Institute of Open and Distance Education

Faculty of Management

Production & Operation Management

Production & Operation Management

2MBA6

Dr. C.V. Raman University
Kargi Road, Kota, BILASPUR, (C. G.),
Ph. : +07753-253801, +07753-253872
E-mail : info@cvru.ac.in | Website : www.cvru.ac.in

DR. C.V. RAMAN UNIVERSITY
Chhattisgarh, Bilaspur
A STATUTORY UNIVERSITY UNDER SECTION 2(F) OF THE UGC ACT

2MBA6

Production & Operation Management

2MBA6, Production & operation Management

Edition: March 2024

Compiled, reviewed and edited by Subject Expert team of University

1. Dr. Rajeev H. Peters

(Associate Professor, Dr. C. V. Raman University)

2.Dr. Rahul Sharma

(Associate Professor, Dr. C. V. Raman University)

3. Dr. Anshul Shrivastava

(Assistant Professor, Dr. C. V. Raman University)

Published by:

Dr. C.V. Raman University

Kargi Road, Kota, BILASPUR, (C. G.),

Ph. +07753-253801, 07753-253872

E-mail: info@cvru.ac.in

Website: www.cvru.ac.in

CONTENTS

Unit 1 Basic Concepts

Unit Structure

- Introduction
- Production Defined
- Production as Heart of an Organisation
- Production Management Function
- Objectives of Production Management
- Scope of Production Management
- Decision-making in Production Management
- Production Organisation
- Historical Evolution of Production/Operations Management
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Production as heart of an organisation
- Scope of production management
- Decision-making in production management
- Historical evolution of production/operations management

Introduction

Production/operations management is the process, which combines and transforms various resources used in the production/operations subsystem of the organization into value added product/services in a controlled manner as per the policies of the organization. Therefore, it is that part of an organization, which is concerned with the transformation of a range of inputs into the required (products/services) having the requisite quality level.

The set of interrelated management activities, which are involved in manufacturing certain products, is called as production management. If the same concept is extended to services management, then the corresponding set of management activities is called as operations management.

Production Defined

Production may be defined as the conversion of inputs – men, machines, materials, money, methods and management (6 Ms) into output through a transformation process. Output may be goods produced or services rendered.

"Goods produced" is for the manufacturing concerns and "Services rendered" is for the service operation units such as banks, hospitals, hotels/restaurants, etc. In this sense production management may be viewed as Operations Management.

Diagrammatically, this can be shown as in Figure 1.1.

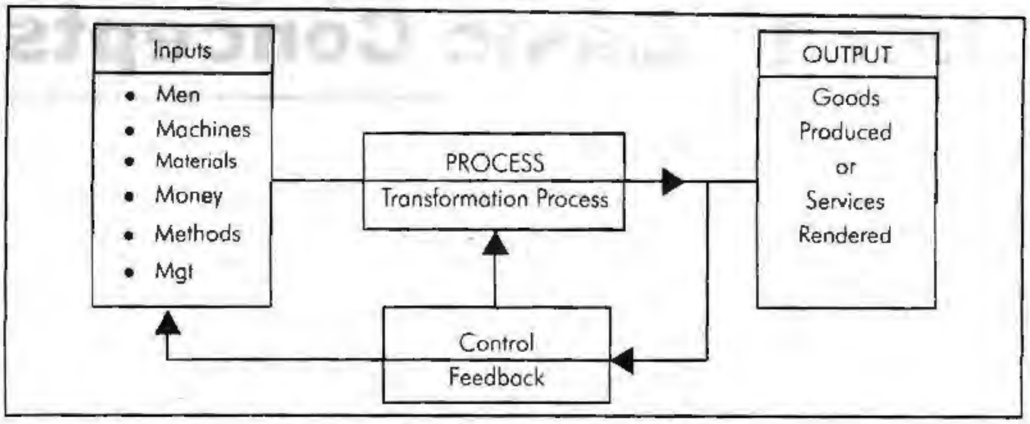


Figure 1.1: Production as a System

Feedback from the output stage is used to adjust the changes required in the inputs or the transformation process, i.e., production control is done to take care of the deficiency of resources, if any.

Production as Heart of an Organisation

Production is a primary business function along with marketing and finance, other management areas being HRD (Personnel and Industrial Relations) and Materials Management, etc. Marketing establishes the demand for goods and services, finance provides the capital and equipment and production actually makes the goods or services. In this sense, it plays a vital role in achieving a firm's strategic plans or goals.

Further, as the production function produces the goods and services, it typically involves the greatest bulk of the companies' employees and is responsible for a large portion of the firm's assets.

Moreover, production has a major impact on the quality of the goods and cost of production, in this respect production is a visible face of the company and is thus the central function of an organisation and hence, we may call production as the heart of any organisation.

Coordination of production with other departments can be depicted diagrammatically as in Figure 1.2.

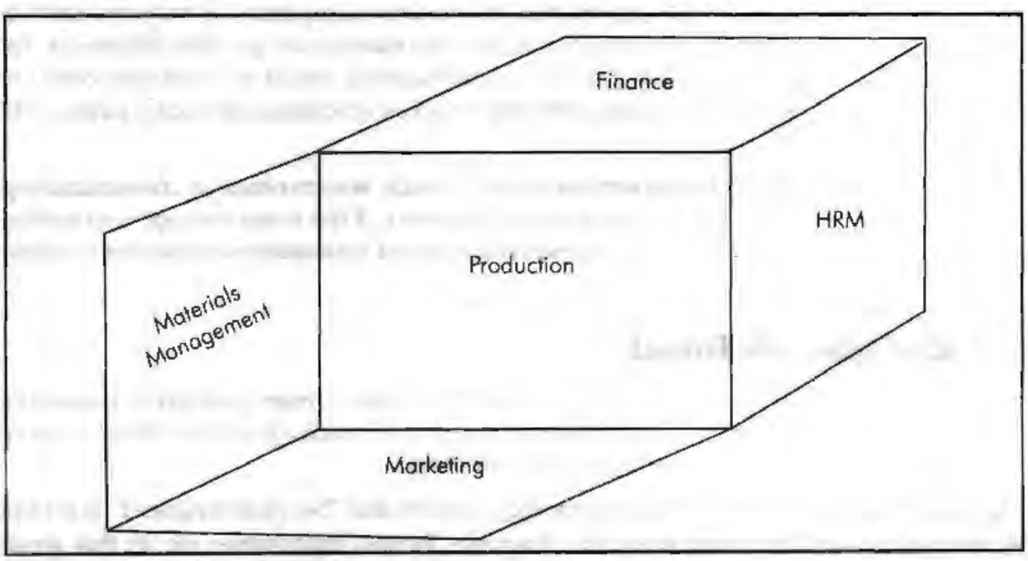


Figure 1.2: Production as Coordination Function

Production Management Function

Production management is viewed as a continuous process of planning, organising and controlling:

1. ***Planning:*** It includes all activities that establish a course of action. These activities guide future decision-making. It involves product planning, facility planning and designing of the conversion process.
2. ***Organising:*** It includes all activities that establish a structure of tasks (organisation structure) and authority. Thus it determines the activities required to achieve the operations, subsystems goals and assign authority and responsibility for carrying them out.
3. ***Controlling:*** It includes all activities that ensure that actual performance is in accordance with planned performance. This is done by developing standards and communication networks necessary to ensure that the organising, staffing and directing functions are pursuing appropriate plans and achieving objectives.

Objectives of Production Management

The major objective of production management is to produce quality goods and services. In present day position, the objective of any firm is to increase profitability through higher efficiency, higher productivity, by improving quality, and to give customer more confidence by providing him products of quality at the right price and at the right time (JIT concept).

This can be achieved through:

1. Optimal use of resources (men, machines and materials).
2. By maximising use of manpower and machines, or minimising wastage of materials.
3. Ensuring quality of goods at minimal cost through use of statistical quality control techniques.
4. Contributing towards all round productivity through decision-making and quantitative techniques.

Scope of Production Management

Scope of production management includes:

1. Activities relating to designing or formulation of the production system.
2. Activities relating to analysing and controlling of production operation after the production system has been activated.

Activities relating to Production System Designing

These activities concern the production engineering which includes problems relating to:

1. Design of tools and drawings.
2. Designing development and installation of equipment.
3. The selection and operation of the size of the firm.
4. The selection of the overall plans.
5. Location plans.
6. Plant layouts.
7. Materials handling systems, etc.

Besides, the human factor problems and research and development are also considered.

Activities relating to Analysis and Control of Production

The major ones are:

1. *Production Planning:* It includes preparation of short-term production schedules, plan for maintaining the records of raw material and finished and semi-finished stock; specifying how the production resources of the concern are to be employed over some future time in response to the predicted demand for products and services.
2. *Production Control:* After planning, the next managerial production function is to control the production plans because the production plans cannot be activated unless they are properly guided and controlled. For this purpose, production manager has to regulate work assignment, service work progress and check and remove discrepancies, if any, in the actual and planned performances. A production manager has to look after the production control activity through:
   (i) Control on inventory such as raw materials, purchased parts, finished goods, etc.
   (ii) Control on work in progress through production control.
   (iii) Control of quality through process control.

Decision-making in Production Management

It determines the firm's mission and strategy and how the firm's resources can most effectively be utilised. Only when the operations manager understands the organisation's overall goal, he can maximise the contribution towards developing an effective operations strategy.

POM (Productions Operations Management) involves both strategic as well as tactical decisions:

1. *Strategic Decisions* are those which have implications of long duration (normally over one year) and may take over a year to implement.
2. *Tactical Decisions* are those that can be substantially implemented in one year or less.

Both types of decisions support POM and company's mission.

Various major decisions required in production management area are:

Product Design: To lead in research and engineering competitions in all areas of our primary business, designing and producing products and services with outstanding quality and inherent customer value.

Process Designing and Equipment Selection: To determine and design the production process and equipment that will be compatible with low product cost and high quality.

Layout: To achieve, through skills, imagination and resourcefulness in plan layout and work methods for production effectiveness and efficiency.

Location and Facility Engineering: To locate, design and build efficient and economic facilities that will yield high value to the company.

Human Resource Management: To provide good quality of work life, with well designed, safe, rewarding jobs, stable employment and equitable pay in exchange for outstanding individual contribution from employees at all levels.

Production Control: To achieve high utilisation of manufacturing facilities through effective scheduling.

Maintenance: To achieve high utilisation of equipment.

Quality Assurance Control: To attain exceptional quality that is consistent with company policy and marketing objective.

Materials Management: To cooperate with supplies and subcontracts to develop stable, effective and efficient sources of supply for those components that are to be processed from outside sources.

Inventory Control: To achieve low investment through scientific inventory control such as A B C, V E D, F S N and R O L techniques and through appropriate customer service levels and high facility utilisation.

Production Organisation

Production may be defined as the conversion of a customer's order into a finished product. This requires the interaction of many functions within the organisation.

A typical organisation chart with major functions of production department are given in Figure 1.3.

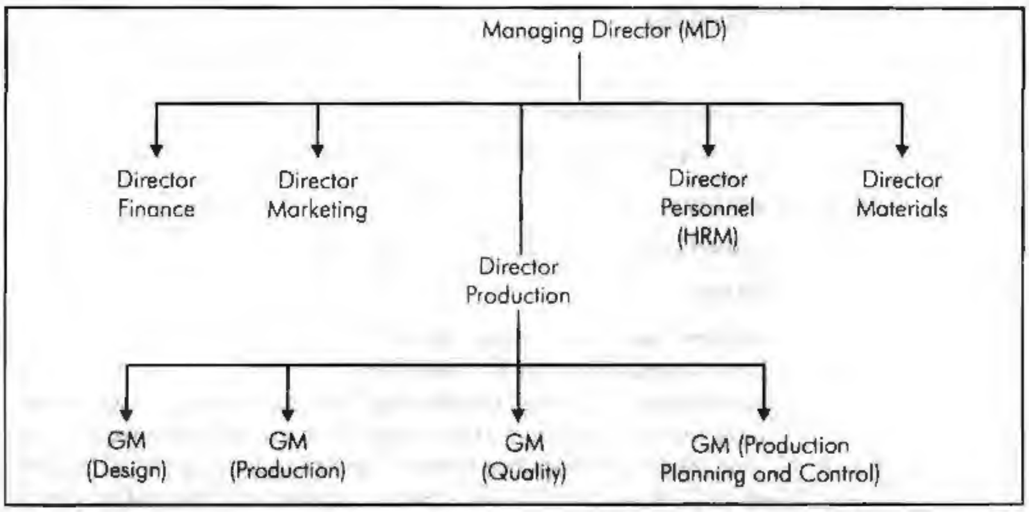


Figure 1.3: Total Organisational Plan

Total Organisation Plan

Organising production management:

1. ***Design and Development of Product:*** Engineering drawings and specifications.
2. ***Planning:*** Determination of sequence and method of manufacturing the product.
3. ***Scheduling:*** Schedule each level of production to support the end product.
4. ***Ordering:*** Production orders, tooling orders and materials request must be written and issued for all components and parts.
5. ***Maintenance and Spares Planning Cell:*** The function of this department is to keep the machinery and equipment in order.

Characteristics of Production Function

The type of activities involved in production function include:

1. Organising work
2. Selecting process/processes
3. Locating facilities
4. Arranging layouts, facilities, manpower, etc.

5. Designing jobs
6. Measuring performance (productivity)
7. Controlling quality
8. Planning and scheduling production including inventory control, etc.

A successful production manager is one who is able to manage all the above functions well.

Historical Evolution of Production/Operations Management

Production management is today more than 200 years old and in its present form is the result of contribution by a number of contributors. Evolution of production/operations management can be studied by dividing the total period into six periods or ERAS:

1. Industrial Revolution Era;
2. Scientific Management Era;
3. Human Relation Era;
4. Quantitative Techniques/Management Era;
5. Advanced Techniques Era; and
6. Quality Revolution Era.

Each era is briefly described below:

1. ***Industrial Revolution:***
   (a) *Concept of Modern Factories:* During the 18^{th} century the concept of large-scale production came through in which small shops were converted into large manufacturing concerns employing mass production techniques notable among them being the textiles, metal fabrication and machine-tool industries. The major contributions were by Spinning Jenny and Carteright's Power Loom in Textiles, James Watt's Steam Engine and Maudslay's Screw Cutting Lathe for mechanisation in industries.
   (b) ***Division of Labour.*** Adam Smith (1776) advocated division of labour. He gave three distinct advantages, i.e.,
      (i) Workmen performing work in repetition develop higher skill.
      (ii) Saving in time results while changing from one activity to another.
      (iii) Improvements in production methods result when workers are made to specialise on certain tasks.

      Charles Babbage (1883) gave the fourth advantage of division of labour called specialisation giving rise to cutting cost of production through better managerial and organisational structures, human relations, product development and management accountability through Profit/Volume (P/V) relationship.
   (c) *Concept of Interchangeability:* Along with the division of labour the concept of interchangeability grew. The major contributor of this concept is Whitne (1790) whose this concept revolutionised the modern manufacturing methods.
2. ***The Era of Scientific Management:*** The era of scientific management began in the United States during the early 20th century.
   (a) The major contribution by FW Taylor who gave a number of contributions notable among them being:

(i) Work measurement and wage payment based on performance.

(ii) Measuring work for each element of men's work.

(iii) Selection of best worker for each particular task and the training and development of the workmen.

(iv) Rewarding performance of the worker (Taylor's Differentiation Piece Rate System).

(v) Division of work between management and workmen. He advocated that management's job is planning, organising, staffing, directing and controlling and that of the workmen is to do the assigned jobs well.

Due to his various contributions which came largely through his own experience, he rose from worker's level to chief engineer's level; as a result he is often called Father of Scientific Management.

(b) Contributions by Frank B Gilbreth and his wife Lilian Gilbreth (a psychologist): In 1917 they developed 'Motion Study', classifying basic motions in 17 divisions called 'Therbligs'(spelled back – gilbreth). Motion study helped in the improvement of methods. This pioneer work made him the father of motion studies.

(c) Contribution by Henry Gantt (1913): He developed the technique of scheduling and monitoring work popularly called Gantt Chart.

(d) Other contributors who helped in scientific management were:

(i) H. Emerson's efficiency plan for payment of wages.

(ii) Wilson's EOQ (Economic Order Quantity) formula for inventory control.

(iii) W. Schewart's Control chart for Statistical Production Control (SPC).

(iv) LHC Tippet's work sampling to determine the machine and manpower utilisation.

(v) Dodge, Romig and Schewarts's development of sampling plans for inspection of incoming (raw material) and outgoing (finished goods) material.

(e) On the basis of concepts of division of labour and parts interchangeability Henry Ford developed the concept of mass production through organised workstations on a conveyorised assembly line.

3. ***Era of Human Relations:*** Scientific management approaches emphasised the physical and technical aspects of work whereas the 'Howthorn Studies' (conducted in 1931 at Western Electric) suggested that the behaviour considerations are also vitally important to 'Productivity'.

Major contributions being by Elton Mayo for Howthorn Studies (1930), Motivational theories by A. Maslow (1940), F Hertzberg (1950) and Douglas McGregos (1960).

Their concepts helped in 'Job Designs' and 'Employee Motivation'.

4. ***Era of Quantitative Techniques/Management Science (1940-80):*** During the World-War II and thereafter the use of Quantitative Techniques in decision-making (popularly known as Q.R. techniques) has further revolutionised the production (Operations) management not only for performing the operations better but also aiding the decision-making through the use of statistical techniques (Probability and Sampling Distributions and Mathematical Modelling (PERI/CPM), Linear Programming, Scientific Inventory Control, Simulations and Dynamic Programming, etc.)

The development of computers further aided in the development of these techniques of management decision-making through its speed and capability of handling voluminous work that can be undertaken by it.

5. ***Era of Advanced Techniques (1970-80):*** With the advent of computer and its use in the design of layouts (Craft-Computerised Relative Allocation of Facilities Techniques, Production Design (CAD/CAM) and Manufacturing System (CIM-Computerised Integrated Manufacturing System). All these have given rise to the advanced technology hi-technological developments like robots and micro-computers.

6. ***Era of Quality Revolution:*** Since 1980s there has been a strategic emphasis on manufacturing in-built quality.

   TQM system converted 'Q C to Q A' and this gave the customers not only customer satisfaction but also the customer delightness.

   ISO 9000 series is called 'Quality Friendly' and ISO 14000 is called "Environment Friendly".

   The major thrust has been on adoption of the Japanese Management/Technology (JMS), Quality Circles and the JIT concept.

Present Day Scenario

The change in technology has brought in various improvements in production function and as a result of this our industrialists today are well informed of the most modern techniques. The new name 'Operations Management' has broadened our fields to service sector which has become more prominent.

Previously there was a big emphasis on integration of operational activities through emphasis on marketing and finance; however, today the operations function is experiencing a renewal role as a vital strategic element.

There has been a tremendous growth of most modern techniques and today's manager is required to have knowledge of commerce and economics also, in addition to information technology.

A number of training centres for workers and management institutes for managers are there to impart training as per requirement of the manufacturing and service systems.

Student Activity

Fill in the blanks:

1. The major objective of production management is to produce ....
2. Production may be defined as the conversion of a ....
3. Charles Babbage (1883) gave the fourth advantage of division of labour called ....

Summary

Production may be defined as the conversion of inputs – men, machines, materials, money, methods and management (6 Ms) into output through a transformation process. Output may be goods produced or services rendered. Production is a primary business function along with marketing and finance, other management areas being HRD (Personnel and Industrial Relations) and Materials Management, etc. The major objective of production management is to produce quality goods and services. Scope of production management includes:

1. Activities relating to designing or formulation of the production system.
2. Activities relating to analysing and controlling of production operation after the production system has been activated.

Keywords

Production Planning: It includes preparation of short-term production schedules, plan for maintaining the records of raw material and finished and semi-finished stock; specifying how the production resources of the concern are to be employed over some future time in response to the predicted demand for products and services.

Strategic Decisions: Strategic Decisions are those which have implications of long duration (normally over one year) and may take over a year to implement.

Tactical Decisions: Tactical Decisions are those that can be substantially implemented in one year or less.

Review Questions

1. (i) Define Production.
   (ii) Production on Management Function.
2. How can the firms recourses be effectively utilised (with reference to Decision making on Production Management)?
3. List various characteristics of Production Function.
4. Briefly explain:
   (i) Industrial Revolution,
   (ii) Scientific Management Era,
   (iii) Human Relation Era, and
   (iv) Quality Revolution Era.

Further Readings

Everett, E. Adam, Jr. Ronald J. Ebert, *Production and Operations Management*, Prentice-Hall of India Private Limited, 5th Edition, 1994.

Joseph, G. Monks, *Operations Management*, McGraw-Hill International Edition, 3rd Edition.

Joseph, G. Monks, *Theory and Problems of Operations Management*, Tata McGraw-Hill Publishing Company Limited, 2nd Edition, 2004.

Kachru, Upendra, *Production and Operations Management:* Text and Cases, Excel Books Private Limited, First Edition, 2007.

R. Pannerselvam, *Production and Operations Management*, Prentice-Hall of India Private Limited, 9th print, 2004.

S. Anil Kumar, N. Suresh, *Production and Operations Management*, New Age International (P) Limited Publishers, 2nd Edition, 2008.

Unit 2 Design and Control of Production Systems

Unit Structure

- Introduction
- Technology Life Cycle (TLC) and Product Design
- Categories of Process Technologies
- Impact of Design Engineering on Technology
- Mechanisation and Automation
- Impact of Computers on Process Innovation
- Flexible Manufacturing Systems
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Technology Life Cycle (TLC) and product design
- Categories of process technologies
- Impact of computers on process innovation

Introduction

The design of manufacturing processes and service delivery systems cannot be made without considering product design decisions. Many aspects of product design can adversely affect operations performance. New products and services must be produced and delivered efficiently, at low cost, on time, and within quality standards. Process technology decisions relate to organizing the process flows, choosing an appropriate product-process mix, adapting the process to meet strategic objectives, and evaluating processes.

First, we need to understand how processes work and how they contribute to the competitiveness of the organization. What is a process? How can an organization choose the best process? How can an organization improve the already built process capacity? How can a process's weaknesses be determined? When to decide to change a process for the better? Answers to these questions are important. In this chapter, we will discuss concepts related to process design and planning.

Technology Life Cycle (TLC) and Product Design

An industrial process technology also follows a typical life cycle – it has an introduction stage, followed by the stage of rapid growth leading to a stage of maturity and decline. However, this cycle resembles the alphabet 'S' and are also commonly referred to as S-curves. A typical TLC is as shown.

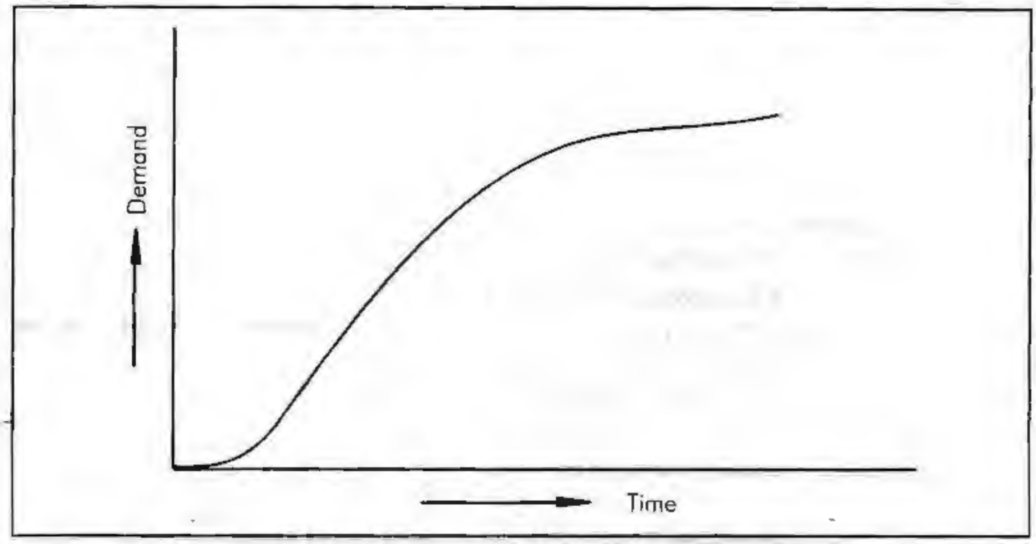


Figure 2.1: Pattern of Technology Life Cycle

Usually, while the existing technology is in the stage of rapid growth, there appears on the horizon a better and superior technology which will replace the present one in course of time. When companies are learning to cope with rising demand for products made with the help of established process technology, top management is faced with the dilemma of choosing one among the several options of process technologies and back it up as a winner for the future.

There is an intimate relationship between the nature of product innovation during its life cycle and strategies of process innovation in supporting the product. A typical curve is as shown on the below.

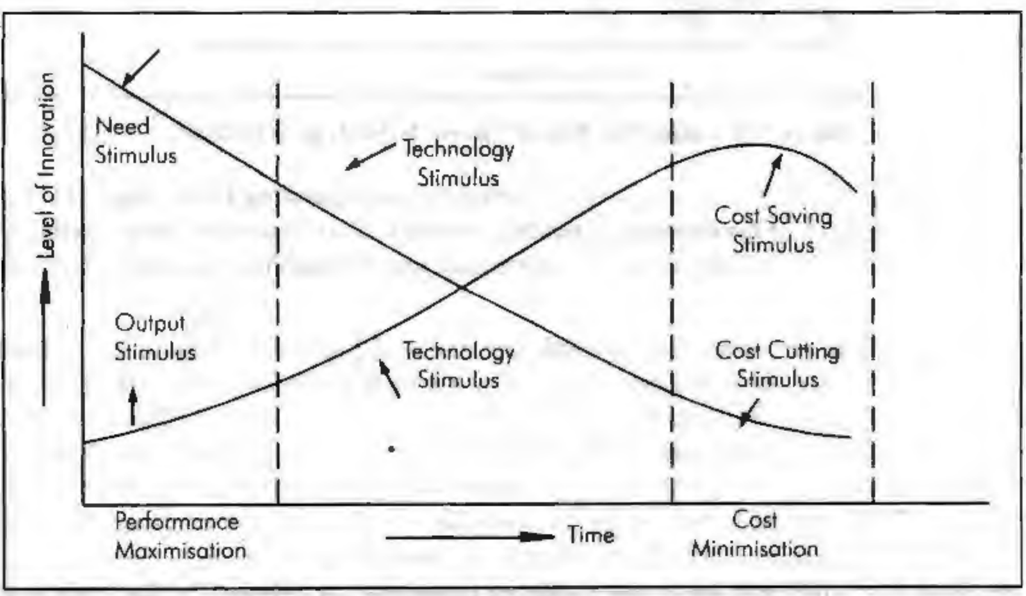


Figure 2.2: Relationship between Product and Process Innovation

If the entire process is visualised in three stages vis., early, middle and final, there is a considerable resemblance in the stimuli for innovation in both the product and process technologies as tabulated below.

Table 2.1: Relationship Between Product and Process Innovation

Sl.	Stages of Development	Product Innovation	Process Innovation
1.	Early stage	Need	Output
2.	Middle stage	Technology	Technology
3.	Final stage	Cost reduction	Cost savings

Thanks to creativity and innovation of human mind, existing technologies (also called defenders) are always being superceded by the new and superior technologies (also referred to as challengers). Researches have confirmed that for a new product for which there is a rapid growth of market, a new and better technology becomes available when the product is half way through its rapid growth stage. As a result, the new technology can make a significant impact on the product design which can boost the sales further and demand cycle of the product can continue to rise. We can have a series of products being launched, each superior to the previous one in many ways. If this trend continues, demand cycle of the product shows a continuously upward trend, as shown in Figure 2.3.

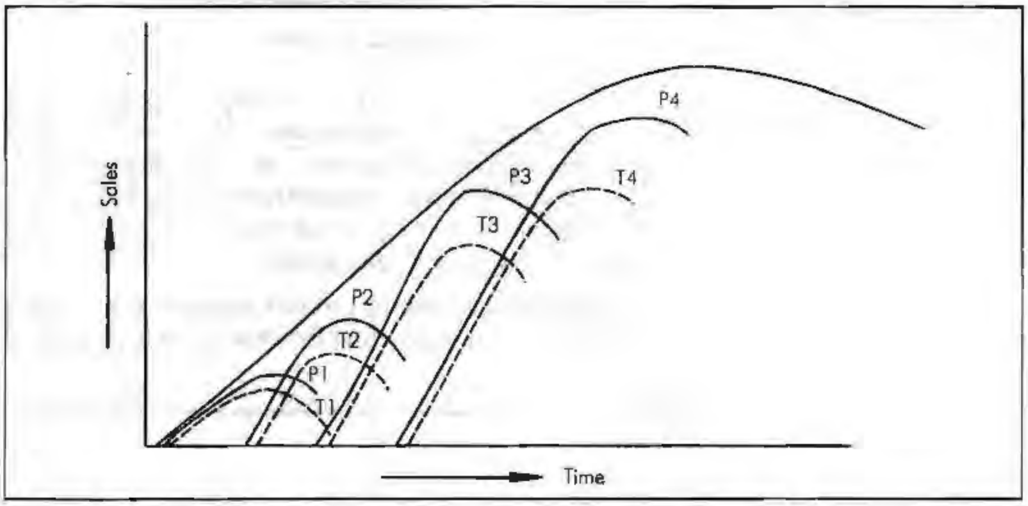


Figure 2.3: Supporting Role of Process Technology to Products

Each product P1, P2, P3, ... is supported by corresponding technologies T1, T2, T3, ... Each of the technology reaches maturity much faster and starts declining in favour of new technology when it is almost half way through the rapid growth phase of that product.

A classical example is the car industry for personal transport. Starting more than 100 years ago, its basic features of being a 4-wheeler vehicle fitted with internal combustion engine have not changed. However, owing to a series of innovations in product design year after year, each better than the previous one, combined with rapid strides in process technology has led to continuously rising demand cycle and it is still rising globally although there might be some countries where the demand might be nearing the saturation point. The product innovation has been of the highest order so much so that when you see a new model of passenger car released by the leaders in industry, you can hardly resist the temptation of jumping into it!

Categories of Process Technologies

Technologies are process specific – each process will require a technology to match. Depending on the way technology is managed, these can be grouped into following categories. Intermittent type which can be divided into:

1. Project type
2. Job type
3. Batch type
4. Assembly line type
5. Continuous type

Project Technology

This technology is suited to one of a kind products which are non-repetitive and are tailored to suit individual requirements of a customer. Since the products are nonstandard, size of facilities may vary widely. There is no set pattern of flow of work. Speed, run length, rate of change may vary to suit specific requirements. Conversion process has to be flexible with general purpose equipment, adaptive human skills and innovative procedures to suit the situation. Examples are construction industry or ship building/breaking units. Conversion process would involve a lot of problem-solving approach, emphasis teamwork, good coordination with designers and production of unique components to satisfy customers needs.

Job Shop Technology

This technology deals with manufacture of small lots of a very large variety of products which are custom designed and built. Since each lot of products is unique, its manufacturing process and routing through different sections of manufacturing facility will have general purpose machines and varied human skills. Facilities are usually small and some equipment are overloaded. There are several patterns of flow – speed is slow, run lengths are short and rate of change is rather slow. Owing to a large variety of jobs, job routing is complex and control system is taxing calling for quick responses, innovation and de-bottlenecking.

Batch Technology

When lot size is larger than job shop, facilities are also of moderate scale. Several jobs repeat in large volumes. There are a few dominant products but their quantity is not so large as to warrant dedicated machines. Although there are a few dominant patterns of flow of work, batch technology is geared to manufacturing a wide variety of products in varying volumes with the help of general purpose machines and varied human skills. This technology has to be flexible to take on high or low volume of production. Speed, run lengths and rate of change are moderate. Similar of products may be manufactured to stock while others are against specific orders from customers.

Production planning and control can be very complex calling for detailed shop/machine scheduling, loading, etc. Responding to diverse and conflicting priorities, balancing loads on work stations, devising innovative procedures and creativity are the hallmark of Batch Technology.

Assembly Line Technology

When product range is small and volumes are large, technology revolves around specialised equipment, specific manufacturing procedures and human skills and management systems. Although size of facilities is rather large to cope with a large volume of production, patterns of flow tend to be rigid. Speed is fast, run lengths are reasonably long and rate of change is fairly high. There is a great deal of emphasis on productivity improvements involving assembly line balancing, staffing in the event of absenteeism, etc. Examples are electronic industries manufacturing a few limited models or automobile manufacturers producing a limited number of models of passenger cars.

Continuous Flow Technology

Chemical plants, fertilizer manufacturing units and oil refineries use continuous flow technologies. Raw materials are processed through different stages in a continuous flow to obtain finished products which are packed as required. Product is highly standardised and manufacturing units are large. Flow pattern is fairly rigid and inflexible. Speed of operation is very fast, production runs are very long and rate of change is moderate to high. Continuous flow technology supports high volume, round the clock working with capital intensive equipment with a fair degree of automation. The challenge is to keep costly overheads to an absolute minimum.

Impact of Design Engineering on Technology

Process of designing is iterative, products and processes are continually redesigned. It is a never ending process – we always get new information from users, production and quality personnel and their help to improve the product and the technology.

There are many instances when products are designed from the viewpoint of:

1. Process technology;
2. Materials;
3. Manufacturing methods; and
4. Metrology or tolerances.

Similarly design of services is also continually modified to improve its quality and/or to reduce its cost. Redesign of service system may imply:

1. More involvement of customer;
2. Elimination of some aspects of service entirely;
3. Automating the service in full or part;
4. Changing of service mix; and
5. Enlarging the range of services offered.

For example, process of manufacturing an electric bulb started off as a manual operation and bulbs were produced in batches. Through progressive improvements in layout, standardisation of operations, etc., it became a continuous process. Simultaneously, a number of changes were made in the product design to facilitate mechanical handling and improving processes. Later these improvements in product, technology and processes were integrated to produce electric bulbs fully automatically.

Similarly, there are many examples of service systems which have been totally automated by better design and technology. Development of new switching system by AT&T in 1970 has resulted in automating the trunk dialling of telephones almost entirely.

Mechanisation and Automation

Although there have been advances in design of almost all the facets of production, it is the way such operations are actuated, sequenced and controlled which has undergone rapid changes. Starting with the operator using his basic senses for starting, running and stopping the machine, the mechanism of control has become high speed and automatic. The element of discretion, based on application of operators' services, has been classified and transformed into a control system. For example, out size components can be identified and ejected automatically from the machine without the need to stop it. Visible and invisible defects can actuate a separating device. The entire programme of detecting and separating such defects can be written into the machine control system.

There are two types of control systems.

1. Open Loop Systems

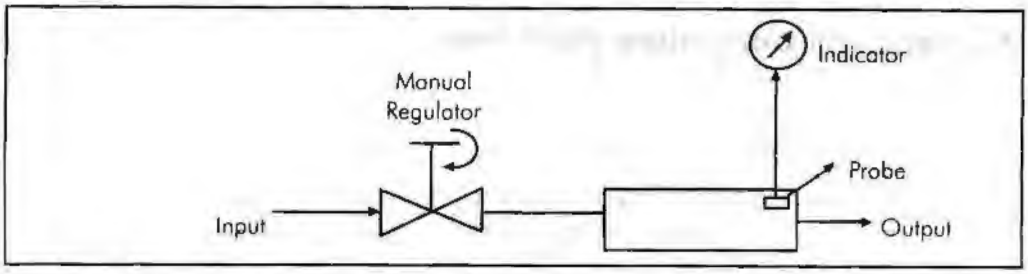


Figure 2.4: Schematic Presentation of a Typical Open Loop System

2. Closed Loop Systems

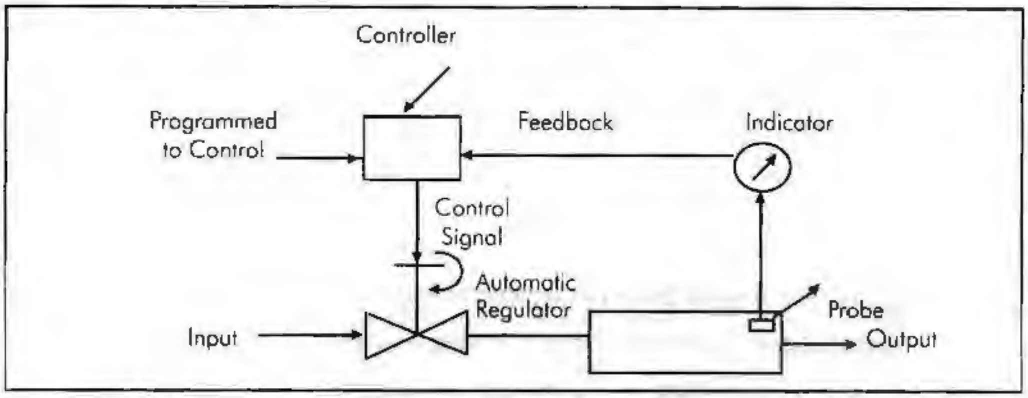


Figure 2.5: Schematic Presentation of a Typical Closed Loop System

Closed loop mechanism is achieved from their feedback of the probe. In the feedback loop, we have a sensing unit to measure and record the characteristic(s) of the output, a means to compare actual with the desired performance and deviation is then fed into the controller, who interprets the deviation and sends signal to regulate the input.

Impact of Computers on Process Innovation

A typical structure of product and process matrix is as below.

As the product shifts to a different matrix position, structure of manufacturing technology also shifts diagonally. In the early stages of the product structure development, flexibility of the manufacturing process and quality are extremely important for a competitive advantage, priorities shift to reliable deliveries and economic costs in later stages.

Product Structure / Process Structure	Low Volume Large Variety of Products	Low Volume Multiple Products	High Volume A Few Major Products	High Volume Standardised Products
Jumbled Flow (Job Shop)	3			
Disconnected Flow (Batch Shop)		3		
Connected Flow (Assembly Line)			3	
Continuous Flow				3

Figure 2.6: Matrix of Product and Process Structure

This matrix highlights why companies have to upgrade their equipment, procedures and human resources to match changes in product volumes, market requirements and competition.

Numerically Controlled Machines

As the name implies, each machine tool has a control and actuating unit which works as per the instructions of a prepared programme which could be in the form of punched card, paper or magnetic tape. These systems have become very versatile and comprehensive machine centres have emerged on the scene – these result from integration of a number of numerically controlled machine tools. Following systems are already in operation.

1. Computer-aided purchasing;
2. Computer-aided raw material inventory control;
3. Computer-aided designing;
4. Computer-aided drafting;
5. Computer-aided planning;
6. Computer-aided control;
7. Computer-aided finished product control;
8. Computer-aided maintenance management;
9. Computer-aided spare parts management; and
10. Computer-aided quality techniques for statistical process control, etc.

