocks daily and report any imbalances to the purchasing department. Changes in production schedules must be communicated immediately to the suppliers so that the delivery schedules can be altered accordingly.

(iv) Variable order variable interval system: This system is also called the S-s system or optional replenishment system or perpetual inventory system. In this system, the maximum stock level is fixed as in the fixed interval system and designated as 'S.' A reordering level is fixed similar to the fixed order quantity system and designated as 's.' At every opportunity to order, i.e. when bulk orders are received or at fixed intervals or when any change in marketing environment occurs, the sum of (stock in hand + stock on order) is compared with 's.' If it is lower, then an order is placed.

The inventory management system that should be chosen for a concern will depend on many more factors besides the consumption rate and its fluctuations, lead time and its fluctuations, cost of inventory. Many modifications to the basic systems explained herein are available and practiced in the industry.

Check Your Progress

20. Name the four groups of inventory.
21. List the common types of inventory.
22. State the various methods by which inventory can be reduced.
23. Define stock level.
24. 'Safety stock is a function of two parameters.' Name them.

4.7 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Work study is 'A management service based on those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts and which lead to the systematic investigation of all the resources and factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement.'
2. The objectives of method study are:
   a. To identify the proper sequence of production operations
   b. To optimize the utilization of machineries

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c. To reduce the manufacturing cycle time by reducing idle time of machinery
d. To choose the right kind and amount of materials and reduce the raw material consumption per unit of production

3. The various techniques of work measurement are:
   a. Time study
   b. Work sampling
   c. Standard data
   d. Predetermined motion time studies
4. The following is the sequence of activities to be followed in a work sampling study:
   - Identify the activity for which the study is to be done.
   - Estimate the percentage of time the selected activity takes, to the total time (e.g., the machine is working 80 per cent of the time). These estimates are made by the analyst from the existing data, guesswork or a pilot work sampling study.
   - State the desired accuracy in the study results.
   - Determine the specific times when each observation is to be made.
5. The basic task of materials management is to improve the productivity of materials.
6. The main objectives of materials management are as follows:
   - The first and foremost objective of materials management, as discussed earlier, is to minimize the materials cost thus paving the way for reducing the cost of the product manufactured.
   - It also aims at procuring and providing materials of desired quality at the lowest possible overall cost of the concern.
7. The functions of materials management are as follows:
   - Materials planning
   - Purchasing of materials
8. Materials management can lead to the reduction of the cost of materials. It also improves the relationship with other departments as the staffs from other departments are not required to solve the materials-related problems.
9. Purchasing activities involve management and combination of internal/external and upstream/downstream supply chain integrated into the customer-employer supplier chain.
10. The basic characteristics of purchasing in the materials context are:
    - Horizontal integrated perspective
    - Total cost ownership
    - Improved skills
    - Use of innovative tools
    - Information insight

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11. Purchasing is the process of obtaining the materials, tools and supplies that are required for the manufacturing of a product.
12. Purchase management is the process that includes various responsibilities, such as buying quality goods in the right quantity, from the appropriate place, at the right time and at the right price.
13. The process of buying large quantities of an item when its price is low so that tentative profits can be earned by selling them later at a higher price is called speculative purchasing.
14. The four types of tender are—single, limited or closed, open, and global.
15. The first step in the purchasing procedure is to indent the purchase requirements that are issued by the purchase department.
16. The invoicing and payment system has a number of benefits such as:
    - After the receipt of GRRs, invoices are raised. This helps in avoiding the delay of materials because the buyer links up necessary papers with invoices.
    - Helps in avoiding the need to raise credit or debit notes for discrepancies in quantities or rejection
17. Store keeping is the process of storing raw materials or goods under the supervision of a person called storekeeper or store controller.
18. The various types of stores available are:
    - Receiving
    - Main
    - Warehouse
    - Special
19. A warehouse performs activities that are concerned with receipt, packing and dispatch of the finished goods to various destinations.
20. Depending on the nature of materials, inventories can be classified into four broad groups which are:
    - Production inventory
    - MRO inventory
    - In-process inventory
    - Finished goods inventory
21. The most commonly identified types of inventory are— raw materials inventory, work-in-progress inventory, finished goods inventory, replacement parts inventory, supplies inventory, transportation (pipeline) inventory.
22. The various methods by which inventory can be reduced are:
    - Reducing the number of items
    - Reducing the quantities of the items
    - Reducing the lead time of procurement

23. Every company fixes certain 'levels' for holding inventory. These are called stock levels.
24. Safety stock is a function of two parameters, which are:
    - Consumption rate
    - Lead time

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4.8 SUMMARY

- A management service based on those techniques, particularly method study and work measurement, that are used in the examination of human work in all of its contexts and that lead to a systematic investigation of all the resources and factors that affect the efficiency and economy of the situation under review in order to effect improvement.
- The primary objectives of work study are:
    1. Effective use of plant and equipment
    2. Effective use of human effort
    3. Evaluation of human work
- A method study is a scientific and methodical approach to determining the best appropriate manufacturing technique for a product.
- The term "critical scrutiny" refers to the process of analysing the facts around a procedure. The facts of a technique should be investigated as they are, not as they should be, in critical assessment. Each stage should be examined in a logical order, with hurried conclusions avoided.
- The process of development entails analysing all of the ideas developed through critical evaluation and putting them into practise.
- Installation is the process of putting the recommended approach into action. The proposal for a technique change is submitted to management, along with the actions that must be followed in order to execute the new plan.
- It is critical to track the effectiveness of a procedure once it has been implemented. The outcomes of the monitoring process must be communicated to the appropriate authorities through a feedback system.
- Work measurement is a technique for determining the time necessary for a competent worker to do any task at a defined level of performance.
- When the task is repeated, time study is commonly utilised as a work measuring method. It is a sampling method that involves taking a few observations from a sample.
- Work Sampling is similar to time study in that it involves watching a section or sample of the work activity. Based on the findings of this sample, inferences are derived and applied to the activity as a whole.
- Because standard data is available, each task does not require a time study. Standard data is used in a similar way as preset motion time data, although at a lower degree of detail.

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- Standard timings for task items that have been defined through extended years of observation and analysis are an alternative to time study.
- Predetermined motion time studies (PMTS are an alternative to time studies that involve the use of predetermined standard timings for job items based on extensive observation and analysis.
- Materials management controls the procurement, storage, amount, movement and consumption of materials that can be used by a company for its production process. It covers various aspects of materials and supplies the necessary materials when required for converting them into finished products.
- Materials management can lead to the reduction of the cost of materials. It also improves the relationship with other departments as the staffs from other departments are not required to solve the materials-related problems.
- Purchasing activities involve management and combination of internal/external and upstream/downstream supply chain integrated into the customer-employer supplier chain.
- Purchasing is the process of obtaining the materials, tools and supplies that are required for the manufacturing of a product.
- Purchase management is the process that includes various responsibilities, such as buying quality goods in the right quantity, from the appropriate place, at the right time and of the right price.
- Store keeping is the process of storing raw materials or goods under the supervision of a person called storekeeper or store controller.
- The raw materials are called stores and the finished goods are called stocks. The place where these materials are stored is called a storeroom.
- Stores management includes various responsibilities such as receiving the raw materials, protecting the materials from damage and spoilage and keeps the finished goods until the goods are dispatched.
- The various types of stores are—receiving, main, warehouse, and special.
- Depending on the nature of materials, they can be classified into four broad groups which are— Production inventory, MRO inventory, in-process inventory, and finished goods inventory.
- Every company fixes certain 'levels' for holding inventory. These are called stock levels.
- Safety stock is a function of two parameters, which are—Consumption rate, and lead time.

4.9 KEY TERMS

- **Work study**: A management service based on method study and work measurement, used in the examination of work.
- **Method study**: A method of examining, recording and analysing the existing way of doing work and proposing a method for improving the efficiency of a system.

- **Work measurement**: A technique to find out the time required to do any activity, at a predetermined level of performance, by a qualified worker.
- **Time study:** A sampling process in which a few observations of a sample are taken and the inferences drawn from the study of the sample are used to determine the time required for subsequent cycles to be performed by the worker.
- **Predetermined motion time studies (PMTS):** A method in which standard times for work elements that have been predetermined from long periods of observation and analysis is used.
- **Materials management**: The control of procurement, storage, amount, movement and consumption of materials that can be used by the company for production purposes.
- **Purchasing:** Purchasing is the process of obtaining the materials, tools and supplies that are required for the manufacturing of a product.
- **Store keeping**: Store keeping is the process of storing raw materials or goods under the supervision of a person called storekeeper or store controller.

4.10 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What are the objectives of work study?
2. What is the relevance of method study?
3. How does work measurement help an industrial engineer?
4. Write short notes on PMTS, use of symbols in method studies, work sampling and time studies.
5. Write a short note on the importance of materials management.
6. State the objectives of purchasing.
7. Write a short note on central purchase organization.
8. What are the functions of stores management?
9. State the objectives of inventory control.
10. What are the factors which influence the determination of safety stock?

Long-Answer Questions

1. Explain the steps involved in method study, giving suitable examples.
2. Write a detailed note on the objectives and techniques of work measurement.
3. 'Is work sampling a better technique than time study for measuring work?' Give reasons and examples to justify your answer.
4. Discuss in the functions of materials management in detail.
5. Explain the functions of a purchase department.
6. Discuss the methods of purchasing.

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7. Describe the steps that constitute purchasing procedure.
8. Discuss the different types of stores.
9. Explain the classification of inventories. What are the components of inventory control?

4.11 FURTHER READING

Bedi, Kanishka. 2007. *Production and Operations Management,* Second edition. New Delhi: Oxford University Press.

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Chary, S.N. 2006. *Production and Operations Management.* New Delhi: Tata McGraw-Hill India.

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UNIT 5 QUALITY CONTROL AND SAFETY MANAGEMENT

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Structure

5.0 Introduction
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5.2 Quality and Quality Assurance
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  5.2.2 Statistical Methods
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5.0 INTRODUCTION

Quality is an important dimension of production and operations management. A company may produce volumes of a product and reach it to the market at the right time, but unless the product adheres to a defined set of specifications, it will not sustain in the market. This characteristic of a product, which makes it acceptable to a consumer, is called quality.

Two American consultants of quality, W. Edward Deming and Joseph Juran did not get any importance in USA. However, they were invited by Japan to teach their concept of quality to the Japanese industry. This helped the Japanese produce goods and sell in the US market at prices much less than the cost of producing similar American products. The Americans woke up with a jolt and began to learn lessons from Japan.

So what is unique about the Japanese way of production? Till that point people thought that quality meant superiority or innate excellence. But the Japanese taught that quality is actually a precise and measurable concept and the difference in quality actually reflects a difference in the quantity of some product attribute.

One of the most interesting approaches to preventing quality problems, started by the Japanese, involves working with suppliers of purchased material in order to improve their quality. Japanese manufacturers often provide free assistance to their suppliers in developing quality assurance programmes or solving quality problems. They believe that if a manufacturer knows that its suppliers are producing quality products, then less effort will have to be spent on verifying the quality of

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incoming material and reworking or scrapping defects that may be found in later stages of production. Companies around the world now work more closely with suppliers and are beginning to insist on sound quality practices throughout their organizations. The attributes of quality, and how they can be measured and controlled will be the topics discussed in this unit.

Further the concept of industrial safety and safety management will also be discussed.

5.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain the concept of quality and quality costs
- Discuss the objectives, advantages and applications of quality control
- Examine the statistical methods of quality control
- Understand risk assessment
- Know the safety issues faced by business organizations

5.2 QUALITY AND QUALITY ASSURANCE

Quality is determined by what a customer wants and is willing to pay for. It is a written or unwritten commitment to a known or unknown consumer in the market. Thus quality can be defined as fitness for intended use or, in other words, how well the product performs its intended function. Quality also means conformance to specifications. That is, quality of conformance is defined as how well the manufacturing is able to meet design specifications. A quality product is one that provides a predetermined level of performance at an acceptable price or provides conformance to design specifications at an acceptable cost.

As stated earlier, quality is determined by what a customer wants and is willing to pay for. Quality does not mean producing the best; it means consistently producing the products and services that give customers their money's worth. McDonalds, the burger giant, is famous for having built quality into its service delivery process. It literally industrialized its service delivery system, so that part time, casual workers could provide the same eating experience anywhere in the country.

Often, the term quality assurance is referred when talking about quality. Quality assurance refers to the entire system of policies, procedures and guidelines established by an organization in order to achieve and maintain quality. The objectives of quality assurance are:

- Improve quality
- Reduce costs
- Increase productivity

Quality assurance is the result of two activities:

- Quality engineering
- Quality control

Quality engineering means to include quality at the time of designing the products and processes. Predicting potential quality problems too exists within the gamut of quality engineering. Quality control consists of making a series of planned measurements in order to determine if quality standards are being met. If they are not being met, it also involves taking corrective and/or preventive action in order to maintain quality. Statistical techniques are extremely useful in quality control. Quality engineering and quality control are also known as quality or design and quality of conformance respectively. The financial performance of an organization depends heavily on these two issues. To achieve high quality of design and conformance, the firm must incur costs associated with developing and maintaining the quality system.

Cost of Quality

The benefit of quality products for an organization is two fold. For one, the organization stands to gain in terms of profits. In addition, such products also improve the image of an organization. Further, they reduce cost of external failure. Also, appraisal will be required less since the products will be correctly made the first time. Quality efforts cost money; they must be well planned and quality costs must be understood at every level of the organization.

Philip Crosby, the quality guru suggested that 'quality is free' in his book by the same title. However, another authority on quality, J.M. Juran, propounded the concept of costs of quality. Quality costs are any costs that are incurred by a company to ensure that a product provides perfect quality. Each time any work needs be redone, for example, re-manufacturing a defective item or re-testing an assembly, the cost of quality increases. Many such costs are overlooked or not recognized because traditional accounting systems are not designed to identify them.

Quality cost data provide useful managerial information for measuring performance and identifying improvement opportunities. This data is also used in strategic planning, budgeting, and capital investment decisions along with production and marketing cost data today. Companies such as Motorola, GE, Texas Instruments, etc. have saved billions of dollars by initially incurring a high cost for implementing quality philosophies like six sigma, to prevent of defects in their products.

The following are the major costs of quality.

(a) Prevention costs

Costs that are incurred in preventing the manufacture of non-conforming products and stopping any such product from reaching the customers are called preventive costs. Preventive costs include a range of costs such as process planning costs, process control costs, training costs and general management costs. Process planning costs include the development costs for establishing procedures, manufacturing controls and setting up instructions for testing and inspection, reliability studies, new equipment design, etc. Process control costs include cost of analysis of production processes in order to improve operations and the implementation of process control plans. Training costs are associated with developing and operating

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formal training programmes or attending seminars on quality assurance. General management costs include those for clerical staff, supplies, and communications related to quality efforts.

(b) Appraisal costs

Appraisal costs are incurred while maintaining quality levels through measurement and analysis of data in order to detect and correct problems. Testing and inspection costs are incurred while testing and inspecting incoming materials, work in process and finished goods and include salaries for inspectors, supervisors, and other personnel. Testing and inspection costs also include cost of equipment, cost of maintaining instruments, calibrating gauges and test equipment, repair, etc.

(c) Internal failure costs

Internal failure costs result from unsatisfactory quality that is found prior to the delivery of a product to the customer. It includes scrap and rework costs, costs of corrective action arising from the time spent determining the causes of failure and correcting production problems. Lost revenue on account of selling a product at a lower price because it does not meet specifications is also an internal failure cost.

(d) External failure costs

External failure costs occur after poor quality products reach the customer. Costs of investigating complaints, product recall costs, warranty claim costs, which include the cost of repair or replacement of products during warranty periods, and product liability costs of legal action and settlements are a major source of external failure costs. It is estimated that sixty to ninety per cent of total quality costs are the result of internal and external failure problems. In the past, increasing inspection has been the stereotype reaction to high failure costs. This approach, however, leads to higher appraisal costs. While this approach may reduce external failures, internal failures are bound to rise. So overall, there is hardly any improvement in quality or profitability. The key then, to improving quality and profitability is prevention. Better prevention of poor quality will clearly reduce internal failure costs since fewer defective items will be made. Consequently, external failure costs will also be reduced. In addition, appraisal will be required less since the products will be correctly made the first time.

Characteristics of Quality

What do we mean by quality? What are the characteristics of a product or a service that a consumer considers, in order to judge quality? A product is called a quality product only when it satisfies various criteria for its functioning. From the consumer point of view, the most common characteristics of a product or service, that are judged while assessing quality are as follows:

1. **Performance:** How well does the product perform with respect to its intended use?
2. **Safety:** How much care has the company taken to make the product safe for users before, during or after use?

3. **Features:** What special features does the product have? These are usually in addition to the basic function of a product, for example, a mobile phone having camera, calculator, games and MMS, etc.
4. **Customer service:** How is the behaviour and treatment of the seller with the customer before, during and after the sale of the product?
5. **Reliability:** What is the probability of breakdowns, need for adjustments, replacement of parts, etc., in the product?
6. **Appearance:** How pleasant is the outward look, smell, taste, feel or sound of the product for customers?
7. **Serviceability:** How easily, cheaply and speedily can the product be repaired and serviced? How fast is the response of the company to a complaint?
8. **Durability:** How long can the product perform before needing any repair or replacement of parts?

From a producer's point of view, the characteristics of quality are as follows:

(a) **Innate:** Quality is innate or inherent in the product. It is not based on any comparison regarding the features and characteristics with other similar products.

(b) **Measurable:** Quality is measurable, i.e., conformance to quality can be quantified by measuring the variation.

(d) **Usability based:** Quality means making products based on specific requirements. So quality of a product is based on the usability or ability to satisfy the given need. A mobile phone may have several additional features but these do not improve the quality for a customer whose need is a basic mobile phone with listening and speaking clarity, at a low cost.

(e) **Design based:** Quality is defined by the design specified for a particular product, that is, a product is designed such that it has a particular quality.

5.2.1 Quality Control: Importance and Objectives

Quality control is one of the critical functions in the management of a plant. Quality control is the process in which the products are made to conform to the quality standards set by the clients or the customers. These quality standards are assessed by the management team and implemented in the production process of the plant in the form of mechanical and manufacturing requirements.

Quality control helps in manufacturing the desired product than finding the errors in the production process and rectifying it. However, to deliver a quality product, it is necessary to control the production process also. Therefore, quality control also includes controlling the stages of the production process to manufacture quality end product. It is the responsibility of the quality control team to regularize the production process. Regularizing will enable the production of an end product that meets all the quality standards.

Functions of Quality Control

As the function of quality control includes assessing the complete production process, it starts with the selection and purchase of raw materials and equipment

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required for production work such as tools and fixtures. Quality control also includes maintaining the quality employees by providing a healthy working environment. Based on these factors, three main functions of quality control are as follows:

- **Inspection:** The quality control team inspects the final goods to check them against the standards specified by the clients or the customers. The various stages involved in the inspection process are:
  - **Receiving inspection:** In this stage, the received or purchased materials are inspected for quality both before and after purchasing.
  - **Process inspection:** In this stage, the production process is checked against the time taken to produce the goods, quality and performance of machines and quality of goods.
  - **End product inspection:** In this stage, the end product is checked against the standards laid by the client.
  - **Maintenance inspection:** In this stage, the maintenance of the plant and machines are assessed for improvements based on the product produced.
  - **Rejected materials:** In this stage, the materials or equipment that do not conform to the quality standards are discarded or rectified.
- **Prevention:** During inspection, the quality control team identifies the faults in the machines or their parts and the production process. After the faults or defects are identified, the necessary preventive actions are taken to avoid any possible breakdown or disruption of work. This includes discarding the faulty equipment or rectifying them and arranging for the standby equipment. Taking preventive actions involves assessing the production process, analysing the occurrence of faults and training the employees to reduce the faults in the production process and avoid downtime.
- **Verification**: The quality control team verifies whether or not the end products are conforming to the quality standards predefined by the clients or the customers. To conform to the quality standards, an end product should be verified at every stage of the production process. The assurance that all the required quality standards are met can be received if proper quality audits are done, inspections are done at the right time and regular reports are maintained and suggestions are implemented.

Advantages of quality control

The various advantages of quality control are as follows:

- Quality control helps meet client requirements and attain customer satisfaction.
- It ensures that the parts of machines fulfil the specified accuracy and are assembled properly.
- Quality control ensures cost-effective production with minimum defects and downtime.

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- It also helps in increasing the utilization of workforce that results in the maximum work in the minimum time.
- Quality control provides control over work as only quality products are produced and on time.

Applications of quality control

The functional areas where quality control is applied in a plant are as follows:

- Deciding upon the quality standards to be followed based on the production line
- Purchasing of raw materials
- Production process
- Inspecting finished goods
- Checking on the violation of quality standards
- Analysing the reports based on inspection and quality audit
- Implementing the results of analysed report for increasing the production
- Reducing the frequency of defective end product
- Updating the quality standards regularly to improve quality
- Training of workforce from time to time

To maintain the production quality of the plant, it is necessary that the suppliers are selected after thorough research and they should be reliable. Quality cannot be implemented in the end product; it is manufactured along with the end product.

Quality Control through Inspection

Inspection is one of the important ways through which quality is controlled in a plant with the minimum cost. Inspection also helps in assessing how viable the quality standards are in the functioning of the production process. In some plants, the two functions —quality control and inspection, are performed together as they are interchangeable and linked with each other. However, in big plants, there are separate departments for these two functions as separate reports are generated and analysed.

Quality control and inspection are interrelated as both ensure that the machine parts are within the specified limits and properly assembled. They help in reduction of defective work and proper utilization of labour and machines. The quality control team inspects the goods to confirm that the standards specified by the clients or the customers are fulfilled. This helps to ensure that the product delivered to the client is of high quality. Figure 5.1 shows the functional pattern of inspection and quality control working together in an organization.

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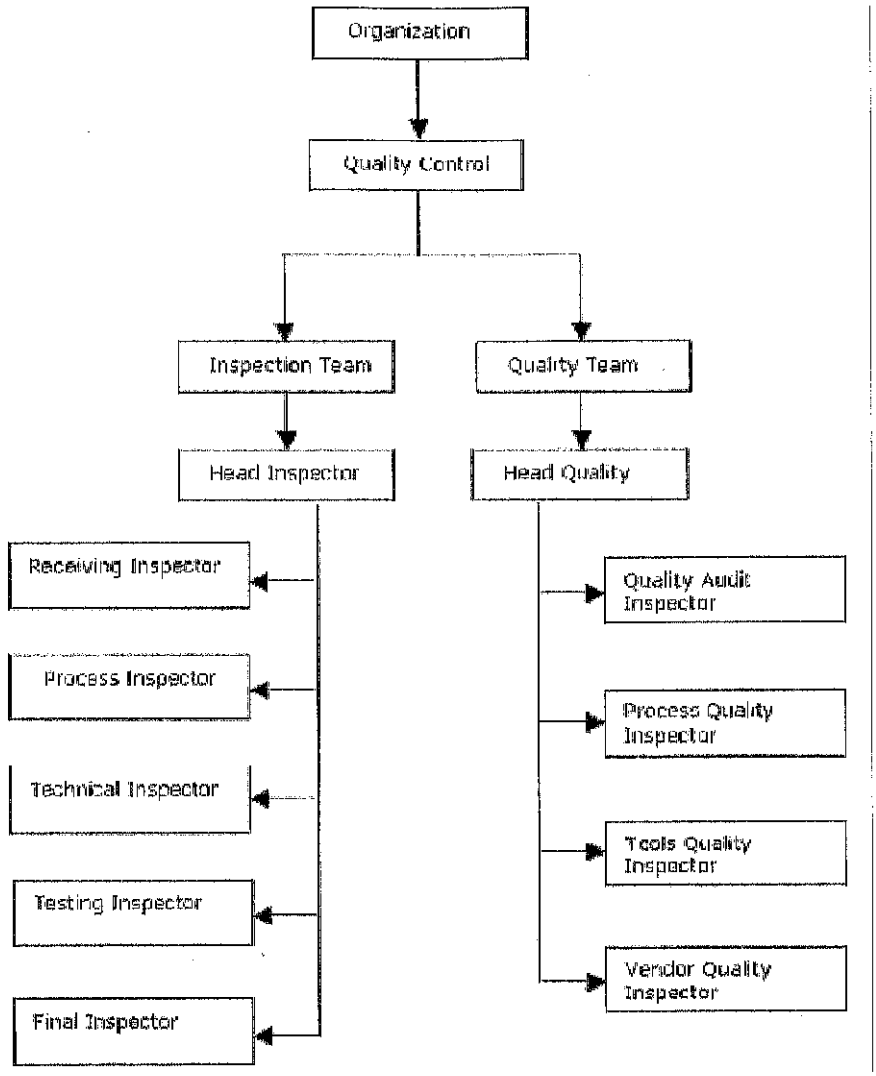

Fig. 5.1 **Inspection and Quality Control**

However, there are also some differences between quality control and inspection, which has been stated below:

- Quality control provides the end products, which fulfil the quality standards specified by the clients and customers. Inspection is one of the ways of producing quality products.
- Quality control identifies the reasons of defaults and suggests the methods to rectify them. Inspection applies the methods suggested by the quality control team and analyses their viability.
- Quality control sets the standard of products, its quantity and the time taken to produce that product. Inspection actually examines the product and motivates the production process to meet the timeline.

5.2.2 Statistical Methods

Performance of a product means the functions and services which it must provide its consumer. This means, a watch should show accurate time, a pen should write

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legibly on paper or the eraser should erase pencil marks clearly without leaving black marks or imprint of the writing, on paper. The same quality of physical performance should be available over a reasonable length of time. Thus, time is also an essential aspect of quality.

There are three aspects of assuring quality:

- Assurance of incoming raw material's quality
- Assurance that proper processes are operating on the raw materials
- Assurance of the quality of the outgoing finished goods

Assurance of incoming raw material's quality is done by several measures, such as inspection of incoming materials, stringent specifications, supplier being made responsible for his quality, buying from companies which are ISO certified, etc.

Statistical Process Control

The objective of process control is to set a process to convert the inputs (raw materials) into output (finished goods) and then monitor the processes frequently. Any deviation from the set processes should be corrected when required. Process control is the monitoring of the various physical variables operating on the materials and the correction of the variables when they deviate from the previously established norms.

The following are the definitions of some terms that are used in common.

(a) Variations

Variation refers to the small difference between the written down specifications and the actual. All processes have some variations due to causes, which may or may not be inherent to them. In any case, the causes responsible for the deviation of the processes from the established norms have to be rectified. The variations which are inherent to nature of a particular process and which are random since they are not traceable to any particular cause are considered to be due to random causes or chance causes. For example, a machine filling tooth paste in tubes may not fill all tubes with exactly the same amount of paste; there will be some variations. In process control, one is concerned only with those causes which can be rectified. Such causes are called assignable causes. The organization can do nothing about chance causes. The problem in this situation is to know when a particular deviation in the process is occurring due to chance causes and when it is occurring due to assignable causes. If a cause like worn-out tool, mistake on the part of a worker in processing the item, improper adjustment of the machine, etc., is found, it is termed as an assignable cause. Whenever variations are due to assignable causes, the process is said to be out of control. The assignable causes of variation are rectified in order to bring the process under control.

Random variations are due to the inherent nature of the process. Some expected random variations are present in every process. The process is said to be in control if variations are only due to random variations. In the above example of an automated machine filling toothpaste in tubes, the machine is programmed to fill a particular weight of toothpaste in every tube. It is quite possible that the

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weight in one tube may be 100.051 grams, in another it may be 100.010 grams, and in still another one it may be 99.998 grams. The machine is not designed to be capable of detecting variation in weight up to the third place of decimal in grams. Therefore, it is expected that this much variation in weight will take place because of the inherent nature of the machine. Such small variations bother neither the manufacturer nor the customer.

The difference between chance causes and assignable causes are shown in Table 5.2.

***Table 5.2** Chance Causes vs Assignable Causes*

Chance Causes	Assignable causes
1. Natural or inherent to the process.	Unnatural or external, due to causes that can be traced.
2. All causes taken together give variation.	A single assignable cause can cause a substantial variation.
3. Slight variation in the machine, could be inherent to it.	Faulty machine set-up gives rise to variation.
4. Lack of human perfection in setting the instrument.	Lack of human perfection in reading the instrument.
5. Cannot be economically eliminated.	Once detected, can be eliminated.

(b) Monitoring the process

The process can be monitored in two ways:

- Actually measuring the variables operating on the raw materials
- Measuring the characteristics of the output product

When a number of variables operate on a product, it becomes easier to observe the quality of the product coming out of the process, rather than monitor the variables operating in the system. That is why in statistical process control, one seeks to monitor the output of the processes and thus control the processes by locating the causes for the deviations (if any) and rectifying the same.

(c) Specification limits for the output

When describing the quality of a particular product, the appropriate range of its performance is referred to. One does not say that the diameter of the pipe has to be exactly 3 centimetres. Rather, one would say that it should be 3 centimetres plus or minus a difference of 0.002 centimetres. This range is called the specification range or specification limits of the output.

(d) Control limits

A product should not exceed the specification limits. To ensure this, the limits for process control purposes should be narrower than the specification limits. These limits, called control limits, should be such that when exceeded, a danger signal is given. However, at this point it is only a signal and the product is not designated as defective.

(e) Cost aspects in designing control limits

While designing the control limits or the danger signals, cost aspects need to be kept in mind as well. There is no point in worrying over every small variation in the output and wasting efforts in rectifying the processes operating on the materials. A certain margin of error, even if the error is assignable, is allowed for.

(f) Central tendency and dispersion

Variations in any process can be described in general in terms of two parameters, namely central tendency and dispersion. Central tendency has to do with accuracy and dispersion with precision. The following example will help understand these two concepts.