It is, therefore, the beginning of the concept of computer-integrated manufacturing (CIM).

Essentially it revolves around a shared database for:

1. Engineering design;
2. Manufacturing engineering;
3. Factory production; and
4. Information management.

Computer-integrated manufacturing is not yet a reality but, as explained above, many of the elements are already operational. This concept integrates the complete process of product development, manufacturing and distribution, i.e., 'from concept to market'.

Flexible Manufacturing Systems

Arising from the application of computer technology, it is now possible to produce moderate variety of products in moderate volumes by computer controlled process technology, called Flexible Manufacturing Systems (FMS). Herein several workstations are automated and programmed together. It involves automatic material handling, selecting, positioning and activating specific tools for each job with hundreds of options available. After completing a batch of products, next programme is also input. Machine automatically repositions its retooling and the previous lot is automatically transferred to the next workstation. FMS is more flexible than the normal production system as it can reduce the setting up time of changeovers from one product to another. It is a mid range system suitable for moderate variety/moderate volume products.

Student Activity

Fill in the blanks:

1. Technologies are process specific ....
2. Production planning and control can be very ....
3. Process of designing is iterative, products and processes are continually ....

Summary

An industrial process technology also follows a typical life cycle – it has an introduction stage, followed by the stage of rapid growth leading to a stage of maturity and decline. Technologies are process specific – each process will require a technology to match. Depending on the way technology is managed, these can be grouped into following categories. Intermittent type which can be divided into:

1. Project type
2. Job type
3. Batch type
4. Assembly line type
5. Continuous type

Process of designing is iterative, products and processes are continually redesigned. It is a never ending process – we always get new information from users, production and quality personnel and their help to improve the product and the technology. Starting with the operator using his basic senses for starting, running and stopping the machine, the mechanism of control has become high speed and automatic.

Keywords

Project Technology: This technology is suited to one of a kind products which are non-repetitive and are tailored to suit individual requirements of a customer.

Job Shop Technology: This technology deals with manufacture of small lots of a very large variety of products which are custom designed and built.

Flexible Manufacturing Systems (FMS): Arising from the application of computer technology, it is now possible to produce moderate variety of products in moderate volumes by computer controlled process technology, called Flexible Manufacturing Systems (FMS).

Review Questions

1. Draw and explain a Technology Life Cycle and Product Design.
2. Briefly explain these categories of Process Technologies:
   (a) Project Type,
   (b) Job Type,
   (c) Batch Type, and
   (d) Continuous flow technology.
3. With the help of figures briefly explain:
   (a) Open loop system
   (b) Closed loop system

Further Readings

Anderson, J., Schroeder, R. and Cleveland, G. (1991). The process of manufacturing strategy. *Int. J. Product. Operations Man.*

Clark, K. (1996). Competing through manufacturing and the new manufacturing paradigm: is manufacturing strategy pass´e? *Product Operations Man.*

Collis, D. and Montgomery, C. (1995). Competing on resources: strategy in the 1990s. *Harvard Bus. Rev.*

Corsten, H. and Will, T. (1994). Simultaneously supporting generic competitive strategies by production management. *Technovation*

Hayes, R. (1985). Strategic planning: forward in reverse? *Harvard Bus. Rev.*

Hayes, R. and Pisano, G. (1994). Beyond world-class: the new manufacturing strategy. *Harvard Bus. Rev.*

Hayes, R. and Pisano, G. (1996). Manufacturing strategy: at the intersection of two paradigm shifts. *Product. Operations Man.*

Kachru, Upendra (2007). *Production and Operations Management: Text and Cases*, Excel Books Pvt. Ltd.

Mills, J., Platts, K. and Gregory, M. (1995). A framework for the design of manufacturing strategy process, *Int. J. Operations Product. Man.*,

Voss, C. (1992), *Manufacturing Strategy*, Chapman and Hall.

Unit 3 Production Life Cycle and Design

Unit Structure

- Introduction
- Product Design
- Product Specification
- Modular Design and Standardisation
- Definitions
- Generation of New Product Opportunities
- Product Life Cycle
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Modular design and standardisation
- Generation of new product opportunities
- Product life cycle

Introduction

Product decisions often make or break companies. Studies indicate that nearly two out of three new products fail after launch. In addition, companies in many sectors are under continual pressure to speed up the pace of product development—even to adapt products that are still in the pipeline to the demands of a constantly changing marketplace. This chapter will discuss product design and process selection, which are crucial areas in operations management.

Product Design

Product design is the structuring of component parts or activities so that as a unit they can provide a specified value. It usually begins with the development of a set of detailed specifications.

Product Specification

Product specification is typically an engineering function – detailed drawings or specifications are prepared which give dimensions, weights, colours and so on. In service industries, the product specification often consists of an environmental requirement to be maintained or a procedure to be followed. For example, a health care environment may be the product of a nursing home or an accessible and quiet reading area, the service offered by a library. Design personnel should be familiar with the production technology and work with operations personnel to be sure that their design makes the best use of the organisation's capabilities. In this way the good or service will emerge with the most desirable material and service aspects.

Firms that are constantly evolving new design such as General Motors and Boeing, make extensive use of computer-assisted design (CAD) techniques during this phase. These approaches enable designers to develop and test a multitude of good or service configurations that could not otherwise be explored.

Modular Design and Standardisation

Modular design and component standardisation are two aspects of product design with special significance to operations management because they directly affect the complexity and cost of the conversion process.

Modular Design. Modular design is the creation of products from some combination of basic pre-existing subsystems. In selecting a personal computer system, for example, you may have your choice of three video monitors, two keyboards, two computers and three printers, all of which are compatible. All possible combinations make a total of 36 ($3 \times 2 \times 2 \times 3$) different computer systems. The modular design concept gives consumers a range of product options and at the same time, offers considerable advantages in manufacturing and product design. Stabilising the designs of the modules makes them easier to service. Problems are easier to diagnose and the modules are easier to service. Production proficiency increases as personnel make refinements to and gain experience with the manufacturing processes for standardised sets of modules.

Similarly, materials planning and inventory control can be simplified, especially in finished goods inventories. Now, rather than storing inventories of all 36 finished computer systems, only some of which will be needed, we instead store just the subsystems or modules. Then, when a particular computer system is demanded, the producer can focus on quickly retrieving and assembling the appropriate modules into the desired configurations and avoid the high costs of idle finished goods inventories.

Standardisation

Product standardisation offers benefits to consumers and producers alike. Customers can count on simplicity and convenience in purchasing standardised products like household doors, screws and other fasteners, spark plugs and so on. Similarly, uniform (standardised) pricing code label has meant greater efficiency for the retailer. In designing new products, standardisation can bolster productivity by: (1) avoiding unnecessary engineering design when a suitable component already exists; (2) simplifying materials planning and control during production because fewer components are in the system; (3) reducing components production (if the components are produced in-house) or reducing purchasing requirements and limiting the number of vendors (if components are purchased). The risky side of standardisation is that your competitor may upstage you with a new product feature that you cannot match because your design capabilities have become stagnant.

Definitions

Product: A product is a bundle of utilities consisting of various product features and accompanying services expected to yield satisfaction or benefits to the buyer. A product is a complex continuation of tangible attributes, including packaging, colour, price, manufacturing organisation's prestige, service, retailer's prestige and service which the buyer may expect as offering satisfaction towards wants or needs.

A product or service is defined in terms of its functions. What it is to do? Product or services are as diverse as manufactured GE toaster, appendectomy, a McDonalds's chicken nugget dish, or a bank account.

Importance of Product

The importance of product can be judged from the following facts:

1. Product is the central point for all marketing activities. Product is the soul of business and without it nothing may happen. All marketing activities, finance, product/operation functions cannot be thought of without product.
2. Product is the starting point of planning. Product policies decide the other policies, the nature, quality, features of product and all other planning actions.

Types of Products

Products are classified into two major categories:

1. ***Consumer goods:*** These are the goods destined for use by the ultimate consumer or household in such form that they can be used without commercial processing. Soaps, sweet and shoes, etc., are the examples of consumer goods.
2. ***Industrial goods:*** These goods are meant for use in producing other goods or rendering services as contrasted with goods destined to be sold primarily to the ultimate consumers.

Product Terminology

Following terms are usually associated with products:

Product Item: Product item means a specific product of certain specifications, such as Lux soap, Colgate toothpaste, Facit typewriter, HMT watch, Bajaj/Chetak scooter, etc.

Product Line: A product line is a group of different product items closely related with each other, either because they satisfy a class of needs, or used together or are sold to the same group of customers or are sold through the same channel of distribution or are within the same pricing range. Toothpastes, watches, TVs, scooters, typewriters, etc., are the examples of a product line.

Product Mix: Product mix is the composite of all the products offered for sale by a business and industrial enterprise. For example if an enterprise manufactures or deals with different varieties of soaps, oil, toothpaste, tooth brush, etc., the group of all these product is called product mix.

Width of Product Mix: Width of product mix signifies average number of product items in a product line of a manufacturer, for example, if the product mix of producer includes six product line and the number of product items in these product lines is 6, 4, 5, 4, 3 and 2, respectively, the depth of the product mix of such enterprise will be $(6 + 4 + 5 + 4 + 3 + 2)/6 = 4$. It follows that depth of the product mix tells only the average number of product items in all the product lines of an enterprise.

Consistency of Product Mix: Consistency of product mix is the study of the fact whether the product lines of an enterprise are related to one another or not, i.e., whether there is any correlation among product lines of an enterprise or not. For example, there are many product lines in Philips India Ltd. such as bulb, tubelights, radio, transistor, tape recorder, two-in-one, stereo, TV, etc. All these product lines are closely related. Therefore, it will be said that there is a high degree of consistency in the product mix of the company.

Expansion of Product Mix: Expansion of product mix means either an increase in product lines in the product mix of an enterprise or increase in the number of product items in these product lines.

Contraction of Product Mix: It means either pruning number of product lines in the product mix or to prune the number of products in a product line.

Optimum Product Mix: Optimum product mix is the product mix at which the enterprise is in a position to get maximum profits.

Product Design: It specifies which materials are to be used, determines dimensions and tolerances, defines the appearance of the product and sets standards for performance. Service design specifies what physical items, sensual benefits and psychological benefits, the customer is to receive from the service.

Product Selection: Product selection is choosing the product or service to be provided to customers or clients, for instance, hospitals specialise in treatment of various types of patients and adoption of various medical procedures. They select their product when they decide what kind of hospital it will be. A hospital's management may decide to operate a general purpose hospital, a maternity hospital or a hospital specialising in hernia operations.

Product selection decisions are influenced by three major factors: (1) the firm's resources and technology, (2) the market environment and (3) the cultural motivation to use the firm's capabilities to meet the needs of the marketplace. The motivation is often economic, but it can also be social, or political, or religious, for example, some firms are very capital-intensive (electric utilities), whereas others are more labour-intensive (clothing manufacturers) and some maintain sophisticated technologies, whereas others do not. These resource and technological capabilities usually relate to the organisation's line of business or industry. The most efficient firms within an industry use their resource and technological base to the fullest extent possible. Research and development is, of course, a primary method of expanding a firm's technological base so that it is in a better position to compete.

From the market environment come both demand and competition. A firm is in trouble unless consumers want the goods and services in volumes being produced at the given time. Of course, competitors can also foil a product selection if they are numerous or strong enough to dominate the market. In addition, society has established certain legal controls on competitive behaviour. However, consumers, competitors and society are all important sources of ideas as to which products are most needed and are likely to be most successful.

The resource capabilities and market demands must be matched in the form of the capability to produce at an economic or social advantage. For monopolistic or public agency organisations, the profit concept is not so crucial, but economy and efficiency continue to be relevant criteria. Forecasts of demand from the market should be compared with existing inventory levels and forthcoming production schedules before any new-product decisions are implemented. The Operations manager is usually in the best position to evaluate inventory, scheduling, quality and cost factors which are relevant to product selection decisions. Cost and capacity constraints often turn out to be critical determinants of product choice.

Product Strategy: Product strategy is the selection, definition and design of the product. The objective of product strategy is to ensure a competitive advantage for the product.

Generation of New Product Opportunities

Product selection, definition and design take place on a continuing basis because so many new product opportunities exist. Five factors influencing market opportunities are:

1. ***Economic change,*** which brings increasing levels of affluence in the long run but causes economic cycles and price changes in the short run. For instance, in the long run, more and more people can afford an automobile, but in the short run a change in fuel prices may alter the demand for automobiles.
2. ***Sociological and demographic change,*** which may appear in such factors as decreasing family size. This alters the size preference for homes, apartments and automobiles.

3. *Technological change,* which makes possible everything from home computers to mobile phones to artificial hearts.
4. *Political change,* which brings about new trade agreements, tariffs and government contract requirements.
5. *Other changes,* which may be brought about through market practice, professional standards, suppliers and distributors.

Operations managers must be aware of these factors and be able to anticipate changes in products, product volume and product mix accordingly.

Product Life Cycle

It has been determined that demand for a particular product tends to follow a pattern which is known as Product Life Cycle. All products go through several steps or stages, which begins with low volume during the market development stage and then proceeds through growth phase, maturity at higher volume and finally the decline sets in. Depending upon the industry in which one operates, the time span of stage can vary considerably. For example, in information technology industry the time frame, from product launch to decline may be as short as few months. In many other products, phases may span many years or even decades. Whatever the case may be, the very nature of product life cycle raises significant questions for operations management. These include, when will the various stages occur and how can the operations increase or decrease to accommodate the rising or falling demands. What kind of investments in facilities, materials labour and systems be done? How should one deal with existing facilities and production processes as products pass through their stages in the product life cycle. In next section let us look at some of the large issues arising in managing operations vis-à-vis the product life cycle.

Operations Issues in the Product Life Cycle

From production and operations management viewpoint the life cycle can be constructed in four stages as conceived by Prof. Hayes and Prof. Wheelwright. This is as shown in Figure 3.1.

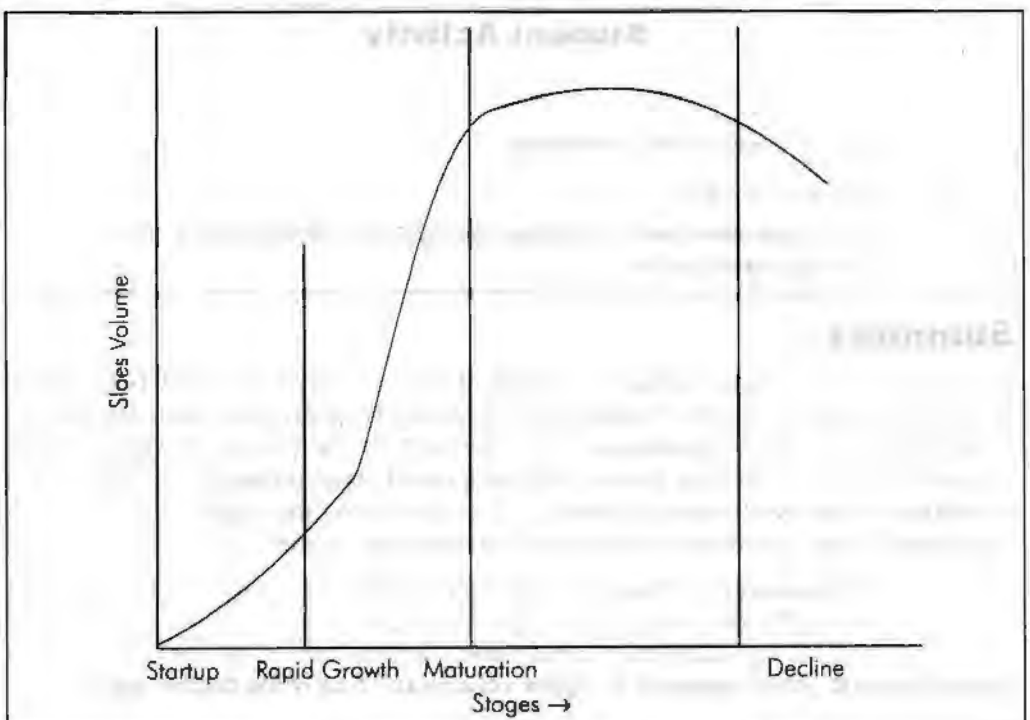


Figure 3.1: Product Life Cycle Characteristics

As depicted both the operation's strategy and production technology need to be adapted throughout the product life cycle because product variety, volume, nature, structure and forms of competition change. Let us take, for example, that in the start up phase design changes are frequent which may put considerable demand on manufacturing process. This may be compared to the final stage when the product designs stabilise so do the production processes.

In a competitive scenario, in the stages of product maturity, huge competition emerges. This requires core competencies in the manufacturing processes. In today's competitive world survival in the marketplace depends upon producing a reliable product with high volume so as to be able to compete on price and delivery capabilities. This is in stark contrast with the early life cycle stage where emphasis is on high product variety and low volume production process. To be adaptive in manufacturing process one should be constantly upgrading human skills, plant and machinery and manufacturing control systems. To do so it is important to have good research and development facilities to keep abreast with both new products and new manufacturing processes.

Stage in Life Cycle / Product Feature	Start-up	Rapid Growth	Maturation	Decline
Product variety	Great variety	Increasing standardisation	Emergence "dominant design"	High standardisation "Commodity" characteristics
Product volume/model	Low volume	Increasing volume	High volume	High volume
Industry structure	Small competitors	Fallout and	Few large consolidation	"Survivors" Companies
Form of competition	Product characteristics	Product quality	Price and dependability and availability	Price

Student Activity

Fill in the blanks:

1. Product design is the structuring of ....
2. Product strategy is ....
3. From production and operations management viewpoint the life cycle can be constructed in ....

Summary

Product design is the structuring of component parts or activities so that as a unit they can provide a specified value. Product specification is typically an engineering function – detailed drawings or specifications are prepared which give dimensions, weights, colours and so on. Modular design and component standardisation are two aspects of product design with special significance to operations management because they directly affect the complexity and cost of the conversion process.

It has been determined that demand for a particular product tends to follow a pattern which is known as Product Life Cycle. All products go through several steps or stages, which begin with low volume during the market development stage and then proceeds through growth phase, maturity at higher volume and finally the decline sets in.

Keywords

Products are artifacts that provide value to the customer. They can be tangible or intangible.

Goods are tangible items that are usually produced in one location and purchased in another.

Services are intangible products that are consumed as they are created.

Contracts are business exchanges in which neither services nor goods are transferred; instead, there is an implicit understanding between the customer and the provider that goods and services will be provided on an 'as needed' basis.

Product Lifecycle: The product lifecycle model is a simplistic representation of the cumulative impact of changes in the business environment on the life of a manufactured product.

Review Questions

1. Define Product specification.
2. Modular design and standardisation.
3. What is a Product? State the importance of products and types of products.
4. Explain Product Life Cycle.

Further Readings

Anderson, J., Schroeder, R. and Cleveland, G. (1991). The process of manufacturing strategy. *Int. J. Product. Operations Man.*

Clark, K. (1996). Competing through manufacturing and the new manufacturing paradigm: is manufacturing strategy pass´e? *Product. Operations Man.*

Collis, D. and Montgomery, C. (1995). Competing on resources: strategy in the 1990s. *Harvard Bus. Rev.*

Corsten, H. and Will, T. (1994), Simultaneously supporting generic competitive strategies by production management, *Technovation*

Hayes, R. (1985). Strategic planning: forward in reverse? *Harvard Bus. Rev.*

Hayes, R. and Pisano, G. (1994). Beyond world-class: the new manufacturing strategy. *Harvard Bus. Rev.*

Hayes, R. and Pisano, G. (1996). Manufacturing strategy: at the intersection of two paradigm shifts. *Product. Operations Man.*

Kachru, Upendra (2007). *Production and Operations Management: Text and Cases*, Excel Books Pvt. Ltd.

Mills, J., Platts, K. and Gregory, M. (1995). A framework for the design of manufacturing strategy process. Int. J. *Operations Product. Man.*,

Voss, C. (1992), *Manufacturing Strategy*, Chapman and Hall.

Unit 4 Product Planning and Development

Unit Structure

- Introduction
- Product Development
- Research and Development
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Product development
- Research and development

Introduction

The conversion of a customer's order to a finished product needs generally the organisation and planning of the manufacturing process. The overall objective of any organisation is to improve its profitability through productivity i.e. by employing various inputs (Men, Machines, Materials, Money & Management) effectively so as to bring about the desired manufacturing results in terms of quality, time and place.

Product Development

Product development encompasses the technical activities of product research, engineering and design.

Product Development Process

It includes the following elements:

Needs Identification: Once a product idea surfaces, it must be demonstrated that the product fulfils some consumer need and that existing products do not already fulfil the need.

Advance Product Planning: Following this demonstration is product planning. It includes preliminary market analysis, creating alternative concepts for the product, clarifying operational requirements, establishing design criteria and their priorities and estimating logistics requirements for producing, distributing and maintaining the product in the market.

An important result from this stage of development is the conceptual design of the product. The conceptual design for a new kind of fishing rod, for example, would articulate its weight, strength, shape, bending characteristics, retail price and so on. These basic properties are also called the product concept or design concept. Many industries have learned that production and operations personnel should be involved in concept design. By doing so, new production processes can be designed and tested early in the development process.

Advance planning poses a point of friction between business and technical personnel when solid technical ideas are adjudged to have insufficient business merit and, hence, fall by the wayside. Preliminary market analysis including sales projections and economic analysis including estimates of production operating costs, overhead and profitability, may suggest abandoning a technically attractive new idea.

Advance Design: Basic and applied researchers investigate technical feasibility and identify in greater detail the trade-offs in product design. Promising design alternatives are evaluated according to critical parameters to determine whether design support such as analytical testing, experimentation, physical modelling and prototype testing will be required.

Detailed Engineering Design: This stage is a series of engineering activities to develop a detailed definition of the product, including its subsystems and components, materials, sizes, shapes and so on. The engineering process typically involves analysis, experimentation and data collection to find designs that meet several design objectives:

(1) design for function so that the product will perform as intended, (2) design for reliability so that the product will perform consistently, (3) design for maintainability so that the product can be economically maintained, (4) design for safety so that the product will perform with minimal hazard to the user and the environment, (5) design for manufacturing (DFM) so that the product can be manufactured at the intended cost and volumes. Computer analysis, simulations and physical prototypes allow for testing various design alternatives and validate that the final design meets the design objectives. Since objectives can conflict with each other, trade-offs are inevitable in the optimal design. Typically, the final design includes drawings and other documentation as well as a working prototype of the product.

Production Process Design and Development

Working with the detailed product design, engineers and manufacturing specialists prepare plans for materials acquisitions, production, warehousing, transportation and distribution. Activities here, however, go beyond just hardware considerations and equipment and formal research all are used to monitor analyse and redesign the product.

Product Use and Support

An important stage of product development considers support for the consumer who uses the product. Support systems might: (1) educate users on specific applications of the product, (2) provide warranty and repair service, (3) distribute replacement parts, (4) upgrade the product with design improvements.

Research and Development

Many corporations, specially the larger ones, take no chance while developing new products and processes. These companies make a conscious effort in creating a new product, finding new uses of existing product, simultaneously evolving new production processes that reduce/cut the operating cost.

As they say, "Rome was not built in a day", same dictum is applicable to product development. The process of developing new successful products or processes requires talent and expertise of lots of people and is a torturous process. All new product ideas must be evaluated for economy, production feasibility, market potential and robustness of design.

Components of Innovation: The four generic components of innovation are basic research, applied research, development and implementation. Basic research is the research that is carried out with the premise of adding to common body of scientific knowledge that may have no immediate commercial uses.

For example, Basic Research be carried out in chemistry which may be of future or present interest to a pharmaceutical company.

Applied research is the research which is carried out with a specific objective of potential commercial use. For example, discovery of new molecule which may counter the HIV virus is the area of applied research for a pharmaceutical company.

Development is a technical activity which is concerned with conversion of applied or basic research results into product or processes which are sustainable for manufacturing. Continuing with pharma industry example, development activity implies creation of a process whereby a new drug can be manufactured reliably and in a cost-effective manner.

Implementation is an activity which follows development and includes all such aspects such as design of plant and machinery, creation of manufacturing facilities and initiation of distribution channels for production and services emerging for research and development effort.

Student Activity

Fill in the blanks:

1. Product development encompasses the ....
2. The four generic components of innovation are ....

Summary

Product development encompasses the technical activities of product research, engineering and design. An important result from this stage of development is the conceptual design of the product. The conceptual design for a new kind of fishing rod, for example, would articulate its weight, strength, shape, bending characteristics, retail price and so on. T he engineering process typically involves analysis, experimentation and data collection to find designs that meet several design objectives: (1) design for function so that the product will perform as intended, (2) design for reliability so that the product will perform consistently, (3) design for maintainability so that the product can be economically maintained, (4) design for safety so that the product will perform with minimal hazard to the user and the environment, (5) design for manufacturing (DFM) so that the product can be manufactured at the intended cost and volumes.

Keywords

Applied research: Applied research is the research which is carried out with a specific objective of potential commercial use.

Development: Development is a technical activity which is concerned with conversion of applied or basic research results into product or processes which are sustainable for manufacturing.

Implementation: Implementation is an activity which follows development and includes all such aspects such as design of plant and machinery, creation of manufacturing facilities and initiation of distribution channels for production and services emerging for research and development effort.

Review Questions

1. Explain the process of Product Development.
2 "Rome was not built in a day" same dictum is applicable to product development. Explain.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see,* Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management,* John Wiley & Sons, 1994.

Clayton Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail,* HBS Press, 1997.

Chase, Jacobs, Aquilano, *Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management: Strategy and Analysis,* Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach,* McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management: Concepts, Methods and Strategies,* John Wiley & Sons, 2004.

Unit 5 Plant Location

Unit Structure

- Introduction
- Facilities Location Defined
- Significance of Plant Location
- Objective of Location Strategy
- Types of Facilities
- Site Selection – Where to Locate?
- Site Evaluation Processes
- Critical Factors in Location Analysis
- Location Analysis Techniques
- Locational Break-even Analysis
- Behavioural Impacts in Facility Location
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Significance of plant location
- Site selection – where to locate?
- Critical factors in location analysis
- Behavioural impacts in facility location

Introduction

The management is often faced with the problem of selecting a new site for locating a new production facility or a new warehouse. Very often the cost of transportation of inputs and outputs to the processing units or the marketplace are critical parameters. In such cases, the transportation method can be used in finding out the lowest cost location insofar as the location factors can be quantified.

Facilities Location Defined

Facilities location may be defined as selection of suitable location or site or place where the factory or plant or facilities to be installed, where plant will start functioning.

Significance of Plant Location

One of the most important long-term cost and revenue decisions company makes is where to locate its operation. Location is a critical element in determining fixed and variable costs for both industrial and service firms. Depending on the product and type of production or service taking place, transportation costs alone can total as much as 25 per cent of the selling price. That is one fourth of the total revenue of a firm may be needed just to over freight expenses of the raw materials coming in and the finished product going out. Other costs that may be influenced by location include taxes, wages and raw material costs. The choice of locations can alter total production and distribution costs by as much 10 per cent. Lowering costs by 10 per cent of total production costs through optimum location selection may be the easiest 10 per cent savings management ever makes.

Once an operations manager has committed an organisation to a specific location, many costs are firmly in place and difficult to reduce. For instance, if a new factory location is in a region with high energy costs, even good management with an outstanding energy strategy is starting at a disadvantage. The same is true of a good human resource strategy if labour in the selected location is expensive, ill-trained, or has a poor work ethic. Consequently, hard work to determine an optimal facility location is a good investment.

Objective of Location Strategy

The development of a location strategy depends upon the type of firm being considered. Industrial location analysis decisions focus on minimising costs; retail and professional service organisations typically have a focus of maximising revenue. Warehouse location, on the other hand, may be determined by a combination of cost and speed of delivery. The objective of location strategy is to maximise the benefit of location to the firm.

Types of Facilities

The various types of facilities are briefly described below:

Heavy Manufacturing

Heavy manufacturing facilities are primarily plants that are relatively large and require a lot of space and as a result, are expensive to construct. Examples include automobile plants, steel mills and oil refineries. Important factors in the location decision for plants include construction costs, modes of transportation for shipping heavy manufactured items and receiving bulk shipments of raw materials, proximity to raw materials, utilities, means of waste disposal and labour availability. Sites for manufacturing plants are normally selected where construction and land costs can be kept at a minimum and raw material sources are nearby in order to reduce transportation costs. Access to rail-roads is frequently a major factor in locating a plant. Environmental issues have increasingly become a major factor in plant location decisions. Plants can create various forms of pool pollution and traffic pollution. These plants must be located where the harm to the environment is minimised. Although proximity to customers is an important factor for some facility types, it is less so for manufacturing plants.

Light Industry

Light industry facilities are typically perceived as smaller, cleaner plants that produce electronic equipment and components, parts used in assemblies, or assembled products. Examples might include plants making stereos, TVs, or computers, tool and die shop, breweries, or pharmaceutical firms. Several factors are important for light industry. Land and construction costs are not generally as crucial, because the plants tend to be smaller and require less engineering. It is not as important to be near raw materials, since they are not received in large bulk quantities, nor is storage capacity required to as great a degree. As a result, transportation costs are somewhat less important. Many parts and material suppliers fall into this category and as such, proximity to customers can be an important factor. Alternatively, many light industries ship directly to regional warehouses or distributors, making it less important to be near customers. Environmental issues are less important in light industry, since burning raw materials is not normally part of their production processes, not are there large quantities of waste. Important factors include the labour pool, especially the availability of skilled workers, the community environment, access to commercial air travel, government regulation and land use requirements.

Warehouses and Distribution Centres

Warehouses are a category of their own. Products are not manufactured or assembled within their confines, nor are they sold from them. They represent an intermediate point in the logistical inventory system where products are held in storage. Normally a warehouse is simply a building that is used to receive, handle and then ship products. They generally require only moderate environmental conditions and security and little labour, although some specialised warehouses require a more controlled environment, such as refrigeration or security for precious metals or drugs. Because of their role as intermediate points in the movement of products from the manufacturer to the customer, transportation and shipping costs are the most important factors in the location decision for warehouses. The proximity to customers can also be an important consideration, depending on the delivery requirements, including frequency of delivery required by the customer. Construction and land costs tend to be of less importance as does labour availability. Since warehouses require no raw materials, have no production processes and create no waste, factors such as proximity to raw materials, utilities and waste disposal are of almost no importance.

Retail and Service

Retail and service operations generally require the smallest and least costly facilities. Examples include such service facilities as restaurants, banks, hotels, cleaners, clinics and law offices and retail facilities such as groceries and department stores, among many others. The single most important factor for locating a service or retail facility is proximity to customers. It is usually critical that a service facility be near the customers who buy from it. Construction costs are generally less important (especially when compared with a manufacturing plant); however, land or leasing costs can be important. For retail operations, for which the saying "location is everything" is very meaningful, site costs can be very high. Other location factors that are important for heavy and light manufacturing facilities, such as proximity to raw materials, zoning, utilities, transportation and labour, are less important or not important at all for service and retail facilities.

Site Selection – Where to Locate?

When we see on the television news or read in the newspaper that a company has selected a site for a new plant, the decision can appear to be almost trivial. Usually it is reported that a particular site was selected from among two or three alternatives and a few reason are provided such as good community or available land. However, such media reports conceal the long, detailed process for selecting a site for a major manufacturing facility. When General Motors selected Spring Hill, Tennessee, as the location for their new Saturn Plant in 1985, it culminated a selection process that required several years and the evaluation of hundreds of potential sites.

When the site selection process is initiated, the pool of potential locations for a manufacturing facility is, literally, global. Since proximity to customers is not normally an important location factor for a manufacturing plant, countries around the world become potential sites. As such, the site selection process is one of gradually and methodically narrowing down the pool of alternatives until the final location is determined. In the following discussion, we identify some of the more important factors that companies consider when determining the district, region, state and site at which to locate a facility.

Country

Until recent years companies almost exclusively tended to locate within their national borders. This has changed somewhat in recent years as US companies began to locate outside the continental United States to take advantage of lower labour costs. This was largely an initial reaction to the competitive edge gained by overseas firms, especially Far-Eastern countries in the 1970 and 1980. US companies too quickly perceived that foreign competitors were gaining a competitive edge primarily because of lower labour costs. They failed to recognise that the real reason was often a new managerial philosophy based on quality and the reduction of all production-related costs. High transportation costs for overseas shipping, the lack of skilled labour, unfavourable foreign exchange rates and changes in an unstable government have often combined to negate any potential savings in labour costs gained by locating overseas. Ironically, some German companies, such as Mercedes-Benz, are now locating plants in the United States because of lower labour costs. An overseas location is also attractive to some companies who need to be closer to their customers, especially many suppliers.

Location factors that are often considered for an overseas site include the following:

• Government stability	• Raw material availability
• Government regulations	• Number and proximity of suppliers
• Political and economic systems	• Transportation system
• Economic stability	• Labour pool and cost
• Exchange rates	• Available technology
• Culture	• Commercial travel
• Climate	• Technical expertise
• Export and import regulations, duties and fees	• Region

The next stage in the site selection process is to determine the part of the country or the state in which to locate the facility.

In India the Western and Central regions are generally most preferable and the Eastern region is least preferable for manufacturing facilities. This reflects a general migration of industry from the Eastern to the Western and Central regions during the last two decades primarily due to labour relations. The factors that influence in what part of the country to locate are more focused and area-specific than the general location factors for determining a country.

Factors that are considered when selecting the part of the country for a facility include the following:

• Labour (availability, cost and unions)	• Government regulations
• Proximity of customers	• Environmental regulations
• Number of customers	• Raw material availability
• Construction/Leasing costs	• Commercial travel
• Land cost	• Climate
• Modes and quality of transportation	• Utilities
• Transportation costs	

State/District

The site selection process further narrows the pool of potential locations for the facility down to several communities or localities. Many of the same location factors that are considered in selecting the country or region in which to locate are also considered at this level of the process. Location factors include the following:

• State/District government	• Concentration of customers
• Local business regulations	• Taxes
• Environmental regulations	• Construction/Leasing costs
• Government services (Chamber of Commerce, etc.)	• Land cost
	• Availability of sites
• Business climate	• Financial services
• State amenities	• Labour pool
• Transportation system	• State inducements
• Proximity of customers	• Proximity of suppliers

Site

The site selection process eventually narrows down to the determination of the best location within a community. In many cases a community may have only one or a few acceptable sites, so that once the community is selected the site selection is an easy decision. Alternatively, if many potential sites exist, a thorough evaluation is required of sites that are potentially very similar. For service and retail operations, customer concentrations become a very important consideration in selecting a site within a community, as does cost. These and other factors in the selection of a site are included among the following:

• Customer base	• Land use restrictions
• Construction/Leasing cost	• Traffic
• Land cost	• Safety/Security
• Site size	• Competition
• Transportation	• Area business climate
• Utilities	• Income level

Site Evaluation Processes

In the previous sections we have identified the important factors that companies often consider when determining where to locate a facility. In the site selection process these factors and others are evaluated by a search team or individual from the company. Sometimes a consulting firm is hired that specialises in site selection for different types of facilities. For example, there are consulting firms that specialise solely in selecting sites for bookstores in university communities. Similarly, there are site location firms that travel around the world evaluating locations for plants for large companies. However, whoever conducts the search, the evaluation process requires large amounts of data and information relative to the different location factors. The cost data alone for different factors such as construction, land, labour and transportation can be voluminous. National, state and community governments generally have department or offices that specialise in attracting businesses and have data and information useful in the site selection process. Government agencies also publish numerous documents with data and information about potential business sites in their jurisdiction. These offices will also usually provide assistance in gathering relevant data from publications, brochures, reports, or a computerised information system. They will also help to gather information that is not readily available. Chambers of commerce for different cities are excellent sources of information about communities and potential facility sites.

Critical Factors in Location Analysis

In the previous section we identified some of the factors that impact on the location decision for a new facility. These factors included some that tend to be ignored regardless of the type of facility or location, such as labour, transportation, accessable customers and markets and community environments. In this section we assess these factors and others in more detail.

Labour

The labour climate is one of the most important overall factors in the location decision particularly for manufacturing operations and even to a certain extent for service operations. Labour climate includes the cost of labour, embodied in wage rates and salaries, the availability of labour, the work ethic of the labour population, the possibility of labour conflict and problems with organised labour and the general skill level of the labour pool.

Wage rates have traditionally been lower in the Central and Southern regions than in other geographic regions, especially the North and West. This has contributed to the relocation of many manufacturing companies to the Central region. However, the eastern region has become less inviting due to labour strife.

Individual communities will often reflect different work ethics in terms of absenteeism, commitment and productivity. This sometimes results from the fact that a new plant in a town where few plants are located often offers a welcome, work experience with higher-paying jobs.

Labour conflict is anathema to many companies and they will avoid union contamination of their workforce at almost any cost. Alternatively, many local unions are able to assist in attracting new plants or keep plants from relocating by the willingness to work with management and make attractive labour compromises and concessions.

Transportation and Logistics

The proximity of suppliers and markets are both important considerations in the location decision. For many heavy manufacturing companies it is essential to be close to raw material sources, such as forestry and wood products companies, mining operations and food-processing plants. Although it is not necessary for some companies to be in close proximity to their source of raw materials, it is important that they be near one of the five primary modes of transportation, . . . highways/trucking, waterways or pipelines that is adequate to meet their shipping and receiving needs. Distribution and supply routes and modes of transformation are also important for many service-related businesses. Fast-food operations, retail stores, groceries and service stations are examples of businesses that use materials or products that must be transported to them from a warehouse or distributor.

The costs associated with transporting materials and finished products can be significant for businesses, especially when frequent deliveries over long distances are required or the items being distributed are large. The magnitude of these costs is often the primary reason that a business will locate near its customers, its suppliers, or both. The closeness of suppliers can also determine the amount of inventory a firm will be required to keep in stock. If a supplier is very near a plant or business then items can be received quickly, negating the necessity to keep large stocks of materials, supplies, or parts on hand, thus reducing inventory costs. As the distance from suppliers increases, the variability of the timing of deliveries increases. This fact magnifies the uncertainties inherent in a company's usage rate, which requires even larger stocks or inventory to guard against any stockouts and work stoppages resulting from late deliveries. The same problems can occur in reverse if a company is far from its customers. Uncertainty in delivery schedules caused by long distances can cause customers to maintain larger than desired inventory stocks. This situation generally decreases the level of customer service that can be provided.

Customers and Markets

Many business simply look for a high volume of customer traffic as the main determinant of location, regardless of the potential competition. A national highway exit onto a major thoroughfare will almost always include a number of competing service stations and fast-food restaurants. Shopping centres are an example of a location in which a critical mass of customer traffic is sought to support a variety of similar and dissimilar businesses. For example, a shopping centre typically has numerous restaurants, several large department stores and a variety of smaller speciality stores that sell similar products. In fact, a large department store in a shopping centre will stock almost every product (not brand) that virtually everyone of the smaller stores around it also stocks. Instead of seeking a location away from large competitors these smaller retail stores cluster together to feed off the customer traffic created by the larger anchor stores. Alternatively, businesses that rely on a steady customer clientele, such as doctors, dentists, lawyers, barber shops and hair salons and health clubs often tend to seek locations with limited competition, which minimises customer turnover.