Suppose a book weighs 150 grams. There are two weighing machines and they show the following readings for its weight:

Machine No. 1	Machine No. 2
140, 151, 159 grams	139, 139.5, 140 grams

Machine number 1 gives an average of 150 grams and is therefore, an accurate machine. Its central tendency (150 grams) does not show deviation, but it has a lot of dispersion (140–159). Machine number 2 is precise, but it is not accurate because its central tendency is 139.5 lb (and not 150 grams) but its dispersion is quite low, ranging from 139–140. The above example shows that in controlling errors one has to control not only the central tendency, but also the dispersion. In other words, both the mean and the amplitude of variation need to be controlled. It needs to be checked whether a process has gone out of control in terms of the central tendency, or dispersion, or both.

During the transformation process of a batch, samples of items are taken at regular intervals and inspected for any variation from established standards. If there are variations, the cause must be found. Whenever variations are due to assignable causes, the process is said to be out of control. The assignable causes are then rectified to bring the process under control. The process is said to be in control if variations are only due to random causes. Such small variations bother neither the manufacturer nor the customer. But whenever a variation beyond a certain limit is observed by the QC manager, it is time to look for assignable causes.

Two methods are generally followed for monitoring variations:

- The first way is to monitor all the physical variables such as tools, machines and equipment, and labour skills acting on the material inputs in the transformation process. Are all the machines working in ideal conditions? Are the workers working according to specified methods? Are the tools properly calibrated?
- The second way is to monitor the variations in the output product or service. If the output product satisfies the specifications evolved during its development stages, it possesses the desired quality. Samples of the output are inspected at regular intervals of time and any variation from previously established standards is detected. This method of monitoring the output is most popularly used to monitor variation in all industries.

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Organizations that are ISO certified follow the first method of monitoring the outputs in combination with the second one, wherein it is ensured that an overall quality system takes care of variations in the physical variables in the transformation process.

Specification and Control Limits

The desired value of a variable during the design and development stages of a product is not expressed in terms of an absolute value but in terms of a range. These specification limits or tolerance limits are set by the manufacturer at the design stage of the product or specified by a customer. It is very important for a QC manager to ensure that the specification limits are never exceeded during the production process, because if this happens, the defective unit produced will be rejected leading to a loss for the company. For example, the diameter of a pencil is expressed by its manufacturer not as 7 mm but as 7 mm $\pm$ 0.05 mm. Thus, the diameter of a pencil produced by the manufacturer can vary from 6.95 mm – 7.05 mm. If these limits are exceeded in a produced pencil the pencil is rejected.

In a control chart, these specification limits are shown along the y-axis. The value 7.00 mm is shown as the central line (CL) and is the targeted value. Theoretically, it is aimed that every pencil produced should have a diameter of exactly 7.00 mm, no more and no less. Because of random variations, though, the diameter of the pencils produced may vary slightly on either side of the CL. The value 6.95 mm becomes the lower specification limit (LCL) and 7.05 mm becomes the upper specification limit (UCL).

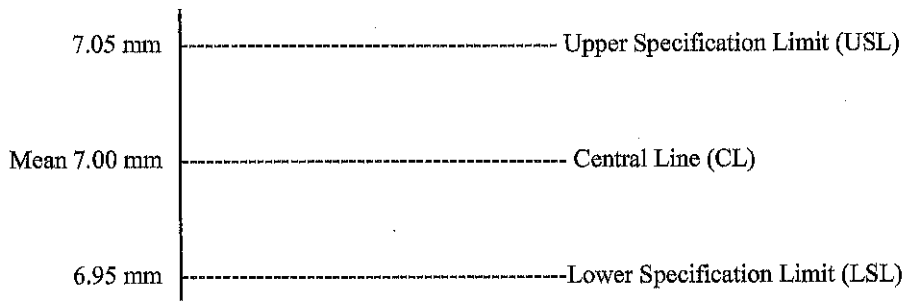

Fig. 5.2 *Control Chart Showing Specification Limits for the Diameter of a Pencil*

As stated earlier, in order to ensure that the specification limits are never exceeded, control limits are established inside the specification limits. These limits serve as a danger signal or indication for the QC manager. Whenever these limits are exceeded by the output, the manager has to look for assignable causes. The lower control limit (LCL) is set usually at $M - 3\sigma$ and the upper control limit (UCL) at $M + 3\sigma$. Here, M is the mean or the targeted value of the diameter for all the pencils to be made, i.e. 7.00 mm, and σ is the standard error of the mean (i.e. the standard deviation of the distribution of sample means).

This can be interpreted thus: suppose n pencils (sample size = n) are drawn at random and their diameters are measured and the mean of these measurements is taken. This sample mean should fall within the control limits. If the sample mean for any sample falls either above the UCL or below the LCL, the process is out of control.

5.2.3 Acceptance Sampling and Operating Characteristic Curve

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Acceptance sampling is a technique which uses the statistical inspection method to evaluate the quality of a complete batch. A company conducts inspection at two stages: one, at the time the raw materials are received, inspection is conducted to confirm that they are as required and the second inspection is conducted to ensure that the finished goods are as per specifications. In both these inspections, either each piece can be tested, or only some out of a lot can be tested. If each and every piece has to be tested, it would require considerable time, effort and resources, which is just not worth the trouble. What then is generally done in industry is that only a few pieces from a whole batch or lot is inspected to verify that the specified and acceptable standards of quality are met. If the sample conforms to the specified standards, then the whole batch or lot is considered accepted, else it is rejected. Since, only a few pieces from a lot are inspected, it is possible that the decision to accept or reject the whole lot may not be correct. Therefore, the sample should be chosen at random from the whole lot so that every portion of the lot has an equal representation. This type of sampling is called random sampling.

After a lot has been defined, an acceptance sampling plan is made. An acceptance sampling plan consists of the following:

- A set of rules that define the procedures for preparing a batch or lot.
- Rules for selecting samples, e.g., they can be picked at random, or every fifth piece can be a sample, and so on.
- Procedure for conducting inspection of the samples.
- Fixing the criteria for accepting or rejecting the batch.

In other words, an acceptance sampling plan specifies the sample size (n) and the number of defectives (c) that are allowed in a batch of acceptable pieces. If the number of defectives in the sample is equal to or less than the permissible number of defectives, then the lot is accepted; otherwise, it is rejected.

Types of Sampling Plans

Different types of sampling plans are used, for acceptance sampling depending on the level of accuracy required. The common ones are as follow.

1. Single sampling plan

In this sampling plan, the inspection results of a single sample size decide whether to accept or reject the complete lot. The lot size is defined from the outset based on which the organization decides the number of samples to be drawn. Thereafter, the acceptance number 'a' is defined. This is the maximum number of defective units which are acceptable. If the number of defectives is a + 1 or more, the lot will be rejected. (a + 1) is also called the rejection number.

For example, in a single sampling plan:

Suppose, Lot size (N) = 5000

Sample size (n) = 150

Acceptance number a = 2

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This means 150 pieces are selected from the batch of 5000 pieces and inspected. If the number of defectives is 0, 1 or 2, accept the lot and if the number of defectives is 3 or more, the lot will be rejected.

2. Double sampling plan

In double sampling plan, the inspection results of two sample sizes are used to decide whether to accept or reject the complete lot. After defining the lot size, the number of samples to be drawn is defined for the first time as well as for the second time. Two acceptance numbers 'a1 and a2' are defined. Consequently, there will be two rejection numbers.

In the above example, if there is a double sampling plan:

Lot size (N) = 5000

Sample sizes: $n_1 = 150$ and $n_2 = 150$

Acceptance number: $a_1 = 2$ and $a_2 = 8$

First, a sample of 150 pieces is selected from the batch of 5000 pieces and inspected. If the number of defectives is 0, 1 or 2, the lot is accepted and if the number of defectives is 8 or more, the lot will be rejected. But if the number of defectives is either 4, 5, 6 or 7, a second sample of 100 units will be drawn.

The combined samples $(n_1 + n_2)$ i.e. 250 units is inspected; if the number of defectives is 10 or less, the lot will be accepted; otherwise, rejected.

3. Multiple sampling plan

When more than two samples are used for deciding the acceptance or rejection of a lot, it is called multiple sampling plan. As the number of samples increases, the complexity of implementation becomes greater.

Which plan the organization chooses for quality control depends on the amount of precision required, the economic aspect and the feasibility of the quality control set up. These vary from company to company and from product to product.

Operating Characteristic Curve

The sampling plan has the ability to separate the good pieces from the batch, which is shown by the operating characteristics (OC) curve. It clearly shows how a sampling plan can separate out the lots of varying quality and evaluate the risks associated with any sampling plan. Acceptance sampling decisions, i.e., whether to accept or reject a batch of items are based on the OC curve. A good sampling plan ensures that the good lots are always accepted, while the bad ones are always rejected. The OC curve can be made more strict (greater quality control) in three ways:

- By increasing the sample size n, while keeping the acceptance number constant
- By decreasing the acceptance number a, while keeping the sample size n constant
- By simultaneously increasing the sample size n and decreasing the acceptance number *a*

Construction of the OC Curve

The OC curve (Figure 5.3) shows the percentage defectives (p) in a batch along the X axis and the probability of acceptance (P_a) of the batch along the Y axis. As the percentage defectives increase, the probability of accepting the batch reduces. Therefore, a batch having zero percentage defectives will always be accepted.

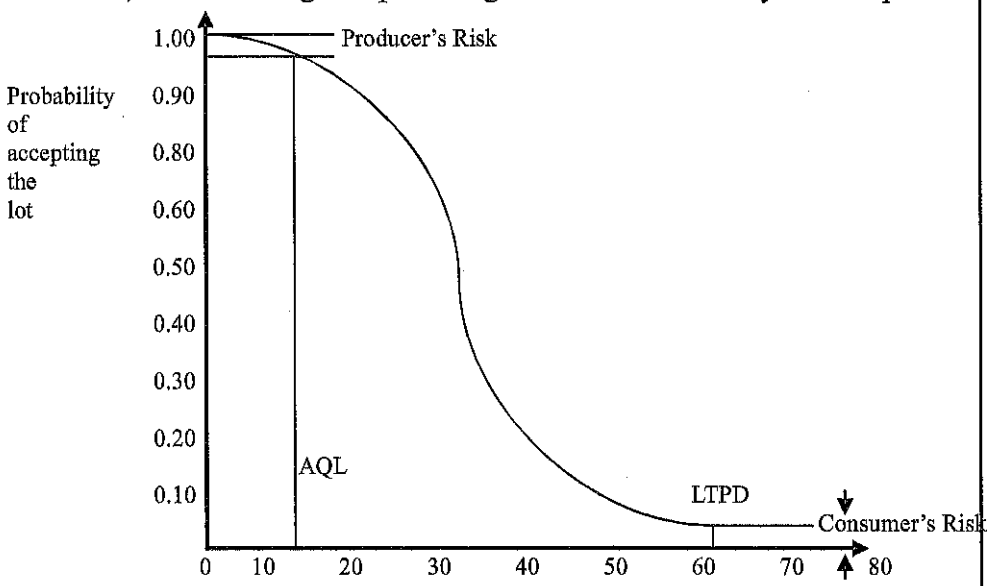

Fig. 5.3 The Operating Characteristics (OC) Curve

Parameters of an OC Curve

There are four parameters associated with an OC curve:

1. **Acceptable Quality Level (AQL):** It is the level of quality at which the lot is defined as a good lot. AQL represents the percentage at which the sampling plan will accept the lot. This level indicates the maximum permissible number of defects in the sample (n) if the lot is to be accepted.
2. **Lot Tolerance Percentage Defectives (LTPD):** It is the level of quality at which the lot is declared to be a bad lot. LTPD represents the percentage at which the sampling plan will reject the lot. This level is measured in terms of rejection number 'r,' which sets the limit for accepting the lot. In other words, it indicates the maximum permissible number of defectives in the sample (n) if the lot is to be accepted. This level is also called unacceptable quality level.
3. **Producer's Risk (α):** It represents the probability of rejecting a good lot by the sampling plan. This risk may vary between 0.01 – 10 per cent. A producer's risk is measured in terms of the probability that the lots of AQL will not be accepted.
4. **Consumer's Risk (β):** Represents the probability of accepting a bad lot by the sampling plan. A consumer's risk is measured in terms of the probability that the lots of the LTPD will be accepted.

There is a strong interrelationship between AQL and producer's risk as well as the LTPD and consumer's risk. While selecting a sampling plan, both producer and

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consumer must agree on the level of inspection that is governed by the AQL and LTPD values. Lower the value of AQL, higher is the probability of accepting a good lot.

5.2.4 Control Charts

In process control, a check is kept on both central tendency and dispersion by a graphical method. The graphs which are used for such monitoring are called control charts. Process control relies mostly on such graphical or visual representations, and monitoring thereafter.

The procedure that is generally adopted is as follows:

- Take a few samples at a time
- Measure their quality characteristics
- Find the mean of the sample
- Measure the range of dispersion in the sample
- Gather statistics for the ranges and the means of the various samples taken over frequent or regular intervals of time
- Plot the results appropriately on a graph paper

The charts thus obtained will guide us as to when a particular process needs to be rectified and in what manner.

Several kinds of quality charts are in use. The following is a description of the most commonly used charts.

(i) X-bar Chart

X-bar chart is used for analysing the control of the mean value of a variable or control of the central tendency. The mean values are plotted in this chart. With the help of the x-chart, a track can be kept on the quality of the product by determining its central tendency. The upper and lower limits of the quality values required by the customer are determined first.

In the diameter of a pencil stated earlier, the specification provided by the manufacturer is 7 mm ± 0.05 mm. Thus, the diameter of a pencil produced by the manufacturer can vary from 6.95 mm to 7.05 mm. 6.95mm denotes the lower control limit (LCL), 7.05 mm denotes the upper control limit (UCL), and 0.05 denotes the maximum allowed deviation from the standard diameter, which is 7 mm. If these limits are exceeded in a pencil produced, the pencil is rejected.

Here, the value mathematical equations to calculate the LCL and UCL are:

$LCL = \mu - 3\sigma$

$UCL = \mu + 3\sigma$

Any time the sample means overshoots the UCL or undershoots the LCL, a red signal is given. This means that assignable causes are looked for by checking the machine/equipment or process that is producing the particular product.

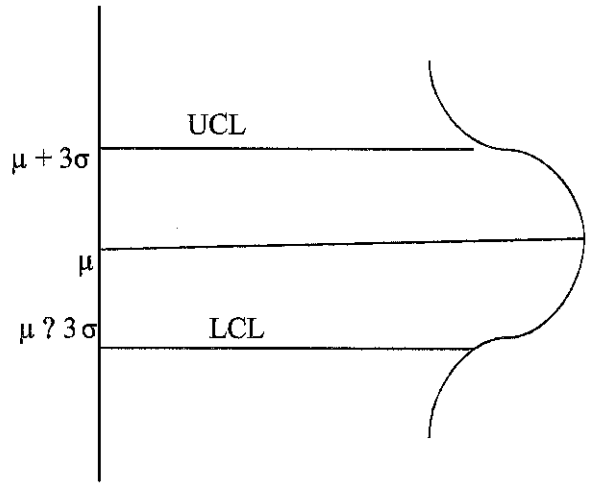

Fig. 5.4 X-bar Chart

(ii) R-Chart

R-chart is used for analysing the control of the variability of a variable or dispersion. The standard deviation and range of a particular quality control variable is first calculated. The range of a variable is defined as the difference between the maximum and the minimum values of the observations in a sample. The distribution of the samples (R) can be denoted by the following equation:

$$R = d_2 * \sigma_{population}$$

Where d_2 is a constant whose value depends on the sample size n.