Although it is important to be located where suppliers are, in order to make sales, it is also important to be near enough to customers to provide a high level of customer service. This is especially true given the current emphasis and expectations regarding quality service. As a result, it has become increasingly important for manufacturing firms to be near their customers, especially if they are suppliers of parts or materials used to produce finished goods. As we have already mentioned on several occasions, there is pressure on suppliers to locate near their customers in order to reduce the uncertainty of delivery schedules and provide better customer service. As international markets have opened up, a number of major manufacturing companies have located plants overseas for similar reasons – that is, to minimise transportation costs and be closer to their customers.

State/District Environment

A number of specific factors associated with the local state/district where a business might locate can be important to the location decision. These factors are as following:

• Climate	• Crime rates
• Available housing in different price ranges	• Medical, fire and police services
• Taxes	• Local population and available labour pool
• Financial health and institutions	• Distance to convenient air service
• Universities and research labs	• Local road system and traffic
• System of local government	• Shopping
• Cultural and entertainment activities	• Environmental, noise and pollution regulations
• Land use regulations and ordinances	• Local attitudes toward business
• Educational system	

State/districts will often aggressively seek out new businesses to locate in their area by enhancing many of these factors including providing tax breaks and low interest loans; easing construction, easing land use and environmental regulation and ordinances; improving and building roads; and issuing bonds to support site preparation and construction of the facility. Alternatively, states/districts will occasionally work to keep out undesirable businesses that might foul the environment or increase the demand on community services without providing acceptable long-term benefits.

Site Characteristics

When locating at a new site, a business can either purchase or lease an existing building or select a parcel of land and construct a new facility. Service-related businesses often rent or purchase existing facilities, for example, in shopping mails or office buildings. It is usually more difficult for manufacturing operations to find a building that is suitable for their specific needs and so construction is usually required.

If a new facility is built, a range of factors must be considered, may of which are the same as for a person building a house. These include the size of the space, potential for expansion, soil stability and content, neighbourhood, drainage, direct access to roads, sewer and water connection, utilities and cost. When evaluating a site for lease or purchase, other considerations (that would be built into a new facility) include structural integrity of the facility, the ability to make alterations to the structure, existing parking and the potential for additional parking, neighbourhood, loading-dock facilities, storage, maintenance and utility expenses, the lease rate (or purchase cost) and if leasing, the length of the lease.

A recent trend in site locations has been a proliferation of industrial and office estates, in which many of the special use needs of businesses have been planned for. Industrial estates usually have a combination of available parcels of land and existing structures that cater to service operations or vendors with storage requirements and light manufacturing. Office estates typically have a number of existing buildings and office suites that are attractive to white-collar service operations such as insurance companies, lawyers, doctors, real estate and financial institutions.

Location Analysis Techniques

Location Factor Rating

The decision where to locate is basically subjective, based on a variety of different types of information and inputs. Mere is no single model or technique that will select "the best" location from a group. However, there are techniques available that help to organise location information and that can be used as, a basis for comparing different locations according to specific criteria.

One of the more popular methods for evaluating and comparing different locations is the location factor rating system. In this procedure the factors that are important in the location decision, are identified. Each factor is assigned a weight from 0 to 1.00 that prioritises the factor and reflects its importance. A score is assigned (usually between 0 and 100) to each factor based on its attractiveness compared to other locations and the weighted scores are summed.

Centre-of-Gravity Technique

In general, transportation costs are a function of distance, weight and time. The centre-of-gravity, or weight centre, technique is a quantitative method for locating a facility such as a warehouse at the centre of movement in a geographic area based on weight and distance. This method identifies a set of coordinates designating a central location on a map that minimises the weighted average of the weight transported to all other locations. As such, it implicitly assumes that by minimising the weight shipped, costs are also minimised.

The starting point for this method is a grid map set up on a Cartesian plane, as shown in Figure 5.1. Note that there are locations identified as 1, 2 and 3, each at a set of coordinates (x_1, y_1) identifying its location in the grid. The value W_1 is the annual weight shipped from that location. The objective is to determine a central location for a new facility that minimises the distance these weights are shipped.

The coordinates for the location of the new facility are computed using the following formulas:

$$x = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i}, \quad y = \frac{\sum_{i=1}^{n} y_i w_i}{\sum_{i=1}^{n} w_i}$$

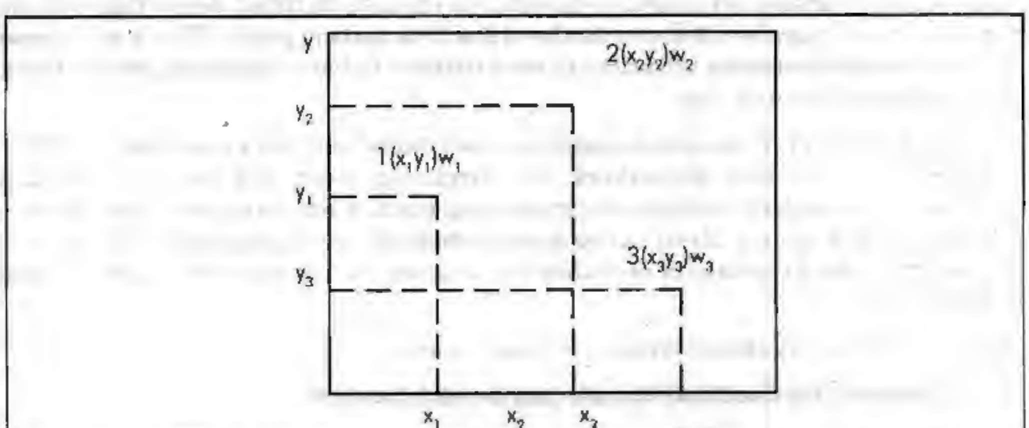


Figure 5.1: Grid-Map Coordinates for Centre of Gravity Method

Where,

x, y = coordinates of the new facility at centre of gravity

x_i, y_i = coordinates of existing facility i

w_i = annual weight shipped from facility i

Load distance Technique

A variation of the centre-of-gravity method for determining the coordinates of a facility location is the load-distance technique. In this method, a single set of location coordinates is not identified. Instead, various locations are evaluated using a load-distance value that is a measure of weight and distance. For a single potential location, a load-distance value is computed as follows:

$$LD = \sum_{i=1}^{n} l_i d_i$$

Where,

LD_i = the load-distance value

l_i = the load expressed as a weight, number of trips, or units being shipped from the proposed site and location

d_i = the distance between the proposed site and location i

The distance d in this formula can be the travel distance, if that value is known or can be determined from a map. It can also be computed using the following formula for the straight line distance between two points, which is also the hypotenuse of a right triangle.

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2}$$

Where,

(x, y) = coordinates of proposed site

(xi, yi) = coordinates of existing facility

The load-distance technique is applied by computing a load distance value for each potential facility location. The implication is that the location with the lowest value would result in the minimum transportation cost and thus would be preferable.

Locational Break-even Analysis

Break-even is the point where total revenue equals the total costs (variable and fixed). It is that level of activity at which an enterprise makes neither a loss nor any profit. At this point or level, the sales revenues are just equal to the costs incurred. Below this level the firm will make losses, while above this level it will be making profits. This is so because that the variable costs vary according to the variations in the volume or level of activity, the fixed costs do not change.

Locational break-even analysis is based on cost-volume analysis to make an economic comparison of location alternatives. By identifying fixed and variable cost and graphing them for each location, we can determine which one provides the lowest cost. Locational break-even analysis can be done mathematically or graphically. The graphic approach has the advantage of providing the range of volume over which each location is preferable.

The three steps to locational break-even analysis are:

1. Determine the fixed and variable cost for each location.

2. Plot the costs for each location with costs on the vertical axis of the graph and annual volume on the horizontal axis.
3. Select the location that has the lowest total cost for the expected production volume.

Behavioural Impacts in Facility Location

Our previous discussions of models focused on the cost consequences. But costs are not the whole story and models can't account for aspects of a problem that are not quantifiable. New locations require that organisations establish relationships with new environments and employees and adding or deleting facilities requires adjustments in the overall management system. The organisation structure and modes of making operating decisions must be modified to accommodate the change. These hidden "system costs" are usually excluded from quantitative models and yet they are very real aspects of the location decision.

Cultural Differences

The decision to locate a new facility usually means that employees will be hired from within the new locale. It also means that the organisation must establish appropriate community relations to "fit into" the locale as a good neighbour and citizen. The organisation must recognise the differences in the way people in various ethnic, urban, suburban and rural communities react to new businesses. Managerial style and organisational structure must adapt to the norms and customs of local subcultures. Employees' acceptance of authority may vary with subcultures, as do their life goals, beliefs about the role of work, career aspirations and perceptions of opportunity. These cultural variations in attitude impact on the job behaviour and talent.

At the international level are even greater cultural differences. Compare, for example, the Japanese work tradition with that of western industrial society. Japanese workers are often guaranteed lifetime employment. Management decisions usually are group rather than individual decisions. Employee compensation is determined by length of service, number of dependents and numerous factors apart from the employee's productivity. Obviously operations managers in Japan face a very different set of managerial problems from their US counterparts. Wage determination, employee turnover, hiring and promotion practices are not at all the same.

The European social system as another example, has resulted in a more "managerial elite" in their organisations than in the US because of education, training and socialisation, including a life-long exposure to a relatively rigid class system, lower subordinates are not prepared to accept participative managerial styles. This has resulted in more authoritarian/centralised organisations than participative/decentralised.

Locating a new facility in a new culture is not simply a matter of duplicating a highly refined manufacturing process. Merely transferring tools and equipment is not adequate. Managerial techniques and skills, in a proper mix, must be borrowed from the culture and so must the cultural assumptions that are needed to make them work. Clearly, the economic, political and cultural make-up of a society has far-reaching effects on the technological and economic success of multinational location decisions.

Job Satisfaction

In recent years managers have been very concerned about employee job satisfaction because it affects how well the organisation operates. Although no consistent overall relationship between job satisfaction and productivity seems to exist, other consistent relationships have been found. As compared with employees with low job satisfaction, those expressing high job satisfaction exhibit the following characteristics:

1. Fewer labour turnovers;
2. Less absenteeism;

3. Less tardiness;
4. Fewer grievances.

These four factors can substantially affect both costs and disruptions of operations. But how is job satisfaction related to facility location? There is some evidence that satisfaction is related to community characteristics such as community prosperity, small town versus large metropolitan locations and the degree of unionisation. Accordingly, a company with facilities in multiple locations can expect variations in employee satisfaction due to variation in attitudes and value systems across locations.

Consumer Considerations

For many organisations, location planning must emphasise consumer behaviour and proximity to customers. If primary product is a service to the public, the customer convenience may be the prime consideration. Theatres, banks, supermarkets and restaurants heavily emphasise customer convenience when choosing a location. In fact, location convenience itself is often considered to be the service. For these reasons the location decision may be regarded as a responsibility of marketing staff instead of production/operations staff, especially as it affects revenues rather than costs.

Example I

The potential locations Bhopal, Delhi and Pune have the cost structure shown for producing telecommunication set expected to sell for ₹ 90. Find the most economical location for an expected volume of 1850 units/year.

Site	Fixed cost/year	Variable cost/unit
Bhopal	20,000	50
Delhi	40,000	30
Pune	80,000	10

Solution

Total cost = Fixed cost + Variable cost

Total cost at Bhopal = 20000 + (50 × 1850) = 112500

Total cost at Delhi = 40000 + (30 × 1850) = 95500

Total cost at Pune = 80000 + (10 × 1850) = 98500

The cost volume graph is shown in Figure 5.2.

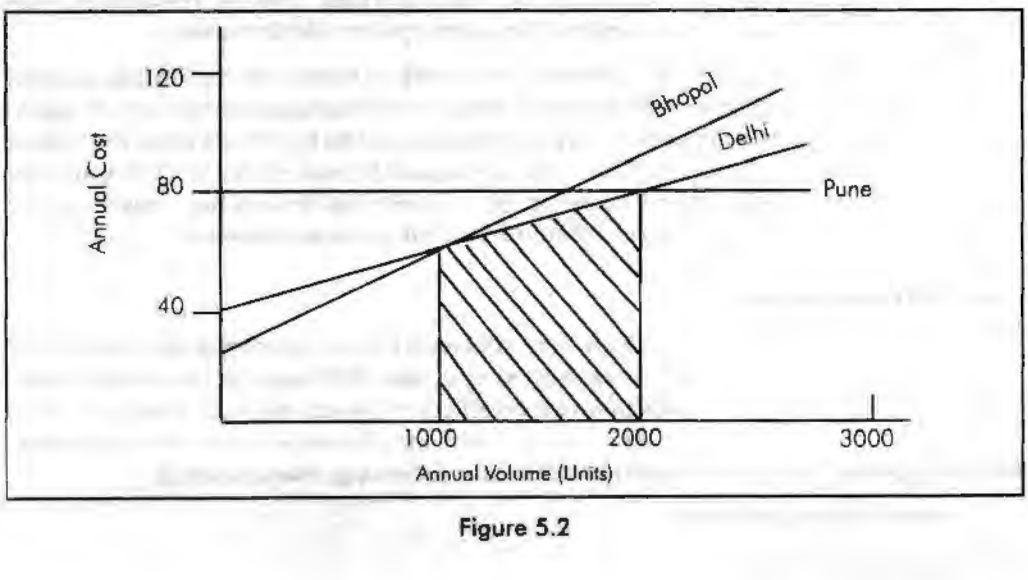


Figure 5.2

From the graph it is evident that the most economical location for a volume of 1850 units is Delhi. Expected profit here is:

Total revenue – total cost = (90 × 1850) – 95500 = 71000/year

Please note that for volumes less than 1000 units Bhopal would be preferred, for volumes greater than 2000 units Pune would be preferred.

Example 2

From the following data select the most advantageous location for setting a plant for manufacturing Television sets.

		Bhopal	Mandideep	Vidisha
(i)	Total initial capital expenditure	400,000	400,000	400,000
(ii)	Total expected sales/year	500,000	600,000	500,000
(iii)	Distribution expenses	80,000	80,000	150,000
(iv)	Raw material expenses	140,000	160,000	180,000
(v)	Power and water supply expenses	80,000	60,000	40,000
(vi)	Wages and salaries	40,000	50,000	40,000
(vii)	Other expenses	50,000	80,000	60,000
(viii)	Community attitude	Indifferent	Wants	Indifferent
(ix)	Employee housing facilities	Poor	Excellent	Good

Solution

Site	*Bhopal*	*Mandideep*	*Vidisha*
Total expenses	390,000	430,000	470,000

(Add iii, iv, v, vi. vii)

$$Rate\ of\ return\%(ROR) = \frac{Total\ sale - Total\ expenses}{Total\ investment} \times 100$$

$$ROR\ of\ Bhopal = \frac{500,000 - 390,00}{400,000} \times 100 = 27.5\%$$

$$ROR\ of\ Mandideep = \frac{600,000 - 430,000}{40,000} \times 100 = 42.5\%$$

$$ROR\ of\ Vidisha = \frac{500,000 - 470,000}{400,000} \times 100 = 7.5\%$$

From economic consideration point of view site of Mandideep is most advantageous. Moreover, intangible factors of community wants business and housing facilities are excellent and also favour the site of Mandideep.

Example 3

The Indian Seamless Tube Company Ltd. which has distribution plants in Gujarat and Andhra is considering adding a third assembly and distribution plant either in Ahmedabad, Bangalore or Cochin.

The company has collected the following economic and other relevant data:

Factor	Cochin	Ahmedabad	Bangalore
Transportation cost/week	₹ 780	₹ 640	₹ 560
Labour cost/ week	₹ 1200	₹ 1020	₹ 1180
Selected criteria scores (Based on a scale of 0-100 points)			
Finishing material supplied	35	85	70
Maintenance facilities	60	25	30
Community attitude	50	85	70

Company Management has pre-established weights for various factors ranging from 0-10. They include a standard of 1.00 for each ₹ 10 per week of economic advantage. Other weights that are applicable are 1.5 on finishing material supply, 0.8 on maintenance facilities and 2.0 on community attitude. Maintenance also has a minimum acceptable score of 30. Develop a quantitative factor comparison for the three locations.

Solution

1. The relevant factors are:
   (a) Relative economic advantage;
   (b) Finishing material supply;
   (c) Maintenance facility;
   (d) Community, attitude.
2. Evaluation scales are all 0-100 points.
3. Factor weights for (a), (b), (c) and (d) per ₹ 10 weekly advantage are 1.0, 1.5, 0.8 and 2 respectively.
4. Weighted scores = E (score) (weight)

First we must determine the relative economic advantage score:

	Cochin	Ahmedabad	Bangalore
Cost/week (transportation + labour)	1980	1660	1740
Relative economic advantage (highest cost/wreck)	0	320	240
Economic advantages score in ₹ 10 units	- 0	32	24

Factors	Cochin	Ahmedabad	Bangalore
Economic	0 x 1.0 = 0	32 x 1.0 = 32.0	24 x 1.0 = 24
Material supply	35 x 1.5 = 52.5	85 x 1.5 = 127.5	70 x 1.5 = 105
Maintenance	60 x 0.8 = 48.0	25 x 0.8 = 20.0	30 x 0.8 = 24
Community	50 x 2.0 = 100.0	65 x 2.0 = 130.0	70 x 2.0 = 140

The Bangalore and Ahmedabad sites do not meet the maintenance minimum criteria of 30. Though Cochin has the least total points and would be recommended on the basis of this limited analysis (even though Bangalore and Ahmedabad have a lower cost structure). If maintenance criterion is lowered to 20 points than Ahmedabad is perhaps the best choice.

Example 4

A manufacturer of farm equipment is considering three location (A, B and C) for a new plant. Cost per year at the sites are ₹ 2,40,000, ₹ 2,70,000 and ₹ 2,52,000 respectively. Whereas variable costs are ₹ 100 per unit, ₹ 90 per unit and ₹ 95 per unit respectively. If the plant is designed to have an effective system capacity of 2500 units per year and is expected to operate at 80 per cent efficiency what is the most economic location on the basis of actual output.

Solution

Actual output = System efficiency × System capacity

= 80/100 × 2500 = 2000 units/year

Cost/site = (Fixed cost + Variable cost) = Actual output

A = (2,40,000 + (100) × 2,000) = 4,40,000

B = (2,70,000 + (90) × 2,000) = 4,50,000

C = (2,52,000 + (95) × 2,000) = 4,42,000

The most economical location is A.

Example 5

A firm is considering 4 alternative locations for a new plant. It has attempted to study all costs at the various locations and finds that the production costs of the following items vary from one location to another. My firm will finance the new plant from bonds bearing 10 per cent interest.

	A	B	C	D
Labour (per unit)	0.75	1.10	0.80	0.90
Plant construction cost (Million ₹)	4.60	3.90	4.00	4.80
Materials and equipment (per unit)	0.43	0.60	0.40	0.55
Electricity (per year)	30,000	26,000	30,000	28,000
Water (per year)	7,000	6,000	7,000	7,000
Transportation (per unit)	0.20	0.10	0.10	0.05
Taxes (per year)	33,000	28,000	63,000	35,000

Determine the most suitable location (economically) for output volumes in the range of 50,000 to 1,30,000 units per year.

Cost	A	B	C	D
Fixed cost (per year) 10% of investment	460,000	390,000	400,000	480,000
Electricity	30,000	26,000	30,000	28,000
Water	7,000	6,000	7,000	
Taxes	3,000	28,000	63,000	35,000
Total	530,000	450,000	500,000	550,000

Cost	A	B	C	D
Variable cost (per unit) labour	0.75	1.10	0.80	0.90
Material and equipment	0.43	0.60	0,410	0.55
Transportation	0.02	0.10	0.05	
Total variable cost/unit	1.20	1.80	1.30	1.50
Total fixed	530,000	450,000	500,000	550,000
and variable costs	1.20/Unit	1.80/Unit	1.30/Unit	1.50/Unit

The points for a plant location Break-even Analysis chart are as follows. As zero units of output use fixed cost values. At 100,000 units of output:

A = (530,000) + 100,000 × 1.20 = 650,000

B = (450,000) + 100,000 × 1.80 = 630,000

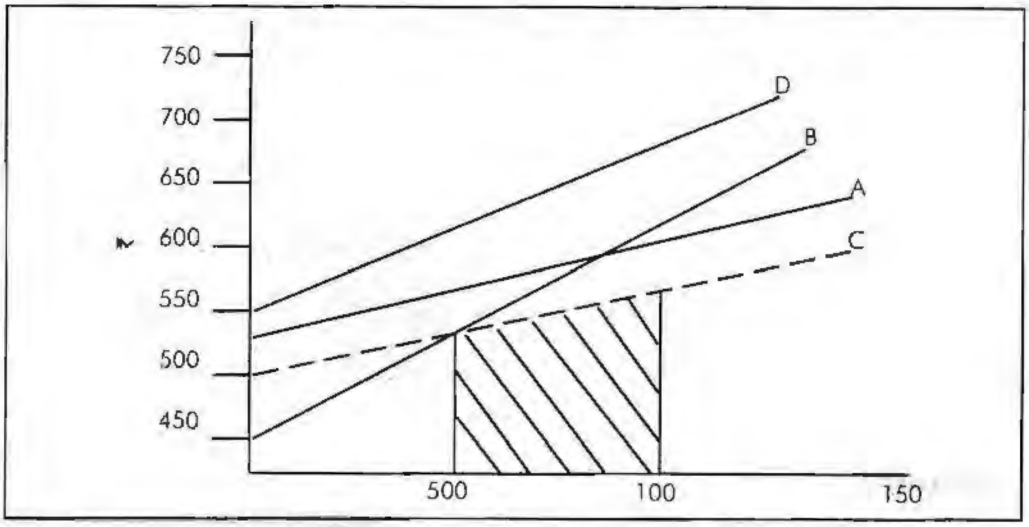


Figure 5.3

C = (550,000) + 100,000 × 1.30 = 630,000

D = (550,000) + 100,000 × 1.50 = 700,000

From the graph it is evident that for a minimum cost use site B, for a volume of 50,000 to 100,000 units use site C and for a volume of 100,000 to 130,000 units.

Student Activity

Fill in the blanks:

1. Facilities location may be defined as ....
2. The development of a location strategy depends upon ....
3. Location factors that are often considered for an overseas site include ....
4. Labour conflict is .... many companies.

Summary

In this unit, we presented the definition, significance and objectives of facilities location/ plant location. Types of facilities viz. heavy manufacturing, light industry, warehouse and distribution centres, retail and services are incorporated. Location is a critical element in determining fixed and variable costs for both industrial and service firms. Depending on the product and type of production or service taking place, transportation costs alone can total as much as 25 per cent of the selling price. The development of a location strategy depends upon the type of firm being considered.

Locational break-even analysis is based on cost-volume analysis to make an economic comparison of location alternatives.

Keywords

Capacity: Capacity is defined as the maximum load that can be handled by a facility during a given period. The load can be expressed in terms of the inputs or outputs.

Layout: Layout of a facility is the physical location of various departments/units of the facility in the premises of the facility.

Effective Capacity: Effective capacity is the maximum rate of output that can be practically achieved under the constraints of time consumed it set-ups, oiling and cleaning, defective items, etc.

Cycle Time: Cycle time is a time period after which completed units come off the assembly line.

Load-distance technique: A variation of the centre-of-gravity method for determining the coordinates of a facility location is the load-distance technique.

Review Questions

1. Although facility location is a planning decision, it has implications for decisions in the organising and controlling and sub function. Explain.
2. Outline the factors that should be considered in locating a nuclear power generating plant. List the factors in order of priority.
3. Contrast the location problems of a manufacturing firm and a supermarket, showing the relevant considerations they share and those they do not.
4. Discuss the possible reasons for changing the location of an emergency services system, such as an urban fire-fighting company.
5. Suppose, for economic reasons you want to locate your manufacturing facility in a small community that currently seems to be unfavourably disposed toward your industry. What strategies might you employ before making your decision?
6. What aspect of different subcultures should be considered in location analysis?
7. If you expand your existing company by opening a new division in a foreign country, should the new division be staffed by local personnel or by personnel imported from the parent organisation? Explain.
8. What is meant by plant location? What factors affect the choice of a suitable place for location of a plant?
9. The governing principle is that a location of plant should be fixed in such a manner that people interested in its success can sell goods most profitably and manufacture them at least expenses. Explain how this objective can be achieved?
10. Explain in brief the factor of selling and buying for consideration regarding the location of plant?
11. Give main criteria of plant location in following cases: Wide range of volumes or bulky resources, medical research centre/hospitals, fire stations, public/professional services, cotton/textile industry, sugar industry, cement industry, jute industry, iron and steel industry/steel mill, paper industry, coal industry.
12. How do international location decision differ from domestic location consideration? You may answer briefly identifying areas that are unique to international locations?
13. Write short notes on the following:
    (a) Localisation (centralised) vs delocalisation (decentralised) of plants.
    (b) Dynamic nature of plant location.
    (c) Multiplant location problems.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see,* Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management,* John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis,* Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach,* McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies,* John Wiley & Sons, 2004.

Unit 6 Plant Layout

Unit Structure

- Introduction
- Facility Layout/Plant Layout Defined
- Objectives of Plant Layout
- Effects of Layout on Cost
- Advantages of Good Plant Layout
- Basic Types of Layouts
- Which Type of Layout to use When?
- Factors Influencing Plant Layout
- Approach to Layout Engineering
- Step in Planning Plant Layout
- Visualise the Layout
- Evaluation of Alternative Layouts
- Effect of Automation on Layout
- Symptoms of a Bad Layout
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Advantages of good plant layout
- Effect of automation on layout
- Symptoms of a bad layout

Introduction

A typical manufacturing plant has a number of diverse activities interacting with each other. Raw materials arrive at a shipping dock, they are unpacked and checked in a quality control area, they may then be processed through several processing areas, and finally the finished product again passes through the shipping dock. In addition to areas specifically related to production, there must be dressing rooms, lunch rooms, and restrooms for employees; offices for supervision, design, and production control; and space for inventory and aisles. In fact, a plant may be viewed as a number of finite geometric areas arranged on the floor space of the building. The problem of arranging these areas in an effective manner is the facility layout problem.

Clearly, the layout problem has relevance in many areas of facility and equipment design. This unit tries to disseminate knowledge on the design and planning of service and production facilities. It discusses the different types of layouts, blending organizational expectations with effective use of space to create a work environment that is efficient.

Facility Layout/Plant Layout Defined

Plant layout may be defined as physical arrangement of industrial facilities. This arrangement includes the spaces needed for material movement, storage, indirect labourers and all other supporting activities or services as well as operating equipment and personnel. Plant layout is:

1. Placing the right equipment;
2. Coupled with the right method;
3. In the right place; and
4. To permit the processing of a product unit in the most effective manner; through the shortest possible distance; and in the shortest possible time.

Objectives of Plant Layout

These objectives of good plant layout lead to:

1. Material handling and transportation is minimised and efficiently controlled.
2. Maximum utilisation of floor space.
3. A good layout permits material to move through the plant at the desired speed with the lowest cost.
4. There is increased productivity and better product quality with reduced capital cost.
5. To reduce internal transport from one operation to the next as much as, possible.
6. Minimisation of the worker movement.
7. Workstations are designed suitably and properly.
8. Better utilisation of machine, manpower and service.
9. Better facilities for maintenance and inspection, etc.
10. Less work in process.
11. Less supervision and indirect labour.
12. Less congestion and better house keeping.
13. Flexible and easy adjustments to changed conditions.
14. Less floor space.
15. Improved safety conditions.
16. Avoidance of production delays.
17. Improved worker morale.
18. Space for future expansion.
19. Fewer accidents.
20. Lighting and ventilating of areas.
21. Proper production control.
22. To estimate waste effort and speed of production.

Effects of Layout on Cost

A bad layout results in excessive handling of materials and movements of men and equipment. While it is unavoidable that materials and men have to move, every move results in increase in cost without necessarily improving the value added to the product. Actually the quality of the product may come down due to damages in process storage thus reducing the value added. Further losses due to breakage, pilferage, deterioration, etc., add to the costs being incurred. In addition, skilled manpower and sophisticated machines are idle or underutilised due to unnecessary movement which could be avoided drastically if not eliminated. All these factors increase the cost of manufacturing.

Advantages of Good Plant Layout

A. *Advantages in Shipment Delivery and Storage*

1. Facilitates receipts and shipment and delivery
2. Provides adequate and convenient storage facilities
3. Permits the maximum possible output
4. Paces production
5. Determines production flows
6. Makes production time predictable
7. Makes scheduling and dispatching automatic
8. Set-up production centres
9. Improves materials handling
10. Reduces the paper work for production control
11. Reduces the number of stock chasers
12. Better utilisation of man, machine and equipment

B. *Advantages in Supervision*

1. Tends to ease the burden of supervision
2. Determines the supervisory control
3. Reduces the cost of supervision
4. Decreases the amount of inspection

C. *Advantages in Manufacturing Costs*

1. Reduces the cost of expenses supplies
2. Decreases maintenance costs
3. Decreases tool replacement costs
4. Effects a saving in power loads
5. Decreases spoilage and scrap
6. Provides better costs control
7. Improves quality of product

D. *Advantages in Manufacturing Cycle*

1. Shortens the moves between work centres
2. Reduces the manufacturing cycle
3. Reduces the length of travel of the products

E. *Advantages in Labour Cost*

1. Increases the output per man-hour
2. Reduces set up time involved
3. Reduces the number of operators
4. Reduces the material handling operations and better utilisation of manpower in all operations

F. *Advantages to Workers*

1. Reduces the effort of the worker
2. Reduces the number of accidents
3. Extends the process of specialisation
4. Provides better employee service facilities
5. Provides basis for higher earnings

G. *Advantages in Capital Investment*

1. Holds permanent investment at a minimum
2. Reduces investment in machinery and equipment
3. Maintains a proper balance of department
4. Eliminates wasted aisle space
5. Reduces the inventory of work in process and of finished products.

Basic Types of Layouts

There are three basic types of layouts: (1) Process, (2) product and (3) fixed position and three hybrid layouts: cellular layouts, flexible manufacturing systems and mixed-model assembly lines. We discuss each basic layout type in this section and hybrid layouts later in the unit.

Process Layouts

Also known as functional layouts, group similar machines together in departments or work centres according to the process or function they perform. For example, all drills would be located in one work centre, lathes in another work centre and milling machines in still another work centre. All painting operations, of course, would be performed in the department. A department store is organised in a way where women's clothes, men's clothes, children's clothes, cosmetics and shoes are kept in separate section. A process layout is characteristic of intermittent operations, job shops, or batch production, in which a variety of customers are served with different needs. The volume of each customer's order is relatively low and the sequence of operations required to complete a customer's order can vary considerably. The equipment in a process layout is general purpose and the workers are skilled at operating the equipment in their particular department. The main advantage of this layout is its flexibility. The main disadvantage is its inefficiency. Jobs do not flow through the system in an orderly manner, backtracking is common, movement from department to department can take a considerable amount of time and queues tend to develop. In addition, each new job arrival to a work centre may require that the machine be set up differently for its particular processing requirements. Although workers can operate a number of machines in a single department, their workload often fluctuates – from queues of jobs waiting to be processed to idle time between job. Figure 6.1 shows a schematic diagram of a process layout with sample job routings.

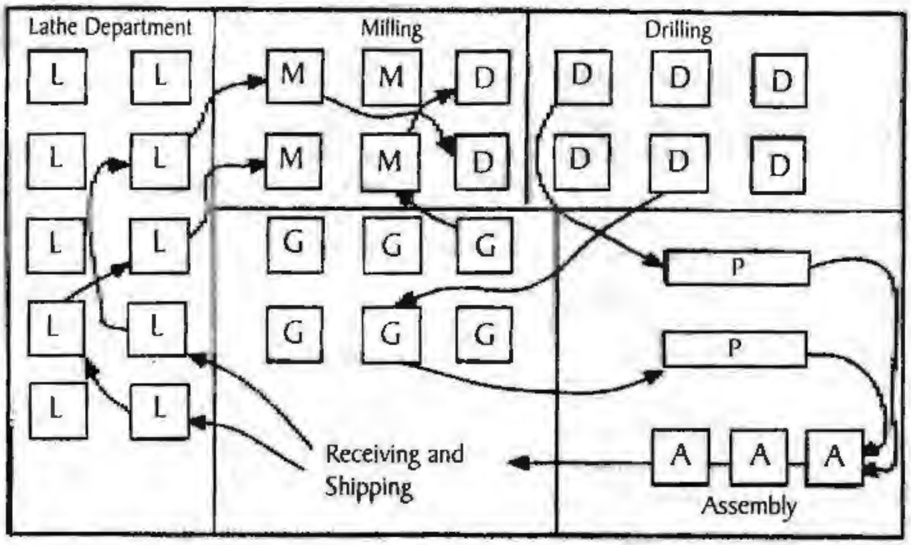


Figure 6.1: Schematic Diagram of a Process Layout with Sample Job Routings

Advantages of Layout by Process

1. This type of layout adjusts itself easily to any changes in the volume of products, in the raw materials used, in the method of production or the rate of production necessitated due to addition of equipment. There is greater flexibility. Changes in operations or sequence of operations do not affect the layout.
2. Succession of operations are not held up due to any breakdown or failure of a machine. The job can be transferred to another machine in the same class. If the job is "rush" and all machines are busy a slight change in the scheduling is made.
3. Maximum utilisation of equipment results in increase in production and reduction in investment in equipment. The overhead costs are spread over a larger number of units bringing down the unit cost of production. Manufacturing costs can be kept down. Under peak loads labour costs are high per unit, but under low production labour costs are lower. Unit overhead costs are lower under medium production. When plant is not near peak capacity the total costs can be lower.
4. New workers have easy training facilities on the job, better opportunities for the utilisation of the skill of the workers and use of the specialised abilities of the supervising staff, workers know-how to run various machines in the group and are able to set up work, perform special operations and gauge the work and quality as mechanics.
5. Adaptable to special condition arising out of the use of particular type of equipment.
6. Due to less duplication, there is lower investment in machines, only necessary number of machines of each type are obtained for handling normal maximum load instead of one in each product line.
7. Machines, being the required number of each kind for normal production, are kept busy most of the time.
8. Foremen and supervisors become specialised in the execution of the jobs and know all about the equipment and its operation.

Disadvantages of Process Layout

1. Work does not flow over any definite mechanical channels. Routing and scheduling is more difficult.

2. It is essential to plan and supervise the work of every department and of every worker and machine in every department. This entails greater difficulties in production control and addition to the cost of the finished product.
3. Excessive back-hauling and handling of materials during operations due to defects and bringing back the material for removal of defects. More hand labour is involved. Higher cost of the material handling due to the separation of operations and longer distances for the raw materials travel. There are no cheaper and automatic devices for internal transport.
4. Comparatively more time is required to produce the same products due to transportation and advance moving of the materials into a department so that the machines are not idle due to non-availability of the necessary raw material.
5. Comparatively excessive work in process inventory, more complicated system of production control and no visual control, all parts and all operations to be checked minutely, more work orders, time tickets, inspection order to be followed and put on records, comparatively much more accounts-keeping and clerical work.
6. More space is required for the same volume of products as automatic material handling is not easy and due to greater spacing between machines. There is more space for aisles, elevators, etc. Thus more floor is required for each unit product.
7. Inspection of work after each operation is essential as the material passes to the next department. The inspection is after each operation and not at the end of the each group of operation. This results in more inspections.
8. There are hold-ups of work for inspection after processing, materials pile up near machines in advance of processing. Movement may not be ready immediately after the work in process has been inspected for next department.
9. More training will be necessary to prepare the workers for the particular jobs: sometimes specialised knowledge is required for which higher wages have to be paid, which adds to the total cost of the product.

Product Layouts

Primarily known as assembly lines, arrange machines in a line according to the sequence of operations that need to be performed to assemble a particular product. Thus, each product has its own "line" specifically designed to meet its requirements. The flow of work is very orderly and efficient, moving from one workstation to another down the assembly line until a finished product comes of the end of the line. Since the line is set up for one type of product, special machines can be purchased that match the specific processing requirements of the product. Product layouts are suitable for mass production or repetitive operations in which demand is stable and volume is high. The product is a standard one made for a general market not for a particular customer.

Because of the high level of demand, product layouts are typically more automated than process layouts and the role of the worker is different. Workers perform narrowly defined fabrication or assembly tasks that do not demand as high a wage rate as those of the more versatile workers in a process layout.

The main advantage of the product layout is its efficiency and ease of use. The main disadvantage is its inflexibility. Significant changes in product design may require that a new assembly line be built and new equipment be purchased. This is what happened to US automakers in the 1970s when demand shifted to smaller cars. The factories that could efficiently produce four-cylinder engines could not be adapted to produce six-cylinder engines. A similar inflexibility occurs when demand volume slows. The fixed costs of a product layout (mostly for equipment) allocated over fewer units can send the price of a product soaring. Contrast this with the flow of products through the process layout shown in Figure 6.1.

In addition to the flow of work and arrangement of machines, product and process layouts look very different in other ways. In-process inventory for a process layout is high because material moves from work centre to work centre in batches waiting to be processed. Finished goods inventory, on the other hand, is low because the goods are being made for a particular customer and are shipped out to that customer upon completion. The opposite is true of a product layout. In-process inventory is consumed in the assembly of the product as it moves down the assembly line, but finished goods inventory may stack up or require a separate warehouse for storage before the goods are shipped to dealers or stores to be sold. Storage space in the process layout is large to accommodate the large amount of in-process inventory. Some of these factories look like warehouses, with work centres strewn between storage aisles. In contrast, the storage space along an assembly line is usually quite small.

Material handling methods are also different for the two layouts. Process layouts need flexible material handling equipment that can follow multiple paths, move in any direction and carry large loads of in-process goods. A forklift fits that description and is typically used to move pallets of material from work centre to work centre in a process layout. A product layout envisages that material moved in one direction along the assembly line and always in the same pattern. Conveyors are the most common material handling equipment for product layouts. Conveyors can be paced (automatically set to control the speed of work) or unplaced (stopped and started by the workers according to their pace). Assembly work can be performed on line (i.e., on the conveyor) or off-line (at a workstation serviced by the conveyor).

The aisles in a process layout need to be wide to accommodate the two-way movement of forklifts. The aisles in a product layout can be narrow because it's an integral part of the assembly process, usually with workstations on either side. Scheduling of the conveyors, once they are installed is simple – the only variable is how fast it should operate. Scheduling of forklifts is typically controlled by radio dispatch and varies from day to day and hour to hour. Routes have to be determined and priorities given to different loads competing for pickup.