$\sigma_{population}$ represents the standard deviation for population.

This means R is a function of the standard deviation of a population. By maintaining R within limits, we can maintain $\sigma_{population}$.

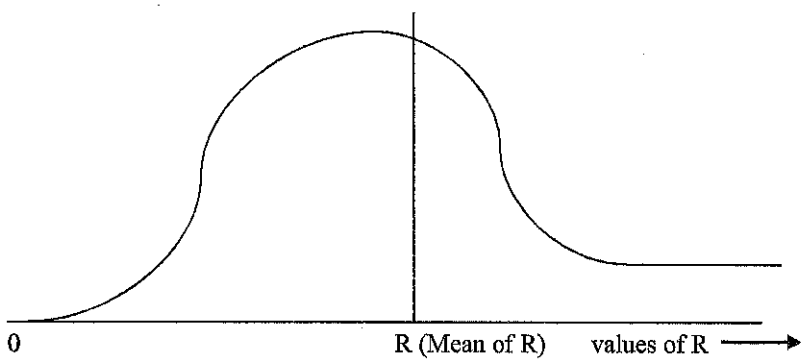

Fig. 5.5 The R-Chart

When the R values fall below the central line, it indicates that the process has less dispersion than the average values of the same. This is desirable and what one works for. If the narrowing down of the dispersion becomes permanent, it should be incorporated and a revised R chart made. However, it needs to be ruled out that this desirable result is not due to some uneconomical methods which might have been employed or some inspection error.

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(iii) P-charts or Fraction Defective Charts

Not in all cases can we describe the samples in terms of their measurable characteristics. Often, inspection is of the go/no – go, or accept/ reject type which means the sample is either defective or not defective. Control charts for such inspection procedures have been named p-charts, where p stands for the fraction defective in a sample. These charts are used to control the overall number of defectives in units of product. The procedure of constructing the p-chart is as follows:

Suppose about 25 samples are taken and it is found that the average fraction defective, p - this is the central line. The normal distribution for the fraction defective data of these 25 samples is assumed. Note that though this is a typical case for the application of the binomial distribution, one can approximate the distribution to a normal distribution when $np \geq 10$. If this requirement is met, then based on the normal distribution assumption, we set the limits for the upper and lower controls as follows:

$$UCL = p + 3\sqrt{\frac{p(1-p)}{n}}$$

$$LCL = p - 3\sqrt{\frac{p(1-p)}{n}}$$

Note that the variance for the fraction defective is: $\sqrt{\frac{p(1-p)}{n}}$

(iv) C-charts or Number of Defects Chart

Often, a product is considered defective not just based on one measurement, but on the basis of a number of defects present in a sample. All the defects have to be taken into account before a decision to accept or reject it can be arrived at. In such situations, where the number of defects is the criterion for acceptance or rejection, a special kind of chart called the c-chart is used. The procedure is to take a sample of fixed size, count the defects in the sample (the number of defects is denoted by c), then plot the distribution of cs for all samples. A Poisson distribution for this will have a mean of c and a standard deviation of $\sqrt{c}$– and the control limits will be $c \pm 3\sqrt{c}$. Figure 5.6 shows a c-chart.

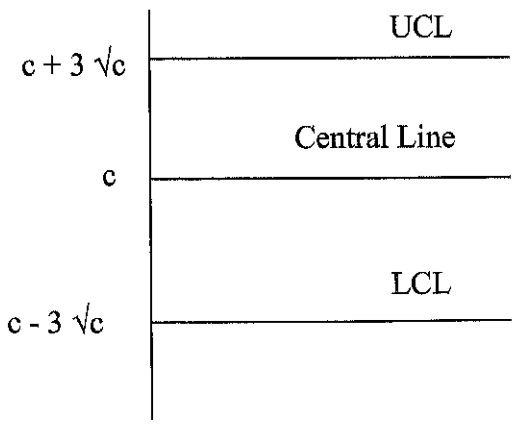

Fig. 5.6 The C-Chart

5.2.5 Total Quality Management

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Total quality management is a management approach that originated in the 1950s and steadily became more popular since the early 1980s. Total quality is the description of the culture, attitude and organization of a company that provides customers with products and services that satisfy their needs. The culture requires quality in all aspects of the company's operations, with processes being done right the first time and defects and waste eradicated from operations. The term total quality management (TQM) was first used by the Department of the Navy of USA in 1985. TQM is a method by which all the employees of an organization become involved in the continuous improvement of the production of goods and services. It is a combination of quality and management tools aimed at increasing business and reducing losses due to wasteful practices.

Total = Quality involves everyone and all activities in the company

Quality = Conformance to requirements (Meeting Customer Requirements)

Management = Quality can and must be managed

Therefore, TQM is a process for managing quality; it must be a continuously evolving way of life; a philosophy of perpetual improvement in everything we do. JIT and TQM have merged in theory as well as practice.

The International Organization for Standardization (ISO) defines TQM as, 'TQM is a management approach to an organization, centered on quality, based on the participation of all its members and aimed at long term success through customer satisfaction, with benefits to the members of the organization and the society.'

TQM seeks to integrate all organizational functions (marketing, finance, design, engineering, production, customer service, etc.) to focus on meeting customer needs and organizational objectives. It is based on the premise that employees want to contribute, and management must create a climate in which this can happen easily. TQM views an organization as a collection of processes. It postulates that organizations must strive to continuously improve these processes by incorporating the knowledge and experiences of its workers. The objective of TQM is to 'do the right things, right the first time, every time.' Some of the companies that have implemented TQM include Ford Motor Company, Phillips Semiconductor, SGL Carbon, Motorola and Toyota Motor Company.

Difference between 'Quality' Management and 'Total Quality' Management

Conventional quality management approach focuses on ensuring that the customers get a defect-free product or service. On the basis of product specifications which are developed according to customer needs, the approach now becomes product orientated, an alignment taken care of by the management through 'Quality Control' and quality assurance' activities. For this purpose, the management sets up a quality control or assurance department to ensure that the specifications are met. This approach often leads to a situation where the quality control department becomes saddled with the sole responsibility for product quality and attending to customer

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complaints in a company; production, marketing or other service agencies of the company are, thus, able to side-step responsibility for any deficiency.

In contrast, TQM approach focuses on the quality and appropriateness of processes that are carried out in the organization for producing and delivering the goods or services to the customers to their satisfaction. Here, emphasis is on 'customer satisfaction'. This is achieved by making all employees involved in those processes through 'internal customer' system. As a result, everybody in the organization feels responsible for the correct delivery and for meeting the customers' needs...or even ascertaining what they actually are, in the first place! It is a team approach to quality, right down the line.

Thus, the approach to conventional 'Quality' management is product or service orientation, whereas the approach to 'Total Quality Management' is product, process, people and customer orientation. For distinguishing the two approaches, product orientation is sometimes referred to as small-q-focus' and total quality involving product, process, people and customer orientation is termed as 'Big–Q-focus'.

Product orientation of quality management system often lacks in providing certain features crucial to continued business success, viz.:

- How to ensure quality superiority (of product or services) over the competition?
- How to retain customers?
- How to provide better value for money to customers?
- How to cope with changing needs of customers?
- How to get total commitment of all the people for continued customer satisfaction?

With the opening up of global competition, the focus is on winning and retaining customers with superior products and services. Marketing people know that it is better to retain one satisfied customer than to win ten new ones! With ever-increasing pressure for business performance, a narrow view of product orientation in quality management has become an inadequate survival response. A more comprehensive model of TQM encompassing customers, people, processes, policies and products of the company has become the 'new mantra' for organization-wide quality management.

Total quality management aims to ensure quality of all processes and activities in the organization in order to fulfil the expectations of customers. All processes under TQM strategy are, therefore, focused on customers' needs and driven by the people in the organization. Everyone associated with the business or processes are considered as 'links-in-the-chain', a chain running horizontally across all the functions in the organization, e.g., R&D, design, materials, operations, finance, marketing etc., to deliver what customers want or what have been promised to them. This is in contrast to conventional quality management where vertical boundaries of different functions often insulate outputs with respect to quality, cost, cycle time, delivery commitment, etc., adversely affecting the goal of customer satisfaction. These horizontal processes are managed in a TQM system by

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empowered cross-functional teams drawn from different functional areas concerned with the particular process. Cutting across boundaries, this cooperative, 'internal customer' modelled, people-driven approach ensures quality in a seamless flow that spans artificial barriers of function.

Evolution of Total Quality Management

The need for organized approach to quality was realised during World War II, because of inconsistent behaviour and functioning of arms and other ordnance. Soon after the war, WE. Deming and Joseph M. Juran, two noted 'Quality Gurus', started their pioneering studies on ways of addressing the quality problems of the post-war US industries and the reconstructed Japanese industries. 'Quality movement' started from this point onwards.

Deming's quality philosophy was based on improving products and services by reducing uncertainty and variability in the design and manufacturing processes. This moved the emphasis from 'product inspection' to 'process improvement' through statistical checking and data analysis advocated by him. In Deming's view, variation from specification of parts is the chief culprit for 'poor quality'. Poor quality not only means inconsistency in achieving quality specification, but also entails lot of hidden cost. As a result, companies fail to provide value for money for a product. This leads to customer complaints and dissatisfaction amongst them. This means loss of reputation, and declining sales and profits!

Post-manufacturing inspection of parts cannot be the solution to this problem; Deming advocated prevention of defects by instituting statistical checking *during* the manufacturing process. Similarly, a variation from any committed service leads to customer unhappiness and damages a company's image. To achieve reduced variations and increased conformance to specifications, he advocated a cycle as follows:

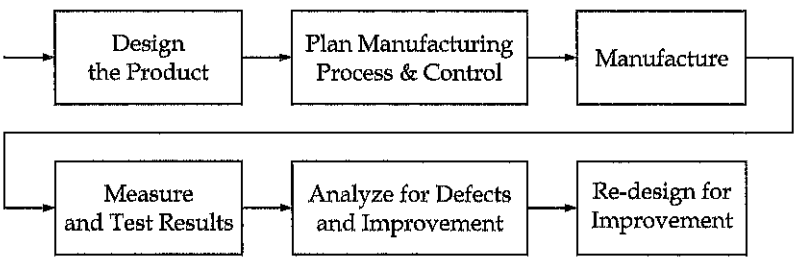

***Fig 5.7** Deming's Cycle*

These checks for ensuring quality later came to be known as: Deming Cycle' of *Plan-Do-Check-Analyse* (PDCA). Deming stressed that the steps to higher quality lead to: decreased cost, improved productivity and increased market share, the essentials of any successful business process. Seeds for the comprehensive quality management by 'total quality' concept lay in these pronouncements of Deming. The fourteen points of Deming are discussed in detail a little later.

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Juran taught quality principles to the Japanese in the 1950s, was a principal force in quality reorganization movement in the Japanese industry in the 1950s and 1960s. Juran focused on three major aspects of quality management, called the '**Quality Trilogy**' of Juran. These three aspects are as follows:

(a) **Quality planning**: A process for pre-setting the quality goals and preparation to meet the goals.

(b) **Quality control**: The process for ensuring that quality goals are being achieved during operations.

(c) **Quality improvement:** The process for breaking through to higher levels of quality for superior performance.

As per Juran, planning for quality starts with identifying customers (be they internal within the organization or external ones who ultimately use the goods or services) and their needs and developing the product quality features for meeting those particular needs. Juran identified **customers** as a critical factor in determining quality goals, and prescribed establishing control methods that meet the needs of customers and suppliers alike at a minimum combined cost. Quality control, as per Juran, should be invoked to (1) determine what to control, (2) establish measures and measurements, (3) set standards of performance, (4) evaluate performance versus goals or standards, and finally (5) take actions on the differences.

This, in a way, is parallel to Deming's emphasis on identifying the sources of variations and improving the work system.

Juran prescribed a detailed programme—a process for quality improvement. The process steps are as follows:

(1) Proving the need for improvement

(2) Identifying specific area or project for improvement

(3) Organizing data and facts for guiding the project

(4) Diagnosing the causes of problems

(5) Identifying and providing the remedies for the causes

(6) Checking that the remedies have solved the problem under the operating condition

(7) Taking steps to hold on to the improvements.

Thus, the philosophies of Deming and Juran provided the fundamentals of 'Total Quality' approach. According to this approach, customers are a critical factor in setting the quality goals. Their recommendations for emphasis on prevention of defects and quality improvement efforts by PDCA cycle have been the cornerstone of TQM practice. Any study of total quality management will be incomplete without discussions on the pioneering work of Deming and Juran, and their recommendations for effective quality management. Total quality management evolved from philosophies of these pioneering works. Following these philosophical approaches, TQM can be defined as the management of the whole chain of business processes in a company involving the quality of management, its people, processes, resources and commitment to do whatever is needed to be done to satisfy its

customers. This comprehensive approach to quality management not only creates a loyal and satisfied group of customers, but also leads to superior business results, which is the ultimate aim of any business organization.

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Approach to Total Quality Management

The approach to "Total Quality" management is based on the quality philosophies of Deming, Juran and Crosby. There could be some common differences in approach from organization to organization, but they have some common basic elements embedded in them. These basic elements are customer focus, strategic planning, enlightened leadership, continuous improvement, empowerment of people and teamwork. The principles of total quality management are concerned with the process of establishing these elements in the organization, with the spirit of those key elements permeating all processes. Thus, total quality philosophies effectively redefine management systems and processes, and evolve a new objective for an organization—performance excellence—leading to superior business results. A brief discussion of the objectives of total quality management prior to discussing the approach and principles will be helpful.

It may appear from previous discussions that the objective of TQM is customer satisfaction, but that is only one of the aims of the TQM process. Objective is a strategic goal, set by the organization through its strategic planning process for attainment of vision in the larger frame of the future. In this respect, the primary objective of TQM can be simply stated as to ensure **performance superiority** of the company over competitors by delivering total customer satisfaction. However, this objective of TQM in an organization cannot be achieved without planning a set of key processes, each having their own objectives. These objectives and their synergistic effect finally add up to the company's overall objective of superior business results. The key business processes for superior results can be planned as per the seven process categories of Malcolm Baldrige Quality Award model with the objectives of:

- making the organization market and customer focused;
- guiding the organization by its values, vision, mission and goals set through strategic planning process;
- changing the organization from function focused to customer focused, where customers' priorities come first in all activities;
- making the organization flexible and learning oriented to cope with change; change in marketplace, business environment, opportunities for improvements as well as organizational culture;
- making the organization believe in—and seek—continuous improvement as a new way of life;
- creating an organization where *people* are at the core of every activity, and are encouraged and empowered to work in teams and
- promoting a transparent leadership process to lead the organization to excellence in its chosen field of business;

These are a few important objectives achievable by suitably designing TQM processes. However, these are broad-based objectives and not a set of specific

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goals and objectives in the conventional sense where they are set with specific targets. For *specific* targets, goals and objectives have to be specific, measurable, attainable, realistic and time-bound (neatly condensed in an acronym: **SMART**). Therefore, when the organization aims for certain specific goals and objectives, they are set in each of the aforementioned areas in quantifiable manner. To illustrate a few examples of such objectives, an organization can take the following specific targets in some of the process areas.

- Increase in the level of customer satisfaction index from 65 to 75 by the end of first year of implementation of TQM.
- Introduction of "internal customer" system in 100% of processes and activities in the operations and marketing areas.
- All employees to be provided with 30 hours of training per year in statistical and quality improvement techniques.
- At least 15 "cross-functional" and empowered teams to be made functional by the end of first year of TQM, in areas of restructured customer-focused horizontal processes.
- Senior leadership to plan and execute at least three customer visits per month.

These goals and objectives are more specific as to what should be achieved in a company's journey towards total quality, but with a short-range target. They fulfil the condition of SMART as mentioned earlier. These specific objectives are often a part of annual plans and targets of a company.

To understand the importance of objectives and the need for setting appropriate targets in TQM processes, it would be worthwhile to refer to Figure 5.8 and understand the process of TQM with respect to *who*, *how* and *what*. The figure shows the interactive process of what drives the business, systems and the expected results. Systems give rise to processes, which are run by people. Therefore, there has to be some objective setting and targets relating to the development of people and employee satisfaction. Organizational objectives should be guided by the need to activate these components of the business process chain with a view to generating results.

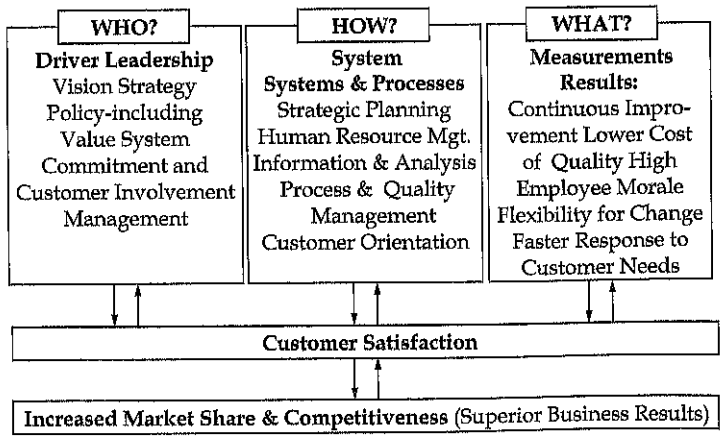

***Fig. 5.8** Process Chain for Total Quality Programme*

(Adapted from IBM's Market Driven Quality Process)

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The results achieved by setting appropriate objectives should lead to:

1. Continuous improvement of the organizational processes and outputs, which must be equal or superior to the competition.
2. Continual and relentless cost reduction, and value addition to products and services.
3. Continuous and relentless thrust for improvement of manufacturing processes, products and services.
4. Creation of an organizational work culture whereby everyone is involved in the process of customer satisfaction and value creation for its customers.

The sum total of the results should lead to superior business performance and make the organization one of the best in its class. The importance of creating this work culture will be evident from the lackluster performance of many public sector enterprises in India and elsewhere, not only in terms of profit but also in respect of employee satisfaction and their commitment to the organizational ambition of customer satisfaction. In spite of their manpower reduction and infusion of capital, many public sector companies failed to regain their viability, because lack of concern to change the work culture and attitudes. As a consequence, the organization, its employees and other stakeholders all stand to lose. TQM system can help to bring the necessary changes into an organization for performance and success. The spirit of total quality management is to create a win-win situation for all associated with the business of the organization, such as the suppliers, customers, employees, society and other stakeholders.

Scope of Total Quality Management

Before discussing the principles of total quality management, it is necessary to understand what TQM is and about its approach. Like any other management process, TQM is also based on certain philosophical postulates originating in the prescriptions of Deming, Juran and Crosby. Various recommendations made by these pioneering philosophers form the bedrock of total quality management principles. Nevertheless, industries and business—along with their business contexts—are constantly changing, as a result of which the approaches and processes of TQM have also undergone some modifications, not so much in concept but in practical approach. In view of this, it is necessary to define what TQM stands for in the present context of global competition, before embarking on a discussion of TQM principles.

In context of a business comprising number of complex functions, TQM can be described as a strategic process of seamlessly integrating all functions, activities and processes of an organization for continuous improvement of the quality of goods and services. The aim of this strategic process is customer satisfaction and the outcome is excellence in performance. Strategically, TQM system drives the business processes of a company for superior business results by changing the focus of all activities in the company to the customer.

To change the focus of all the activities to customers and customer needs, TQM system presumes that the:

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1. entire business process of a company is an unending "chain" for delivery of continuously improved products and services to the total satisfaction of its customers, and
2. individuals or groups within the company who are performing an activity or activities concerning those products or services are "links" in that chain.

More specifically, this means that each link in the chain that delivers products or services receives and provides some service or subset of the product from the preceding or succeeding links. Thus, each link has one or more supplier and customer in the chain, and quality has to be maintained at each of these points in order to satisfy their respective needs. Such a concept and linkage between people and processes in the organization helps in building the much-needed customer orientation throughout the organization, fundamental to TQM practice. Following this method, TQM strategy tries to build customer orientation in such a way that everybody in the organization feels involved and committed to the process of customer satisfaction.

This dedicated participation is crucial for the success of a company's business and superior performance, and this methodology simultaneously enables the company to transform the TQM process to people driven' system as well. TQM places people at the core of any system, driving it from within. TQM philosophy believes in people's ability, and holds that 'give people an opportunity to succeed: they will; give people clear goals: they will meet them'.

Thus, TQM is a process of promoting the integration of customers, people and the processes of the organization aimed at the common goal of 'customer satisfaction'. TQM systems bind people in the organization together by involvement and commitment towards this common goal. TQM is, thus, a people driven customer focused strategy, which is designed to lead to all-round performance excellence of the organization by integrating people, processes and resources together for achieving total customer satisfaction.

Principles of TQM

The concept of TQM is based on the following principles:

- Quality can and must be managed.
- Everyone has a customer and is a supplier.
- Processes, not people are the problem.
- Every employee is responsible for quality.
- Problems must be prevented, not just fixed.
- Quality must be measured.
- Quality improvements must be continuous.
- The quality standard is defect free.
- Goals are based on requirements, not negotiated.
- Talk life cycle costs, not front end costs.
- Management must be involved and must lead.
- Plan and organize for quality improvement

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In other words, processes must be managed and improved. This involves:

- Defining the process
- Measuring process performance (metrics)
- Reviewing process performance
- Identifying process shortcomings
- Analysing process problems
- Making a process change
- Measuring the effects of the process change
- Communicating both ways between supervisor and user

Concept of Continous Improvement by TQM

TQM is concerned with continuous improvement in all work, from high-level strategic planning and decision-making, to detailed execution of work elements on the shop floor. It reinforces the belief that mistakes can be avoided and defects can be prevented. Continuous improvement means not only improving results, but more importantly improving capabilities to produce better results in the future. A central principle of TQM is that mistakes may be made by people, but most of them are caused, or at least permitted, by faulty systems and processes. Therefore, the root cause of such mistakes can be identified and eliminated by changing the process.

There are three major mechanisms to prevent such mistakes:

- Preventing mistakes (defects) from occurring (Mistake - proofing or Poka-Yoke).
- Where mistakes cannot be absolutely prevented, detect them early to prevent them from being passed down the value added chain (Inspection at source or by the next operation).
- Where mistakes recur, stopping production until the process can be corrected, to prevent the production of more defects. (Stop in time).

TQM encourages participation amongst shop floor workers and managers.

Deming's 14 Points

W. Edwards Deming was an American statistician who is credited with the invention of total quality management (TQM) and also the rise of Japan as a manufacturing nation. Deming went to Japan just after World War II to help set up a census of the Japanese population. While he was there, he taught statistical process control to Japanese engineers—a set of techniques which allowed them to manufacture high-quality goods without expensive machinery. In 1960 he was awarded a medal by the Japanese Emperor for his services to the industry. Thereafter, Deming returned to the US and spent some years in obscurity before the publication of his book *Out of the Crisis* in 1982. In this book, Deming set out fourteen points which, if applied to the US manufacturing industry, would save the US from industrial doom at the hands of the Japanese.

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The fourteen points of Deming are outlined here:

1. Create constancy of purpose towards improvement: Replace short-term reaction with long-term planning.
2. Adopt the new philosophy: The implication is that management should actually adopt his philosophy, rather than merely expect the workforce to do so.
3. Cease dependence on inspection: If variation is reduced, there is no need to inspect manufactured items for defects, because there would not be any.
4. Move towards a single supplier for any one item: Multiple suppliers mean variation between the raw materials.
5. Improve constantly and forever: Constantly strive to reduce variation.
6. Institute training on the job: If people are inadequately trained, they will not work the same way, and this will introduce variation.
7. Institute leadership: Deming makes a distinction between leadership and mere supervision. He said that supervision is merely target based.
8. Drive out fear: Deming sees management by fear as counter-productive in the long term, because it prevents workers from acting in the organization's best interests.
9. Break down barriers between departments: Another idea central to TQM is the concept of the internal customer, that each department serves not the management, but the other departments that use its outputs.
10. Eliminate slogans: Another central TQM idea is that it is not people who make the most mistakes, it is the process they are working within which allow errors. Harassing the workforce without improving the processes they use is counter-productive.
11. Eliminate management by objectives: Deming saw production targets as encouraging the delivery of poor-quality goods.
12. Remove barriers to pride of workmanship: Many of the other problems outlined reduce worker satisfaction.
13. Institute education and self-improvement.
14. Transformation is everyone's job.

5.2.6 Six Sigma

Organizations have proceeded beyond TQM and are now adopting six sigma as a solution to produce products that are free of defects.

Six sigma is a data driven, structured problem-solving methodology for solving chronic issues facing a business. It is a breakthrough management process that is used to improve a company's performance by variation reduction. The method encompasses breaking down customer requirements into steps to pinpoint problem areas in a process. This results in the reduction of defects and sustenance of process improvement. Six sigma is defined as a broad and comprehensive system for building and sustaining business performance, success and leadership.

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The key focus of six sigma is on processes, but with measurement of both processes and products. Six sigma advocates variation as an enemy of quality. With six sigma, companies strive to achieve the statistical six sigma goal of near perfection as measured at defects per million opportunities (DPMO). It is calculated as follows:

$$\text{DMPO} = \frac{\text{No. of Defects} \times 10,00,000}{\text{No. of opportunities for error / unit} \times \text{No. of units}}$$

Here, defect is any item or event that does not meet the customers' requirement

The six sigma process is basically as follows:

1. Six sigma starts with the customer, that is, a clear definition of customer's requirements.
2. Once the requirement has been defined, defect too can be defined and one can measure almost any type of activity or process. Late deliveries, incomplete shipments, part shortages, etc., are some examples of defects.
3. Set a goal. Having an entire organization focused on a performance objective of three defects per million opportunities can create significant momentum for improvement.

The difference between TQM and six sigma is that TQM programmes focus on improvement in individual operations with unrelated processes, whereas six sigma focuses on making improvements in all operations within a process.

Six Sigma Themes

The six themes or doctrines on which the entire philosophy is based are stated below:

- **Theme one—Focus on customer**

In six sigma, customer focus is the top priority. Six sigma improvements are defined by their impact on customer satisfaction and value.

- **Theme two—Data and fact-driven management**

Six sigma begins by outlining the steps necessary to gauge business performance. It then uses the data to build an understanding of the key variables for optimizing results.

- **Theme three—Focus on process**

Six sigma considers the process as the key vehicle of success irrespective of whether the organization is producing a product or a service.

- **Theme four—Proactive management**

Proactive management means defining clear goals and reviewing them frequently, setting clear priorities, focusing on problem preventions instead of fire fighting, questioning why one does things instead of blindly defending them as 'how one does things here,' etc.

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• **Theme five—Boundary-less collaboration**

Six sigma emphasizes total collaboration within the company, with their suppliers as well as customers. It seeks to eliminate disconnect and competition between groups that should be working for a common cause, i.e., providing value for customers.

• **Theme six—Drive for perfection, intolerance for failure**

No company will get anywhere close to six sigma without launching new ideas and approaches, which always involve some risk. If people who see a possible path to better service, lower costs, new capabilities, etc., are too afraid of the consequences of mistakes, they will never try.

Successful implementation of six sigma is based on sound personnel practices as well as technical methodologies. A brief introduction of practices that are commonly followed in six sigma implementation is given here.

Executive Leaders and Champions: Champions are drawn from the rank of executives and their job is to identify appropriate metrics in the project and make certain that the improvement efforts do not lose focus of company objectives. They promote it throughout the organization and take ownership of the processes that are to be improved.

Professionals are given training in six sigma techniques and given martial arts titles reflecting their skills and roles. Different companies use different combinations of these belts. Thus one has,

Black belts: They lead a six sigma improvement team. They are also responsible for providing the proof that the problems are fixed permanently.

Master black belts: They perform the same functions of black belts but for a larger number of teams.

Green belts: They are employees who have received enough six sigma training to participate in a team or in some companies to work individually on a small-scale project directly related to their own job.

It is the responsibility of the top management to set the objectives for improvement. Continuous reinforcement and rewards are essential in order to sustain the interest on six sigma. Six Sigma forms a major part of GE's operations. The company spends over $600 million on six sigma projects every year, mostly on salaries for the experts and employees, who have undergone basic training. They believe that each step or activity in the company represents an opportunity for defects to occur and six sigma programmes seek to reduce the variation in the processes that lead to these defects.

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Check Your Progress

1. State the objectives of quality assurance.
2. What are appraisal costs?
3. What are the major reasons for external failure costs?
4. Define quality control.
5. State three functions of quality control.
6. What are the three aspects of assuring quality?
7. What are the two ways in which statistical process can be monitored?
8. What are the inclusions of acceptance sampling plan?
9. What are the three ways in which the OC curve can be made strict?

5.3 SAFETY MANAGEMENT

Safety is not a resource nor an influence, it is not even a procedure and it is certainly not a program. It is a state of mind, an atmosphere that must become an integral part of each and every procedure that the company has. Every business has the legal responsibilities to ensure the health and safety of the employees and other people affected by their business activities, such as customers and suppliers. But the right approach is not just about doing the minimum required to comply with the legal requirements. It can also benefit your business. Poor health and safety leads to illness and accidents and significantly affects your business. Effective health and safety practices pay for themselves. They also improve your reputation with customers, regulators and your own employee. In case an accident occurs at the work locations, the work is stopped right away. When the work is resumed, the performance is greatly influenced for covering losses and recovering delayed works. The employer shall pay medical treatment fees, hospitalization expenses and compensation fees, and repair damaged facilities or broken machine. In case of construction site, the accident is also likely to affect the image of the organization. Also, the client is responsible for the accident as the plant owner. Construction work involves a series of occupational risks, which are specific to the sector. A specific approach to the occupational safety and health in the construction industry is also required as a result of the temporary character of its work place. Continuous changes of work sites also call for a specific approach to occupational safety and health management at the construction site, where planning, coordinating and budgeting becomes extremely important.