The major problem, in terms of layout, for a process layout is where to locate the machine centres (i.e., groupings of similar machines) in relation to each other. Although each job potentially has a different route through the shop, there will be some paths between machines that are more common than others. Past information on customer orders and projections of customers' orders are used to develop typical patterns of flow through the shop. For a product layout, the major layout problem is balancing the assembly line so that no one workstation becomes a bottleneck and holds up the flow of work through the line. Summarises the differences we have discussed between the product and process layouts.

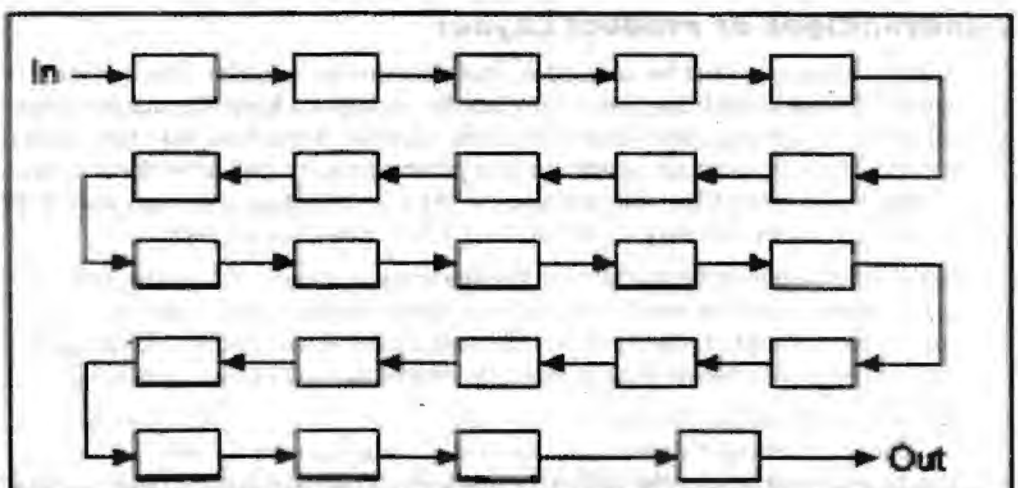


Figure 6.2: A Schematic Diagram of a Product Layout

Advantages of Product Layout

1. Manufacturing time shortened as the flow of work is over direct mechanical routes cutting down delays from first operation onward till final operation.
2. Highly expensive operation of "back-hauling" and internal transportation of processed materials are reduced to the minimum.
3. Material handling minimised due to shorter travel of work over adjacent machines.
4. Due to automatic material handling devices there is a definite reduction in the cost of internal transportation.
5. Production being continuous, there are smaller quantities of work in process.
6. There is no possibility of side tracking of a product when it has been started along the line.
7. The work-schedule planning is very much simplified.
8. It facilitates production control.
9. Definites sequence of operations over adjacent machines leads to close coordination of manufacturing process.
10. Smaller floor areas occupied per unit of product due to the elimination of wide aisle essential for storage and hand trucking of materials at the machines for a functional layout.
11. Use of gravity and power conveyors for material handling purposes lessens the necessity of aisles.
12. Amount of inspection is minimised to one before the product goes on the line and one after it comes off the line and no necessity of supervision in between.
13. The finished product accounting work is reduced.
14. Production control is greatly simplified.
15. Promise for supply of products to customers are more reliable.
16. Much of the paper work is replaced by visual control and forms, records, time tickets and move orders are minimised.
17. "Bottle-necks" are reduced to the minimum.
18. Breaking in workers on an operation in the production line is much easier.

Disadvantages of Product Layout

1. All machines may not be utilised to their maximum capacity. The quantity of work allotted to each mechanic may not be enough to keep the machine busy all the time, causing considerable machine idleness. A machine may be required to perform only a certain operation in a given sequence and after this has been completed, the machine may remain idle. At a certain stage the plant may have several machines that may not be working to the maximum capacity.
2. In the event of one of the machines in the line breaking down, all the other machines will remain idle till the machine is again in working order. Unless there are several machines of a kind or reserve of replacement equipment or immediate emergency repairs executed to keep work flowing the machines are bound to remain idle.
3. There is much greater difficulty in providing the proper supervision specialisation facilities at particular operations. Supervisors attending to a series of different machines do not acquire the skill in the work of any one particular type of machine, so the supervision is not very efficient.

4. There is less flexibility in getting work done. In case of a change in the product to be manufactured the entire layout may have to be rearranged as jobs lots cannot be handled with ease nor they can be assigned to other similar machines.
5. For expansion purposes it is not possible to add a few machines. The production rate depends on the speed of the slowest operation in the line. To increase the production capacity of the plant it is essential either to revise the complete line or to set up a duplicate line of machines, which means high investment.
6. Machine or workstation is usually automatic equipment fed by operator. Each worker learns job at a particular machine, so he is not skilled for other machines or operations.
7. Considerable flexibility can be achieved within the capacities of the lines, if the workers are taken off or added and conveyor speeds are accordingly adjusted to suit the decreased or increased number of workers.
8. High factory overhead on production lines may result higher manufacturing costs in spite of labour costs per unit being lower. The manufacturing cost will be still higher when the machines are idle or are not having enough work to be busy all the time.

Combination

It is not uncommon for product and process layouts to be combined within a single manufacturing or service facility. Fabrication processes are normally handled with a process layout, whereas assembly operations fit nicely into a product layout. A hospital, which is predominantly a process layout with separate patient-registration departments, X-ray departments and radiology departments still registers patients in an assembly line fashion and operates its cafeteria as a product layout. Figure 6.3 shows a simplified drawing of a chain saw factory that includes both a product and process layout. The process layout is shown in areas A and B. In area A, four injection molding machines are used to form small plastic parts for the chain saw, such as the trigger. One worker operates the four machines by pouring plastic bits in the top of the moulding machines, inserting the proper moulds and starting the machines. Each machine chugs away, producing parts that tail into a basket beneath the machine. The operator takes the baskets and dumps them into the plastic finishing area, where he or she breaks off rough edges by hand to make the parts smooth. The parts are then put into bins and taken to the assembly area or to the store room. Area B consists of four machines for pre-production machining and a parts washer. Two workers operate these machines, in which parts are welded together, holes are drilled, or other adjustments are made to components that have been supplied for the chain saws. The process often involve heat or metal chips as a by-product, so a parts washer is available to cool or cleanse the finished parts. As with the plastic parts, the finished parts are placed in bins and are moved to the assembly area or store room as needed.

The product layout portion of the factory is represented by two assembly lines at locations C and D. Each line produces a different model chain saw. In contrast to the sizeable and small number of workers required for the process layout each assembly line shown has 30 workers. Notice that the 60 assembly line workers take up less space than the 3 workers involved in machining and plastic parts production. The bulge in each assembly line, occurring near the end of the assembly process, is a booth, where the chain saw is started up and put through a battery of tests. This testing process takes longer than the other operations on the assembly line . . . two workers are assigned to each booth and they alternate taking chain saws from the line to be tested. In this way the line can maintain a balanced workload between stations and the testing booth does not become a bottleneck.

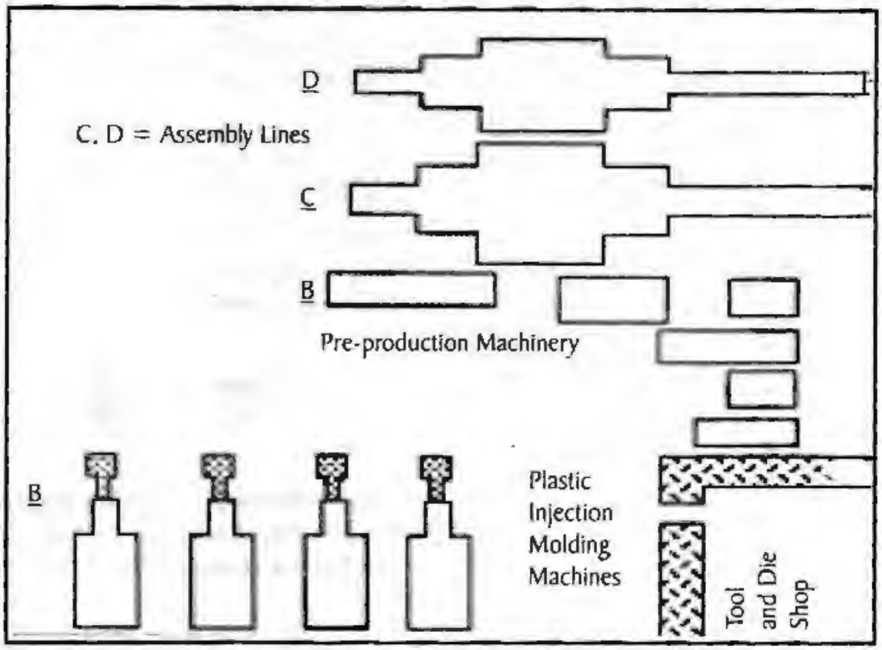


Figure 6.3: Factory Layout for a Chain Saw Manufacturer (Mixed Product and Process Layout)

Fixed Position Layouts

The third basic type of layout is the fixed-position layout. Fixed-position layouts are typical of projects in which the product produced is too fragile, bulky, or heavy to move. Ships, houses and aircraft are examples. As the name implies, in this layout, the product remains stationary for the entire manufacturing cycle. Equipment, workers, materials and other resources are brought to the production site. Equipment utilisation is low because it is often less costly to leave equipment idle at a location where it will be needed again in a few days, than to move it back and forth. Frequently, the equipment is leased or subcontracted, because if one were to look at the cost breakdown for fixed-position layouts, the fixed cost would be relatively low (equipment may not be owned by the company), whereas the variable cost would be high (due to high labour rates and the cost of leasing and moving equipment).

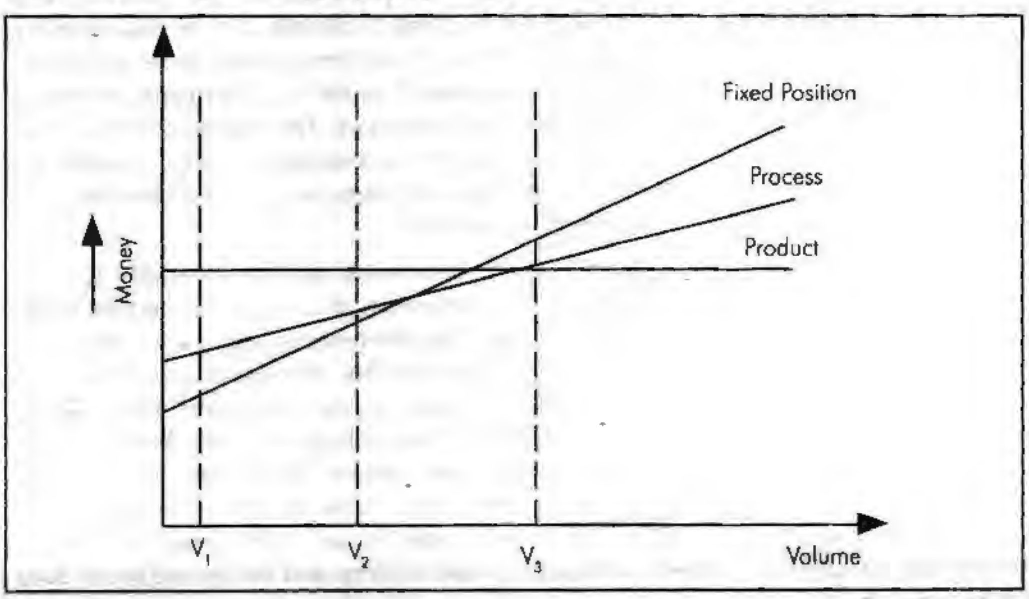


Figure 6.4: Schematic Diagram of a Fixed Position Layout

The fixed position, process and product layouts can be compared on the basis of cost in a break-even analysis format. Figure 6.4 is a graph of the three layouts, with representative values of fixed and variable costs. Examining the y-intercepts of the three layouts, the product layout has the highest fixed cost, followed by the process layout and then fixed position layout. From the slope of the lines, we can see that the fixed-position layout has the highest variable costs, followed by the process layout and then product layout. A major determinant of the appropriate layout is demand volume. At volume v_1, a low-demand volume, the fixed-position layout would have the lowest total cost. But at volume v_2, a medium volume, the process layout would be preferred and at volume v_3, a high demand volume, the product layout would be best.

Because the fixed-position layout is quite specialised, we concentrate on the product and process layouts and their variations for the remainder of this unit. In the sections that follow, we examine some quantitative approaches for designing product and process layouts.

Which Type of Layout to use When?

We use layout by fixed position, or fixed material location:

1. When our material-forming or treating operations require only hand tools or simple machines;
2. When we are making only one or a few pieces of an item;
3. When our cost of moving the major piece of material is high; and
4. When the skill of workmanship lies in the abilities of our workers or when we wish to fix responsibility for product quality on the workman.

We use layout by process, or function:

1. When our machinery is highly expensive and not easily moved;
2. When we are making a variety of products;
3. When we have wide variations in times required for different operations; and
4. When we have a small or intermittent demand for the product.

We use line production, or layout by product:

1. When we have a large quantity of piece or products to make;
2. When the demand for it is fairly steady; and
3. When we can maintain balanced operations and continuity of material flow without difficulty.

In actual practice, most layouts are a combination of these classic types. They are made to utilise the advantages of all three types.

Factors Influencing Plant Layout

The factors influencing any layout breakdown into eight groups:

1. The materials factor including design, variety, quantity, the necessary operations and their sequence.
2. The machinery factor-including the producing equipment and tools and their utilisation.
3. The man factor-including supervision and service help as well as direct workers.
4. The movement factor-including inter and interdepartmental transport and manual handling at the various operations, storages and inspections.
5. The waiting factor-including permanent and temporary storage and delays.

6. The service factor-including maintenance, inspection, waste, scheduling and dispatching.
7. The building factor-including outside and inside building features and utility distribution and equipment.
8. The change factor-including versatility, flexibility and expansion.

What has been stated above in regard to the factors that have to be considered in layout planning can be restated in another way.

1. ***Hazards:*** Nature of risks due to moving parts, projecting machine elements, suspended weights, air-pollution at the production centres, other physical or chemical risks and the types of precautionary measures required to ensure the safety of personnel and plant.
2. ***Type of production:*** Job, batch or continuous, also whether the production is by a continuous process or is an assembly line and whether it involves single or multiflows.
3. ***Type of operation:*** Wet or dry, using heavy or light machinery, involving swarf, scrap, reprocessing, etc., characteristics of the production and service centres.
4. ***Sequence of operations:*** Dependency of the operation on another, rigidity of the sequence, reprocessing and its effect on the flow being undirectional or retractional.
5. ***Integration of production:*** Single flow or multiflow, relation of parts of the flow system to each other, coordination of sub-lines that feed major assembly lines.
6. ***Type of product:*** Its weight, volume, physical state (solid, liquid or gas) its durability, susceptibility to transportation and difficulty connected with its storage.
7. ***Type of inspection:*** Centralised or decentralised, its effects on amounts of work inprocess and machines readjustments.
8. ***Management policy:*** Plans for future output and expansion changes in product design and variety.

Each of these 8 factors can be broken down into a large number of features and considerations. For example, in the material factor the features of the material (raw material, finished product, rejects, packing materials, maintenance materials, etc.) their physical and chemical characteristics (size, shape, condition, characteristics like hot, cold, vibration, fumes, etc.) or quantity and variety, etc., will have different effects for each type.

Machinery: Features, process methods, machine utilisation, special requirements, etc.

Men: Direct, or indirect labour, supervisors, safety features, working conditions, etc.

Movement: Handling features, moving and waiting time, flow pattern, space for movement, etc.

Waiting: Storage or delay features, location or storage or delay points, space for waiting point, method of storing safeguards or waiting material, etc.

Service: Features involved for men, materials and machines, paper-work procedures, maintenance procedures, etc.

Building: Type, site features, environmental conditions, etc.

The solution of any layout problem will of necessity be a compromise of the various considerations and of the various objectives of good plant layout. The relation of machinery to handling, of service to building, of change to man, are all tied together, one feature or consideration influences many others. And constantly in layout work, engineers end up "robbing Peter to pay Paul".

Weakness in layouts come because the compromise that is worked out overlooks some features that should be provided or fails to recognise some consideration that has an important effect. A careful check of the guide lists will avoid this. It will lead to the more positive course of determining in advance what features or considerations are the important ones.

Approach to Layout Engineering

The scientific approach to management problems is repeated here because plant layout is a management responsibility. The solution to layout problems follows the same approach.

1. ***State the problem:*** Plant layout involves so many considerations beyond just the physical arrangement of materials, machinery and supporting facilities that the nature and scope of the job assigned must be clearly defined at the beginning.

   Besides a clear statement of the problem, a plan and schedule of the job should be made. Each of the four phases of layout work: (a) location of the area to be laid out; (b) general overall layout; (c) detailed layout plan; and (d) installation should be programmed against a time schedule.

2. ***Get the facts:*** As with any engineering problem, if we get the facts, the solution often becomes readily apparent. Without facts, we are guessing or relying on opinion. Here is where the uninitiated layout engineer usually falls down. He jumps too quickly into trying to make the new layout without having the facts on which to base it.

   We must gather data on the material and products, the machinery and equipment the men and the other factors involved. And be sure these are correct facts gathered by actual measurement, tally, or approved figures – not merely the hunches or hopes of other people and not inaccurate or out-of-dates records, prints and data. For example, it is surprising how wrong the drawings of building floor plans can be.

3. ***Restate or clarify the problems in the light of the facts:*** Here is the chance to point out inconsistencies or misconceptions. The facts may show that the original statement or scope of the problems should be changed. Perhaps the layout should wait until new machinery under consideration is actually selected, for example. To go ahead with the layout as originally planned may mean only doing an incomplete job or one that must be soon re-arranged. Therefore, get any new decisions clarified at this time. This reclarification of the problem will indicate what further facts must be considered.

4. ***Analyse and decide on the best solution:*** Analysis of the facts in line with the objectives of good layout is the main problem of layout work. The various considerations are weighed against each other, the data is assembled and evaluated; alternative arrangements are compared; the plans are visualised, tried out and checked. The analysis ends with a decision – a decision for best solution to the problem.

5. ***Take action for approval as the next phase:*** When the solution is decided upon for that phase of the layout project being analysed, it must be approved. This involves approval by major department heads as well as top management. It ensures that work done on the next phase of the layout project will be integrated with an approved plan; it saves time on the project, it keeps others informed about the project and gives them a chance to point out early any deficiencies or errors.

   When each phase is generally approved, the next phase will be tackled.

6. ***Follow-up:*** There should be an overlapping of the four phases of plant layout. Before each phase can be solved, the next phase must be investigated in part. However, the next phase is not itself solved at this stage; it is solved in the next

round or cycle of applying the six-step approach to management problems. As a result, the follow-up of one phase is in reality the solving of the succeeding phase. This is a true follow-up, for even though the prior phase is generally approved, it may be adjusted as the solution to the next phase develops.

Get the Facts: In setting adequate facts for any plant layout project put emphasis on the features that are important. The following list will indicate how to get at the features to be stressed.

1. ***Features involving essential or major consideration:*** Refer to Plant Layout Guide Lists for each factor. (Annexure).
2. ***Features where greatest operating costs are involved:*** Refer to breakdown of expenditures, budget or cost data.
3. ***Features that will cost most to install or rearrange:*** Identify major installations and consult plant engineering costs.
4. ***Features involving safety or danger to operators:*** Refer to accident and first aid records.
5. ***Features involving employee dissatisfactions and working conditions:*** Identify popular shop gripes, known complaints, grievances or suggestions dealing with employee dissatisfactions.
6. ***Features involving important aspects of space or location:*** Identify key locations like receiving, shipping and critical operations.

"Plan the process and machinery around the material requirements; plan the layout around the process and machinery." Always begin with the requirements caused by the material or product. We are going to form some material, treat it and assemble it to other pieces to make a product. The very first step is to get data on the product and/or material itself.

The information wanted about the product or material was shown as the consideration in the Plant Layout Guide List-Material. Use this as a guide for what data to gather. The feature listed at the top of the guide list ensure coverage of all materials that may be involved.

In gathering the data, be sure to cover anticipated as well as current or past conditions; long-range forecasts, new-product plans, seasonal variations, trends in the industry; increased service-parts requirements. After a layout is carefully engineered and installed, it is difficult to crowd in forgotten of additional features unless excess space is deliberately planned.

There are number of different ways of tallying or recording material data. A product-material data sheet has universal application for layouts involving one product or several. It is a good all-round way of compiling data on product material. When the layout project is a comprehensive one, more information will be needed. For example, one plant making air-conditioning equipment set up its sales forecast for 10 years ahead for each of its products. Then it set up a schedule of requirements sheet for a proposed fiscal year. This sheet had the following column headings.

1. Item
2. Product
3. Model
4. Specification (size and capacity)
5. Gross anticipated requirements
6. Details of manufacturing period
7. Length of period-beginning and ending dates

8. Net number of weeks
9. Shifts per clay
10. Hours per shift
11. Days per week
12. Number of operating house per year
13. Average rate of output per hour
14. Other rate (basis other than yearly operating hours)
15. Other basis (48 week fabrication, for example)
16. Maximum anticipated rate

Such a breakdown gives the manufacturing volume of each item in the programme and anticipated output requirements. It is based on data built up from parts list, operation times and machine loading. Thus it becomes apparent that as soon as the product-material data are compiled, the next step is to get data on the process and machinery.

Following the product and volume requirements the operations must be determined and the machinery specified. This involves:

1. The list of component parts;
2. The way these parts go together;
3. The sequence of operations;
4. The operations to be performed;
5. The machinery, equipment and tools required;
6. The operating times;
7. The machine loading and set-up frequency; and
8. Machine requirements or characteristics.

As is obvious, correct data must be available in respect of all the above items.

Steps in Planning Plant Layout

The layout planning is basically an arrangement of space. When material and machinery requirements are determined, we can begin to plan the space required diagram for the following areas:

1. ***Machinery and equipment:*** Include area between machines for workers material in process and access for men, handling and maintenance.
2. ***Waiting material:*** Base size of unit price, or stack multiplied by the quantity, equals the space needed. Base size vanes with method of storing, quantity vanes with lot size, production scheduled and amount of protection wanted.
3. ***Service or supporting activities:*** List each service or activity and assign space required for each. Do this by departments. Then add space for independent service areas like receiving, shipping, shop offices.
4. ***Aisles, stair wells, elevators:*** Allow 15 per cent for single-storey buildings and 22 per cent for multi-storey buildings.
5. ***Special requirements:*** Determine and note special area requirements for odd-shaped space, for expansion or anticipated changes.

These space calculations can be used as a basis for building requirements and for allocating activity or department space when the layout is actually being planned. The general space requirements are what will first be laid out.

Determine the Flow

The sequence of operations is the basis of the flow of materials and is the heart of any plant layout. After gathering data and facts the layout should begin here.

It might be a single product or multiple product. There are different types of basic flow patterns.

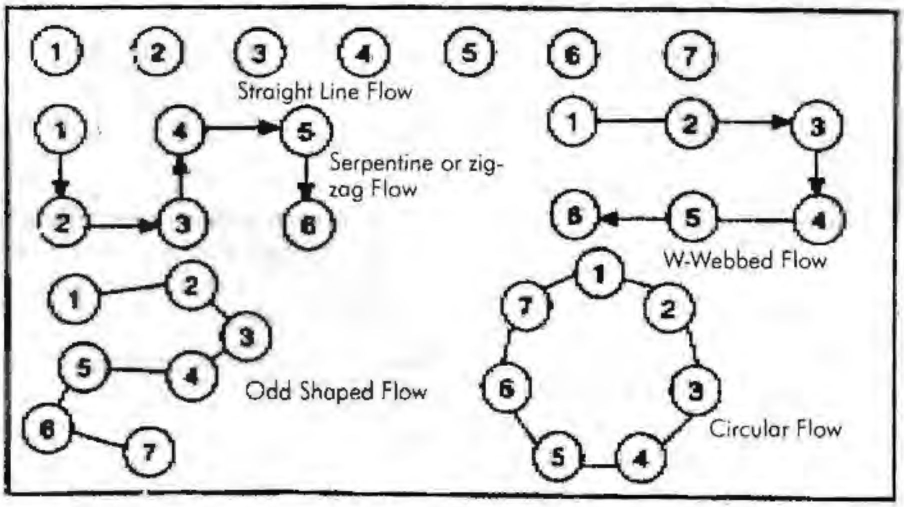


Figure 6.5: Various Types of Flow Patterns

A flow diagram is drawn of the actual flow pattern where the movements as sketched out. The flow diagram is used to determine the best flow pattern as consequently the layout required for such a flow pattern.

Visualise the Layout

Experienced layout men know that clearly understanding the plan they are making is the only way to get a sound layout. They have to visualise how the layout will look and how it is going to work. They also have some clear picture reproduction of their layout to discuss with other people. They must have something others can see clearly.

The three common ways of visualisation involve:

1. Drawings and diagrams
2. Templates and your board
3. Three-dimensional models

Of these three drawings and diagrams are the most basic. They are readily made, easily altered and inexpensive. In actually putting together, a reproduction of a proposed layout, templates are most valuable. There are many kinds and they can be used in many ways. Essentially they permit reproduction of as many different layout proposals as desired merely by rearranging the templates on the board.

To prove out and check on the layout plan or to help others visualise what is planned, the three dimensional model comes into play. For these latter purposes the model is supreme. But the great misunderstanding is that models themselves are a substitute for layout planning. They are not. They glamorise the layout job, to help sell the layout proposed, they develop interest, they help in training workers and former and staff personnel and they act as a check on the planning of the layout engineer. But for his own visualisation or planning, he does not need them and in fact, it is usually better without them.

Table 6.1: Comparison of Different Types of Layouts

Aspect of the Conversion Process	Layout Type		
	Product-oriented	Process-oriented	Fixed Position
Product	Standardised product, large volume, stable rate of output	Diversified products using common operations, varying volumes, varying rate of output	Made to order, low volume
Work flow	Straight line of product, same sequence of operations for each unit	Variable flow, each order (product) may require unique sequence of operations	Little or no flow, equipment and human resources brought to site as needed
Human skills	Able to perform routine, repetitive tasks at fixed pace highly specialised	Primarily skilled craftsmen, able to perform without close supervision adaptable	Great flexibility required, work and be moderately assignments and locations vary
Support staff	Large, schedule materials and people, monitor and main work	Perform tasks of scheduling, materials handling and production and inventory control	Schedule and coordinate skillfully
Material handling	Predictable, flow, systematised and often automated	Flow variable, handling often duplicated	Flow variable, often low may require heavy duty, general purpose handling equipment
Inventory	High turnover of raw material and work in process inventories	Low turnover of raw material and work in process inventories, high raw materials inventories	Variable inventories and frequent tie-ups because production cycle is long
Space utilisation	Efficient utilisation, large output per unit space	Small output per unit space, large work in process requirements	Small output per unit space if conversion is on site
Capital requirements	Large investment in specialised equipment and processes	General purpose, flexible equipment and processes	General purpose, mobile equipment processes
Product cost	Relatively high fixed costs,	Relatively low fixed cost	Relatively low fixed costs.

Evaluation of Alternative Layouts

The best layout is compromise – a compromise of the various factors considerations, layout objectives and types of layout. To select the best compromise, plan alternative layout proposals and eliminate those or the portions of them that compare unfavourably. Evaluating alternative plans should determine which proposal offers the best layout compromise.

Various techniques of evaluation have been used successfully, certain ones being used where they are especially applicable. Here are several

1. *List of pros and cons:* The simplest to way evaluate alternative layouts is by listing the pros and cons the advantages and disadvantages – of each alternative it is surprising how often such a listing quickly clarifies which alternative should be selected.

2. ***Tally of gains and losses expected:*** This is similar. The tally lends itself especially to relayouts. List each manufacturing area involved and the company as a whole. Under each one, list the gains and losses to that area of the alternative in question. Do this for each alternative layout.

3. ***Ranking:*** Ranking may be used when there are three or more alternatives. Select the factors or considerations felt to be important to the layout. List them and in adjacent columns rank the alternative in numerical order of each consideration.

4. ***Value rating:*** A similar method is the value, or point values, rating. Prepare a comparison sheet on which is listed each consideration that affects the layout in question. Classify each according to its importance (A, B, C, D, E). This becomes a class or weight. Then opposite each consideration, determine appropriate values for each alternative.

5. ***Factor analysis:*** Whether we use ranking or point values, the selection and weighing of the significant factors are the basis of making a proper evaluation, property chosen, weighted and analysed each factor, will when combined with the others lead to the best solution. Here column headings would (a) factor, (b) weight, (c) rating alternative 1, (d) weighted rating alternative 1 and so on for all alternatives. The weighted ratings are totalled for each alternative and compared to give the best solution.

6. ***Rating objectives:*** An almost identical system with universal use is based on the objectives of good layout. Here the objectives over all integration, minimum distance, flow of work, space utilisation, satisfaction and safety and flexibility are assigned weight factors depending on the importance of each objective to the particular layout. Each alternative is rated, weighted, totalled and compared.

7. ***Apply an audit:*** Several advanced plant-layout departments have developed layout audit procedures. Audit is usually applied to new facilities that a company may consider buying or to existing installations where no layout work has been done for some time. An audit is like a check list where one answers are recorded and rated typical questions from one section of an audit include.

   (i) How will the layout handle volume peaks?

   (ii) Where is the material stored when schedules change suddenly or production fluctuates?

   (iii) Can the layout be adjusted to new machinery and equipment yet to be selected or designed?

   When evaluating alternatives, the layout engineer checks each layout against the list of questions. He rates his answers and selects the best alternative based on his answer.

8. ***Cost comparison:*** The most common method of weighting alternatives is by comparing the cost involved. This means everything that goes into the cost of installation and operation. In establishing costs, the layout engineer should consider the following list and charge against his installation each and everyone that should be included. Costs to be considered include:

   (a) *Investment:* Initial cost of new facilities of all kinds. Accessory costs, installation costs, depreciation and obsolescence.

   (b) *Operating costs:* Material, labour, general and burden. No matter how many layouts are investigated, none of them will have everything. There has got to be a compromise somewhere to get a practical solution. As a result, develop from the theoretical layout two or three practical solutions. Evaluate these and pick one that looks good. Then go ahead and develop it. Otherwise, we may spend all the time debating which solution is best and then have no time to develop its details.

Effect of Automation on Layout

The fully automatic factory is still a dream of the future, but automated individual sections or production lines are becoming more and more frequent in industry and are having considerable impact on the layout of plants. The automated line provides for:

1. A constant flow of materials through the system;
2. Automatic loading, positioning and unloading;
3. Automatic handling between operations;
4. Inspection after certain predetermined operations;
5. Automatic sorting of goods components from bad ones; and
6. Adjustment of machines and processes as dictated by inspection results.

The significant implication of automated production lines is the reduction of work in process and of temporary storage to a minimum, resulting in substantial saving in space (up to about 50 per cent) and costs of material handling.

Automatic installations are usually associated with major capital expenditure and naturally the question of flexibility immediately arises, i.e., the adaptability of the automated line to variations in design or to multiproduct. Clearly, if the line is a rigid system which requires major changes in layout structure or even minor changes in product design, automation can be justified only for very high volumes of production where the line can turn out the same components for an appreciably long time if however, flexibility in automated lines can be achieved it can be adopted for backing production and have a marked effect on small and medium-size establishments, the integration of these lines into one layout, the output capacity ratio of automatic feeding lines to non-automated assembly lines, the maintenance procedure and general equipment policy, all these remain major problems affecting both layout considerations and production planning and control systems in industry.

Symptoms of a Bad Layout

A plant layout usually grows and develops. Not every major change in the production programme or additions of machines or sections justify redesign of the plant layout, but these accumulate and gradually alter the basic pattern of flow lines in the plant, until replanning of the layout becomes inevitable. The symptoms of a layout in need of redesign are:

1. Congestion of materials, components and assemblies;
2. Excessive amount of work in process;
3. Poor utilisation of space;
4. Long transportation lines;
5. Production bottlenecks at certain machines while similar or identical machines lie idle;
6. Excessive handling by skilled operators;
7. Long production cycles and delays in delivery;
8. Mental or physical strain on operators; and
9. Difficulty in maintaining effective supervision and control.

Student Activity

Fill in the blanks:

1. Plant layout may be defined as physical arrangement of ....
2. Three basic types of layouts ....
3. Machine or workstation is usually automatic equipment fed by ....
4. The product layout portion of the factory is represented by ....

Summary

This unit establishes that design of an operations layout is a strategic issue. It provides an integrated approach by analyzing the basic production systems and moves on to explain the different kinds of layouts. A study into the factors influencing plant layout and the guiding fundamentals to a successful layout is also dealt with layout Engineering as separate topic lends an overview into the technicalities of their area. Also, the increasing role of computers and the enhanced information access as a mode of layout planning have also been provided.

The layout is basically an expression of the various relationships between different operations or work areas, e.g., the two departments having close relationship with each other may be required to keep adjacent to each other, e.g., for each of supervision, minimum distance need for common lighting, etc. Similarly, the two departments may not be required to keep adjacent to each other as in the case of surgical and gynaecology departments.

Keywords

Fixed Position Layout: Material remains fixed and tools, machinery and men are brought to the location of the material.

Flexible Manufacturing: Ability of a manufacturing system to respond at a reasonable cost and at an appropriate speed.

Group Layout: Combination of both process and product layout and incorporates the strong points of both of these.

Mixed Layout: Produces several items belonging to the same family.

Process Layout: Similar machines or similar operations are located at one place as per the functions.

Product Layout: Facilities are located based on the sequence of operation on parts.

Review Questions

1. Define the term layout and state its objectives.
2. How does layout affect the efficiency of an organisation?
3. Describe different types of layout and the advantages and disadvantages of each.
4. Distinguish between a product and process layout.
5. "A good plant layout should provide for the present as well as future needs of the industries." Elaborate the statement.
6. What factors influence plant layout? Explain two types of layouts and their advantages and disadvantages.
7. Describe guiding fundamentals to a successful layout.

8. Explain how layout planning is done.
9. Write short notes on:
   (i) Effect of automation of layout,
   (ii) Symptoms of a bad layout,
   (iii) Work flow.
10. The information given in the Table Q. 10 regarding total movements of the load in 12 different departments is collected from an analysis of the annual activities of a factory. It is required to locate the 12 areas of responsibility within an area of 60m × 80m. The approximate dimensions of each are given in the Table Q.10. Previous experience indicates that gangways occupy about 25 per cent of the total available area.
    (i) Prepare journey between network,
    (ii) Indicate the most heavily loaded path,
    (iii) Prepare the layout by locating the different departments in an optimum way.
    (Utilise the Graph Q.10 provided on next page)

Table Q.10

Area of Responsibility	Approx. Dimensions (M)
A	10 x 25
B	10 x 30
C	15 x 40
D	20 x 30
E	10 x 25
F	10 x 10
G	10 x 20
H	10 x 15
I	15 x 35
K	10 x 20
L	10 x 20
M	10 x 15

	A	B	C	D	E	F	G	H	I	J	K	L	M
A		10											
B			10	4			4						3
C				6	1								
D						4	7						
E							2						
F				3				3	4				2
G						2		6	4				
H						6			6				
J										12			3
K												10	
L													4
M						2							

Graph Q.10

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior*, Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see*, Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management*, John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail,"* HBS Press, 1997.

Chase, Jacobs, Aquilano, *Operations Management for Competitive Advantage*, Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis*, Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach*, McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies*, John Wiley & Sons, 2004.

Unit 7 Materials Handling

Unit Structure

- Introduction
- Definition
- Functions of Materials Handling
- Importance/Significance of Materials Handling
- Factors on which Materials Handling System Depends
- Principles of Materials Handling
- Selection of Materials Handling Equipment
- Types of Materials Handling Equipment
- Principle of Unit Load and Concept of Containerisation and Palletisation
- Relation between Plant Layout and Materials Handling
- Mechanisation and automation in Materials Handling
- Assessment of Handling Problems for Mechanisation
- Care and Safety in Materials Handling
- Some Guidelines for Cost Reduction in a Materials Handling System
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Factors on which materials handling system depends
- Types of materials handling equipment
- Relation between plant layout and materials handling
- Assessment of handling problems for mechanisation

Introduction

Material management procedures are strategically placed within an organization. They have different meanings for different people. Some of the material management procedures may give more weightage to purchasing, while others may attach a lot of importance to inventory control. A good material management process may have a strong backing of quality management and quality assurances of material purchasing and handling. This combination has a great impact on profitability and productivity as this may reduce the rejection rates of materials, thus, bringing down the overall cost of production in a well managed system. It is sometimes stated that it is the control of quality from the procurement to final distribution of the product that improves productivity and corporate image.

Definition

"Materials handling is the art and science involving the movements, packaging and storing of substances in any form. Materials handling is concerned with:

1. Movement
2. Time
3. Quantity
4. Space

1. *Movement:* Material handling experts are primarily concerned with how raw materials reach the operator and how finished or processed articles are removed from the work area. Parts, materials and finished products must be moved from location to location. Materials handling is concerned with them in the most efficient manner.
2. *Time:* Materials handling must ensure that no production process or customer need will be hampered by having materials arrive on location too late or too early.
3. *Quantity:* Materials handling must ensure that each location continually receives the correct quantity of parts, raw materials, etc.
4. *Space:* Space requirements are generally influenced by the material handling flow pattern. Storage of raw materials, parts and semi-finished or finished products involves materials handling.

Materials handling involves movements of materials mechanically or manually in batches or one by one within the plant. Movement may be horizontal, vertical or a combination of both.

Functions of Materials Handling

1. Selection of machines/equipment and plant layout to eliminate or minimise materials handling requirement.
2. Selection of appropriate, efficient and safe materials handling equipment.
3. Minimise the cost of materials handling by:
   (a) minimising movements of semi-finished goods during production,
   (b) to plan movement of optimum number of pieces in one unit,
   (c) minimisation of distance moved,
   (d) increased speed of materials handling operation through mechanisation,
   (e) eliminate/minimise back tracking and duplicate handling,
   (f) utilise gravity for handling,
   (g) standardise materials and methods,
   (h) training of operators,
   (i) safety in materials handling.

Importance/Significance of Materials Handling

Materials handling accounts for approximately 25 to 40 per cent of the total cost of production. Though materials handling operations add no value to the end product but the operation may help in reducing the cost of production since materials handling operations offer enough scope for minimisation of handling cost provided materials are moved with speed and a safety. Poor handling operations results in delay. Delays check the speed which obviously leads to idling of materials and equipments adding to carrying costs and halting or slowing down the production.