The risks, construction workers face largely is the result of the poor planning. Hence, it is necessary to organize construction workers at each stage during the project. Each of the construction work and operation should be planned ahead of time. In addition, the workers safety and productivity and the quality of the work

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can only be guaranteed if there are sufficient skilled workers, appropriate tools and equipment at a given time.

One of the best ways to approach planning for construction safety is to write down the measures for hazard prevention (control measures) that are applicable to the particular project site. As experienced in a construction site, sub-contracting of a job reaches to several levels. This sort of risk transfer business becomes complicated for achieving safety in the sites. Every contractor shares the responsibility or no one share the responsibility of safety. The safety management plan gives an overview of best ways to approach in planning for construction safety. This ensures that good planning can eliminate the causes of many potential accidents at project site.

Secondary effect may also protect the following:

- Co-workers
- Employers
- Suppliers
- Family members
- Customers
- Nearby communities

Need for Safety

Safety can be defined as identifying the hazards and controlling them. It is the degree of preventive measures/protection, which are taken to control the hazards.

Hazard is the inherent property of substance by virtue of which it may cause harm to a man, machine, environment, system, animal etc. It can also be defined as a characteristic of the plant/process/system representing potential (possibility) of an accident.

- If you are killed in an accident, your life finishes, and your family and relatives will suffer their lives with troubles. When you are injured, you will feel a pain, suffer after effects and give worries to people around you. You cannot be engaged in the same job and your income will be reduced.
- In case an accident occurs during construction, the construction work gets stopped right away. When the work is resumed, the site is greatly influenced for covering losses and recovering delayed works.
- To the client who ordered the work, the accident is not an honourable matter. Also he is responsible for the accident as the plant owner.
- The contractor who contracted the work has responsibility for the administration and issues a report to the government. In some cases, the representative is punished and the company is prohibited for business activities.

The reasons for establishing good occupational health and safety standards are frequently identified as the following:

- **Moral:** An employee should not have to risk injury or death at work, nor should others be associated with the work environment.
- **Economic:** Many governments realize that poor occupational health and safety performance result in cost to the state. Employing organizations also sustain costs in the event of an incident at work.

- **Legal:** Occupational requirements may be reinforced in civil law and/or criminal law. It is accepted that without the extra 'encouragement' of potential regulatory action or litigation, many organizations would not act upon their implied moral obligations.

Occupational health and safety officers promote health and safety procedures in an organization. They recognize hazards and measure health and safety risks, set suitable safety controls in place, and give recommendations on avoiding the accidents to management and employees in an organization.

Some Specific Terms of Safety Management

Some specific terms related with safety management are as follows:

- **Accident:** Accident refers to the unplanned, unexpected and uncontrolled event, which may result either in injury or in property damage or in both. It is an undesired event that results in physical harm to a person or damage to the property.
- **Near miss:** Near miss refers to an incident where no injury, ill health or fatality occurs.
- **Hazard:** Hazard is a dangerous condition, potential or inherent, which can bring about an interruption with an expected orderly progress of an activity.
- **Risk:** Risk is degree of a hazard. It is combination of hazard consequences and its frequency of occurrence. It is a measure of potential in terms of probability and magnitude of loss.

Responsibility of Management Towards Safety

Health, safety and environment (HSE) management is a line responsibility requiring active participation of all levels of management and supervision.

Individual HSE roles and responsibilities, along with task and target shall be distributed to the individuals for action, as described Table 5.3.

Table 5.3 Actions of Individuals in Management

Manager

NO.	TASK	TARGET
1.	Responsible for completion of the project with total implementation of the company's HSE policy requirement, HSE management system and requirements of this plan and comply with the relevant statutory rules and regulations.	Project duration
2.	Responsible for ensuring that all staff and workmen are competent to perform their tasks safely in compliance with HSE management system and this plan requirement.	Project duration
3.	Ensure that sufficient resources are available at site.	Project duration
4.	Site HSE inspection and HSE plan implementation monitoring	Project duration
5.	Investigate all high potential incidents and non-compliance and ensure immediate remedial action to stop recurrence.	As & when notified

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HSE manager

NO.	TASK	TARGET
1.	Supplement site HSE inspections and relevant HSE training at the jobsites in co-ordination with HSEOFFICER	Once in Six Months
2.	Examine all serious accidents/dangerous occurrences and suggest precautionary measures at sites	As and when required
3.	Coordinate purchase and quality control activities related to PPE/safety gadgets	After receiving MR
4.	Monitor all HSE OFFICER activities and coordinate with clients, project incharges, CPMs, CPLM, service unit heads	As and when required
5.	Organize campaigns, competitions and other special emphasis programmes to promote HSE at workplace	During January & as and when required
6.	Conduct HSE audit and inspection during the project duration.	As per schedule
7.	Evaluate the legal compliances and ensure applicable legal and other requirements are fulfilled	Bi-annually

Unsafe Acts and Unsafe Working Conditions

An unsafe act (UA) is a departure from an accepted, normal or correct procedure or practice, which has in the past actually produced injury or property damage or has the potential for producing such loss in the future.

An unnecessary exposure to a hazard or conduct reducing the degree of safety normally present. Not every UA produces an injury or loss, but by definition, all UAs have the potential for causing future accidents. An unsafe act may be an act of commission (doing something which is unsafe) or an act of omission (failing to do something that should have been done).

A few unsafe acts generally observed are as follows:

- Cleaning, oiling, adjusting or repairing of moving, electrically energized or pressurized equipment
- Failure to use available personal protective equipment
- Failure to secure or warn
- Improper use of equipment (overloading etc.)
- Improper use of hands or body parts (gripping objects insecurely, using hands instead of hand tools etc.)
- Making safety devices inoperative
- Operating or working at unsafe speed (Running, throwing material, jumping from elevation etc)
- Taking unsafe position or posture (under suspended loads, riding on forks of lift, truck etc.)
- Unsafe placing, mixing, combining etc.

Causes leading to unsafe acts

- Lack of knowledge or skill
- Improper attitude
- Physical or mental deficiency

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Detection and correction of unsafe acts

- Safety observations
- Careful on jobs with history of accidents
- No leniency in observance of safety rules

Elimination of unsafe Acts

- Initial job instructions
- Priority to engineering revision over work method
- Stressing the after effect of an accident
- Appeal to the worker's love for his family
- Showing disapproval of unsafe acts
- Education

Unsafe conditions

Any physical state which deviates from that which is acceptable, normal or correct in terms of its past production or potential future production of personal injury and/or damage to property or things. Any physical state which results in reduction in the degree of safety normally present. It should be noted that accidents are invariably preceded by unsafe acts and/or unsafe conditions.

A few unsafe conditions generally observed are as follows:

- Defect of agencies

Causes leading to unsafe conditions

- Created by workers (removal of guards)
- Created by normal use (frayed electrical insulation)
- Poor design
- Omission on the part of the management

Detection and correction of unsafe conditions

- Regular and planned safety inspection
- Conditions such as material left in the passage, guard which has been removed, improperly stacked material etc can be eliminated without the assistance of any one in higher management.
- Reporting to appropriate authority and strive to eliminate the hazard
- Priority to eliminate hazardous conditions
- Better not to depend too much on human elements

Multiple causation theory

Behind every accident there lies many contributing factors, causes and subcauses. The theory of multiple causation is that these factors combine together in a random fashion, causing accidents. Our investigation of accident should identify as many possible causes so that proximate as well as root causes of the accident can be identified and rectified.

Unsafe act and unsafe condition are the proximate causes. If you deal only with unsafe act and/or unsafe condition you deal only at symptomatic level. To

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affect permanent improvement one must deal with root causes of accidents.

Root causes are those which would affect the permanent results when corrected. They are those weaknesses which not only affect the single accident being investigated, but also might affect many other future accidents and operational problems. Root causes often relate to the management system. They may be due to the management's policies, its procedures, supervision and its effectiveness, training, etc.

Some root causes could be the lack of inspection procedures, the lack of management's policy, poor definition of responsibilities (supervisors did not know they were responsible for removing the defective ladder), the lack of supervisory or employee training.

Cost of Accidents

Normally, the cost involved or the losses in an accident is not evident to the full extent and hence people do not have an awareness about it. However, for sure the cost of accident is the driving factor in any accident prevention programme as financial language is understood by the management more effectively. The cost of accident has two components, which are as follows:

- **Direct cost:** It is a definite outlay of money and represents the compensation paid to accident victims, medical expenses borne by the management towards the injured persons, insurance premium paid etc. This cost is definite and can be insured.
- **Indirect (uninsured) cost:** It is not a definite outlay of money. However, the indirect cost is several times higher than the direct cost. Direct cost is just like a tip of an iceberg whereas indirect cost is hidden part of the iceberg (Figure 5.10).

  Indirect cost varies from factory to factory, nature of injury, etc.

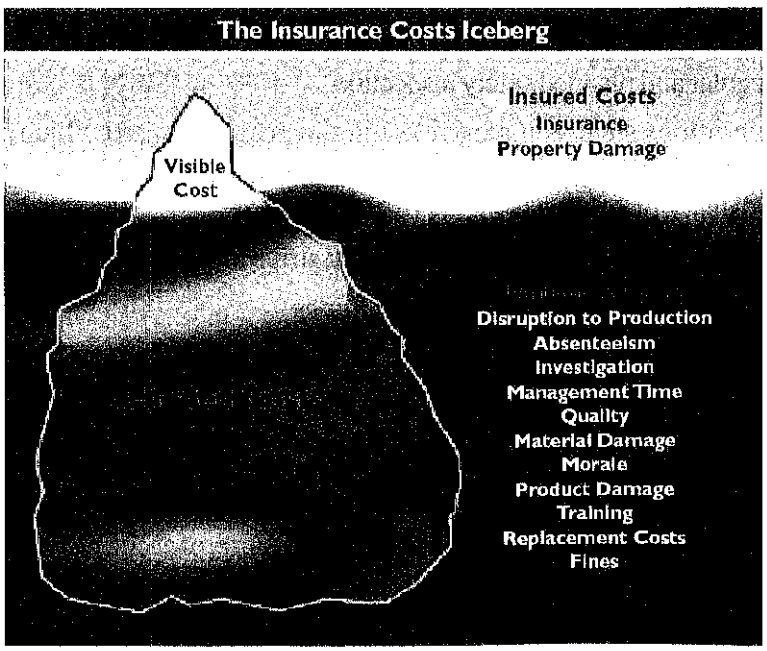

Fig. 5.10 Insurance Costs Iceberg

1. Cost of the working time lost by the workers who were not injured. This is equal to No. of workers × Average amount of time lost (in hrs) × Average hourly wages.
2. Net cost to repair/replace or straighten up material or equipment that was damaged in the accident.
3. Cost of wages paid for working time lost by the injured person other than the compensation paid.
4. Extra cost due to the overtime work necessitated by an accident is equal to Overtime wages – normal wages + extra cost for supervision and utilities.
5. Cost of wages paid to supervisors while there time is required in activities necessitated by the accidents like supervisors for accident investigation is equal to total time spent (hrs) × Hourly wage rate of supervisor.
6. Wage cost due to decreased output of injured person after his return to work assessment as per supervisor's report.
7. Cost of learning period of new worker. (wages of the trainer for the time spent by him + wages losses due to reduce output of trainees).
8. Uninsured medical cost borne by the company.
9. Cost of the time spent by the senior officers and secretarial staff on investigation or processing of compensation and application forms.
10. Miscellaneous unusual costs like
    (i) Public liability claims
    (ii) Loss of profit on contracts (if within stipulated period work not completed)
    (iii) Orders lost
    (iv) Cost of excessive spoilage
    (v) Demurrage

5.3.1 Role of Management, Supervisors and Workers in Safety

Responsibility of safety has to be shared to achieve optimum results and organizational goals at the project site. Top executive of the site should act in this direction so as to achieve his targets in safety. The safety manager/engineer is responsible for developing, implementing and monitoring of the management plan. Department chiefs are responsible for developing department-specific safe operating procedures (SOPs) and its implementation and monitoring. All staff, workers and other personnel are responsible for obeying the site specific safety rules.

Duties and responsibilities of the key members of the organization have to be outlined to make the management plan goal specific. For an example, roles and responsibilities of some of the key members of the project site are being discussed in the subsequent sections.

(i) Project Manager/Site Incharge

The Project Manager/Site Incharge is the key figure at the project site. He should monitor the contractual obligations of the company and the various sub-contractors

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on the job; one of the obligations is safety. The project manager is responsible for training and directing of site engineers for their safety responsibilities.

The project manager should take an active part at the safety committee. He should be made chairman of the safety committee.

The project manager coordinates activities with the safety officer regarding the company and sub-contractor performance and takes the required steps to ensure safety at the project site.

(ii) Production Manager(s)

The production manager is directly responsible for the proper coordination and implementation of the site activities and is also responsible for the establishment of the project safety programme. This programme is according to the company policy with the recommendation and assistance of project manager/site in-charge. Accident procedures will be included in all the activities by the application of correct safety planning. The production manager should set a pace for the safety programme and should act as follows:

- Supervise all safety activities on the project in cooperation with the safety engineer/officer
- Follow closely the safety committee's activities
- Provide full support to the safety programme by fully advocating it
- Ensure full safety compliance by all departments
- Maintain the awareness of the project's safety rules
- Enforce the disciplinary actions necessary to develop a good functioning of a safety programme
- Carry out accident investigation and ensure that proper reports are handed over to safety engineer
- Activity coordination with the planning of operations which have potential risk

(iii) Construction Supervisors

The site supervisors are directly responsible for the control of activities performed by the workers at the construction projects. They play a key role in the implementation and maintenance of an effective job site safety programme.

The standards for a good safety programme are established by the project manager and the safety engineer. The actual performance of the safety programme is with the construction supervisors also having direct contact with the workers. The construction supervisors are responsible for a wide range of activities. They must plan their safety activity with the same care and efforts as they do other portions of their work programme.

The specific safety responsibilities of the construction supervisors are as follows:

- Review all work and all new personnel for safety needs. Complete familiarization with safety requirements is an integral part of the total job responsibility.
- Monitor continually all the safety attitudes of the foreman, his responsibility towards safety.

- Insist on compliance with all established safety regulations before and during performance of work.
- Conduct safety inspection and make corrections on daily basis.
- Participate in safety meetings.
- Ensure that workers safety training is provided.
- Assist in accident investigations to ensure proper reporting and documentation and ensure prompt corrections to eliminate recurrence of accidents/incidents.

(iv) Safety Committee

Every construction site should have a site safety committee where 500 or more workers are engaged in construction activities at the project site as outlined in Section 38 of building and other construction workers (regulation of employment and condition of service) Act, 1997.

The formation of a safety committee should be constituted by taking equal representatives from workers and management. The duties and responsibilities of a safety committee are as follows:

- Identifying situations that may be a source of hazard to the workers
- Making recommendations regarding safety and health measures
- Identifying workers not using protective devices or the required safety measures
- Reporting any unsafe conditions to the respective department and safety engineer

(v) HSE Engineer/Officer (HSEO)

The HSE engineer/officer is responsible for the site health, safety and environment (HSE) programme. He must be a change agent in the project activities, assist the project manager and actively promote the HSE effort.