The importance of materials handling lies in the fact that the cost and the time of materials can be reduced to a greater extent by adopting a sound system of materials handling procedure.

An improved system of materials handling procedure results in the following:

1. Increased productivity capacity of labour;
2. Increased production capacity of the pants;
3. Full utilisation of plant capacity;
4. Saving in man-hours resulting in reduction in the cost of production;
5. Reduction in inventory thereby helping in the advantageous use of working capital;
6. Making the factory working easy;
7. Clean shop-floors enabling smooth, less strenuous and efficient functioning of the factory;
8. Less utilisation of available space which helps in the processing of products within least possible time and that too with less effort and better results;
9. Less wastage, spoilage and damages;
10. Minimum supervision due to minimisation of interruption in production schedule; and
11. Reduction in fatigue of workers leading to greater job satisfaction and more work with greater safety.

Economic utilisation of materials brings prosperity to the organisation. This fact has now been realised and people have become more and more conscious. This factor enables an organisation to effect economy and bring better results by efficient materials operation. Materials handling operations offer good scope for improvement which is rather higher in this field than any other industrial operations through the complete cycle of operations from procurement of raw materials, including reception and storage, its handling into the process and in between processes and handling of the finished products outwards.

Factors on which Materials Handling System Depends

Materials handling system mainly depends on the following factors:

1. ***Nature of the production process:***
    (a) For intermittent industries with process layouts, prime requirement of materials handling is the volume of load. The equipment can be mobile trucks, tractors, trains, cranes, etc.
    (b) For continuous industries using line or product layout some direct means of transportation between various operations are required. Depending upon the nature of the product, we may need some special type of equipment for materials handling. In some instances this can be coordinated by simply arranging the flow of materials in such a way that it can be picked up by the subsequent operation, e.g., trolly's conveyor belts, etc.
2. ***Layout of the plant:*** Layout and materials handling are not separate problems and so these should always be considered jointly. One important consideration in planning the details of a layout is to provide easy access to all operations by providing an efficient materials handling system.

3. *Building construction:* Usually, once a building has erected, it is not possible, at a reasonable cost, to make too many changes in the construction merely for the purpose of installing materials handling equipment. The equipment used for materials handling should be such that no undue loads or other strains be placed on the structural members of the building.

Principles of Materials Handling

1. *Planning principle:* All handling activities should be planned:

   Handling activities should be planned and not left to chance, or to the vagaries of performance likely to result if operating personnel are left on their own to devise methods of handling. Handling may account for 25 to 80 per cent of all productive activity. Management most certainly deserves to have this sizable portion of total activity planned and not left to chance.

2. *Systems principle:* Plan a system integrating as many handling activities as possible and coordinating the full scope of operations (receiving, storage, production, inspection, packaging, warehousing, shipping and transpiration).

3. *Materials-flow principle:* Plan an operation sequence and equipment arrangement to optimise materials flow.

   Materials handling and plant layout are intimately interrelated. The material-flow pattern is actually the backbone of most production facilities and one of the first steps in planning a materials handling system is the design of the materials-flow pattern. This may be largely determined by operation sequence, which in turn will determine the pattern of equipment arrangement.

4. *Simplification principle:* Reduce, combine, or eliminate unnecessary movements and/or equipment.

   Simplification is one of the bywords of efficiency, motion economy and many other aspects of industrial operation. It should like-wise be a goal in materials handling. As used there it implies, primarily the reduction or elimination of moves as well as the elimination or reduction of equipment that is not being properly utilised.

5. *Gravity principle:* Utilise gravity to move materials whenever practicable.

   This is certainly a very obvious principle but one that is all frequently overlooked because of its simplicity. Many materials can be made efficiently by the proper application of the law of gravity.

6. *Space utilisation principle:* Make optimum utilisation of building cube:

   Factory and warehouse space are expensive. Therefore, wasted space is wasted money. Inherent in this principle is that square feet and cubic feet as "clear" height will permit items to be stacked. In this way, a square foot can be "Used" many times over – with 15, 20, 30, 40 foot stacking of materials.

7. *Unit size principle:* Increase quantity, size, weight of load handled: In general, the larger the load, the lower the cost per unit handled. Wherever practical, individual items should be gathered and made up into unit loads. We have discussed in the next unit the load concept, since it is one of the keystones of modern, efficient materials handling.

8. *Safety principle:* Provides for safe handling methods and equipment: All handling activities in operation or being planned should be safe, since an objective materials handling is to improve working conditions by providing safer work situations. A high proportion of all industrial accidents is in the materials handling aspect of the production activity.

9. *Equipment selection principle:* In selecting handling equipment, consider all the aspects of the materials to be handled, the Move(s) to be made, the Method(s) to be utilised.

This principle is primarily a reminder to be extremely careful in selecting and specifying handling equipment by being sure that all phases of the problems are thoroughly analysed.

10. ***Mechanisation/automation principle:*** Use mechanised or automated handling equipment when practicable.

    Used judiciously, mechanised or automated handling devices and equipment can be of extreme value in increasing materials handling efficiency. However, handling operations should not be mechanised for the sake of mechanisation along, nor should they be over-mechanised in terms of the function to be performed.

11. ***Standardisation principle:*** Standardise methods as well as types and sizes of handling equipment.

    In almost any field of endeavour it is wise to standardise the "one best way" after it has been determined. This is not, however, meant to imply that methods, equipment, etc., should be "frozen" and adhered to indefinitely. A search for a better method should always be under way. Standardisation does not mean only one type or make of equipment to be used. It should be interpreted to mean the fewest practical number of types, makes, models, sizes, etc.

12. ***Flexibility principle:*** Use methods and equipment that can perform a variety of tasks and applications.

    Equipment that can perform a wide range of handling tasks and which has a variety of uses and applications can often be more fully utilised than a single-purpose one.

13. ***Dead-weight principle:*** Reduce the ratio of mobile equipment dead-weight to pay load.

    Excess weight of mobile equipment not only costs money, but may require additional power and be slower to operate. It is, therefore, unwise to invest in a heavier weight piece of equipment than is required by the task to be performed.

14. ***Motion principle:*** Equipment designed to transport materials should be kept in motion.

    This principle implies that mobile equipment should be kept moving, that is performing the function for which it was designed. It should be tied up for unduly/long periods of time for loading and unloading.

15. ***Idle-time principle:*** Reduce idle or unproductive time of both handling equipment and manpower.

    Idle time is undesirable in nearly any industrial or commercial activity and especially so in the use of materials handling equipment or manpower. Equipment and manpower are "making money" when fully utilised. Therefore, every effort should be made to plan methods and schedule equipment to permit full use of both resources.

16. ***Maintenance principle:*** Plan for preventive maintenance and scheduled repair of all handling equipment.

    The suggestions for application of the previous principles have implied the importance of preventive maintenance and scheduled repairs to the effectiveness of materials handling activities. Probably very few phases of the materials handling programme can contribute more to overall plant efficiency than a well-organised maintenance and repair function.

17. ***Obsolescence principle:*** Replace obsolete handling methods and equipment when more efficient methods or equipment will improve operations.

    As with any other type of physical equipment, materials handling devices are subject to obsolescence, as well as depreciation. And, in a similar sense, so are handling methods. New ideas, techniques, methods and equipment are reported everyday and one should be continuously alert to be sure he is aware of the latest developments.

Physical depreciation is not difficult to observe and to take consideration in an analysis but obsolescence is a less obvious characteristic. Many old, or even "ancient" pieces of equipment "still work" and even at relatively low costs for maintenance and repairs. However, new equipment may be faster, higher capacity, more efficient, etc., and result in a lower cost per unit handled even though it does require a capital investment.

18. ***Control principle:*** Use material handling equipment to improve production control, inventory control and order handling.

    Since materials handling equipment is used to move materials through the plant and the production processes, its use can have a great effect on the control of the items being moved. In many cases, handling equipment provides a direct mechanical path for the movement and thereby facilitates the control of the material.

19. ***Capacity principle:*** Use handling equipment to help achieve full production capacity

    In many ways, this principle is a summation of all the preceding ones, in that a major objective of materials handling is to increase production capacity. Nearly everyone of the foregoing principles will contribute in some way to higher production levels. However, the emphasis here is on those facets of operation and other principles that are directed specifically towards increasing or making full use of production capacity.

20. ***Performance principle:*** Determine efficiency of handling performance in terms of expense per unit handled.

    As pointed out above, there are many objectives of materials handling. However, an effective handling method may achieve one or several of these objectives. The primary criterion for measuring the efficiency of a handling technique is costs. Although efficiency could be measured in terms of total cost (and sometimes is) or equipment performance (as judged against selected criteria), the most effective means of measurement is in terms of rupees per unit handled. This is usually the ultimate measure from the point of view of management.

    It should be pointed out that there are cases where maximum economy is not the overall goal. Some materials handling devices may be installed to provide higher production rates, safer working conditions, or reduced physical effort. Time or effort saved may be the primary criteria and the cost of handling may be of little or no interest.

Selection of Materials Handling Equipment

The following factors may be considered while selecting a materials handling equipment:

1. ***Material to be moved:*** The size of material, its shape, weight, delicacy, nature (solid, liquid, gas) and its chances of getting damaged during handling, etc., should be considered.

2. ***Plant buildings and layout:*** Widths of aisles, inequality in floor levels, width of the doors, height of the ceiling straight of floor and walls, columns and pillars, etc., to a great extent influence the choice of a materials handling equipment. For example, low ceiling heights may not permit stacking of palletised materials, weak roofs limit the use of overhead conveyors and steps between two floors will not allow trucks to operate.

3. ***Type of production machines:*** Different machines have different outputs per unit

time. The materials handling equipment should be able to handle the maximum output.

4. *Type of materials flow pattern:* A vertical flow pattern will require elevators, conveyors, pipes, etc., whereas horizontal flow pattern will need trucks, overhead bridge cranes, conveyors, etc.
5. *Type of production:* The type of production affects to a large extent the selection of the materials handling equipment. Conveyors are more suitable for mass production on fixed routes and powered trucks for bath production; because conveyors though costly, can handle more volume of production per unit time as compared to trucks, whereas a truck is a more flexible equipment.
6. *Cost of materials handling equipment.*
7. *Handling costs.*
8. *Life of the equipment.*
9. *Amount of care and maintenance required for the materials handling equipment.*

Types of Materials Handling Equipment

1. *Manual handling:* It variably happens that manual handling is often the easiest, most efficient and least expensive method of moving materials. So before thinking of an equipment explore the possibility of manual methods.

   Some of the characteristics which lend themselves to manual handling are:

   i. The material is a unit.
   ii. It is small, light, fragile, costly, safe to handle, containerised or solid.
   iii. Small or low volume of single items are involved one at a time.
   iv. The movement is confined to a small area.
   v. The movement is infrequent, non-uniform, irregular, variable speed, low percentage of handling.
   vi. It requires manoeuvering or positioning.
   vii. Small amount of operation time is required.
   viii. There are no major physical or other constraints.

2. *Non-powered or manual equipment:* The following list indicates some of the situations in which non-powered or manual equipment may fit into the handling system:

   i. Where handling volume is limited, or handling activity can be extended over a long period of time;
   ii. Where building limitations preclude use of heavier or bigger devices;
   iii. Where service conditions, such as confined areas, explosive atmospheres, or quiet surroundings necessitate the advantages of non-powered equipment;
   iv. Where equipment is used not only for handling, but for semi-live storage or display;
   v. When investment capital is limited;
   vi. When the required flexibility, utility, mobility and portability can only be obtained in a non-powered floor device;
   vii. Where the mobile equipment facilities are minimal or non-existent;
   viii. Where the mobile equipment must be tailored to the product or need;
   ix. Where the operating efficiency of non-powered equipment is higher than that of any other type;

x. When loads are relatively light an equipment is to be manually moved;

xi. For stand-by use; and

xii. For durable, low-cost operation.

The above possibilities should be checked before mechanised or powered equipment is seriously considered.

3. ***Basic handling equipment types:*** In general, it can be said that there are three "basic" types of material handling equipment: conveyors, cranes and hoists and trucks. There are sub-classifications under each, plus additional categories for accessories, attachments and other related equipment. However, since the three basic types form a convenient framework for discussing handling equipment, they are briefly described as follows:

Conveyors

These are gravity or powered devices commonly used for moving uniform loads continuously from point-to-point over fixed paths, where the primary function is conveying.

A. ***Common examples.***

(a) Roller conveyor

(b) Belt conveyor

(c) Chute

(d) Trolley conveyor

(e) Bucket

(f) Pneumatic

B. ***Conveyors are generally useful when.***

(a) Loads are uniform;

(b) Materials move continuously;

(c) Route does not vary;

(d) Load is constant;

(e) Movement rate is relatively fixed;

(f) Conveyors can by pass across traffic;

(g) Path to be followed is fixed;

(h) Movement is from one fixed point to another point;

(i) Automatic counting, sorting, weighing, despatching is needed;

(j) In-process storage or inspection are required;

(k) Necessary to pace production;

(l) Process control is needed;

(m) Controlled flow is required;

(n) Handling hazardous materials;

(o) Handling materials at extreme temperatures or under adverse conditions:

(p) Handling is required in dangerous areas;

(q) Manual handling and/or lifting is undesirable;

(r) Integrating machines into a "System";

(s) Handling between workplaces;

(t) Flexibility is required to meet changes in production processes, volume or pace;

(u) Conveyors can be installed overhead to save floor space; and

(v) Necessary to make constant visual check of production processes.

Cranes and Hoists

These overhead devices are usually utilised to move varying loads, intermittently, between points within an area fixed by the supporting and guiding rails, where the primary function is transferring.

A. ***Common examples.***

(a)	Overhead travelling crane	(d)	Hoist
(b)	Gantry crane	(e)	Stacker crane
(c)	Jib crane	(f)	Mono rail

B. ***Cranes and hoists are most commonly used when.***

(a) Movement is within a fixed area;

(b) Moves are intermittent;

(c) Loads vary in size or weight;

(d) Cross traffic would interfere with conveyors; and

(e) Units handled are not uniform.

Industrial Trucks

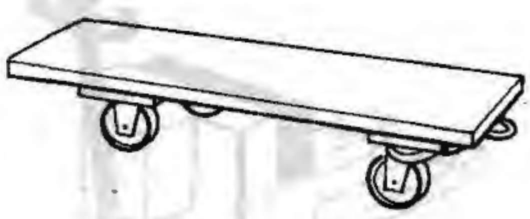
These are hand or powered vehicles (non-highway) used for the movement of mixed or uniform loads, intermittently, over various paths having suitable running surfaces and clearances, where the primary function is maneuvering or transporting.

The following are the important types of industrial trucks:

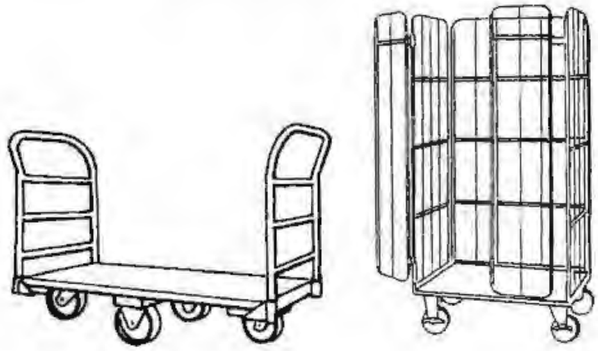
1. *Hand Truck:* Non-pallet + manual + no stack

(a) *Two-Wheeled Hand Truck:* Load tilted during travel

(b) *Dolly:* Three or more wheeled hand truck with a flat platform in which, since it has no handles, the load is used for pushing



(c) *Floor Hand Truck:* Four or more wheeled hand truck with handles for pushing or hitches for pulling. Sometimes referred to as a "cart" or "(manual) platform truck"



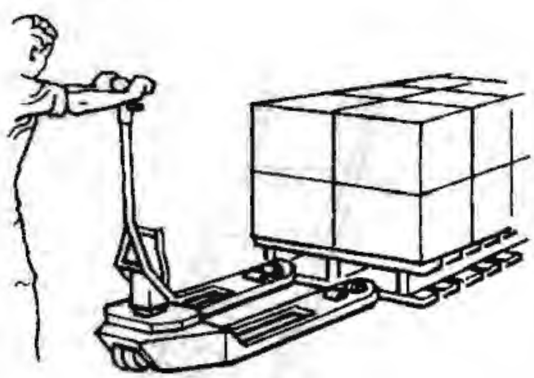
2. ***Pallet Jack:*** Pallet + walk + no stack

- Front wheels are mounted inside the end of the forks and extend to the floor as the pallet is only lifted enough to clear the floor for subsequent travel
- Pallet restrictions: reversible pallets cannot be used, double-faced nonreversible pallets cannot have deck boards where the front wheels extend to the floor, and enables only two-way entry into a four-way notched-stringer pallet because the forks cannot be inserted into the notches

(a) *Manual Pallet Jack*

Pallet + walk + no stack + manual

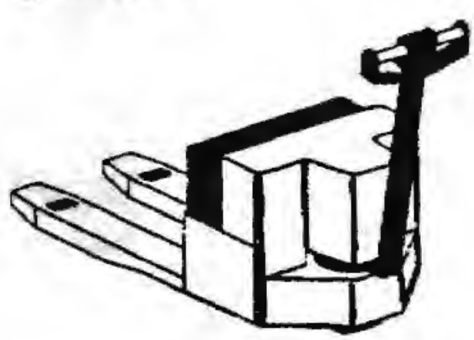
Manual lifting and/or travel



(b) *Powered Pallet Jack*

Pallet + walk + no stack + powered

Powered lifting and/or travel



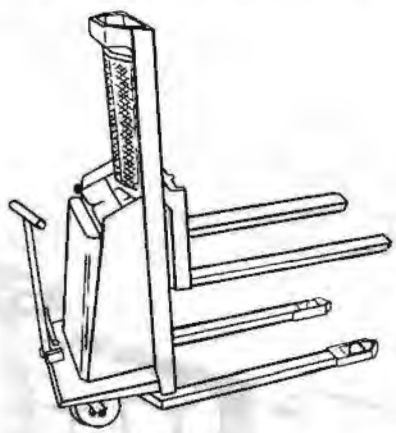
3. ***Walkie Stacker***

Pallet + walk + stack

(a) *Manual Walkie Stacker*

Pallet + walk + stack + manual

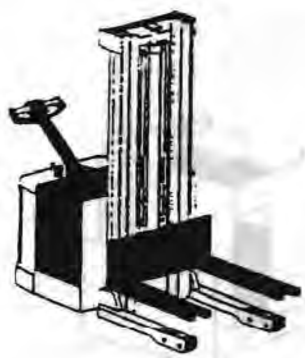
Manual lifting and/or travel (and straddle load support)



(b) *Powered Walkie Stacker*

Pallet + walk + stack + powered

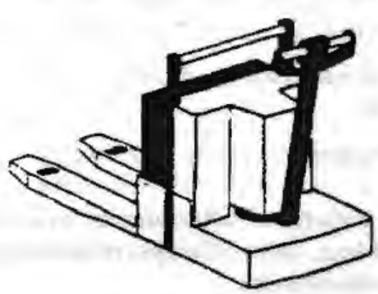
Powered lifting and/or travel (and either counterbalance or straddle load support)



4. ***Pallet Truck***

Pallet + ride + no stack

- Same pallet restrictions as a pallet jack
- Control handle typically tilts to allow operator to walk during loading/ unloading
- Powered pallet jack is sometimes referred to as a "(walkie) pallet truck"



5. ***Platform Truck***

Non-pallet + powered + no stack

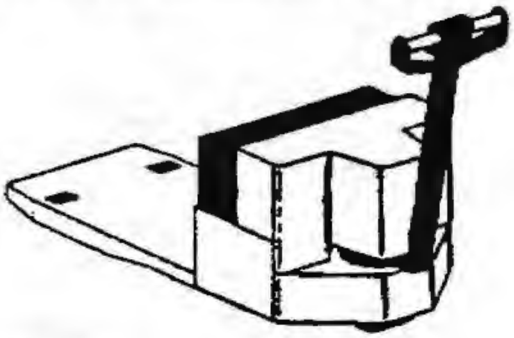
- Platform used to provide support for non-palletized loads
- Used for skid handling; platform can lift skid several inches to allow it to clear the floor
- Greater lifting capacity compared to fork trucks because the platform provides a greater lifting surface to support a load

(a) *Walkie Platform Truck*

Non-pallet + powered + no stack + walk

Operator walks next to truck

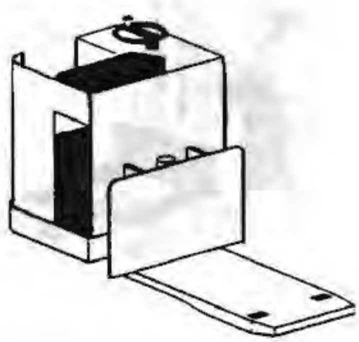
Floor hand truck is sometimes referred to as a "(manual) platform truck"



(b) *Rider Platform Truck*

Non-pallet + powered + no stack + ride

Operator can ride on truck



6. ***Counterbalanced (CB) Lift Truck***

Pallet + ride + stack

- Also referred to as fork truck.
- Weight of vehicle (and operator) behind the front wheels of truck counterbalances weight of the load (and weight of vehicle beyond front wheels); front wheels act as fulcrum or pivot point.
- Rated capacity reduced for load centers greater than 24 in. and lift heights greater than 13 ft.
- Workhorses of material handling because of their flexibility: indoor/outdoor operation over a variety of different surfaces; variety of load capacities available; and variety of attachments available—fork attachments can replace the forks (e.g., carton clamps) or enhance the capabilities of the forks (e.g., blades for slip-sheets).

(a) *Sit-Down Counterbalanced Lift Truck*

Operator sits down

12-13 ft. minimum aisle width requirement

(b) *Stand-Up Counterbalanced Lift Truck*

Operator stands up, giving vehicle narrow-aisle capability

9-11 ft. minimum aisle width requirement

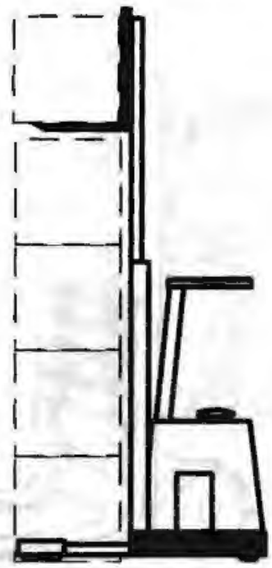
Faster loading/unloading time compared to NA straddle and reach trucks

7. ***Narrow-Aisle (NA) Straddle Truck***

These types of trucks are:

- Similar to stand-up CB lift truck, except outrigger arms straddle a load and are used to support the load instead of the counterbalance of the truck
- 7-8 ft. minimum aisle width requirement
- Less expensive than stand-up CB lift truck and NA reach truck
- Since the load is straddled during stacking, clearance between loads must be provided for the outrigger arms

- Arm clearance typically provided through the use of load-on-beam rack storage or single-wing pallets for load-on-floor storage



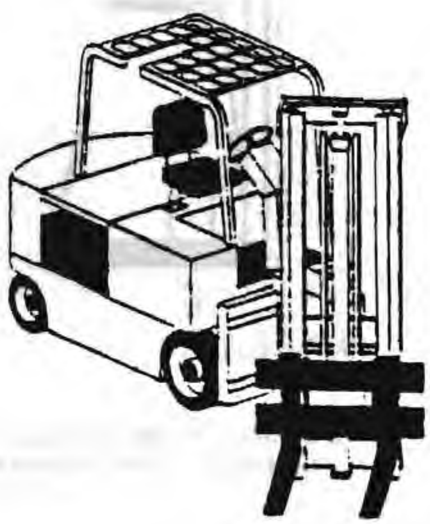
8. *Turret Truck*

These types of trucks include:

- Greater stacking height compared to other narrow-aisle trucks (40 ft. vs. 25 ft.), but greater investment cost
- Forks rotate to allow for side loading and, since truck itself does not rotate during stacking, the body of the truck can be longer to increase its counterbalance capability and to allow the operator to sit
- Can function like a side loader for transporting greater-than-pallet-size load

(a) *Operator-Down Turret Truck*

The key features of Operator-Down Turret trucks are:

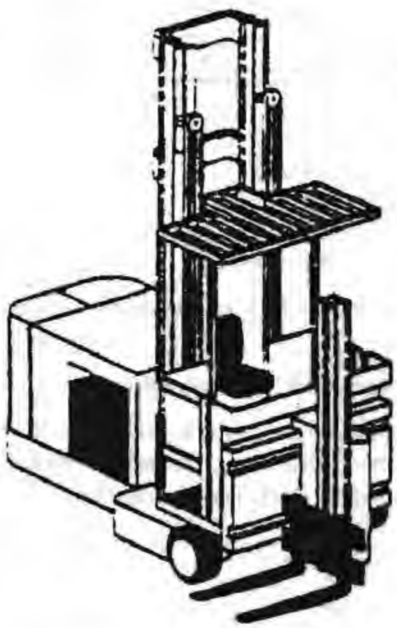


- Operator not lifted with the load
- 5-6 ft. minimum aisle width requirement

- Termed a swingmast truck (picture shown) when, instead of just the forks, the entire mast rotates (thus can store on only one side of a aisle while in aisle)

(b) *Operator-Up Turret Truck*

The key features of Operator-Up Turret trucks are:

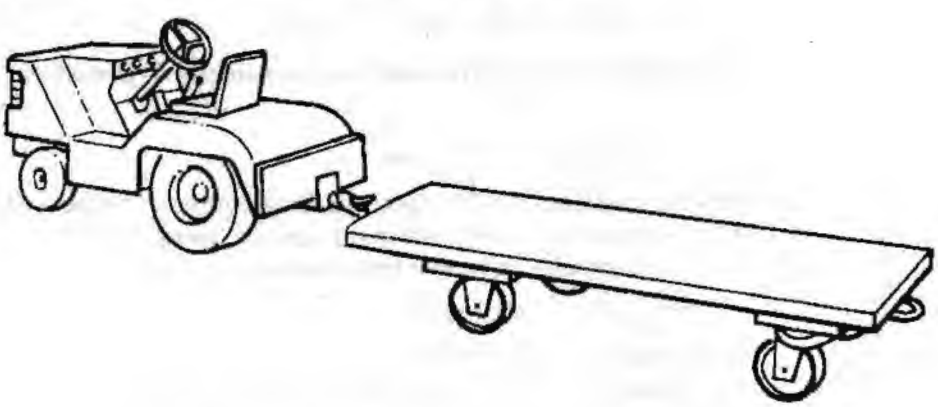


- Operator lifted with the load to allow precise stacking and picking
- 5-7 ft. minimum aisle width requirement

9. ***Tractor-Trailer***

The tractor-trailer includes:

- Non-load-carrying tractor used to pull a train of trailers (i.e., dollies or floor hand trucks)
- Extends the transporting capacity of floor hand trucks
- Typically used at airports for baggage handling



10. ***Personnel and Burden Carrier:***

Non-load-carrying vehicle used to transport personnel within a facility (e.g., golf cart, bicycle, etc.)

11. *Automatic Guided Vehicle (AGV)*

The key features of AGV are:

- AGVs do not require an operator
- Good for high labor cost, hazardous, or environmentally sensitive conditions (e.g., clean-room)
- Also termed "automated" guided vehicle
- AGVs good for low-to-medium volume medium-to-long distance random material flow operations (e.g., transport between work cells in a flexible manufacturing system (FMS) environment)

A. ***Common examples.***

(a) Fork lift truck	(d) Tractor-trailer train
(b) Platform truck	(e) Hand stacker
(c) Two-wheel hand truck	(f) Walkie truck

B. ***Industrial trucks are generally used, when.***

(a) Material is moved intermittently;

(b) Movement is over varying routes;

(c) Loads are uniform or mixed in size and weight;

(d) Length of move is moderate;

(e) Cross-traffic would prohibit conveyors;

(f) Clearances and running surfaces are adequate and suitable;

(g) Most of the operation consists of handling (or maneuvering, stacking, etc.); and

(h) Material can be put up into unit loads.

Basic handling systems: In addition to the basic handling equipment types outlined above, handling activities may be classified in terms of types of "handling system, which is sometimes helpful in conceptualising production situations and problem solutions.

The basic handling systems can be characterised as follows:

Equipment-oriented system: Like industrial truck system (platform trucks and skids constitute one system. So also fork truck and patters or tractor-trailer). Next have the conveyor system. These are adaptable to mass movement. Then there are overhead system (like overhead cranes).

Material (load) oriented system: Examples are bulk handling or liquid handling systems.

Method (production) oriented system: These can be manual systems, mechanised or automatic systems, mass production handling system, job shop handling systems etc.

Functions oriented handling systems: Examples are:

a. ***Transportation systems:*** Horizontal motion over fixed or variable, level or nearly level routes by pulling or pushing, on surface riding vehicles.

b. ***Elevation systems:*** Vertical motion over fixed vertical of steeply inclined routes with continuous or with intermittent motion.

c. ***Conveying systems:*** Horizontal, vertical or compound motions, through the air, over fixed routes by gravity or by power.

d. ***Transferring systems:*** Horizontal, inclined or declined motions through the air over fixed routes or limited areas, with intermittent motion.

e. ***Self-loading systems:*** Intermittent motion with machines that pick up, move horizontally, set down and in some cases, loads without other handling. Also known as unit-load systems.

Another classification possible divides the entire list of equipment into:

a. Potential movement. Pallets, stillages, bins, hoppers, mobile racking.

b. Discontinuous movement.

A. ***Lifting equipment:*** Vertical and horizontal positioning

   (i) Point.

   Guided. Jacks, elevating tables, elevators.

   Free point. Capstan, winches, hoists, pulleys.

   (ii) Line.

   Straight. Girder trolleys, fixed girder cranes.

   Curved. Overhead mono rails.

   (iii) Area.

   Angular. Travelling bridge and gantry cranes.

   Circular. Revolving cranes jib cranes, derricks.

   Angular and circular. Hinged Jib loading cranes, stacking cranes.

   Unrestricted. Mobile cranes.

B. ***Mobile Equipment:***

Horizontal Movement.

Line. Guided; rail vehicles.

Area-free. Powered and manual trucks and trolleys, tractors and trailers.

Lifting and horizontal movement.

Area-free. Straddle trucks, stillage trucks, elevating platforms, pallet trucks.

C. ***Stacking equipment. Horizontal and vertical movement.***

Unrestricted. Fork trucks, reach trucks, stacking trucks, side loaders.

D. ***Continuous movement. Conveying equipment.***

Transporting.

   (i) ***Towing mechanism:*** Overhead tow line trolley conveyors, infloor trolley conveyors, robot tugs.

   (ii) ***Powered conveyors:***

Continuous carrying. Flat belt through, closed belt, slat, carrier and chain conveyors.

Linked carriers. Bucket enmasse, apron and pan conveyors, cross bar conveyors.

Detachable carriers. Overhead trolley conveyors, overhead chain conveyors.

Continuous propulsion. Powered roller conveyors, pneumatic conveyors, air film conveyors.

E. *Free rolling.*

Line-unpowered. Roller, wheel and ball tracks.

F. *Sliding.*

Unpowered-intermittent. Chutes

G. *Propelling.*

Powered-continuous. Screw conveyors, spiral elevators.

H. *Vibrating.*

Powered-continuous. Vibratory feeders, screens, elevators.

There are various ways in which equipment can be classified. A system of classification uses the decimal system and is quite comprehensive.

Principle of Unit Load and Concept of Containerisation and Palletisation

It is easier and faster to move hundred small parts say castings or cardboard sheets by grouping them in one unit than moving them individually one by one. This principle of unit load can also be explained like this. If the bearer of a hotel removes cups, plates and other crockery from a table by placing them in a tray, it is called material handling by unit loads, Definitely, he would have spent much more time and effort in removing all the crockery by one cup or one plate at a time.

By using available machines (like one for strapping steel strips around cotton bales), fork-lift trucks, skids and pallets, it is easy to handle materials in unit loads and stack them neatly and properly (even as high as the ceiling) thereby reducing the storage space requirements.

Depending upon the types of items to be transferred a suitable pallet can be designed. For example, items irregular in shapes and liable to be damaged by crushing utilise a post pallet whereas small jobs can be placed in wire mesh box. Containerisation uses principle of unit load. In this system big metal containers have number or small products filled in them. These containers are placed on the truck or in the trailors which are pulled by tractors or trucks. Afterwards, the containers can be loaded on railway trailers and can be taken to places from where, with the help of cranes, they can be shipped. Items like refrigerators, air-conditioners or televisions can be sent to distant places using the principle of containerisation. The system is much safer and involves a lot of saving.

Relation between Plant Layout and Materials Handling

There exists a very close relation between plant layout and materials handling. The methods of handling materials definitely influences the plant layout and the plant building. If all the devices required for a particular set of operations are determined but failed to arrange them properly then it is said that layout is not a good one. Effective layout means minimum handling operation.

In the part: (i) If materials are to be moved by hand operated or power trucks, passages are provided for their operation. (ii) If materials are to be moved by overhead cranes, passages are almost missing but the overhead space be unobstructed. (iii) If materials are to be moved by pipe lines, ducts such as paint in automobile body plants and saw dust as in wood working plants, arrangement should be made for their methods of handling. (iv) If the building is multi-storeyed, elevators, life conveyors of different types may be utilised. Gravity conveyor may be utilised in moving material in a multi-storeyed building or one built on a sloping grade.

Modern materials handling technique make possible continuous flow of materials and work in process between building and from one floor to another, thus removing restrictions of space and building construction, which was handicapped in the past. Today in advanced countries to connect machines with each other, handling devices operated by electronics control are used in automatic plants.

Mechanisation and Automation in Materials Handling

Materials handling operations can be divided broadly into three categories.

(a) ***Manual:*** In which all operations are performed by hand.

(b) ***Mechanised:*** Where human effort is assisted by such equipment as lift trucks and conveyors. This generally permits higher stacking and larger handling units. It may also involve rather sophisticated equipment, such as tracker-retriever units and mechanised stock picking trucks but all under manual control (hand, card, tape, etc.).

(c) ***Automated:*** Where equipment does the work of the operators and all activity is self-regulating and controlled – usually by an on line computer.

It is not always necessary or desirable to mechanise a handling operation so that costs may be reduced. Often a well-planned rearrangement of the plant layout uncovers savings which may be obtained without investing in materials handling equipment. A plant may be over conveyorised or over equipped to the point where the new equipment requires more additional maintenance cost than can be saved in materials handling cost. Such situations have developed in some plants largely as a result of the lack of a proper layout design, or of arbitrary decisions made under force of circumstances, or of well-intentioned but overzealous salesmanship by equipment suppliers, representatives.

Assessment of Handling Problems for Mechanisation

There has been remarkable progress in the field of mechanical handling equipment and an enormous variety of general and special purpose machines is now available. Before making a choice of one or more types of equipment from the wide range on offer, it is advisable to make a detailed assessment of the problem:

1. Ascertain the tonnage to be moved keeping in view the future expansion.
2. Types of vehicles making deliveries, how their loads are arranged and how they are to be unloaded.
3. The nature of weight of the packages and materials to be handled.
4. Assess the possibilities of using existing bins, racks and other storage equipment.
5. Consider the available storage space and the height, length, width and layout of the buildings to be used.

6. Check the arrangements required for stores issues.
7. Ascertain the lifting power, speed, mobility, versatility, size, operating-space requirements, purchase price and running costs.
8. Assess the labour force required.
9. List any new storage equipment necessary to employ the machines efficiently, e.g., pallets, special containers, additional operating attachments.
10. Make a detailed assessment of both the capital and running costs of any proposed new scheme.

A careful examination of these points will disclose what is physically practicable and subsequently what is most profitable.

Care and Safety in Materials Handling

Good materials handling involves the safety of personnel, of materials and of equipment. Some general aspects of care and safety are discussed below:

(i) *Care of Equipment:*

  (a) Prevent corrosion by good storage, cleaning and lubrication.

  (b) Equipment should never be dragged along floors.

  (c) Return all equipment to stores when not in use so that regular inspection and maintenance, is done.

(ii) *Care of Loads, Stacks and Vehicles:*

  (a) Protect corners of loads with packing material to prevent damage from slings, etc.

  (b) Prevent the load from resting on a wire rope. The strands may be crushed and the rope rendered unsafe.

  (c) Ensure that there is a good foundation for the load or stack before setting it down.

  (d) While stacking make provision for de-stacking.

  (e) Do not overload vehicles.

  (f) Do not load vehicles with heavily unbalanced loads.

  (g) When loading vehicles make sure there is no dangerous projection, ensure that all loads are safe and secure for transport.

  (h) When loading vehicles provide for off-loading (i.e., correct sequence).

(iii) *Safety of Personnel:*

  (a) Before finally loading, the operator must ensure that no person's hands are on the lifting gear.

  (b) Clear warning should be given to bystanders before lifting.

  (c) Riding on crane or load should be forbidden.

  (d) Loads should not be lifted over the heads of persons.

  (e) Public must be forewarned of loads carried on a thoroughfare.

  (f) Protective gloves must be worn when handling goods or materials with sharp edges.

  (g) Protective footwear must be worn.

  (h) Protective headgear must be worn by all engaged in lifting operations.

  (i) Loose boxes, drums or moving loads must not be used for standing on.

(iv) *Use of Equipment:*

Slings:

(a) Wire ropes must not be bent sharply at any point.

(b) They must not be used in contact with hot metals or acids.

(c) They must not be used as single legs if they terminate in a handspliced eye. (The rope is apt to unwind at the splice and slip.)

(d) Slings must not be shortened by (x) Knotting, (y) wrapping around the load, (z) wrapping around a hook.

(e) Chains must only be joined by the use of correct attachments, D-links, etc., of correct size.

(f) Angle between legs of sling must not be excessive. 120° is the usual limit; 90° is easier to check visually and is often recommended.

(g) Too short slings produce too wide an angle, as also extra long slings lose headroom.

(h) With more than two legs make sure the load is correctly shared.

(i) Do not use only one leg of a multileg sling. Stretching may occur so that unequal loading results on the next multiple sling load.

(j) Slings should be protected from sharp edges and corners of load.

Tackle:

(a) Avoid shock loadings.

(b) The correct sizes of all fittings especially pulleys must always be used.

(c) End fitting (mast links, etc.) must ride freely on hooks or other fittings.

(d) Ensure that the lifting attachment is at the point of equilibrium. If in doubt rock legs of sling very slightly as load takes up. (If the problem persists fit a load equaliser.)

(e) Ensure that the load is evenly distributed. Take particular care if some attachments to load are for steadying only.

(f) Make sure that the Mad is centrally placed when setting down, especially when loading into, a bogie, etc.

(g) Ensure that all tackle has adequately tested lifting capacity for the load handled.

(h) Slings out of use are not to be hung on the loaded hook. (They may drive the sling onto the nose of the hook.)

(i) When using out-triggers ensure that the bearing surface has adequate loading capacity.

Miscellaneous:

(a) Never use damaged ropes, fittings, etc.

(b) Scrap any corroded ropes.

(c) Operation and controls must be well-known and learned by all who use the equipment.

(d) Hand signals must be made clearly.

(e) Hand signals are preferable to oral signals.

(f) Signals must only be given by one person responsible for the lift.

(g) Don't use tackle not stamped with the safe working load.

(h) Safety guards must be in position before setting to work.

(i) Management must ensure all notices and instructions are understood and obeyed.

Some Guidelines for Cost Reduction in a Materials Handling System

The following may be enumerated as the guidelines for cost reduction in a materials handling system:

(i) ***Reduce materials handling to its minimum:*** Materials handling adds no value instead it increases the cost in the form of increase in the production cycle time. What is needed is that handling should altogether be eliminated. But elimination is not possible at all, therefore, it should be reduced to its minimum by careful planning, better layout and handling design, proper selection of handling equipments, minimisation of transportation lines and avoidance of transport bottlenecks.

(ii) ***Logical sequence of operations:*** It may yield results if a sequence in a logical manner is decided upon and strictly adhered to in order to ensure smooth, controlled and well-directed operations.

(iii) ***Conserve power and fuel:*** While making use of equipments it is worthwhile to attempt a cost reduction by conserving power and fuel. It is better to use gravity wherever it is possible. Such a use would help in conserving the power and fuel.

(iv) ***Consult materials management department:*** Technological considerations are supreme in taking a layout decision. Usually here the materials management department is not consulted. A layout decision should not be taken unilaterally. It would be better if materials management department is consulted in this regard. This would necessarily result in: (a) reducing the handling cost, (b) reducing the investment in materials handling equipment, (c) reducing the production cycle time, (d) maximum utilisation of floor space and (e) minimisation in handling operations. All these savings would naturally lead to reduction in total product cost.

(v) ***Proper selection of handling equipment:*** As per the requirement of the storehouse, handling equipment should be standardised to the extent it is possible. This will help in interchanging their use and better utilisation of the equipment.

(vi) ***Minimise the breakdown of equipment:*** Equipment are there to help materials handling. But their frequent breakdown may not help in realising the purpose. Hence it should be minimised by having a regular maintenance programme which may take necessary steps in preventing frequent breakdowns.

(vii) ***Have maximum weight of units load:*** So that every handling trip of the equipment in use is productive. This will not only minimise the handling but will also help in avoiding unnecessary movement of materials.

(viii) ***Minimise non-productive handling operations:*** Slinging, loading, unloading, etc., are non-productive materials handling operations. They consume time and add to the handling cost at the same time. As far as possible such operations should be minimised. Scrap movement with the help of magnetic cranes is an example in this respect.

(ix) ***Avoid wasteful movements:*** A 'method' study should be carried out to help in avoiding the wasteful movements.

(x) ***Centralised storekeeping:*** Minimises the handling and helps in the minimisation of the investment in materials handling system. The storehouse should be located near the plant and other user-departments. This also minimises the handling operations.

(xi) *Ensure coordinated efforts:* A coordination between the selection of equipment and training of the personnel, who are to handle such equipment, is one of the factors which goes a long way in reducing the cost of materials handling. This is one aspect of coordination. Materials movement within the plant also needs effective coordination. This has to be ensured right from product design to final transportation of materials. Damage, delays and man-hour losses within the plant can be effectively minimised with coordinated efforts. A well-planned integrated materials handling system may ensure coordination and customer's satisfaction both inside and outside the storehouse.

Student Activity

Fill in the blanks:

1. "Materials handling is the ....
2. Materials handling accounts for approximately ....
3. Economic utilisation of materials brings prosperity to the ....

Summary

Material handling experts are primarily concerned with how raw materials reach the operator and how finished or processed articles are removed from the work area. Materials handling accounts for approximately 25 to 40 per cent of the total cost of production. There exists a very close relation between plant layout and materials handling. The methods of handling materials definitely influence the plant layout and the plant building.

There has been remarkable progress in the field of mechanical handling equipment and an enormous variety of general and special purpose machines is now available.

Keywords

Materials handling: "Materials handling is the art and science involving the movements, packaging and storing of substances in any form.

Conveyors: These are gravity or powered devices commonly used for moving uniform loads continuously from point-to-point over fixed paths, where the primary function is conveying.

Manual: In which all operations are performed by hand.

Automated: Where equipment does the work of the operators and all activity is self-regulating and controlled – usually by an on line computer.

Review Questions

1. What do you understand by the term Materials Handling? State the functions and importance of Materials Handling.
2. Explain the factors on which Materials Handling System depends.
3. State principles of Materials Handling.
4. Write short notes on:
   (a) Selection of Materials Handling Equipment.
   (b) Types of Materials Handling Equipment.
   (c) Principles of unit load and concept of containerisation and palletisation.
   (d) Relation between Plant Layout and Materials Handling.
   (e) Mechanisation and Automation in Materials Handling.
   (f) Assessment of Handling Problems for Mechanisation.

5. Explain care and safety in Materials Handling.
6. Explain guidelines for Cost Reduction in a Materials Handling System.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior*, Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see*, Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management*, John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail,"* HBS Press, 1997.

Chase, Jacobs, Aquilano, *Operations Management for Competitive Advantage*, Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis*, Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach*, McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies*, John Wiley & Sons, 2004.

Unit 8 Demand Forecasting

Unit Structure

- Introduction
- Need for Forecasting
- Forecasts and Predictions
- Types and Time Horizon of Forecasts
- Categories of Forecasting
- Levels of Forecasting
- Qualitative Methods of Forecasting Demand
- Selecting the Appropriate Method of Forecasting
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Forecasts and Predictions
- Types and Time Horizon of Forecasts
- Qualitative Methods of Forecasting Demand

Introduction

Forecasts are needed throughout an organization and forecasting is a continuous process. Decisions are based on forecasts of future conditions as they become operational in future.

As time moves on, the impact of the forecasts on actual performance is measured; original forecasts are updated; and decisions are modified, and so on. That is the reason Mr. Guzder wanted a high level of accuracy in the forecasts, so that the major decisions could be taken correctly by DHL.

Our vision of the future guides us in deciding what product to provide, what process to use, and what values are to be provided to the customers. We need to be able to see around the corner to ensure that things do not go out of hand. To do so, we require a variety of tools. Forecasting tools help in the analysis of the environment and provide inputs on how the organization can use its resources for maximum leverage. This chapter will explore some of these forecasting techniques.

Need for Forecasting

Competition in marketplace is compelling companies to hear the voice of the customer. Only those corporations which are good at understanding the needs and wants of customers will do well in competitive environment.

Managers are always concerned and obsessed with future because all their planning pertains to a framework for the future. It may sound axiomatic but it is true that we live our entire lives in the future. Future is, will and shall remain uncertain but if we predict and provide for uncertainties, our plan of action will be then subject to fewer variability and vagaries although they will never ever be eliminated entirely.

Forecasts and Predictions

Forecast is a detailed estimate of the future events and their trends and is based on a meticulous collection of primary data from the marketplace, carrying out analyses of the data about the past and projecting the trends into the future in a systematic manner. It relies more on data from the past and less on judgement and conjectures.

In contrast, prediction is a guess-estimate about the future events and trends in a subjective manner without taking into account the past data and without undertaking any objective analysis. It is a hunch or a gut feeling about an issue.

Types and Time Horizon of Forecasts

Demand forecasting exercise is time-consuming and expensive and is normally undertaken for meeting specific requirements of management. For instance:

1. Demand forecasting covering a short duration, say up to a year, is undertaken for aiding decision-making on production planning, distribution planning, etc. Such a forecast has to be very specific and sufficiently accurate in order to be useful for the intended purpose.
2. If the forecast extends over a period of three to five years, the information required would be broad; it may be the aggregate demand of product groups. These forecasts are used for decision-making regarding selection of machines and other hardware.
3. Similarly, a forecast covering longer time horizon may aim at collection of data and information for facilitating decision-making on choice of technology, site selection, etc.

Various types of demand forecasts, their time horizon and type of data and information required are tabulated below:

Type of Forecast	Time Horizon	Type of Data and Information
Short-term forecast	Up to one year	Demand of specific items
Medium-term forecast	3 to 5 years	Overall demand of group of items
Long-term forecast	Over five years	Broad data on technology, site, etc.

Categories of Forecasting

Very broadly, there are two approaches for building up demand forecasts for the future:

1. *Normative forecasts:* These forecasts fall in the category of what ought to be done to achieve a certain predetermined target fixed for a future date. These forecasts emphasise 'future to present' approach. For example, if India has to achieve a literacy rate of 90 per cent by the year 2010 (say), what do we need to do in the intervening period to achieve the preset target.
2. *Exploratory forecasts:* These forecasts embody the more common types of forecasts based on 'present to future' concept. They rely heavily on the compilation of past periods data, analysis and projection of trends into the future.

Levels of Forecasting

There is an array of demand forecasts that can be carried out at a firm's level, industry, region, national or international level – the composition and contents of these forecasts would vary accordingly.

(a) *Firm Level:* These forecasts aim to estimate the demand of firm's products locally at state, regional or national level and focus on demands at micro-level. Sometimes, these forecasts may be intended to estimate the demand of a firm's products in a specific market segment or industry.

(b) *Industry Level:* These forecasts extend over an industry in a region or at national level and may be undertaken by a group of companies or by an industry or trade association.

(c) *National Level:* These forecasts are usually for economic parameters like national income or national expenditure, industrial or agricultural production, etc. They facilitate governmental decisions for formulating policies of imports, exports, pricing, etc.

(d) *International Level:* Transnational and multinational companies operating in several countries would require demands of their products, rents, etc., in different national economies.

Qualitative Methods of Forecasting Demand

These are subjective assessments carried out by individuals at various levels and are greatly influenced by their intuitions, experience, exposure, prejudices and preferences and should generally be adopted with a certain amount of reservation. Important methods are as described below.

(a) *Collective Opinion Survey or Sales Force Composite:* This forecast derives its origin from a simplistic assumption that our sales personnel are stationed nearest to the customers and are expected to have an intimate knowledge and feel of the customers' pulse. Each and every salesperson in the organisation makes an estimate of the sales of company's current and future products for his/her area, territory or market, state and region and the data and information is collected, reviewed and revised at various levels by the concerned personnel before being finalised. It is customary to estimate the total demand for the industry and then work out own market share in each field. Although, this method of forecasting is simple, direct, first hand and perhaps most acceptable, it has several disadvantages.

- Individual judgements may be biased.
- Individuals have knowledge about own area and aggregation of the same may be risky.
- Salespersons may not do the exercise with meticulous care.
- Usually in their employment, knowledge and experience of salespersons may be limited.

(b) *Delphi Method:* Delphi method is a process of involving experts in marketing research and demand forecasting to arrive at a consensus of the members who are coordinated by a knowledgeable person. The drill is as below.

- Coordinator sends a written questionnaire to all the panel members who are expected to send back in writing the prediction about the product under study.
- On receipt of panel members' response, the same are collated, edited and summarised by the coordinator.
- Coordinator then draws up a new set of questionnaire and sends them to the experts who send the answers back in writing once again.

- Coordinator collates, edits and summarises the responses again.
- Coordinator repeats the last two step until convergence of experts' opinion is reached.

Coordinator has a very significant role in this exercise. In the event of very divergent opinions among the experts, he has to resolve it with tact and skill requiring a great degree of talent and experience. In Delphi method direct contact among the experts is avoided. This method is also popular for technology forecasting.

(c) ***Nominal Group Technique:*** Derived from Delphi method, the panel comprises of seven to ten experts who interact, discuss and rank all suggestions in descending order. They follow the procedure as detailed below.

- Experts assemble around a table in full view of one another but are asked not to speak to each other.
- Facilitator hands in questionnaire for the forecast and each member is expected to write in the respective pad a list of ideas about questions asked.
- After every one has written their responses, facilitator asks every member to share only one idea with the group. The idea is written on a 'flip chart' which everyone can see.
- Experts give their ideas in rotation until all of them are written on the 'flip chart'.
- In the next stage, experts debate ideas among themselves. Facilitator makes sure all ideas on the flip chart are discussed – during these interactions, similar ideas are combined and consensus obtained on reduced number of ideas.
- After discussions are complete, experts are asked to rank the combined ideas in writing in accordance with their perceptions or priorities.

Overall consensus can then be derived mathematically. This technique is superior than Delphi method because it is based on:

- Defining questionnaire clearly;
- Allowing creativity;
- Encouraging debate and discussions; and
- Striving for consensus.

These methods are becoming increasingly popular because of the objective approach in evolving the forecasts. These forecasts have several features as below.

- Analysing the trend;
- Isolating seasonal fluctuations or variations;
- Understanding cycles or cyclic variations; and
- Identifying variations arising from non-recurring and random events.

Of the above, cyclic variations are medium term and are caused by circumstances which repeat in cycles – these are usually associated with economic cycles like booms and recessions in the economy and these may last a few years. These cyclic variations are longer than seasonal variations.

Non-recurring and random variations are caused by unforeseen happenings such as change in the government, a war, fire, collapse of a firm or a major technological change sweeping in nature.

Generally, we focus on the first two dimensions which are described below.

Analysing the Trend

There are many techniques used over years.

Simple Average Method

Herein we take a simple average of all past periods – it could be the monthly or quarterly average consumption or sale of an item and is computed thus

$$\text{Simple average} = \frac{\text{Sum of demands of all periods}}{\text{Number of periods}}$$

This ignores fluctuations between periods and assumes a flat trend – no increase or decrease in the entire period and same weightage is accorded to all past periods.

Moving Average Method

It can be argued that a higher weightage to the recent past period would be more appropriate and would be closer to the current trend. Whatever the period selected – three, four or five it should remain constant. Thus

$$\text{Moving average} = \frac{\text{Sum of demands of chosen periods}}{\text{Number of periods}}$$

This is the most widely used method and has several variations.

Illustration

Moving average for odd no of periods (say three)

Moving averages for the following data for yearly consumption of an item.

Year	Consumption	Moving total for 3 years	Moving average of 3 years
1991	600		
1992	560	1,780	593
1993	620	1,690	563
1994	510	1,770	590
1995	640	1,810	603
1996	660	1,980	660
1997	680		

The moving average of seven periods are only five and have been shown against the middle period for which they are the average. There is upward trend.

Moving average for an even no. of periods (say four)

Moving averages for the following data for quarterly consumption of an item

Year	Quarter	Consumption	Moving total of 4 periods	Moving average of 4 periods	Mid-point of two moving averages
1996	1	400			
	2	750	2,150		537.5
	3	360	2,190	547.5	542.50
	4	640	2,260	565.0	556.25
1997	1	440	2,300	575.0	670.00
	2	820	2,420	605.00	590.00
	3	400	2,480	620.0	612.50
	4	760	2,510	627.5	623.75
1998	1	500	2,550	637.5	632.25
	2	850	2,480	620.0	628.75
	3	440	2,480	620.0	
	4	690			

Moving average has to be written at the mid-point of four periods, i.e., between two and three quarters. By taking the mid-point of two moving averages, we are able to relate the figure to specific quarter.

Weighted Moving Average

An improvement over the standard moving average method, it assigns varying weightage to different past periods. These weightages should add to 1, i.e.,

w1 + w2 + w3 + ... + w n = 1

Weighted moving average = w1 D1 + w2 D2 + w3 D3 + ... + w n D n

The weight, have to be decided by the forecaster and underpin the accuracy of the forecast.

Exponential Smoothing Average

Similar to the weighted moving average, herein we assign higher weightage to the most recent past period and reduce it exponentially for the preceding periods; the decrease in the weightage is non-linear.

Forecast of next	Actual demand of	Demand forecast for
(w)	+	1–w
period's demand	most recent period	most recent period

That is, F (t)= (w) D(t-1) + (1-w) F (t-1) where t is the time period and w varies between 0 and 1.

Continuing further

F (t-1) = (w) D(t-2) + (1-w) F (t-2)

F (t-2) = (w) D(t-3) + (1-w) F (t-3)

Thus, if forecasts have to be computed for successive periods, it is simple.

Illustration

Serial	Month	Forecast	Demand	Weightage
1	January	250(0.7)+83(0.3)=200	300	0.7
2	February	300(0.7)+200(0.3)=270	350	0.7
3	March	350(0.7)+270(0.3)=326	400	0.7
4	April	400(0.7)+326(0.3)=378	450	0.7

Once again, choice of weightage is critical and following guidelines are suggested.

New products or items for which demand is shifting significantly ..... 0.7 to 0.9

Stable trend in demand ..... 0.1 to 0.3

Trend is somewhat unstable ...... 0.4 to 0.6

Adaptive Exponential Smoothing

Where demand is not stable, this method is recommended. Herein, the value of weightage is not fixed – it is varied in line with fluctuations in demand.

Sometimes there is too much of noise in a situation as is typical in drug and pharmaceutical industry. In such cases, double exponential smoothing is adapted which is as below:

	First order exponential	Double exponential
Forecast of next period = (w)	smoothing forecast for	+ (1-w) smoothing forecast for
next period	most recent period	

Regression Analysis

This method is becoming very popular and works out a mathematical relationship between two variables, mostly linear. Let us say, the equation is

Y = a + b X where X is the independent variable and Y is the dependent variable;

If the data for a pair of variables is being collected, it is easy to determine the value of Y when X is zero – this will give us the value of 'a' in the equation. A representative value of 'b' in the equation can be computed from the other pairs of data compiled and we obtain the mathematical expression of this relationship which stands for the trend.

This relationship can also be worked out by using the technique of least sum of squares which facilitates the search for the line of best fit.

Determining the Seasonal Variations

Once the trend has been established by one of the several methods above, we can find the seasonal variations. There are two methods.

- Additive model; and
- Proportional model or multiplicative model.

Illustration

A firm, working five days in a week, records the following daily sales over three weeks.

Days	1st Week	2nd Week	3rd Week
Mondays	120	124	128
Tuesdays	142	150	146
Wednesdays	136	139	140
Thursdays	114	111	119
Fridays	135	140	144
Saturdays	105	108	111

The trend has already been determined by using the technique of regression analysis and can be computed by using the linear equation Y = 123 + 0.6 X. Seasonal variations can be calculated by using any one of the above methods as detailed the following.

Additive Model

The data for fifteen days can be tabulated as below:

Week	Days	Actual sales	Trend (92.7+0.42 X)	Seasonal variation
1	Monday	120	123	– 3.0
	Tuesday	142	123.6	+18.4
	Wednesday	136	124.2	+11.8
	Thursday	114	124.8	– 10.8
	Friday	135	125.4	+ 9.6
	Saturday	105	126.0	– 21.0
2	Monday	124	126.6	– 2.6
	Tuesday	150	127.2	+22.8
	Wednesday	139	127.8	+11.2
	Thursday	111	128.4	– 17.4
	Friday	140	129.0	+ 11.0
	Saturday	108	129.6	– 21.6

Contd...

3	Monday	128	130.2	– 2.2
	Tuesday	146	130.8	+15.2
	Wednesday	140	131.4	+ 8.6
	Thursday	119	132.0	– 13.0
	Friday	144	132.6	+11.4
	Saturday	111	133.2	– 22.2

Variations on each day of the week in the three weeks' data may not be the same. Even so, an average of these can be taken as below:

Week	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays
1	– 3.00	+ 18.40	+11.80	– 10.80	+ 9.60	– 21.00
2	– 2.60	+ 22.80	+11.20	– 17.40	+11.00	– 21.60
3	– 2.20	+ 15.20	+ 8.60	– 13.00	+11.40	– 22.20
Total	–7.80	+ 56.40	+ 31.60	– 41.20	+ 32.00	– 64.80
Average	**– 2.60**	**+ 18.80**	**+ 10.53**	**– 13.73**	**+ 10.67**	**– 21.60**

Variations around the basic line should add up to zero. Let us check

Variation = (18.80 + 10.53 + 10.67) – (2.60 + 13.73 + 21.60)

= 40.00 – 37.93 = 2.07

This must be spread across the six days – Monday to Saturday equally – 2.07/6 = 0.34 to be subtracted from the values against each day respectively.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Daily variations	– 2.60	+ 18.80	+10.53	– 13.73	+ 10.67	– 21.60
Correction	– 0.34	– 0.34	– 0.34	– 0.34	– 0.34	– 0.34
Corrected variation	– 2.94	+ 18.46	+ 10.19	– 14.01	+ 10.33	– 21.94
Say	– 3	+ 19	+ 10	– 14	+ 10	– 22

These are rounded off so that the total is zero.

Multiplicative Model or Proportional Model

The above problem can be worked out as below:

Week	Days	Actual	Trend	Seasonal Variation (%)
1	Monday	120	123.0	95.6
	Tuesday	142	123.6	114.9
	Wednesday	136	124.2	109.5
	Thursday	114	124.8	91.3
	Friday	135	125.4	107.7
	Saturday	105	126.0	83.3
2	Monday	124	126.6	97.9
	Tuesday	150	127.2	117.9
	Wednesday	139	127.8	108.8
	Thursday	111	128.4	86.4
	Friday	140	129.0	108.5
	Saturday	108	129.6	83.3
3	Monday	128	130.2	98.3
	Tuesday	146	130.8	111.6
	Wednesday	140	131.4	106.5
	Thursday	119	132.0	90.2
	Friday	144	132.6	108.6
	Saturday	111	133.2	83.3

The summary of seasonal variation is as below:

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	95.6	114.9	109.5	91.3	107.7	83.3
2	97.1	117.9	108.8	86.5	109.5	83.3
3	98.3	111.6	106.5	90.2	108.6	83.3
Total	291.0	344.4	324.8	268.0	324.8	249.9
Av	97.0	114.8	108.3	89.3	108.3	83.3 = 601
Correction	– 0.2	– 0.1	– 0.1	– 0.2	– 0.2	– 0.2
	96.8	114.7	108.2	89.1	106.1	83.1 = 600

The proportional model is superior than the additive model when the trend is increasing or decreasing over time. In the additive model when absolute seasonal variations increase or decrease, the figures become out of date but when we use proportional model, percentage variations need little adjustments.

Selecting the Appropriate Method of Forecasting

Method to be adopted for forecasting should be selected on the following criteria.

1. *Accuracy in Forecast:* Accuracy of a forecast can be easily measured by comparing past forecasts with actual demand during the respective period and even the percentage deviation can be calculated. We should check the validity of assumptions in real life. Although forecasts are future oriented, they cannot always be correct. Even so, accuracy of forecast is always desired.

2. *Plausibility of Forecast:* Forecasts must be reasonable and consistent and assumptions should stand scrutiny. Forecast proposals should invariably incorporate an explanatory note on these aspects and commensurate methodology should be used.

3. *Economy of Forecast:* Forecasting exercise should not be expensive in relation to the objectives to be achieved – there should always be a balance between additional accuracy and the incremental costs.

4. *Quick Results:* Forecasts are intended to aid decision-making within reasonable time-frame. Always remember, "Best is the enemy of good."

5. *Availability and Timeliness of Forecast:* Changes can always happen in the demand relationships and the methodology should be such that the forecast can be easily updated.

6. *Durability of Forecast:* Durability of the forecast is a function of simple and stable relationship between the supply and demand, advertisement and sales promotion campaigns, etc. Earnest effort should be made to achieve durability of results.

7. *Flexibility of Forecast:* It is desirable to be able to modify the co-efficients of variables from time to time to cope with the changing business conditions as it imparts flexibility which is an added advantage.

Student Activity

Fill in the blanks:

1. Forecast is a detailed estimate of the ....
2. Demand forecasting exercise is ....
3. There is an array of demand forecasts that can be ....
4. Delphi method is a process of involving ....

Summary

Forecasts are needed to aid in determining what resources are needed, scheduling existing resources, and acquiring additional resources. Forecasts are more accurate if a set of assumptions about technology, competitors, pricing, marketing expenditures, and sales efforts are given. The qualitative methods of demand forecasting are subjective assessments carried out by individuals at various levels and are greatly influenced by their intuitions, experience, exposure, prejudices and preferences and should generally be adopted with a certain amount of reservation.

Keywords

Forecast: A forecast is an estimate of a future event achieved by systematically combining and casting forward in a predetermined way data about the past.

Prediction: A prediction is an estimate of a future event achieved through subjective considerations other than just past data; this subjective consideration need not occur in any predetermined way.

Normative forecasts: These forecasts fall in the category of what ought to be done to achieve a certain predetermined target fixed for a future date.

Exploratory forecasts: These forecasts embody the more common types of forecasts based on 'present to future' concept.

Delphi method: Delphi method is a process of involving experts in marketing research and demand forecasting to arrive at a consensus of the members who are coordinated by a knowledgeable person.

Review Questions

1. What is demand forecasting and how it differs from prediction?
2. Distinguish between normative and exploratory approaches to forecasting.
3. What are the different types of forecasts and their uses in management?
4. Describe the nominal group method of forecasting and how it differs from the Delphi method?
5. What are the various methods of identifying trend analysis?
6. What is seasonal variation and describe the methods of determining seasonal variations?
7. What are the attributes of a good forecast and how do they aid decision-making?

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see,* Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management*, John Wiley & Sons, 1994.

Clayton Christensen, "*The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*", HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis,* Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach,* McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies,* John Wiley & Sons, 2004.

Unit 9 Production Planning

Unit Structure

- Introduction
- Characteristics of Production Planning
- Objectives of Production Planning
- Importance of Production Planning
- Planning and Manufacturing Systems
- Factors Determining an Efficient Production Planning System
- Steps or Procedure for Production Planning
- Prerequisites of Production Planning Department
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Characteristics of Production Planning
- Importance of Production Planning
- Planning and Manufacturing Systems
- Steps or Procedure for Production Planning

Introduction

Production planning defines what, how, where, when and why to produce a product and who will produce that considering the relevant factors in mind. Thus managerial function of production planning is to decide the production objectives, to determine the manufacturing requirements such as available materials, money, men, machines, production process and other priorities, etc., within the scope of industrial unit, to make production plans for efficient production of goods to cope with its sale requirements.

Characteristics of Production Planning

The characteristics of production planning may be summarised as follows:

1. Production planning is a universal production activity.
2. Production planning is the basis and prerequisite of production control.
3. Production planning includes routing of production activities and layout of production facilities such as buildings, machines, equipment, etc.
4. Production planning is related to planning, directing and controlling of production methods for the manufacturing of product.

Production planning may be short-term or medium-term or long-term. Short-term planning is made for period of one month or less. Medium-term or intermediate term planning may be for a year or less, while long-term planning is done for more than a year.

Objectives of Production Planning

The main objectives of production planning are:

1. To predetermine from sales forecasts and engineering information the kind of materials, machines, tools, building methods and labour necessary in the proper quantities and qualities when and as required, to produce the desired goods in the most economical way.
2. To make all preparations necessary for manufacturing to reach the production goals established in the production budget and master schedule and by the fluctuating demands of the customers.

In short, the objective of production planning is to make sure that customers will be supplied their orders on their delivery dates at minimum overall cost by planning the sequence of activities. This objective can be broken into the following constituent objectives:

1. Planning of supply of materials, parts and components so that they are brought together at the right time and in the right work location.
2. Making the most economical use of plant and equipment by smoothing out production processes and scheduling to the best machine utilisation.
3. Fulfilling of the marketing plan, in cooperation with the staff of the marketing section, by spotlighting imbalance in production shortages and sales activity requirements.
4. Arrangement for the best use of labour in fulfilling the promises as per the sales order book.
5. Provision of an information service for production management for production, manufacturing instructions, routes and other background production information.
6. Supply of up-to-date statements of the progress of all orders through the factory.
7. To plan for the provision of adequate stock of finished goods according to marketing needs.
8. Provision of an information service for controlling the distribution of products.

Importance of Production Planning

Planning plays a very important role in the business. The success of an enterprise largely depends upon planning. Without planning production, becomes random in nature and results are meaningless. The present age of uncertainty, rapid changes in the methods and techniques of production, and cut-throat competition among different production organisations, has made the production planning a highly important function. The importance of production planning may be judged from the following facts:

1. *Production Planning Sets Objectives:* Production planning sets objectives enterprise. In accomplishing its objectives, for an enterprise, it chooses out best out of available alternatives considering the available resources of the plant. Production planning, in normal conditions, may be applied mathematically for selecting the best alternative course which may yield the desired and predetermined results at the minimum cost on the basis of known facts. After selecting the best alternative it becomes imperative to prepare a plan to achieve the goal.

2. *Facing the Unforeseen Conditions:* Under abnormal conditions, production planning proceeds. It helps in meeting out the risk of uncertainty at operational stage because production manager takes care of difficulties which may be faced subsequently.

3. *Best Utilisation of Resources:* Production planning helps in utilising the available resources in the possible manner because it helps coordination of the working of various individuals and departments of the concern which leads to better utilisation of time, efforts materials. It ensures the best use of available plants and regular supply of raw materials and other things for the production of goods and services.

4. *Basic for Control:* Production planning provides the basis for production control which is also major function of production manager. As a matter of fact, production planning and control are inseparable because unplanned work cannot be controlled. Production planning sets the targets quantitatively and also qualitatively and fixes the standard time for completing the job whereas production control keeps the operation along with the predetermined course of action by minimising deviation from standards. Reasons for deviation are located and then removed in the next planning process.

Planning and Manufacturing Systems

The method of production planning basically depends on the nature of manufacturing systems. The manufacturing systems can be classified into three main categories, namely:

1. *Continuous type* like rayon, cement, paper plants.
2. *Intermittent type* like automobiles, typewriters, locomotives plants.
3. *Non-standardised job-shop types* of plants producing parts for various industries.

In continuous type of manufacturing systems planning is rather easy. Here one has to decide only about what to produce and when to produce. How and where aspects are inherent in the system itself. More emphasis is laid on mechanisation.

Planning is more complicated in intermittent type of plants. The same machine can be used to manufacture different types of components and one is faced with the problem to plan the operations in such a way that all the machines can be used in the most efficient manner. Again, the various components of the system work independently and there is necessity of proper coordination between them, e.g., a sub-assembly process is not complete unless various parts produced by other sections of the plant are completed.

The nature of equipment and machines required for manufacturing items in the non-standardised type of plants determines the process of planning.

Factors Determining an Efficient Production Planning System

1. Future rate of sales, production and inventory levels, etc.
2. Input requirements, viz., raw materials, spare parts for machine and equipment, capacity of plant and present load, etc.
3. Estimated output desired.
4. Nature of operations, sequence of these operations and duration of each operation.

Steps or Procedure for Production Planning

In fact, the basic steps involved in production planning are as under:

1. ***Determination of Targets:*** The first step in production planning is to set the target for production for the planning period keeping in mind the past experience, production capacity, production facilities such as buildings, plants and equipment, manpower, etc. If functional organisation is followed in the organisation, the targets for each department or function should be set.

2. ***Collection and Interpretation of Information:*** The next step is collection of data regarding available raw materials, machines and equipment, capital, market characteristics, etc. These information may be collected from the past records of the company, publications of chambers of commerce, government and other institutions, and other concerns in the same industry. Having collected the required information, it should be analysed and interpreted in the manner most suited to the company. Certain important facts can be gathered from the interpretation of such data which may help the preparation of production plans. These facts are sales or demand forecasts, production capacity and facilities, availability of raw materials required, etc. These are the facts on which production planning is based.

3. ***Developing Plans:*** Under this step various production plans are developed such as production policies, programmes, budgets, sales budget, etc. These plans are the main elements of the production planning. In order to develop these plans, various techniques are used such as graphical technique, operating research techniques and Heuristic techniques.

4. ***Putting Plans into Operation:*** After developing the plans, the next step is to act upon them and put them into operation. For this purpose, necessary instructions are issued to the concerned foremen and executives to convert the plans into production. These foremen or executives arrange for the necessary factors and resources to execute the plans and organise them in such a coordinated manner that maximum production at minimum cost can be achieved within the standard time.

   During the course of implementation of some corrective measure necessary to be taken the production planning department takes the necessary steps during the process of production planning.

   These plans or the amended plans are sent to the concerned executive officer of the organisation for necessary approval for implementation.

5. ***Follow-up Action. Implementation of plans is not the last step in planning:*** The planning process is on even after it. The result collected at the end of the execution of plans may be analysed and compared with the past records and the plan targets fixed for the period. If there is a deviation, the reason for that should be located and if it is negative deviation, it should be removed either by improving the planning process or by tightening the controlling process. If results are positive (above the targets), efforts should be made to maintain them. But necessary action should be taken only after considering the special circumstances prevalent during the course of execution of the plan and thereafter.

It should be remembered that the success of planning depends upon the mutual cooperation of various authorities and the workmen. There should be a team spirit among the staff.

Prerequisites of Production Planning Department

The production planning department can proceed to its planning function if it is fully equipped with the following information. This information is required for planning in both favourable and unfavourable conditions:

1. Data regarding product-engineering, product-design, basic type of processes and operations, assembly and sub-assembly methods.
2. Sequence of operations what is most advantageous and with minimum production cost.
3. Material specifications and standardisation and the quantity of raw materials required to acquire the maximum economy on a large-scale.
4. Economic lots and economic order quantity which will usher in most frequent inventory turnover.
5. Rate of output per hour, per day, per week and per month.
6. Materials cost, labour cost and overhead cost per unit and labnur and overhead costs per hour.
7. Customers' order in hand and their expected dates of delivery.
8. Information regarding fixtures, tools, jigs and dimensional gauging instruments which will be required for production.
9. Normal and maximum and average production capacity of the plant.
10. Immediately required quantity for stock purposes and for delivery purpose.
11. Full particulars regarding operating personnel and personnel policy of the enterprise.
12. Information regarding job analysis, merit-rating, type of training to workers for the effective performance of different jobs.
13. Full knowledge about the sources of row materials, power generation systems and internal transport system.
14. Information regarding time fixed for each operation, rate of obsolescence of the plant and loss in storage, etc.
15. Fixed rate of interest on invested capital.
16. Up-to-date knowledge of modern developments in the field of production methods, process and techniques.

Level of Production Planning

Production planning can be done at three levels namely Factory Planning, Process Planning, and Operation Planning.

1. *Factory Planning:* At this level of planning, the sequence of work tasks is planned in terms of buildings, machines and equipment required for manufacturing the desired goods and services. The relationship of workplaces in terms of departments is also planned at this stage taking into consideration the space available for the purpose. This stage deals with plant location and layout.

2. *Process Planning:* There are many operations involved in factory planning for transforming the inputs into some desired end product. In process planning these operations are located and the sequence of these operations in the production process is determined. Plans are also made for the layout of work centres in each process.

3. *Operation Planning:* It is concerned with planning the details of the methods required to perform each operation, viz., selection of work centres, designing

of tools required for various operations. Then the sequences of work elements involved in each operation are planned. Specification about each transfer, work centres, nature of tools required and the time necessary for the completion of each operation are prescribed.

Student Activity

Fill in the blanks:

1. Production planning defines ....
2. Production planning is the basis and prerequisite of ....
3. Production planning can be done at three levels namely ....
4. There are many operations involved in factory planning for ....

Summary

Production planning is concerned with the planning of various inputs (Men, Machines, Materials etc.) for a given period of time so that the customer could get the right quality of products at right place, price and in time. Production Planning may be done as:

- ***Long-term Planning:*** Strategic Planning – normally more than a year's time.
- ***Medium-term Planning:*** Aggregate Planning – up to a year's time.
- ***Short-term Planning:*** Routine Planning – monthly/weekly.

Planning plays a very important role in the business. The success of an enterprise largely depends upon planning. Without planning production, becomes random in nature and results are meaningless.

The method of production planning basically depends on the nature of manufacturing systems. The manufacturing systems can be classified into three main categories, namely:

(a) Continuous type like rayon, cement, paper plants.

(b) Intermittent type like automobiles, typewriters, locomotives plants.

(c) Non-standardised job-shop types of plants producing parts for various industries.

Keywords

Production planning: Production planning defines what, how, where, when and why to produce a product and who will produce that considering the relevant factors in mind.

Factory Planning: At this level of planning, the sequence of work tasks is planned in terms of buildings, machines and equipment required for manufacturing the desired goods and services.

Process Planning: There are many operations involved in factory planning for transforming the inputs into some desired end product.

Operation Planning: It is concerned with planning the details of the methods required to perform each operation, viz., selection of work centres, designing of tools required for various operations.

Review Questions

1. How would you differentiate between characteristics of Planning and objectives of Production Planning?
2. How would you show the importance of Production Planning? Discuss about the planning and manufacturing systems.

3. Show all these factors which shows the factors determining an efficient Production Planning System.
4. Discuss the important steps for production planning.
5. Identify the Production Planning in short.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see,* Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management,* John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis,* Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach,* McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies,* John Wiley & Sons, 2004.

Unit 10 Production Control and Scheduling

Unit Structure

- Introduction
- Production Control
- Objectives of Production Control
- Advantages of Production Control
- Requirements of Production Control System
- Scheduling Defined
- Dispatching for Batch Production
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Production Control
- Objectives of Production Control
- Dispatching for Batch Production

Introduction

Production Control measures the actual performance of the production units and taking remedial action called for to see that the production actually achieved is not less than the target or standard set in advance. Thus Production Planning and Control is to set the realisation targets in terms of Standard Output, measure the actual production performance against the target set in advance and take remedial action as and when necessary.

Production scheduling may be defined as "the detailed planning of material, labour and machine time so that materials and parts will be at the right place, at the right time so that a job can be completed within the time planned and in accordance with the requirements."

Production Control

The British Standards Institute takes the term production control to include the following:

(a) Production plan or planning,

(b) Scheduling,

(c) Machine or labour utilisation or dispatching,

(d) Stock control,

(e) Manufacturing control or routing, and

(f) Progress.

The production control is the function of management which plans, directs and controls the material supply and processing activities of an enterprise so that specified products are produced by specified methods to meet an approved sales programme. It ensures that the activities are carried in such a way that the available labour and capital are used in the best possible way.

Objectives of Production Control

The objectives of production control may be summarised as under:

(i) Issuing the necessary orders to the proper personnel through the prescribed channels for effecting the plan.

(ii) To insure availability of the means of carrying out the orders – the materials, machines, tools, equipment and manpower – in the required quantity, of the required quality and at the planned time.

(iii) To ensure the carrying out of the orders by the personnel so that goods are produced in the required quantities of the specified quality at the predetermined time.

Thus the underlying principle of production control is that highest efficiency in production is obtained by producing the product in the required time, by the best and cheapest method.

Procedure/Functions/Duties of Production Control

Following factors are involved in the practice of production control:

(a) ***Control of Activities:*** This is done by releasing manufacturing orders through dispatching. Thus plans are set in motion at assigned times.

(b) ***Control of Material Movement:*** The time at which material is received from the supplier, and issued to the plants is observed and a close watch is kept on its movement from one plant to another to ensure that this movement is in accordance with the production plans.