The HSE engineer/officer must take the following responsibilities at the sites:

- Co-coordinating the site safety effort along with other line people.
- Keeping the site management aware of person of the HSE programme and making recommendations for site related HSE improvements.
- Administering HSE policies and procedures within the framework of the HSE instruction with particular emphasis on potential hazard operations.
- Proposing programmes to implement and accomplish short and long term site HSE objectives and motivate employees to participate to achieve these objectives
- Maintaining and continuing HSE inspection programmes and reporting the findings and recommendations to the appropriate supervisor/sub contractor
- Facilitating the creation of a safety committee/site safety committee and coordinating their activities
- Supervising HSE training in accordance with the site requirements
- Coordinating with the site medical centre and rescue services

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- Establishing a fire prevention programme, supervising and training a site fire brigade
- Investigating all accidents, injuries, fires, property damage and other safety related incidents and making the required reports
- Assisting sub-contractors with their HSE programmes to meet various site HSE requirements
- Evaluating the need for safety, first aid and fire protection equipment needed on the job. Also ensure that safety equipments are maintained in good condition
- Effectively displaying and maintaining publicity material, posters, safety signs, banners and distributing safety literatures
- Administering and monitoring the site hazardous waste programme
- Attending pre-job meeting with the company and the sub-contractors, reviewing with them the HSE policies and procedures requiring their compliance
- Planning the job site HSE programme so that timely implementation of required site HSE policies and procedures can be achieved
- Maintaining current knowledge of HSE regulations
- Maintaining knowledge of current state of art concepts of accident prevention and continuously contributing to upgrade the site HSE effort

(vi) HSE Supervisors/Stewards

HSE stewards are the eyes and ears of HSEO. Some of the responsibilities of HSE supervisors are as follows:

- The main task of an HSE supervisor is to assist the HSE officer for keeping vigilance on the project/site, informing any untoward incident to HSE officer and site in charges, providing first aid in case of emergency.
- Create HSE awareness through PEP talks.
- Carry out general HSE inspection of the work area, work method, etc. for identifying the unsafe acts/unsafe conditions and taking necessary action for removal of deficiency. Apprising the HSE officer for further action.
- Inspect ELCB, electrical distribution boards, electrical hand tools etc. available in their respective area for ensuring good condition.
- Check the driving license of the drivers and reverse horn of all vehicles coming to their respective area

5.3.2 Motivation for Safety

The changing face of the workplace and composition of the work force have necessitated new approaches to workplace safety that focus on motivating trainees to learn and practice safe workplace behaviours. Unfortunately, most knowledge regarding work motivation is theoretical and not directly usable by safety training professionals. The notions of intrinsic and extrinsic motivation can help safety training professionals understand industrial/corporate problems such as the decline in the work ethic and can help them prepare workers for future workplaces, which are

anticipated to include more teamwork and less supervision. Research on intrinsic motivation has established the effectiveness of using goals, incentives and feedback as reinforces of the intrinsic motivation. Research has also shown that intrinsic motivation is increased through both physiological and psychological design/redesign of jobs to include motivators. Among the various intrinsic characteristics attributed to the job that have been developed and that should be considered when safety training is an issue are the following: achievement, activity, authority, creativity, importance, independence, interest, knowledge of results, personal growth and development, promotion opportunity, recognition, responsibility, service to others, utilization and variety Figure 5.11.

- **Motivation:** An impulse, emotion, desire, or psychological need acting as incitement to action.

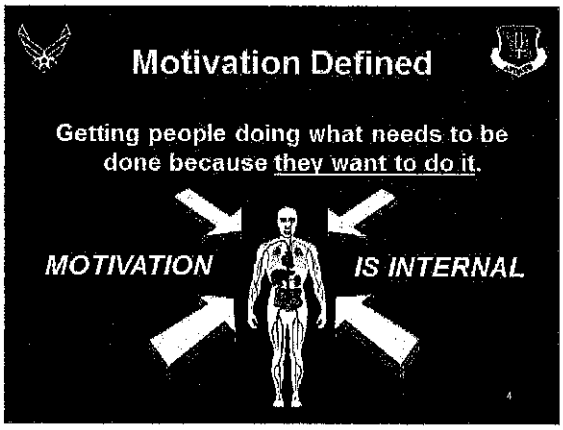

Fig. 5.11 Internal Motivation

Motivation chain contributes

The contributes to a motivation chain are as follows:

- Ability
- Desire
- Reward
- A lower level need must be satisfied before the next higher level becomes important in motivating behavior.
- Only relatively unsatisfied needs are capable of motivating people.
- **Survival needs:** For example food, clothing and shelter
- **Safety needs:** For example
  - o Physical safety: Safe from harm
  - o Psychological safety: Job, retirement, savings accounts
- **Belonging needs: For example,** love, acceptance, approval, warmth
- **Self Actualization**
  - o Self-fulfilment
  - o Personal growth
  - o Realizing potential

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Ensure a safer work environment with motivational quantitative measurement

By isolating an employee's motivations through assessment, a firm can better identify, develop and reinforce each aspect of an employee's career journey. Regardless of the industry, safety challenges should be addressed towards the individual participant's motivations. A person with high negative motivations may be safe for years until the spouse leaves or the child develops a drug problem—then this person is waiting for an accident to happen. By using this simple methodology, the career will be fruitful for both participants.

Ensure a more productive work environment with motivational based understanding

The management has a responsibility to provide a work environment that is favourable to productivity and profitability. The management should not allow the employees to behave as they wish, as some behavioural specialists claim. Win – Win scenarios provide an opportunity for a worker to enjoy what he or she does while providing the company a good return for the investment of wages. When an employee's motivational needs are addressed his or her attitude is better, work performance improves and the environment is safe because the worker cares.

Ensure developing optimum environment using 'best fit' analysis training

Identification and placement based on assessment and screening is vital for long term productivity and safety. However, placement based on assessment is only the first step. Motivational-based training developed for an individual participant is also vital for long-term success.

Traditional approach

The condition is identified and corrected but the source of the unsafe condition (employee) persists (Figure 5.12).

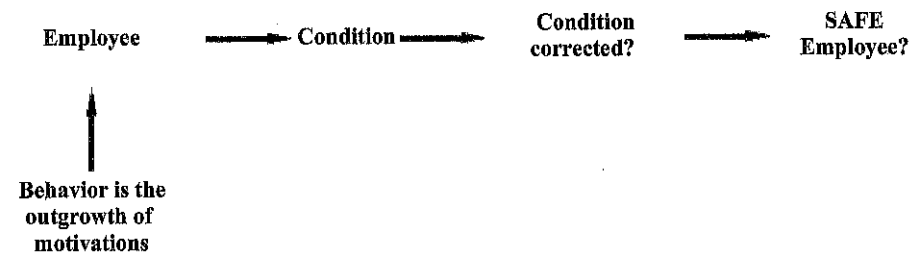

Fig. 5.12 Traditional Approach

Behavioural approach

The behaviour is identified and corrected with no assurance of continued long-term safe behaviour of the employee (Figure 5.13).

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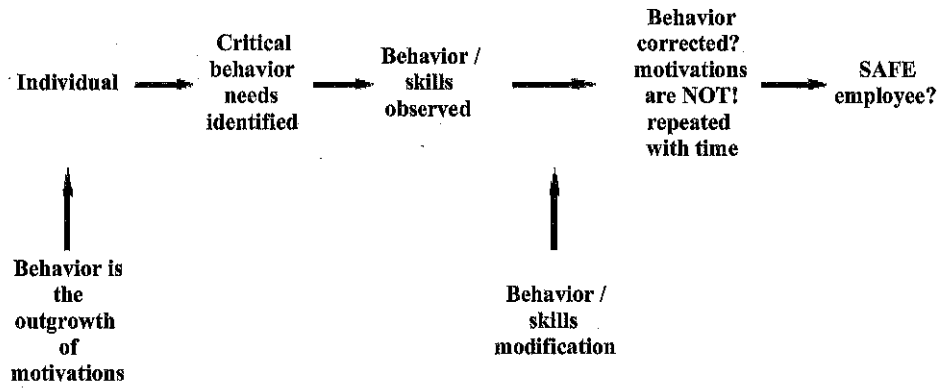

Fig. 5.13 Behavioural Approach

Motivational approach

The source of unproductive behaviour (motivation) is identified and corrected to ensure long term safe behaviour both in a personal and corporate manner (Figure 5.14).

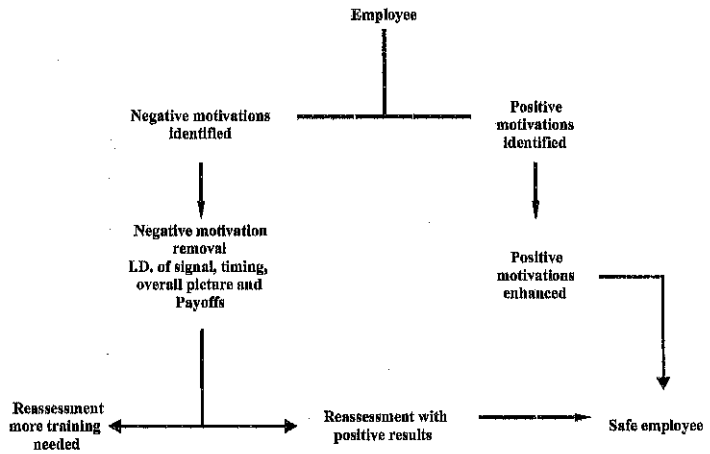

Fig. 5.14 Motivational Approach

Motivating employees to take part in the company's safety programs is important in the maintenance of a safe and skillful working atmosphere. Safety programs are customized according to the industry the business is in. However, irrespective of the workflow that is made use of to suit the requirements of the company, a safety program's effectiveness depends its suitability to the several factors under consideration: the kind of business, the size and location of the company, the number and distribution of workers and the resources and equipment made use of by the workers.

Setting the company vision

Setting the right goals and sharing them with the workers to maintain a solid vision in the workplace. A mantra, a slogan or a tag line specific to the company vision can function as a guide and inspiration to the employees. This should also be incorporated into the safety programs to be implemented in the workplace.

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Consult safety experts, industry specialists, architects and engineers along with the workers themselves in order to make specific safety programs fit the company. These should correlate to the company vision. This enables the employees to relate with the program in a better manner, who will be motivated to follow such safety procedures for their own and the company's enhancement.

Promoting safety programs

Information dissemination is important for the success of any company safety program. The workers must have knowledge about the details of these programs to implement them in their everyday task. Provide handbooks and internal marketing materials like posters, fliers, brochures or even videos and giveaway items like key chains, stickies and memo pads for informing and reminding them about these programs and their importance in maintaining a perfect workplace.

Incentives

Good safety programs work from the bottom up. One helpful tip in motivating workplace safety to employees is by offering incentives to them. Incentives sensitive to the workers' needs and interests can further encourage participation in such safety programs.

In creating the incentive programs, part of the safety policy should be a clear system of rewards based on safety performance while in the workplace. The workers should acknowledge the concept that behaviour is the means to safety, and incentives are a proven means to improve behaviour. An incentive can be changed periodically as the program matures or when it requires specific changes. A good incentive reward amount should be around 3 to 5 per cent of the salary.

Reports and meetings

In making company reports and updates, include information about the safety programs and incentives to remind the employees about them. Feedback is vital in improving the safety programs and incentives, so encourage employee comment following dissemination of the reports.

Seminars and workshops

Regular seminars or workshops, irrespective of the departments or the employees of the company, can provide the employees with a better idea of maintaining a safe workplace. The company needs to be proactive instead of being reactive. This signifies that dangerous behaviour be identified and education and incentive programs be used for reducing or eliminating it. This is a more complete and effective process than simply tracking accidents as they occur in the workplace.

5.3.3 Industrial Safety

Accidents present a serious problem and can possibly have a crippling effect on the operations of the organization, in addition to heavy losses by way of workmen's compensation, lost production and possible morale of the workforce.

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Though the cost to individuals is a major concern, production losses and property damage attributable to work accidents are much higher. This need not be the case, as it is both possible and practicable to control industrial accidents.

The Indian Factories Act, 1948 has the following objectives:

- To protect human beings from being subjected to unduly long hours of bodily strains of manual labour.
- Employees should work in healthy and sanitary conditions as far as the manufacturing process will allow and precautions should be taken for their safety and prevention of accidents.

The terms 'accidents' and 'injuries' are often used interchangeably. Actually, the meanings are somewhat different. An industrial accident may be defined as an unintended occurrence arising out of employment that either causes personal injury or causes property damage or interference with production or other business activity under such circumstances that personal injury might have resulted.

Accidents do not just happen; they are caused. High public awareness, stricter statutory regulations and a responsive judiciary make it necessary for stores to upgrade their safety management capabilities, which include identifying, assessing, communicating and controlling risks. The prime purpose of accident prevention is to prevent personal injuries and deaths. Apart from this, there are intangible gains to be made from accident prevention like morale and public relations.

Any effective safety programme must first isolate the causes for accidents. Practically, every accident is caused by more than one factor . Unsafe physical conditions are those factors, which are present due to defects in condition, errors in design, faulty planning or omission of essential safety requirements. These may be grouped into seven categories:

1. Inadequate mechanical guards on moving equipment
2. Operating poorly maintained or defective equipment
3. Unsafe design or construction
4. Hazardous processes or operations
5. Inadequate illumination of workplace
6. Inadequate ventilation in workplace
7. Improper or inappropriate safety apparel or accessories

For example, the chemical industry is a point in case. Many prominent chemical industries producing soda ash, caustic soda, carbon black, acetic acid, phenol use large quantities of flammable, explosive, toxic or corrosive materials. The requirements related to storage and handling of many of these chemicals, in terms of safety, should be considered when assessing its dangers and benefits. Safety is an attempt to prevent all hazardous occurrences and eliminate unsafe conditions.

Some guidelines for safety in stores are given in Exhibit 5.1. This has been adapted from a note on plant safety written at IIM(A).

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***Exhibit 5.1** Guidelines for Safety in Stores*

Layout & Design: Some considerations that should be kept in mind while approving the design are:

- Adequate aisle and storage space to minimize materials handling hazards
- Location of fuses and electricals at proper locations away from hazards
- Provision of permanently installed ladders for operating at a height of more than 8 feet
- Other 'built-in' safety equipment

Apart from these, other factors like providing non-skid floors, hand rails for stairs, correct light intensity, ventilation, etc., must be looked into.

Materials handling: The handling of objects is responsible for approximately one-fourth of the occupational disabling injuries. Proper training must be given to the workers in lifting and lowering objects and in the use of manually operated vehicles.

In the case of powered trucks, only trained operators must be allowed to operate; in-plant routes must be barricaded, where it passes alongside or over work areas.

Conveyors, although safe, demand the use of precautions, because of certain inherent factors. The conveyor must be barricaded, where it passes alongside or over work areas.

Material storage: The location must be such that it offers no hazards to personnel. Bulk storage of flammables are special problems and call for the attention of an expert.

Adapted from a Note on Plant Safety, IIM(A) .

Responsibility for accident prevention

Accident prevention is a major task of the management. It is up to the owners or the board of directors to establish or at least review and approve the long-run objectives. They should know that until accidents have been reduced to a very low level, they cannot maximizing their profits, because prevention is cheaper than the costs resulting from accidents.

1. Emergency procedures

- Specialized staff should be trained and equipped for responding and investigating accidents and hazards, including crimes, medical emergencies and fire. In case of emergencies, they should be contacted.
- Supervisors and workers should know where to report an emergency.
- Staff officers should be trained to provide appropriate assistance which may include notification to the fire departments or police.
- Buildings should have fire alarm systems to alert the occupants of the building. Upon hearing the fire alarm, occupants should vacate the building at once, via the nearest exit.

2. Investigation of accidents

- Accidents during the course of a job result in a no-win situation. Employees suffer from injury and the organization suffers from having employees off

the job. For this reason, an important goal of the management should take measures to prevent accidents.

- However, in case of an occurrence of an accident, it should always be immediately reported and accidents like fatal injury, two or more persons admitted to the hospital or excessive property damage that require in-depth investigation should be investigated by an outside agency.
- Any action or activity, even if not a very significant one or that does not require immediate aid should be reported.
- Employees should also report 'near-miss' injuries or accidents like stumbling, slipping or the falling of an object that caused no immediate harm to their supervisor. These reports will help in identifying the potential hazards or conditions that should be addressed for avoiding an injury in the future.
- A written report about the accident should be filed. An investigation into the cause of the accident should be done and should be reviewed by the Safety Committee, which would work towards the implementation of changes for preventing such accidents in future.

3. Care in the use of material and equipment

- Safe use and care of material or equipment used by employees irrespective of ownership should be practised.
- All supervisors should have the responsibility to monitor that the employees are properly using the equipments and that they are maintained and remain in good working condition.
- Employees must know how to properly operate, maintain as well as recognize when equipment is no longer safe to use.
- The manufacturer's recommendations should be followed in using and maintaining all equipment. In case of non-availability of such instructions, the manufacturer should be contacted for obtaining a new copy.
- In case a new copy is not available, then qualified persons within the department should be given the responsibility of developing guidelines for the safe use and maintenance of the equipment.
- Instruction manuals should be kept with all equipment or at a particular location known to all persons who use the equipment.
- After laying down the adequate safety measures as one of the requirements, the chief executive should directly charge the different functional departments with specific safety responsibilities. For example, the maintenance department should be particularly charged with the responsibility for seeing that the work of this department is carried on in such a way that no temporary hazards exist. Also, the major objective should be to keep the materials handling equipment, etc. safe for work.
- In addition, special focus needs to be given to personnel or industrial relations. The safety specialist should be charged with organizing, stimulating and guiding the safety programme.

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- The stores manager is the key man in safety programmes, particularly with regard to unsafe acts. Accident prevention is comparable to waste reduction. The stores manager must be taught to get work done with safety.
- Trade unions, wherever applicable, should be established to support the management in enforcement of safety regulations.

4. First aid

- For providing immediate assistance to injured employees, all safety officers, maintenance supervisors and laboratory supervisors should have current certification in first aid.
- Stores should have first-aid certified employees responsible for arranging initial assistance in case of accidents.

Costs associated with accidents

It is becoming increasingly important for any department in an organization to show the value of its services to the higher management from time to time. A minimum level of safety operation is absolutely essential. But once that is achieved, it is a matter of judgement as to how serious an effort must be made to accomplish a good or perhaps, an excellent accident record.

Very often, there is commercial sensitivity connected to the costs of accidents. Companies may not prefer to admit huge losses from accident because:

- The information could affect the valuation of the company on the stock market.
- The disclosure could give an edge to its competitors.
- The information could create concern among the consumers about the likely impact on cost of the product.

However, some of the costs related to accidents can be identified quickly like cost for medical treatment, lost wages and decreased productivity. These expenses which can be identified easily are often called the direct costs associated with accidents. There are two major classes of costs resulting from accidents, the insurance (or insured) cost and the uninsured costs (some prefer to call these as the direct and indirect costs). The insurance cost is the payment made under workmen's compensation laws and medical expenses of that type usually covered by insurance. This cost is easily estimated. The uninsured cost may consist of a combination of the following elements:

1. Cost of wages paid for working time lost by workers who were not injured
2. Damage to tools, materials and equipment
3. Cost of wages paid for working time lost by injured workers other than workmen's compensation payment
4. Extra cost due to overtime work necessitated by an accident
5. The time and cost of getting a temporary replacement for the injured worker
6. Time used by supervisors in investigating the accident, preparing the report of accident and adjustments made to work schedules
7. Time used by other employees in assisting the injured worker

8. Wage cost due to decreased output of injured worker after returning to work
9. Cost of learning period of new worker
10. Uninsured medical cost borne by the company
11. Cost of time spent by supervisors and clerical workers on investigations
12. Miscellaneous unusual costs

The expenses associated with accidents which are not very evident and cannot be easily calculated are known as indirect or hidden costs. It can be several times higher than the direct costs. The key point is that accidents are much more costly than just the basic or direct costs.

Safety organization

The number of people, if any, engaged full time in promoting safety, varies with the size of the company and the nature of its activities. But, it has been found that the companies which employ full-time safety personnel have much better accident records than those that do not. The number of employees is not always a comparable basis for judging the number of potential hazards. For example, an assembling plant doing only light assembly work has less risk of personal injury though it may employ a very large workforce.

The safety department is usually located within the personnel department. But, the safety personnel should preferably report to someone senior in the organization. It may be ideal for the safety personnel to report to the works or production manager. This can help in proper implementation of major safety programmes, as operations and production are areas more prone to accidents. The safety specialist should have the authority to stop any process he considers unsafe, until adequate measures have been taken to remove the hazard apparent to him. The education and experience of the safety specialist can vary widely.

A safety specialist should possess the following:

- Certain specific knowledge about emergency procedures and how to implement and enforce such procedure
- The ability to investigate accidents or direct such investigations
- A certificate in first aid
- Should also be familiar with safety principles and techniques, and if working in an industry, a good knowledge of the plant and equipment

In addition, he must have certain personal characteristics:

1. Ability to get along with people. This is a very important trait, as he must achieve his objective more by persuasion than by command.
2. Enthusiasm, drive and perseverance.
3. Readiness for new ideas and approaches.

Risk assessment

Risk assessment is an essential part of safety operations. All processes and equipment need to be assessed from the point of compatibility, fire protection,

storage, hazard index rating, toxicity fire and explosion hazards. There should be an ongoing programme for assessing the reliability of process equipment, incorporating safety trips and interlocks, etc. Evaluation of electrical safety, areas and equipment using high voltage should be carried out. Protection provided against these hazards as well as warning and caution signs should be highly visible.

Safety procedures and practices should be periodically assessed. Assessment of the performance of safety systems and gadgets along with follow-up measures is essential. It should be ensured that proper maintenance of plant and equipment is carried out on schedule. If there is a delay, the reasons for the delay should be investigated and if found necessary, the use of the equipment should be forbidden.

There should also be a comprehensive risk analysis plan to indicate the impact of specific practised emergency procedures. Safety induction and periodical refresher training for the regular employees and contract workmen should to given. All risks should be thoroughly identified and analysed and insurance planning should also be done for effectively managing interruption and public liability risks.

Check Your Progress

10. What are the objectives of the Indian Factories Act?
11. Why do companies not prefer to admit their losses incurred from accidents?
12. Define safety.

5.4 ANSWERS TO 'CHECK YOUR PROGRESS'

1. The objectives of quality assurance are:
   - To improve quality
   - Reduce costs
   - Increase productivity
2. Appraisal costs are incurred while maintaining quality levels through measurement and analysis of data in order to detect and correct problems.
3. Costs of investigating complaints, product recall costs, warranty claim costs, which include the cost of repair or replacement of products during warranty periods, and product liability costs of legal action and settlements are a major source of external failure costs.
4. Quality control is the process in which the products are made to conform to the quality standards set by the clients or the customers.
5. Three important functions of quality control are inspection, prevention and verification.
6. There are three aspects of assuring quality
   - Assurance of incoming raw material's quality
   - Assurance that proper processes are operating on the raw materials
   - Assurance of the quality of the outgoing finished goods

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7. The statistical process can be monitored in the following two ways:
   - Actually measuring the variables operating on the raw materials
   - Measuring the characteristics of the output product
8. An acceptance sampling plan consists of the following:
   - A set of rules that define the procedures for preparing a batch or lot
   - Rules for selecting samples, e.g., they can be picked at random, or every fifth piece can be a sample, and so on
   - Procedure for conducting inspection of the samples
   - Fixing the criteria for accepting or rejecting the batch
9. The OC curve can be made more strict (greater quality control) in three ways:
   - By increasing the sample size n, while keeping the acceptance number constant
   - By decreasing the acceptance number a, while keeping the sample size n constant
   - By simultaneously increasing the sample size n and decreasing the acceptance number a
10. The following are the goals of the Indian Factories Act of 1948:
    - To prevent humans from being subjected to undue bodily pressures from manual labour over lengthy periods of time.
    - Employees should work in as healthy and hygienic a manner as the production process allows, and safety and accident prevention steps should be followed.
11. Companies do not prefer to reveal large losses incurred due to accidents because:
    - The information might influence the company's stock market valuation
    - The disclosure could offer its competitors an advantage.
    - The information may cause consumers to be concerned about the product's anticipated cost effect.
12. Safety can be defined as identifying the hazards in a work environment and controlling them. It is the degree of preventative measures/protection, which are taken to control the hazards.

5.5 SUMMARY

- Quality can be defined as fitness for intended use or, in other words, how well the product performs its intended function.
- The objectives of quality assurance are:
  - o Improve quality
  - o Reduce costs
  - o Increase productivity

NOTES

- Quality efforts cost money; they must be well planned and quality costs must be understood at every level of the organization.
- Quality control is one of the critical functions in the management of a plant. Quality control is the process in which the products are made to conform to the quality standards set by the clients or the customers.
- Inspection is one of the important ways through which quality is controlled in a plant with the minimum cost. Inspection also helps in assessing how viable the quality standards are in the functioning of the production process.
- Performance of a product means the functions and services which it must provide its consumer.
- Process control is the monitoring of the various physical variables operating on the materials and the correction of the variables when they deviate from the previously established norms.
- Acceptance sampling is a technique which uses the statistical inspection method to evaluate the quality of a complete batch.
- Different types of sampling plans are used, for acceptance sampling depending on the level of accuracy required.
- In process control, a check is kept on both central tendency and dispersion by a graphical method. The graphs which are used for such monitoring are called control charts.
- Total quality management or TQM is a management approach that originated in the 1950s and steadily became more popular since the early 1980s.
- The term total quality management was first used by the Department of the Navy of USA in 1985.
- TQM is a method by which all the employees of an organization become involved in the continuous improvement of the production of goods and services.
- TQM approach focuses on the quality and appropriateness of processes that are carried out in the organization for producing and delivering the goods or services to the customers to their satisfaction.
- Soon after the war, WE. Deming and Joseph M. Juran, two noted 'Quality Gurus', started their pioneering studies on ways of addressing the quality problems of the post-war US industries and the reconstructed Japanese industries. 'Quality movement' started from this point onwards.
- The approach to "Total Quality" management is based on the quality philosophies of Deming, Juran and Crosby.
- There could be some common differences in approach from organization to organization, but the quality philosophies of Deming, Juran and Crosby have some common basic elements embedded in them. These basic elements are customer focus, strategic planning, enlightened leadership, continuous improvement, empowerment of people and teamwork.

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- The principles of total quality management are concerned with the process of establishing these elements in the organization, with the spirit of those key elements permeating all processes.
- In context of a business comprising number of complex functions, TQM can be described as a strategic process of seamlessly integrating all functions, activities and processes of an organization for continuous improvement of the quality of goods and services. The aim of this strategic process is customer satisfaction and the outcome is excellence in performance.
- TQM is concerned with continuous improvement in all work, from high-level strategic planning and decision-making, to detailed execution of work elements on the shop floor. It reinforces the belief that mistakes can be avoided and defects can be prevented.
- Six sigma is a data driven, structured problem-solving methodology for solving chronic issues facing a business.
- Accidents are a severe concern that may have a devastating effect on an organization's operations, resulting in significant costs in terms of workers' compensation, lost output, and perhaps worker morale.
- Accident prevention is a fundamental managerial responsibility. The owners or board of directors are responsible for establishing, or at the very least reviewing and approving, long-term objectives.
- It's becoming more necessary for each department in a business to demonstrate the value of its services to upper management on a regular basis. It is vitally necessary to operate at a minimal degree of safety.
- Typically, the safety department is housed within the personnel department. However, the safety staff should ideally report to a higher-ranking member of the business. It could be best if the safety employees reported to the production manager or the works manager.
- Risk assessment is an important component of any safety activity. All processes and equipment must be evaluated for compatibility, fire safety, storage, hazard index rating, and toxicity, fire, and explosion threats.
- Safety is not a resource nor an influence, it is not even a procedure and it is certainly not a program. It is a state of mind, an atmosphere that must become an integral part of each and every procedure that the company has.
- Hazard is the inherent property of substance by virtue of which it may cause harm to a man, machine, environment, system, animal etc. It can also be defined as a characteristic of the plant/process/system representing potential (possibility) of an accident.
- Responsibility of safety has to be shared to achieve optimum results and organizational goals at the project site.

NOTES

5.6 KEY TERMS

- **Quality assurance:** It refers to the entire system of policies, procedures and guidelines established by an organization in order to achieve and maintain quality.
- **Prevention costs:** They are costs that are incurred in preventing the manufacture of non-conforming products and stopping any such product from reaching the customers.
- **Internal failure costs:** It results from unsatisfactory quality that is found prior to the delivery of a product to the customer.
- **Acceptance sampling:** It is a technique, which uses the statistical inspection method to evaluate the quality of a complete batch.
- **X-Bar chart:** It refers to the chart used for analysing the control of the mean value of a variable or control of the central tendency.
- **R-Chart:** It is the chart used for analysing the control of the variability of a variable or dispersion.
- **Six sigma:** It is a data driven, structured problem-solving methodology for solving chronic issues facing a business.
- **Accident:** It refers to the unplanned, unexpected and uncontrolled event which may result either in injury or in property damage or in both.

5.7 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Define the terms – quality, quality assurance and quality control.
2. What is sampling? What are the different types of sampling plans?
3. What are the common parameters of quality?
4. What are the functions of quality control.
5. List the advantages of quality control.
6. What is the responsibility of management towards safety?
7. Why can't businesses ignore environmental issues?

Long-Answer Questions

1. What is the relevance of inspection in ascertaining quality? Why are statistical methods used?
2. Discuss the OC curve. What is its relevance to a producer?
3. What is a control chart? Briefly explain any three types of control charts.
4. What is TQM?

5. Discuss the themes of six sigma.
6. Discuss the evolution of TQM.
7. Describe the safety considerations in production and operations management.

NOTES

5.8 FURTHER READING

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