(c) ***Availability of Tools is Controlled:*** This involves steps taken to ensure that tools specified in the production plan are available as and when required.

(d) ***Control of Due Dates:*** Effect of delays in or stoppages of work on machine-loading are observed so that work assigned to each machine is completed in time. "Machine-loading" means the assignment in advance of the amount of work to each machine.

(e) ***Quantity Produced is Controlled:*** Work in process at predetermined stages of production is observed to determine that right quantity of specified quality work is processed.

(f) ***Control of Replacement:*** Quantity of raw material and work in process which fails to pass each stage of inspection, is observed. Provision is made to issue replacement orders for each material or work.

(g) ***Labour-Efficiency-Control:*** Time taken on each unit of work in process is observed and recorded. Comparison of time taken is made with the time allowed in scheduling. Also comparison is made between total man-hours consumed and that allowed in the plan for any specified period.

(h) ***Control of the Progress on the orders made:*** Completed wnrk is marked off on the production schedule and on the copy of the combined manufacturing order of the production department as well as the route sheet.

Advantages of Production Control

A good production control system means greater production on the same investment without unduly speeding up workers. It makes for an even flow of production. The advantages of production planning and control are listed below:

(a) ***Better Service to Customers:*** Promised delivery dates are kept. Production flows as per scheduled time. This injects confidence in the travelling salesmen of the firm to set delivery dates. Delivery in time wins customer's confidence, improves customer-relation and promotes profitable repeat orders.

(b) ***Less Overtime Work:*** As flow of production is evened out matched with the promised delivery-dates or expected demand periods, there will be few rush-orders. Therefore less overtime work will be needed as compared to other firms in the same industry without adequate production planning and control system.

(c) ***Need of Smaller Inventories of Work-in-process and of Finished Goods:*** Enterprises working under an effective production planning and control system require lower inventories of material, parts, components, etc., for work-in-process and less of finished goods in stocks. This results in less investment in inventory. Funds thus freed may be put to other more income-earning uses. Also, orders of customers can be supplied in full. This would bring the benefits of economy in transport costs because single large shipment generally costs less than two or more small shipments.

(d) ***More Effective Purchasing:*** Due to better materials management leading to effective inventory control purchasing is more scientific, economical and timely.

(e) ***More Effective Use of Equipment:*** Management is constantly kept informed on the current position of all orders in process and on equipment and personnel requirements for next few weeks ahead. Therefore, workers can be informed in advance of possible lay-offs. transfers, etc. Also belated purchases of equipment and materials can be avoided and idleness of men and machine eliminated or minimised.

(f) ***Less Loss of Time:*** (a) Because of phased flow of material workers need not wait for the material for long. Hence there will be less loss of workmen-hours. (b) Time of executives is conserved in two ways: First, their personal attention is claimed only when there is any serious flaw in the working of the system (which is infrequent); second, executives need not spend time on research data, etc., required for long-range planning as they can proceed to prepare such plans for expansion on the basis of the data made available by the production planning and control system.

(g) ***Savings in the Cost:*** A properly designed and introduced system of production planning and control frequently results in major cost-savings. These savings are greater in amount than the cost involved in introduction of the planning and control system.

(h) ***Less Work-stoppages:*** Work-stoppages are avoided or minimised in terms of time-duration. Obviously, therefore, delays in dispatch of goods to customers are very infrequent.

(i) ***Industrial Harmony:*** Effective production control helps in establishing harmonious industrial relations.

Requirements of Production Control System

A good and effective production-control system requires sound organisational structure, reliable information, a relatively high degree of standardisation and trained personnel for its success.

Factors needed to make production control successful are summarised below:

1. ***Reliable information about requirements and productive capacities:***
   - (a) Complete knowledge of products to be produced.
   - (b) Detailed information about the number and types of each machine and processing unit together with the complete tabulated data on power, speeds, and feeds of all machines.
   - (c) Information in detail about the time and sequence of operations for each part of the product and for the finished product as a whole.
   - (d) Accurate up-to-date information regarding total material requirements, materials in stores, the quantities to be purchased, time required to get the item purchased and quantities used per unit of production.
   - (e) All the information regarding the manufacturing operations for each part, the special tools such as jigs and fixtures needed for each part and their availability.
   - (f) Information in detail about the labour-force in the plant and their productive capacities.
   - (g) Complete information on time taken and costs incurred on previous performances.
   - (h) Records of best performances of similar work with best combinations of tools, feeds and speeds.
   - (i) Exact knowledge of the progress of the work in process.
2. ***The following should conform to scientifically determined standards:***
   - (a) Fabricated and purchased materials.
   - (b) Tools and equipment, to the extent possible.
   - (c) Operations on all parts, depending on the designs and the procedure of these operations.
   - (d) Production standards for labour force.
   - (e) Requirements of quality with provision for adequate inspection to make sure that quality is maintained.
   - (f) Reports on production performance in comparison with the scheduled production.
3. ***The best organisation-structure and set-up:***

   First, support from the top management with recognition of the need for production planning followed by delegation of their authority with fixed responsibility.

   Second, full understanding on the part of the supervisory staff that the determination of their work-schedule from the central planning room is just extension of the functional principles and in no way amounts to erosion of their prestige or power.
4. ***Suitable personnel should be available:***
   - (a) Personnel should understand the scheduled operations.
   - (b) They should have full training to fit into the requirements for the particular system adopted.

(c) They should possess the planning, clerical and operational capacities and requisite aptitude and interest in the work to be done.

(d) They should be property remunerated to enlist their interest. Method of incentives should be scientifically determined.

Scheduling Defined

Kimball and Kimball defined scheduling as "the determination of the time that should be required to perform each operation and also the time necessary to perform the entire series, as routed, making allowance for all factors concerned."

In the words of Alford and Beatty scheduling means, "fitting specific jobs into a general timetable so that orders may be manufactured in accordance with contracted liability, or, in mass production, so that each component may arrive at and enter assembly in the order and at the time required."

Thus, production scheduling may be defined as "the detailed planning of material, labour and machine time so that materials and parts will be at the right place, at the right time so that a job can be completed within the time planned and in accordance with the requirements."

Basic Scheduling Problems

(a) ***Flow Production Scheduling for Fluctuating Demand:*** When the sales of a certain product are subject to seasonal fluctuations, management may decide to meet the demand in one of the following ways:

   (i) Have a static production programme, coupled with an inventory large enough to satisfy the fluctuating demand. The inventory level would fluctuate according to the demand pattern, replenishment being provided by a constant flow from the plant. This method is greatly favoured by the production department, since it simplifies planning, ensures high machine utilisation, allows better supervision and control, and promotes a sense of security among the workers. Average stock level is high, however, thus tying up capital and involving high carrying costs.

   (ii) Have a fluctuating production programme, to cater to the changing demand, and keep a constant inventory level. The purpose of the inventory in this case is to provide a safety cushion between production and marketing. Any change in the demand pattern requires a certain time lag before production can follow suit, and the safety stock enables management to satisfy demands in the interim period. The stock level does not, strictly speaking, remain constant, but the fluctuations and the average stock level are fairly low, compared with the previous method.

   (iii) Have a combination of the two systems, so as to bring the total costs to a minimum. The problem is, therefore, to achieve a proper balance between the amount of fluctuations in the production programme and those of the stock level.

(b) ***Multiproduct Scheduling in Batch Production:*** If the rate of production is higher than the rate of consumption, the plant has to resort to batch production, and if the available time is to be fully utilised, the plant must undertake to produce several products in succession. The procedure becomes as follows: The plant is fully engaged in producing one product until a certain predetermined inventory level is attained, and then it proceeds with the production in sufficient quantities, the plant proceeds to the third product, and so on. In the meantime, the stock level of the first product slowly declines owing to the regular consumption rate, until such a level is reached that the plant must start again on that product so that the sales department will be able to meet the demand for it.

The problem may therefore be defined as follows: The plant is producing N products one at a time, and the manufacturing cycle is concluded when all products have been produced, so that the cycle length is determined by the total time required to produce all products in the cycle. The quantities produced must be such that they will cater to this cycle time precisely; otherwise the plant will either run out of stock prematurely or have excessive stocks which have to be carried over to the next cycle. The problems that we have to analyse are therefore:

- How to go about optimising the whole schedule, i.e., the whole cycle, rather than one product at a time.
- What criterion should be used for optimisation?
- Does the optimised schedule specify quantities for the individual products that are compatible with optimal batch sizes computed?
- If not, now can the two objectives be bridged?

(c) ***Assignment Problem:*** In the case of job or batch production an array of tasks is defined at the beginning of a production period and these tasks have to be performed by use of available processing time of several facilities. The problem is to assign the tasks to the machines or to the operators in such a manner as to minimise the cost of processing time during the period.

(d) ***Scheduling Orders with Random Arrivals:*** When a plant is engaged on job production or on comparatively small batches, most of which do not recur in any regular fashion, production planning is faced with the problem of scheduling orders with random arrivals. The main difference between this situation and the one described in the preceding problem is that programming in this case is not geared to production periods. There is no array of tasks given at predetermined times to be scheduled during subsequent periods. Orders arrive at random and have to be scheduled on arrival, so that scheduling is a continuous process. When machine time have to wait in a queue until machines become available. If the processes or machines are not identical, the jobs may be arranged in increasing order of operating costs for the products concerned, so that cheaper processes are used first; when the specific process or machine capacity is exhausted, the next process is used, and so on; the same procedure would apply to the use of overtime and sub-contracting.

Table 10.1

Product										
	A		B		C		D		E	
Operation	Machine	Time (hr)	Machine	Time (hr)	Machine	Time (hr)	Machine	Time (hr)	Machine	Time (hr)
1	M2	10	M2	5	M1	5	M1	2	M1	2
2	M5	12	M1	5	M2	6	M2	2	M5	5
3	M1	14	M6	5	M3	7	M4	4	M6	6
4	M6	2	M4	8	M4	2	M6	2	M4	7
5	M4	5	M3	2	M5	1	M5	6	M3	15
6	M3	6	M5	6	M6	5	M3	8	M2	2
7	M7	2	M8	1			M8	1	M8	2
8	M8	4					M7	1		

(e) ***Product Sequencing:*** In job or batch production we often have at the beginning of a production period several products that have to be manufactured on certain machines according to a predetermined sequence. The data can be presented (Table 10.1) and the problem is to determine the best sequence in which the products should be loaded on the machines. There is, naturally, a conflict between performance at maximum machine utilisation (implying that there is a queue scheduling to customer satisfaction) (i.e., complying with predetermined delivery dates), and a satisfactory compromise has to be struck on the basis of costs ratios.

Objectives of Scheduling

(i) Ensure maximum utilisation of the plant at minimum cost.

(ii) Ensure that requirement of manpower is optimum and is evenly distributed, there being no peaks and valleys.

(iii) Keep itself abreast of hiring, dismissals, retrenchment, holidays, leaves, etc., of the workforce.

(iv) Possess up-to-date information regarding availability of materials, expected delivery dates, materials rejection, shortages, purchase orders cancelled, etc.

(v) Possess up-to-date data on each machine regarding its breakdown, availability of spares, average frequency of breakdowns, servicing, and overhauling schedules, replacement schedules, etc.

(vi) Possess complete information on performance standards and their revisions, method improvement, changes in materials and machines, etc.

(vii) Obtain quick feedback from shops regarding delays and interruptions which may hold up production activity.

Forms of Schedule

In what form should a production schedule be presented? This depends on the purpose of the schedule.

(a) ***A Production Flow Programme:*** If a number of components or assemblies have to be manufactured for the final assembly line and these components are to be made concurrently, the master flow programme takes into account the sequence of operations and indicates when work on each component should start, in order to comply with the required date for completion of the product.

(b) ***A Production Master Programme for Integrating Work on Large Objects:*** This programme is particularly useful in cases of static layouts where the tools, materials, machines, and teams of operators flow from one object to another, and it is extremely important to coordinate the activities of these facilities by appropriate phasing.

(c) ***A Cumulative Output Progress Chart:*** When a new job undertaken is likely to last for several months or years, the programme must take into account the initial period required for preparation and the incremental change in the rate of production due to the learning curve. This rate is normally reduced toward the end of the job, to allow for gradual phasing out, and the effect of changes in the projected rate of production on the output is clearly indicated in the cumulative output progress chart.

(d) ***An Outline Master Programme:*** This programme merely translates the general requirements specified by the sales department, and it is useful as a basis on which final and detailed schedules can be worked out.

(e) ***A schedule for breakdown....*** the rate at which the work should progress, and it is particularly useful in decentralised scheduling because it specified only quantities and the dates on which they should be completed. In other words, it indicates production targets, but it does not suggest how they can be achieved, and the responsibility for planning the activity of the production centre related to the appropriate target rests with the production department in question.

(f) ***A cycle schedule:*** If the plant is engaged on batch production in a cyclic fashion, this schedule shows how the cycle time is distributed between the various products.

(g) *A detailed schedule:* This shows in a planned multi-activity chart how the facilities should actually be employed during the production period.

Inputs of Scheduling

The following are the major inputs included in the scheduling function:

(a) *Performance Standards:* The information on performance standards enables the scheduler to determine the machine capacity in order to assign required machine hours and man-hours for the various operations.

(b) *Unit of Measurement:* Refers to the unit in which the loading and scheduling is to be extended. This unit of measurement is usually different for different industries. Industries such as sugar, cement, fertilizers foundries, steel mill, etc., generally use weight (metric tonne) as a unit of measurement while in textile mills, it is in length (metres). The most common unit of measurement in engineering firms is "man-hour" or "machine hour".

(c) *Unit of Loading and Scheduling:* Refers to the duration for which loading and scheduling should be done. The unit of loading and scheduled start and finishing timings depends on the company's scheduling needs and the operating cycles. This implies that scheduling should be done on daily basis if the company makes promises in days and it should be done on weekly basis if promises are made in weeks and if the operating cycle is less than six months.

(d) *Effective Capacity per Work Centre:* Implies effective hours available for production on a machine or on a work centre in a week, or in a month. Theoretical capacity equals number of normal working hours of that machine. When determining this capacity, one should, of course, take into consideration the interruptions like power failure, maintenance, inspection time, absenteeism, re-work, etc. This figure should be realistic.

(e) *Extent of Rush Orders:* Provision of rush orders is another important consideration in scheduling. No machine should be scheduled for its cent per cent (100 per cent) effective capacity because if a rush order to be put through the production process. Such rush orders, if received frequently, are bound to put the company's scheduling out of gear.

The disturbance due to rush orders can be avoided by not scheduling the machine for 100 per cent effective capacity thereby leaving some uncommitted capacity per period per machine. The uncommitted time is utilised to accommodate rush orders, and thereby avoiding the need to alter the remainder of the scheduling.

Time needed for rush orders depends on the frequency of rush orders. Each firm should work out its own average time spent on processing rush orders. If no rush order is received the unscheduled capacity may be utilised for the new jobs or for early completion of the already scheduled jobs.

(f) *Overlapping of Operations:* Overlapping of operations is yet another useful consideration in scheduling. Overlapping of operations refers to running of a job simultaneously on more than one machine and it naturally occurs in those jobs which involve two or more operations. Overlapping of operations though is desirable to reduce the manufacturing cycle time and hence the delivery period, yet for scheduling it may pose some problems.

(g) *Individual Job Schedules:* A part or component generally undergoes a number of operations some of which may be carried out simultaneously while others may need to be completed before the next operation is started. The process sheet of the component does not indicate overlapping of operations whereas the job schedule does. The job schedule of the component is generally fixed and does not require to be changed unless there is change in method of manufacture.

How many job schedules? One job schedule is prepared for each component. A company which manufactures a wide range of products therefore, prepares large number of schedules which are filed to be used as a basis for production control.

Such schedules are not dated but specify the time required for each operation. Once delivery date is fixed, the job schedule is dated and starting and completion dates of each operation are derived considering the load chart.

A job schedule contains the following information:

(i) Identification data such as part name, part number, etc.

(ii) Batch quantity

(iii) Variable information in the form of columns to show:

- Operation number
- Operation description
- Machine/work centre
- Effective capacity/day
- Set up time
- Standard time

(iv) Columns to record the running time for each operation.

Factors Influencing Scheduling

(a) Degree of centralisation determines the extent of detailed shop planning. The centralised system of scheduling relieves shopmen of all scheduling problems as the "start" and "completion" date for each operation listed on the process sheet is given by planning. The decentralised system of scheduling leaves complete scheduling activity into the hands of shopmen. It is then the foremen's duty to determine when each operation should begin. Decentralised scheduling has one major snag. There is no coordination between foremen because each of them decides his own schedule which may completely obstruct operations in other departments. A midway approach (semi-centralised) is more rational where each department is told of the completion date, the latest finish date by which the job must leave the department. The day-to-day shop planning is left to the foreman. This eliminates much paper work and thus lowers the cost of scheduling.

(b) Relative job priority of incoming job is another important consideration in scheduling, especially in a job production unit. Certain jobs are given preference over others and hence require to be loaded and scheduled first. The job priority is generally gauged on the basis of the following:

(i) Items with fewest remaining operations are scheduled first.

(ii) Delivery commitment of critical items are given preference over others. A simple method to establish priority number is:

$$\text{Priority Number} = \frac{\begin{pmatrix}\text{Man or machine}\\ \text{hours available}\end{pmatrix} - \begin{pmatrix}\text{Standard hours}\\ \text{required for remaining}\\ \text{operations till due date}\end{pmatrix}}{\text{Number of remaining operations}}$$

Items with the smallest priority numbers rescheduled first.

(iii) Penalty clause items are given preference over others.

(iv) Long pending jobs which might have been set aside due to delay in procurement of materials/tools are given preference over fresh jobs.

(v) Certain customers are given preference for the completion of their jobs over others.

Such customers are those:

- from whom the company gets more business;
- who are in the market upsuring;
- whose terms of contract are attractive;
- who are known for business ethics; and
- on whom the company depends for bottleneck operations.

(vi) Items which fetch better price always carry an edge over other. Similarly bigger lots are given preference over smaller lots.

(vii) Jobs which give feed to more work missing words. Over jobs going through limited work centres.

(viii) Hot items causing production hold-ups at the customer's plant or the company's own plant are pushed through first.

(ix) Jobs currently being manufactured by the competitors are given preference over others.

(c) Load Charts exhibit the accumulated load at a given time for a given machine and periods available for allocation to future incoming orders needing this machine. The failure to identify this undoubtedly will lead to broken promises, foreman shouting at the top of the voice when delivery date rolls round, or entire section working on overtime, etc. The correct fitting of the order considerably lessens foreman's burden.

Procedure for Scheduling

Scheduling is a complex activity as there are too many variables. Systematic procedure to translate requirements into production schedule, therefore, is necessary. The following steps are generally necessary to prepare production schedules in a batch production unit.

1. ***Preparation of Individual "Job Schedules":*** A job schedule as mentioned earlier, is the graphic representation of operations. One job schedule is prepared for each component. A company which manufactures a wide range of products, therefore, prepares large number of job schedules which are filed to be used as a basis for production control. The job schedule in batch and mass production units are prepared for economic batch quantities. The job schedules are not dated but specify the time required for each operation.

   A job schedule in a jobbing production unit is prepared on the finalisation of the contract and is prepared for the quantity required by the customer.

2. ***Assign "Start" and "Finish" Dates to Each of the Operation on the Job Schedule:*** The job schedule of the component to be scheduled is withdrawn from the file and "finish" date, for each of the operations to be performed are entered. To assign dates, the scheduler needs to consult his load charts. (This step, therefore, pre-supposes the preparation and existence of load charts.)

   The most common practice is to "proceed operation-wise, consult load chart to fit the operation into the uncommitted capacity available on the machine, enter scheduled start and finish dates for operations on the schedule, compare completion date of last operation with the delivery date (if delivery date has already been confirmed). Effect adjustment (if necessary and possible) when the job requires longer time than the delivery committed earlier.

3. ***Post Load of Each Schedule into the Load Chart:*** Once each of the operations on the job schedule has been scheduled, the scheduler should post the load due to each shop order into the load chart.

   Load and scheduling are akin to each other. The load can be derived only from the schedule and the schedule in turn can only be drawn up in consideration of the load.

   The accuracy of the delivery date depends upon now accurate the loading is. It is bad practice to set a delivery date without considering the load. Such delivery promises usually cost lot of money for their fulfillment and are generally associated with broken promises.

4. ***Setting Delivery Date for an Item:*** A real good situation is one when job can be fitted for the delivery date as desired by the customer. But, rarely it is possible. To confirm or set a delivery date, the following steps are necessary.

   (a) Prepare a job schedule for the item.

   (b) Assign starting date and completion date for each operation considering the load.

   (c) Add safety factor (days) to above to get delivery date.

Relationship between 'Routing' and 'Scheduling'

'Routing' and 'Scheduling' are independent and either of these activities cannot be undertaken independently. It is very difficult to prepare schedules without determining the routing of sequence of operations. Routing is the prerequisite of scheduling. Unless route or sequence of operations, tools, equipment and plants and the persons, by when operations are to be performed, are established, the time taken by each operation, the idle time of men and machine and total time for the whole process cannot be ascertained in a convincing manner.

Conversely, scheduling is equally important for routing. It is quite difficult to route an item efficiently through a plant without consulting previously designed schedules. The main aim of routing is to pass the item through the process of manufacture by a route which is the best and the most economical. And a route or sequence of operations may be considered best which utilises the men, materials and machines to the maximum and which consumes the shortest time during the process of production. This information (time schedule of each operation) can be obtained from schedules. So, scheduling is necessary for effective routing.

Thus, we can conclude that routing and scheduling are interrelated, inter-connected and interdependent activities of production planning and control.

Dispatching for Batch Production

Dispatching is another very important mechanism of production control. The literal meaning of the term dispatching is sending to destination or 'starting something on its way'. When applied to production control, it means assignment of work to definite machines or workplaces which involves issuance of orders and production forms in order of their priority as determined by scheduling. In fact, dispatching translates into reality or physical work which has been planned X scheduling.

In other words dispatching is the routine of setting productive activities in motion through the release of orders and instructions, in accordance with previously planned times and sequences, embodied in route sheets and schedule charts.

Student Activity

Fill in the blanks:

1. The production control is the function of ....
2. The objectives of production control ....
3. A good and effective production-control system requires ....
4. Kimball and Kimball defined scheduling as ....

Summary

The production control is the function of management which plans, directs and controls the material supply and processing activities of an enterprise so that specified products are produced by specified methods to meet an approved sales programme. It ensures that the activities are carried in such a way that the available labour and capital are used in the best possible way.

Scheduling of manufacturing order takes care of the following:

- Preparation of machine loads.
- Fixation of calendar dates of various operations/sequence of operations to be performed on the jobs & follow-up the same.
- Coordination with sales to confirm delivery dates of new items and keeping them informed about the periodical dispatch schedules.

Keywords

Production Control: It measures the actual performance of the production units and taking remedial action called for to see that the production actually achieved is not less than the target or standard set in advance.

Production scheduling: Production scheduling may be defined as "the detailed planning of material, labour and machine time so that materials and parts will be at the right place, at the right time so that a job can be completed within the time planned and in accordance with the requirements."

Product Sequencing: In job or batch production we often have at the beginning of a production period several products that have to be manufactured on certain machines according to a predetermined sequence.

A cycle schedule: If the plant is engaged on batch production in a cyclic fashion, this schedule shows how the cycle time is distributed between the various products.

A detailed schedule: This shows in a planned multi-activity chart how the facilities should actually be employed during the production period.

Review Questions

1. Differentiate between objectives and advantages of Production Control.
2. How can we say that there is need of Production Control System, currently?
3. Describe main basic Scheduling Problems?
4. What are the objectives and inputs of Scheduling?
5. Describe those factors which influence 'Scheduling'.
6. Show the relationship between Routing and Scheduling.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior*, Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see*, Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management*, John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage*, Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis*, Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach*, McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies*, John Wiley & Sons, 2004.

Unit 11 Dispatching and Follow-up

Unit Structure

- Introduction
- Dispatching
- Qualities of a Chaser
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Dispatching
- Qualities of a Chaser

Introduction

Dispatching is concerned with the starting the processes. It gives necessary authority so as to start a particular work, which has already been planned under 'Routing' and 'Scheduling'.

Therefore, dispatching is 'release of orders and instruction for the starting of production for any item in acceptance with the route sheet and schedule charts'. The function of follow-up is to report daily the progress of work in each shop in a prescribed proforma and to investigate the causes of deviations from the planned performance.

Dispatching

Dispatching is another very important mechanism of production control. The literal meaning of the term dispatching is sending to destination or 'starting something on its way'. When applied to production control, it means assignment of work to definite machines or workplaces which involves issuance of orders and production forms in order of their priority as determined by scheduling. In fact, dispatching translates into reality or physical work which has been planned X scheduling.

In other words dispatching is the routine of setting productive activities in motion through the release of orders and instructions, in accordance with previously planned times and sequences, embodied in route sheets and schedule charts.

Principal Functions of Dispatching

The principal duties of dispatching staff are given below:

(a) Dispatchers assign work to definite machines or work places and men in order of priority and in proper sequence which has already been listed on the schedule charts. In this connection it should be remembered that job tickets are of fundamental significance. These job tickets record in full the details as to machine loading capacity, present and advanced operations and their correct sequence, etc. – all in order of priority.

(b) The necessary authority for preparing, assembling and issuing the required materials, tools, jigs, fixtures, dies and gauges for various jobs, etc., to their correct points of use – when job tickets have been assigned to machines and operations, such necessary machines, tools, jigs, fixture, etc., must be issued to their correct point of use.

(c) Release of necessary order and production forms so that the operations may be switched on or started by dispatchers. Before the processing actually starts, issuance of production forms and necessary orders to storerooms, operators and inspectors and workers becomes necessary. On the basis of such orders and forms necessary adjustments to schedules are made in accordance with the conditions prevailing. At this stage job tickets, time tickets, identification stage, inspection forms and other requisition forms play their own vital role as they are like genuine cheques authorising the genuine holders of the cheques to encash them when necessity arises.

(d) The responsibility of guiding and controlling materials and operations in processing. Route sheets and schedules provide the basis for the guidance and control of the movement of work from machine to machine, i.e., ascertaining whether work is moving on the preplanned road of its traveling in its correct sequence. The dispatcher here works in close cooperation with the foreman. Guidance and control also become necessary to adjust immediately whenever unforeseen emergencies occur and conditions change which are likely to disrupt processing.

(e) Contacting the routing and scheduling sections so that their plans and schedules may not overlap. The dispatcher here acts as a liaison officer linking the activities of routing and scheduling sections. The aforesaid activities of the dispatcher are likely to vary with the type of manufacture.

In brief these activities may be listed as follows:

(i) Movement of material from stores to the first process, and from process to process.

(ii) Issue of tool orders instructing the tool department to collect and make ready tools; jigs, and fixtures in advance of the time at which the operation will commence.

(iii) Issue of job order authorising operating, in accordance with dates and times previously planned and entered on the machine loading charts, route sheets and progress control sheets or boards.

(iv) Issue of time tickets, drawings, instruction cards and other necessary information to personnel performing the work.

(v) Issue of inspection orders after each operation to determine the result in number of pieces 'good' and the 'bad' and the causes of spoilage.

(vi) Issue of more orders and collection of time tickets, drawings and instruction cards for all completed operations.

(vii) Recording time of beginning and completing jobs, and calculating duration, forwarding complete records to production department and time card to pay roll department.

(viii) Recording and reporting idle time of machines and operators.

Dispatching Procedures

The schedules prepared, by scheduling section, for serialised or semi-serialised manufacture are issued by dispatching section to the department or machines concerned just before the start of the period. Similarly in case of job order manufacture, individual manufacturing orders for each production item are issued to the various departments or machines to authorise the work to be done. The manner in which schedules or orders are issued depends upon whether the dispatching is decentralised or centralised.

Common Forms Raised by Dispatcher

Among the more common forms dispatched are:

1. ***Material requisitions:*** Typical material-requisition form prepare in duplicate. No material may be drawn from the store room without the written requisition.
2. ***Job cards:*** Which authorise a work stationer employee to start a work on a certain material, indicate what is to be done, and also serve as a means of recording production progress.
3. ***Labour cards or wage payment cards:*** Which are used to report labour time utilised and quantity of work performed on a lot of material and to supply other information required in the preparation of the pay roll and production reports. The job and labour cards are frequently combined into one form.
4. ***Move tickets:*** Which authorised the movement as per materials between operations and which also may be used to report production progress.
5. ***Inspection cards***: Which are employed to report the quantity of work passed and the quantity rejected at each inspection operation.
6. ***Tool and gauge tickets:*** Which are furnished to the tool crib or gauge room as authorisation to issue such equipment.

Dispatching Rules

(a) ***Simple Rules:***

(i) *Earliest due date:* Run the job with the earliest due date, results in good due date performance.

(ii) *First come first served:* Run the job which arrived in the waiting line first. Results in low variance of manufacturing cycle time.

(iii) *Shortest processing times:* Run the job which has the shortest set-up plus machining time for the current work centre, one of the best of the simple rules, results in low in process inventory, low average manufacturing cycle times and good due date performance.

(b) ***Combination Rules:***

(i) *Minimum slack:* Slack equals calendar time remaining minus processing time remaining or slack equals due date minus present time minus set up and machining time for all remaining operations. Run the job with the least slack. Results in a very good due date performance.

(ii) *Critical ratio:* The critical ratio for made to order work is a slack type rule. Critical ratio equals due date minus present time divided by number of days required to complete the job order.

The rules for parts manufactured for inventory critical ratio equals available stock over reorder point quantity, divided by standard lead time remaining over total manufacturing lead time.

The ratio compares the rate at which stock on hand if being depleted with the rate at which total lead time is being used up.

Performance of the Dispatching Function

How dispatching function is performed. The dispatching function is performed through the use of a board called control board. A control board contains sections, one for each machine. Each section is divided into compartments, which are used as under:

(i) The top compartment contains the copy of the job order of the item currently being worked on the machine.

(ii) The middle compartment contains the copy of the job-order of the item to be processed next on the machine.

(iii) The bottom compartment contains the bunch of job orders of the items, arranged one after another in the sequence in which they are to be processed.

(iv) As the work progresses and the job order in 'top' compartment is completed, the job order in 'middle' compartment is transferred to the top compartment and next held in 'bottom' compartment is moved into middle compartment.

A control board thus gives an immediate view of the machine loading activity in the workshop. Such pictorial view is useful to:

- know whether all machines in the workshop arc engaged. Machines which are idle can be identified immediately, these being the machines whose top compartment is lying vacant.
- identify the machine to which no farther job has been allocated; this being indicated by absence of the job card in the "middle compartment."
- obtain an idea of the reserve load on a machine, indicated by the number of cards in the 'bottom compartment'.
- avoid crowding of the jobs at a particular machine by change of route of some of the jobs or by diverting work to other machines.
- know at a glance the machines which are idle because of breakdowns, lack of orders, operator's absenteeism, etc. This is known from the colour of the card in the top compartment inserted by the dispatcher as soon as cause was reported.

The complexity of dispatcher's work varies with the type of manufacture. The dispatching function is of very little importance in flow and mass production units as the dispatcher's work is merely limited to the dispatch of the materials necessary to manufacture the product. The materials automatically pass through different stages of the production line.

Dispatching in jobbing production units is usually complex. New tools are often necessary revision in the route of the parts is necessary so that work is evenly distributed (there being over loading on some machine and shortage on others, etc. As the flow of materials is discontinuous, it therefore becomes the duty of the dispatcher to control movement of materials between machines.

Dispatching as a principle needs to be a centralised function. Dispatch racks may be used to post shop orders to show the work in progress at each machine and the jobs which are to follow. The shop orders may be posted either machine-wise or operator-wise depending upon the conditions surrounding the work.

Progressing or Expediting or Follow-up Defined

"Follow-up or Expediting" is that branch of production control procedure which regulates the progress of materials and parts through the production process. Follow-up closely interrelated with the activities of a dispatcher to whom is delegated the scheduling responsibility. However, follow-up needs a separate description because of the complexities of production which thinks that it is a distinguished mechanism of production control. And of course, it should be such.

Follow-up is that novel tool which acts as a regulator of materials and component parts when they are travelling on the path of performances as laid down by routine sheets and schedule charts. It materialises and backs up the promises made by the routing and scheduling sections. It investigates thoroughly variations arising through production process in the light of the predetermined time schedules. It "serves as a catalytic agent to fuse the various separate and unrelated production activities into the unified whole that means progress", or, in other words, follow-up is the means by which the execution of the production plan is efficiently coordinated so as to reveal and, as far as possible to eliminate any variations from the plan which has set the engine of productional control moving to a definite goal.

Need for Follow-up

Follow-up becomes necessary because there are many factors over which the manufacturing department has no control. Even the slight irregularities relating to one or more of these factors may seriously deflect the progress of production from the scheduled programme. Late delivery of materials, associated departments falling behind schedule in their respective production, unexpectedly excessive labour absenteeism, breakdowns of machines and tools beyond anticipation, errors in drawings or/and plans, strikes or some natural calamities holding up production are some of these factors.

Qualities of a Chaser

A good chaser is he who possesses the following qualifications:

(i) *Tenacity:* Robust health; ability to mix well at all levels, excellent memory and amicable disposition.

Follow-up men or "chasers" or "expeditions" may be responsible for the processes or for die products.

(ii) *Process Responsibility:* It means that the responsibility is confined to the process or department allotted to a follow-up man and the 'progress clerk'. Under this system all products will be expedited through a particular process, say the lathe department, or the drill department. When each article moves to another process the responsibility for its 'progressing' passes into the hands of another follow-up man.

The process responsibility has two advantages. Firstly, the follow-up man becomes very familiar with each concerned with the procedure knowing but their strong and weak points and, secondly, he knows intimately the geographical features of his department and can, therefore, know immediately the places where items are likely to be mislaid.

(iii) *Product Responsibility:* Under this method a follow-up man is responsible for the progress of a single product "from inception to packing". In other words, the following-up man is assigned to follow up a particular product through all its operations and through all departments from the raw material to its completion.

Two Problems of Follow-up

Follow-up section has to meet two important problems. Obtaining information from the production department (also known as feedback); and the problem of volume.

Information can be obtained from the production department in any of the following ways:

(a) Mechanical counting and/or recording device may be used.

(b) Operator's work record may be used which would show the particulars and number of operations carried out by the operator concerned.

(c) *Use of job card:* Job card is different from the work record in that each operator is supplied with a card specifying the work to be done by him. This card is prepared in the routing section. In this the operator fills in the quantity of the operation carried out by him, the serial numbers, his own name.

(d) *Use of detachable tickets:* A ticket is prepared which accompanies each item. Each ticket bears the job-number of the product, its serial number and a list of operations through which the product will pass. On completion of the product the ticket is detached and kept in record.

(e) The progress man may walk around the department and count the work done.

The volume of information obtained varies according to the type of production. It is most difficult in batch production.

Types of Follow-up

(i) *Materials:* Follow-up of materials purchased is primarily the responsibility of the purchase department. Nevertheless the follow-up section of the production control department has to follow the outstanding material requisition which are vital for keeping the plan schedules. For this purpose a copy of the requisition may be obtained from the purchase department.

(ii) *Work-in-process:* The follow-up of work-in-process varies according to the type of production. Inflow production with product layout follow-up consists of checking of materials required and recording the production completed for comparison with the pre-planned schedules.

But in job production as well as in batch production record has to be kept of the commencement and completion of each product or batch of products and operations. Also records of number of pieces made, of defective and special pieces, of the time of operators and machines spent in producing them are prepared. Analysis is to be made of the time lost as well as the causes of spoilage or defective production.

(iii) *Assembly and Erection:* In case of assembly manufacture the responsibility for assembly and erection is usually vested in one follow-up man.

In case of large and highly complicated products usually the assembly and erection have to be done at the customer's site. This is particularly so in case of heavy machines and highly technical articles. The follow-up man in such cases have to be well-versed with engineering details of the product.

Student Activity

Fill in the blanks:

1. Dispatching .... mechanism of ....
2. The dispatching function is performed through ....
3. Follow-up becomes necessary because ....

Summary

Dispatching is another very important mechanism of production control. The literal meaning of the term dispatching is sending to destination or 'starting something on its way'. Follow-up is that novel tool which acts as a regulator of materials and component parts when they are travelling on the path of performances as laid down by routine sheets and schedule charts.

Follow-up becomes necessary because there are many factors over which the manufacturing department has no control. Even the slight irregularities relating to one or more of these factors may seriously deflect the progress of production from the scheduled programme.

Keywords

Dispatching: Dispatching is the routine of setting productive activities in motion through the release of orders and instructions, in accordance with previously planned times and sequences, embodied in route sheets and schedule charts.

Follow-up: "Follow-up or Expediting" is that branch of production control procedure which regulates the progress of materials and parts through the production process.

Review Questions

1. Define Dispatching. Explain the principal functions of dispatching.
2. List out various Dispatching Rules.
3. What are the qualities of a 'Good Chaser'?

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see,* Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management,* John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis,* Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach,* McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies,* John Wiley & Sons, 2004.

Unit 12 Inspection

Unit Structure

- Introduction
- Return to Suppliers
- Goods Received Notes
- Bin Cards
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Return to Suppliers
- Goods Received Notes
- Bin Cards

Introduction

Materials and supplies received should be subjected to inspection or test to ensure that they comply with the required specifications as to both quality and quantity as stated in the purchase order. Practice as to the extent and rigidity of inspection varies with the requirements. Sometimes every item may require inspection while in case of some other commodities it may be sufficient to inspect, say, every tenth unit. For truck load shipments of bulk raw materials, it is the general practice to inspect samples taken from top, bottom and middle of the truck. The results of the inspection should be contained in Inspection

Report which should be forwarded to purchase department for guidance regarding future placement or orders. A specimen form of Inspection Report is given below. These reports are referred to as ICRR, i.e., incoming Inspection cum Receipt Report.

INSPECTION REPORT
ABC CO. LTD., BOMBAY

Bought of ______________ No. Date
______________ Purchase Order No Date
______________ Mati. Recd. Report No. Date

Item No.	Code No.	Particular	Quantity on Order	Quantity Received	Passed	Rejected	Remark

Suggested Disposal Action for Rejected Amount

Signature

Return to Suppliers

If there are rejections, the Inspectors will prepare a Special Rejection Report which will enumerate the items of goods rejected and reasons therefore. This report will be forwarded to the Purchase Department who can contact the supplier and the material along with a copy of the rejection report supported by requisition for replacement, if necessary. If replacement is not necessary, a credit memoranda should be obtained from the supplier.

If there is any shortage or overshipment of orders, references should be made to the supplier by the Purchase Department for necessary adjustments. Sometimes, it may be the custom to consider deliveries in order if the quantity delivered is within a stipulated tolerance limit on either way.

There should be a record of all goods returned and claims made which should be closed only on receipt of a credit memorandum from the supplier or replacement on no charge basis. The Purchase Department must keep adequate records of all claims and settlement thereof. It is advisable that the claims record should be maintained by the Accounts Department also as an additional check upon the follow-up action of the Purchase Department.

Goods Received Notes

Materials and supplies accepted after inspection are entered on Goods Receiving Notes by the Receiving Department, or where there is no separate Receiving Department by the Stores Department. The Goods Received Notes contain, inter-alia, reference to Purchase Order and particulars as to the name of supplier, date of supply, code number and description of gods, quantity, price, total value of purchase, etc. One copy of the Goods Received Note along with the material is then passed on to stores where these are kept in appropriate bins, drawers, racks or other receptacles or are stacked at properly marked space in the storeroom. Copies of Goods Received Notes should also be sent to the departments as under:

(a)	Purchase Department	2 copies
(b)	Accounts Department	1 copy
(c)	Department initiating the purchase requisition	1 copy
(d)	Retained in Receiving Department	1 copy

A specimen form of Goods Received Note is given below.

GOODS RECEIVED NOTE
ABC CO. LTD., BOMBAY

BOUGHT OF	No.	Date	
____________	Purchase	Order No.	Date
____________	Delivery	Note No.	Date
____________	Carrier		

Item No.	Code No.	Particulars	Quantity in Order	Quantity Received	Weight	Rate	Value	Alteration and Changes

Excise Duty
Sales Tax (Registration No. and Declaration Notes No.)
Discount
Packing
Returnable Entries
Carriage and delivery
Marking
Terms of payment

Bin Cards

The materials received are unpacked and quantities checked against Purchase Orders by a Receiving Department wherefrom they, if everything is in order, are sent to storeroom storing the particular type of material received. Materials kept in appropriate bins, drawers, receptacles, racks, etc., or are stacked. For each kind of material, a separate record is maintained showing quantitative records of receipts and issue and balances. This record is known as Bin Card. On the top of the Bin Card particulars of maximum, minimum and reordering levels are also recorded. The Bin Cards portray physical movement of stores and indicate the physical balances at any moment. This facilitates keeping proper watch over observance of the prescribed stock levels and introduction of a system of continuous stock taking. The Bin Cards are also known as Perpetual Inventory Records and are usually attached to the relevant bins, shelves or racks.

Description .... Bin No ....

Code No...

Normal Quantity to Order................ Maximum Level ....

Re-ordering Level..................................

Stores Ledger Folio........................ Minimum Level....................................

	Receipt			Issue		Balance	Remarks
Date	G R No	Quantity	Date	Reg No	Quantity	Quantity	Goods on order

> **Student Activity**
>
> Fill in the blanks:
>
> 1. Materials and supplies received should be subjected to ....
> 2. The Purchase Department must keep ....

Summary

Practice as to the extent and rigidity of inspection varies with the requirements. Sometimes every item may require inspection while in case of some other commodities it may be sufficient to inspect, say, every tenth unit. There should be a record of all goods returned and claims made which should be closed only on receipt of a credit memorandum from the supplier or replacement on no charge basis. The Purchase Department must keep adequate records of all claims and settlement thereof.

The Goods Received Notes contain, inter-alia, reference to Purchase Order and particulars as to the name of supplier, date of supply, code number and description of gods, quantity, price, total value of purchase, etc.

Keywords

Goods Received Notes: Receiving Notes by the Receiving Department, or where there is no separate Receiving Department by the Stores Department.

Bin Cards: For each kind of material, a separate record is maintained showing quantitative records of receipts and issue and balances. This record is known as Bin Card.

Review Questions

1. Draw and explain an Inspection Report.
2. Define Bin Cards.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see,* Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management,* John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis,* Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach,* McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies,* John Wiley & Sons, 2004.

Unit 13 Maintenance Management

Unit Structure

- Introduction
- Maintenance Defined
- Maintenance Policy
- Problems on Maintenance
- Service Level Defined
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Maintenance Defined
- Maintenance Policy
- Service Level Defined

Introduction

The term 'maintenance' means to keep the equipment in operational condition or repair it to its operational mode. Main objective of the maintenance is to have increased availability of production systems, with increased safety and optimized cost. Maintenance management involves managing the functions of maintenance. Maintaining equipment in the field has been a challenging task since the beginning of industrial revolution. Since then, a significant of progress has been made to maintain equipment effectively in the field. As the engineering equipment becomes sophisticated and expensive to produce and maintain, maintenance management has to face even more challenging situations to maintain effectively such equipments in industrial environment.

Maintenance Defined

Wear and tear due to passage of time and/or normal usage of plant and machinery is an accepted fact. Any action aimed at bringing back or restoring an item to its original or acceptable position or to keep it and retain its healthy, workable position is known as maintenance. The importance of maintenance in a capital scarce country like ours cannot be over emphasised.

Objectives of Maintenance

1. To increase the effective life of an asset at affordable cost;
2. To make sure that the plant and machinery as available can be put to optimum use;

3. To anticipate the emergencies that might occur due to non-availability of plant and machinery and guard the same through advance planning, e.g., emergency service, having an extra machine, etc.,
4. To provide a neat, clean and safe work environment;
5. To ensure the quality of the product by keeping the machines at their optimum working condition;
6. To achieve reliability and enabling to stick to production plan; and
7. To reduce downtime of plant and machineries.

Types of Maintenance System

1. Preventive Maintenance
   (i) Running Maintenance
   (ii) Shutdown Maintenance
   (iii) Preventive Replacement
2. Corrective Maintenance
3. Design-out Maintenance

A brief account of each is given here below:

1. *Preventive Maintenance:* By far the most popular maintenance concept is the preventive maintenance. One way of increasing system reliability is to add relevant machine in the system. As would be obvious, a cost-benefit trade off is necessary rather than blindly adding assets to the system. Usually statistical analysis of past performance and failure pattern provides clue for this purpose.

   A preventive maintenance policy is based on the principle "prevention is better than cure" and has been found to be quite useful. It consists of:

   (i) *Running maintenance* or schedule maintenance like lubricating, oiling, greasing, cleaning, small repairing on a routine and planned basis.

   (ii) *Shutdown maintenance* as compared to running maintenance results in complete stoppage of the plant for a stipulated period. During this time the plants and machines are overhauled, replaced, condition checked, etc. Detailed PERT/CPM network is usually prepared for this purpose. Shutdown of steel plants, power plant, paper mill, fertilizer unit, etc., are common.

   (iii) *Preventive replacement:* Preventive replacement depends upon the nature of equipment/components, availability of manpower and spare parts, etc., for example, the replacement of bearings in an automobile wheel assembly, replacing bulbs particularly installed at high-up places in a factory where the replacement of each individual part is very costly as compared to the cost of a bulb.

   Normally an unplanned system causes emergent condition wherein we have to stop production and do maintenance immediately to avoid heavy loss of production/hazardous condition leading to accident, etc. Breakdown maintenance falls into this category.

2. *Corrective Maintenance:* A plan for inspection of machinery and replacement of parts, when an opportunity to do so is available, e.g., when any of the equipment breakdown and the plant comes to a halt.

3. *Design Out Maintenance:* This is a new concept which is gaining ground. This is based on the use of statistical techniques relating to 'Failure Statistics' and use the concept of Mean Time Between Failures (MTBF) for repair replacement of the equipment, etc.

Preventive vs. Breakdown Maintenance

Preventive maintenance as stated above is a useful concept as it helps in reducing the number of breakdown, thereby resulting in mere machine time available and hence in higher productivity.

Therefore, the question arises when to do Preventive Maintenance and when to do Breakdown Maintenance. This necessitates a trade-off between preventive and breakdown maintenance. This can be achieved through:

(a) Cost of preventive and breakdown maintenance.

(b) Failure statistics such as MTBF, etc., of the equipment/machine is consideration.

(c) Effect of preventive maintenance is reducing breakdowns.

If we plant a graph, it will be of the following shape:

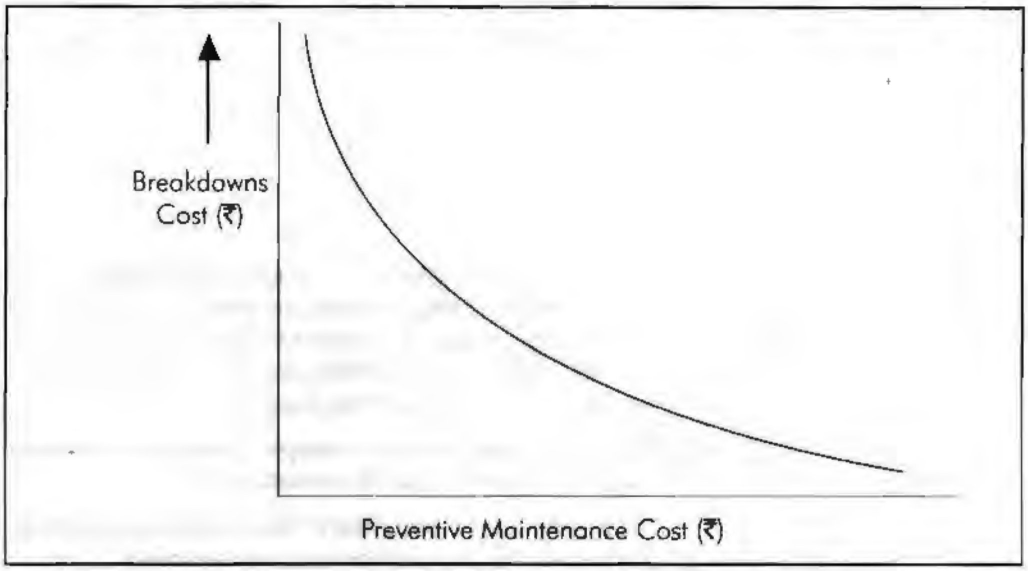


Figure 13.1: Trade-off between Preventive and Breakdown Maintenance

Maintenance Policy

As we know that in a plant or factory there is nothing like a purely preventive maintenance or a purely breakdown maintenance, there is always an appropriate of preventive and breakdown maintenance.

The trade-off between Preventive Maintenance Cost and Breakdown Maintenance Cost shows where each type should be used.

For Planning and Controlling the Spare Parts. Information on 'Failure Statistics' play a very prominent role. Based on 'Failure Statistics', there are three failure probability distributions:

a. Normal failure behaviour

b. Negative exponential distribution

c. Hyper exponential distribution

(a) *Normal Failure Behaviour.* The items normally fail at some mean operating age.

(b) *Negative Exponential Failure Behaviour:* The items which do not wear out but give way due to overload or defect in the system which is external to them fall under this category, e.g., an electrical fuse.

(c) *Hyper Exponential Distribution:* For the equipment which fail during the initial stages itself due to some teething problems than during the subsequent life.

When an item shows all the three modes of failure, viz., normal, negative exponential and hyper exponential, then the curve between the 'Age' of the equipment vs the 'Time to Failure' is like a bathtub and hence is called 'Bathtub Curve'. This is shown as below:

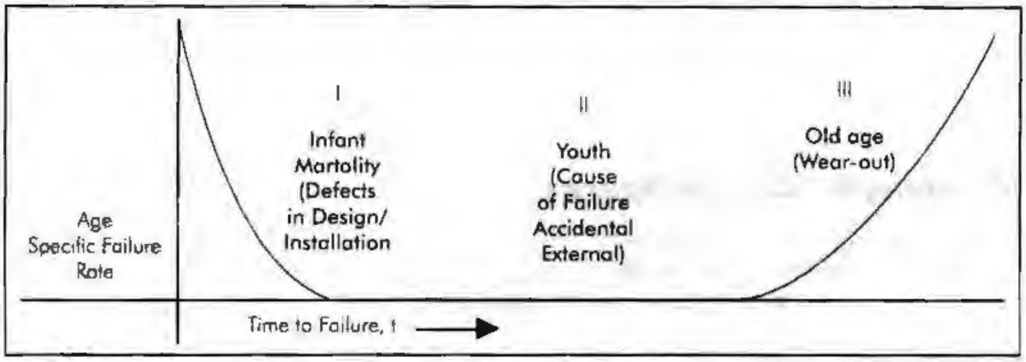


Figure 13.2: Bathtub Curve

(i) Infant Mortality (defects in design/installation)

(ii) Youth (cause of failure is accidental/ external)

(iii) Old age (wear out)

Planning of Regular Spares

The spares which are required regularly and in substantial numbers are those which are required for preventive and breakdowns. The breakdowns occur either according to the normal distribution (wear out of the parts) or according to the Poisson Distribution (overload failures). The measures of central tendency like the Mean, Standard Deviation characteristics are well-known through the past experience.

Having known the opportunity cost and understanding, we can calculate the Service Level given by

$$\text{Service Level} = \frac{ku}{ku + ko}$$

where,

ku = opportunity cost of understanding one unit and

ko = opportunity cost of overstocking one unit

Now, knowing the Service Level, the Mean, Standard Deviation characteristics of spares, we can compute the regular stock required as below:

(a) Buffer stock is the stock required to cover the lead time consumption only. It is given by, DELTA = The mean of the poission distribution (the mean breakdown rate).

(b) The Average Inventory Level

$$= \frac{EOQ}{2} + \text{Buffer stock}$$

where, EOQ = Economic Order Quantity

Planning of Insurable Spares

Spares of this class have a very high reliability and require very rarely, hardly once during the life time of an equipment. These are very costly items on the other hand and hence a decision is required whether to stock it or not?

As these items are 'critical' from production point of view and their non-availability can cost very high breakdown cost. The decision whether to buy and keep a spare or not depends upon the following rule:

"If (Probability of Failure) × (Down Time Cost) = purchase price of a spare, then buy and keep otherwise not", e.g., if the probability of failure is = 1, Reliability = 0.01 (say) and the cost of equipment = ₹ 3 lakh and the Down Time Cost is approximately ₹ 40 lakh, then (Probability of Failure) × (Down Time Cost) = 0.01 × 40

= 4 lakh

As cost of equipment is less than the expected cost of down time, hence we should buy and keep the spare.

Planning of Capital Spares

Capital spares are the ones which fall between the two extremes, i.e., the Insurable Spares, the Regular Spares. As the name given, these spares are expensive and hence only the desired quantity should be bought and kept in store as inventory.

The calculation of spares need the following data:

(i) Spares needed for over the life of the equipment,

(ii) The cost of the Spare (c),

(iii) The Under-stocking cost (ku),

(iv) The Salvage Cost (s) and

(v) The Probability (Pi) that 'i' spares would be needed over the life of the equipment.

Then the total number (N) of spares required to be kept in inventory is given by:

$$\sum_{i=0}^{n-1} Pi \leq \frac{ku - c}{ku - s} \leq \sum_{i=0}^{n} Pi$$

Rotable Spares

Rotable spares are the ones which can be used and again after reconditioning the same (after failure) and can be put back in operation, e.g., an electric motor.

For calculating the number of spares needed, we require to compare the down time cost and the cost of stocking the spares.

Prob 1: A workshop has 30 of identical machines. The breakdown failure pattern of the machine is:

Elapsed time since the maintenance job is over	Probability of Failure (in months)
1	0.25
2	0.20
3	0.15
4	0.15
5	0.25

It costs ₹ 200 to replace a machine. Compute the yearly down time cost.

Solution

Expected Time before failure

= 0.25(1) + 0.20(2) + 0.15(3) + 0.15(4) + 0.25(5)

= 0.25 + 0.40 + 0.45 + 0.60 + 1.25

= 2.95 Months.

No. of repairs/machine/year

= (12 / 2.95)

Annual cost of servicing the breakdown machines

= (12 / 2.95) × 30 × 200

= ₹ 24,406

Prob 2: The breakdown probability of an equipment is given below:

Month	Probability
1	0.25
2	0.20
3	0.15
4	0.15
5	0.25

There are 30 such equipment in the plant. The cost of individual preventive replacement is ₹ 20 per equipment and the cost of attending individual breakdown replacement is ₹ 50 per equipment. Find out the Optimal Maintenance Policy.

Solution

Individual Preventive Replacement

Let us take the following cases:

Case I:

Preventive Replacement Period = One month.

(a) Cost associated with it when the item fails before the replacement age

= 0.25 × 50

= ₹ 12.50

(b) Cost of the component when it does not fail before replacement age

= 0.75 × 20

= ₹ 15.00

Total cost of replacement per equipment under Case I

= ₹ 12.50 + ₹ 15.00

= ₹ 27.50

Expected life of the equipment under preventive maintenance and replacement period of one month is one month only, as the first breakdown coincides with the preventive replacement.

Therefore, cost per month

$$= \frac{₹\,27.50 \times 30}{1} = ₹\,825.00$$

Case II:

Preventive Replacement Period = Two months.

(a) Cost associated with it when the item fails before the replacement age

= (0.25 + 0.20) × 50

= ₹ 22.50

(b) Cost of the component when it does not fail before replacement age

$= 0.55 \times 20$

$= ₹\ 11.00$

Total cost of replacement per equipment under Case II

$= ₹\ 22.50 + ₹\ 11.00$

$= ₹\ 33.50$

Expected life of the equipment under preventive maintenance and replacement period of two months is:

$= (1 \times .25) + (2 \times .75)$

$= 0.25 + 1.50$

$= 1.75$ months.

Therefore, Cost per month

$$= \frac{₹\ 39 \times 30}{1.75}$$

$= ₹\ 668.57$

Case III:

Preventive replacement period = Three months

(a) Cost associated with it when the item fails before the replacement age

$= (0.25 + 0.20 + 0.15) \times 50$

$= ₹\ 30.00$

(b) Cost of the component when it does not fail before replacement age

$= (10.60) \times 20$

$= 0.40 \times 20$

$= ₹\ 8.00$

Total cost of replacement per equipment under Case III

$= ₹\ 30.00 + ₹\ 8.00$

$= ₹\ 38.00$

Expected life of the equipment under preventive maintenance and replacement period of three months is:

$= (1 \times .25) + (2 \times .20) + (3 \times .55)$

$= .25 + .40 + 1.65$

$= 2.30$ months.

Therefore, Cost per month

$$= \frac{₹\ 38.00 \times 30}{2.30}$$

$= ₹\ 495.65$

Case IV:

Preventive Replacement Period = Four months.

(a) Cost associated with is when the item fails before the replacement age

$= (0.25 + 0.20 + 0.15 + 0.15) \times 50$

$= 0.75 \times 50$

$= ₹\ 37.50$

(b) Cost of the component when it does not fail before replacement age

$= (1 - 0.75) \times 20$

$= 0.25 \times 20$

$=$ ₹ 5.00

Total cost of replacement per equipment under Case IV

$=$ ₹ 37.50 + ₹ 5.00

$=$ ₹ 42.50

Expected life of the equipment under preventive maintenance and replacement period of four months is:

$= (1 \times .25) + (2 \times .20) + (3 \times .15) + (4 \times .40)$

$= .25 + .40 + .45 + 1.60$

$= 2.70$ months.

Therefore, Cost per month

$$= \frac{₹\,42.50 \times 30}{2.70}$$

$=$ ₹ 472.22

Individual Breakdown Maintenance

Average number of individual breakdown replacements per month

$$= \frac{\text{Number of equipments}}{\text{Mean life of an equipment}}$$

Now, mean life of an equipment

$= (1 \times .25) + (2 \times .20) + (3 \times .15) + (4 \times .15) + (5 \times .25)$

$= .25 + .40 + .45 + .60 + 1.25$

$= 2.95$ months.

Therefore, Average number of breakdowns per month

$$= \frac{30}{2.95}$$

$= 10.17$

Cost of Replacement under individual breakdown maintenance

$= 10.17 \times 50$

$=$ ₹ 508.50

SUMMARY OF COST COMPARISONS

Policy	Cost per Month (₹)
Individual Preventive Maintenance:	825.00
Case I: Replacement Period One Month	668.57
Case II: Replacement Period Two Months	495.65
Case III: Replacement Period Three Months	472.22
Case IV: Replacement Period Four Months	
Individual Breakdown Maintenance :	508.50

Result: Preventive maintenance after every four months is the best replacement policy.

Service Level Defined

Service Level can be defined as F(x), the probability that the demand will not exceed the stocking level, where 'x' is the amount of stocking level.

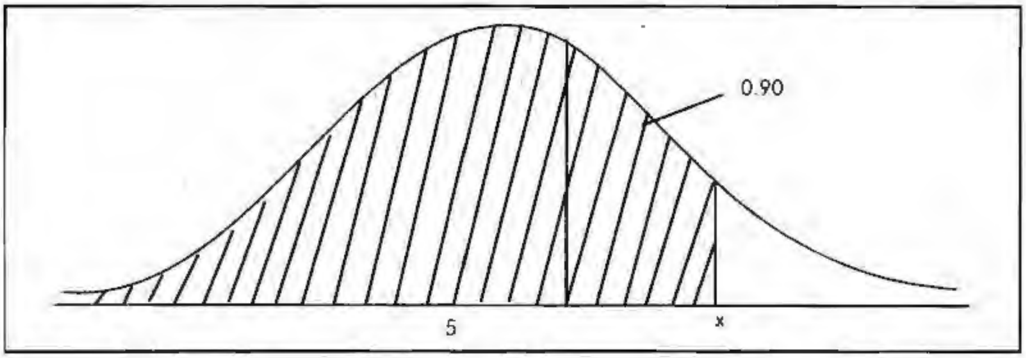


Figure 13.3

F(x) = Ku / (Ku + Ko)

where, Ku = Opportunity cost of understanding

= (cost of stock out – unit price of a spare)

Ko = Opportunity cost of overstocking

= (cost of spare – its salvage price)

A particular item has a selling price of ₹ 70 per unit and if the same is sold next day the selling price gets reduced to ₹ 30 only. Find the service level if the cost of this item is ₹ 50 per unit.

Case I:

F(x) = Ku/(Ku + Ko) = (70 – 50)/[(70 – 50) + 30]

= 20 / 50

= 0.40

Case II:

The cost of stockout for shortage of spares is ₹ 6000 whereas the cost per spare is only ₹ 1500. Find out the service level if the salvage value of the spare is

(a) Nil

(b) ₹ 500

(i) F(x) = Ku/(Ku + Ko) = (6000 – 1500)/[4500 + (1500 – 0)]

= 4500/6000

= 0.75

(ii) F(x) = Ku/(Ku + Ko) = (6000 – 1500)/[4500 + (1500 – 500)]

= 4500 / 5500

= 0.81

Prob 3: If the service level required for maintenance system is 90 per cent, find what buffer stock should be maintained for spares whose failures exhibit Poission Distribution with a mean failure rate of 12 units per month and the average lead time for spares is 2 months?

Sol. Service Level = 90% = 0.90

Lead time consumption = l (lambda) = 12 × 2 = 24 units corresponding to lλ = (lambda) = 24 and Cumulative probability 0.90, We have $\phi = 30$

which is the value of maximum stock required

Buffer stock = Maximum Stock (EOÑ in case of Ñ system) Lead time-consumption

= 30 – 24

= 6 units

Reliability

It is the probability that a given system/product will successfully perform the given task in the expected manner of customer use. System reliability can be decided by the manner in which various components/machine are limited to each other in process.

(1) *In Series:* When the system is in series the failure of even one unit in the system results in the failure of the entire system.

If there are two components in series then system reliability is given by

R(t) = R(t1) R(t2)

where, R(t1) = reliability of component 1

R(t2) = reliability of component 2

R(t) = Reliability of the whole system

R(t) will be less than both R(t1) and R(t2)

Example:

R (t) = 0.90 × 0.80 = 0.72

where R (t1) = 0.90

R (t2) = 0.80

(2) *In Parallel:* When the system components are arranged in parallel then the failure of one component does not lead to failure of the system.

System in parallel will fail only when each of the component has failed.

This has obvious advantage. It can allow for the component to be repaired without affecting production.

The system reliability in a parallel system given by

P(t) = 1 – [1 – p (t1)] [1 – P(t2)]

where,

P(t1) = reliability of component 1

P(t2) = reliability of component 2

P(t) = reliability of the whole system which is higher than the reliability of individual components.

Example:

Rp = 1 – [(1 – .90) (1 – 0.80)]

= 1 – [.10 .20] = 1 – .02 = 0.98

The reliability of the whole system is greater than each of the individual reliabilities.

Prob 4: If the service level required for maintenance system is 90 per cent, find what buffer stock should be maintained for spares whose failures exhibiting Poission Distribution with a mean failure rate of 12 units per month and the average lead time for spares is 2 months?

Sol. Service Level = 90% = 0.90

Lead time consumption = l = l = 12 × 2 = 24 units

Corresponding to l (lambda) = 24 and Cumulative probability 0.90,

We have $\phi = 30$

which is the value of maximum stock required

Buffer stock = Maximum Stock (ROÑ in case of Ñ system)

= Lead time-consumption

= 30 – 24

= 6 units

Prob 5: If the failures are taken to follow a Poission Distribution Behaviour

(a) What buffer stock of spares shall be needed for a service level of 90 per cent if the lead time for processing these spares is 1 month and the arrival of breakdown equipments is 10 per month.

(b) If the ordering cost is ₹ 100 per order and the inventory carrying cost is ₹ 3 per item per year, find the average inventory level of spares?

Solution:

(a) Arrival of breakdown per month $\lambda = 10$

From table of Poission Distribution:

Value of x against $\lambda = 10$,

$\lambda = 13$ service level = 0.864

x = 14 service level = 0.917

Therefore,

Demand = Max. demand rate = 14 units. Consumption during the average lead time = 10 units.

Therefore, bufferstock = 14 – 10

= 4 units during the lead time.

(b) Average Inventory

= Buffer Stock + (1/2) Economic Order Quantity

= Buffer stock + (1/2) EOQ

Now, EOÑ = $\sqrt{\dfrac{2AD}{Ci}}$

$$\sqrt{\frac{2 \times 100 \times (10 \times 12)}{3}}$$

= $2 \times 10 \times 2 \times 5$

= 40×2.236

= 89.44 units.

Therefore,

Average Inventory

= 89.44 / 2 + Buffer Stock

= 44.72 + 4

= 48.72

= 49 units (say)

Prob 6: The transformer of a steel melting shop comes from Japan has a high reliability of 0.990. However the cost associated with down time is extremely high and is estimated to be ₹ 50 crore towards total loss. The cost of transformer (CIF) is ₹ 12 crore. Should we have a spare transformer in inventory or not?

Solution:

The expected down time cost

= (Probability of failure) × (The breakdown loss)

= (1 – 0.990) × (50)

= 0.110 × 50

= ₹ 5.5 crore.

The cost of procuring a spare

= ₹ 12 crore.

As the expected down time cost < The cost of the spare, hence we should not buy a spare and keep as inventory.

Prob 7: A large Maruti workshop dealer has a probability of demand for a particular spare item is given below:

No. of spares needed	Probability
0	0.05
1	0.10
2	0.15
3	0.20
4	0.25
5	0.25

The cost of not having an item in stock is estimated to be @₹ 200 and the cost of each spare part is ₹ 60 only. If the salvage value of the spare part is ₹ 10, find the number of spare items to be stocked?

Solution:

Cost of item not in stock = Ku = ₹ 200

Cost of item = C = ₹ 60

Cost of salvage value = Cs = ₹ 10

Therefore,

$$\frac{Ku - C}{Ku - S} = \frac{200 - 60}{200 - 10}$$

$$= \frac{140}{190}$$

$$= 0.7368$$

No. of spares needed	Probability	Cum. Probability
0	0.05	0.05
1	0.10	0.15
2	0.15	0.30
3	0.20	0.50
4	0.25	0.75
5	0.25	1.00

Now, the probability of 0.736, lies between having spares 3 & 4

$\Rightarrow 0.50 < 0.7368 < 0.75$

Therefore, we should have a policy of having 4 spares in stock.

Student Activity

Fill in the blanks:

1. A preventive maintenance policy is based ....
2. Rotable spares are ....
3. When the system components are arranged in parallel then the ....

Summary

Maintenance is expected to play even much bigger role in years to follow, as industries worldwide are going through an increasing and stiff competition and increased automation of plants. The down time cost for such systems is expected to be very high. To meet these challenges, maintenance has to use latest technology and management skills in all spheres of activities to perform its effective role in profitability of the company.

Keywords

Maintenance: Any action aimed at bringing back or restoring an item to its original or acceptable position or to keep it and retain its healthy, workable position is known as maintenance.

Corrective Maintenance: A plan for inspection of machinery and replacement of parts, when an opportunity to do so is available, e.g., when any of the equipment breakdown and the plant comes to a halt.

Rotable Spares: Rotable spares are the ones which can be used and again after reconditioning the same (after failure) and can be put back in operation, e.g., an electric motor.

Review Questions

1. Define Service Level.
2. Define Reliability. How it can be built into the product?
3. Define System Reliability. What is the system reliability when two or more components are connected in (1) Series (2) Parallel?
4. Define 'Maintenance' and state its 'Objectives'.
5. What are the various types of Maintenance System? Describe briefly the function of each.
6. What 'Maintenance Policy' should be adopted for 'Planning and Control' of spares.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior*, Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see*, Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management*, John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis,* Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach,* McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies,* John Wiley & Sons, 2004.

Unit 14 Materials Management

Unit Structure

- Introduction
- Management of Material Resources
- Definition of Materials Management
- Scope of Materials Management
- Goals and Objectives of Materials Management
- Importance of Materials Management to Business Management
- Materials Management as Profit Centre
- Functions of Materials Management
- "Planning and Control" Function
- Interdependencies between Materials Management and other Allied Functions
- Integrated Materials Management Organisation
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Goals and Objectives of Materials Management
- Importance of Materials Management to Business Management
- Functions of Materials Management
- Integrated Materials Management Organisation

Introduction

The inbound system in the logistics function has been traditionally named as Materials Management. When viewed as a business function, it is the management of materials and their flow to, within, and from the firm. The Association for Operations Management (APICS) dictionary defines Materials Management as:

"The grouping of management functions supporting the complete cycle of material flow, from the purchase and internal control of production materials to the planning and control of work in process to the warehousing, shipping, and distribution of the finished product."

Management of Material Resources

Materials management is a specialised area of management which concerns itself with the management of Material Resources. What we are attempting to do in managing materials is to reduce and control the cost relating to this important resource, which normally accounts for about 50 per cent on average, of the cost of production. In other words if it costs ₹ 100 per cent to produce an item one may take it for granted than ₹ 50 is likely to be related to material which, it will be appreciated, is a very high percentage of the total cost. Some representative figures for Indian industries are as follows:

	Cost of raw materials (%)
Woollen Textiles	71%
Sugar	68%
Jute	66%
Pharmaceuticals	60%
Cotton Textiles	59%
General Engineering	51%
Paper	53%
Chemicals	50%
Steel	40%
Cement	38%

Traditionally, we are used to thinking of the cost of materials which is the price we have paid to acquire the materials, i.e., the basic cost of the materials. This is the figure usually displayed in a company statement of annual accounts. Materials management concerns itself not with this cost, which as we have seen is very high, but also with a large number of other costs which add to the price. These costs are called 'Cost in Materials' as distinct from 'Cost of Materials'. These costs are:

1. Cost of purchasing, often called procurement cost which may be anything from ₹ 60 per Purchase Order upward.
2. Duties, like excise, customs, sales tax, octroi.
3. Packaging costs.
4. Transportation costs, including clearing costs from the rail-head, port, airport, etc.
5. Insurance costs.
6. Receiving and inspection costs.
7. Materials handling costs.
8. Scrap arising on the factory floor or due to breakages or damages.
9. Inventory carrying costs, i.e. cost of storing the materials which involves interest on blocked-up capital rents, taxes and other overheads on the warehouse building, wages and salaries of the staff employed in the warehouses, pilferage, deterioration, spoilage, or evaporation of the materials and obsolescence.
10. Finished goods rejected by Quality Control, etc.

All these are costs incurred at various points of time during the passage of the raw materials from the vendor's premises to one's own factory, through manufacture and distribution of the finished goods to customers.

When we speak of materials management, we are not merely referring to the control of the cost of materials but of each and every type of cost that is incurred on materials, as indicated above, which have to be reduced and controlled.

Definition of Materials Management

The following definition of Materials Management has been accepted by the International Federation of Purchasing and Materials Management.

"The Materials Management is a total concept involving an organisational structure unifying into a single responsibility, the systematic flow and control of material from identification of the need through customer delivery.

Included within the concept are the material functions of Planning, Scheduling, Buying, Storing, Moving and Distributing. These are logically represented by the disciplines of Production and Inventory Control, Purchasing and Physical Distribution.

The objectives of Materials Management is to contribute to increased profitability by coordinated achievement of least materials cost. This is done through optimising capital investment, capacity and personnel, consistent with the appropriate customer service level."

Another definition adopted by the National association of Purchasing Management (USA) reads as follow:

Materials Management. An organisational concept in which a single manager has authority and responsibility for all activities principally concerned with the flow of materials into an organisation. (Purchasing, Production, Planning and Scheduling. Incoming Traffic, Inventory Control, receiving and stores normally are included).

In these definitions of Materials Management one will notice the concept that all authority and all responsibility for the acquisition and control of materials should be coordinated through one executive authority, the Materials Manager.

Scope of Materials Management

Areas of materials management can be described as the functions or scope of materials management. Limiting the areas of materials management, the study team on public sector undertakings had identified the following areas:

(i) Materials Planning and Programming;

(ii) Purchasing and Inventory Control;

(iii) Receiving, Warehousing and Storekeeping;

(iv) Transportation and Materials Handling; and

(v) Disposal of Scrap and Surplus, including the utilisation of by-products.

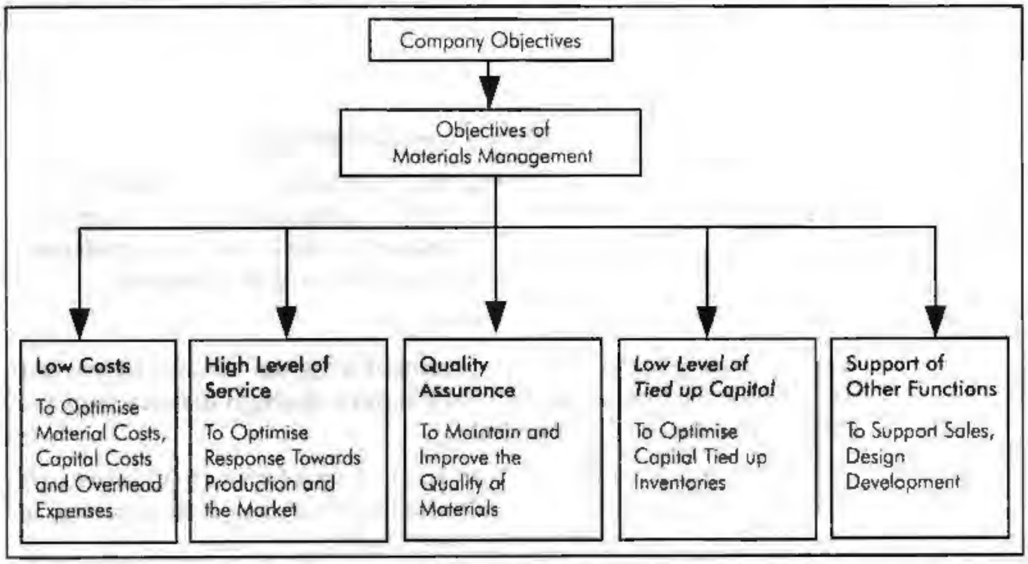


Figure 14.1: Derivation of Materials Management Aims from the Company's Objectives

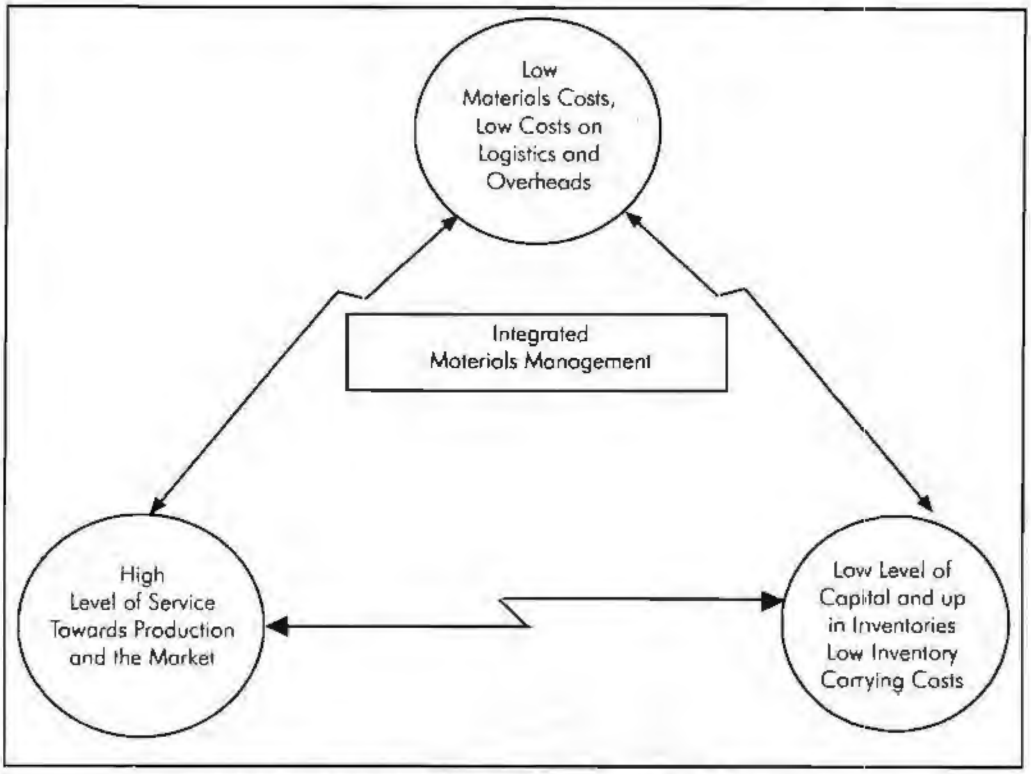


Figure 14.2: Clashing Objectives in Integrated Materials Management

The General Electric Company of the USA has grouped together the following function of material management:

(i) Materials Planning and Programming;

(ii) Purchasing;

(iii) Inventory Control;

(iv) Receiving and Warehousing;

(v) Storekeeping;

(vi) Value Analysis and Standardisation;

(vii) Pre-design Value Analysis;

(viii) Transportation;

(ix) Materials Handling; and

(x) Disposal of Scrap and Surplus.

Goals and Objectives of Materials Management

Materials Management's considerable effect on profits demands that its objectives be derived from the general business objectives "maintaining competitiveness" and "satisfactory profitability". The principle connections between business objectives and the objectives of Materials Management are depicted in Figure 14.1.

Materials Management as an integrated function has to balance conflicting objectives. The following essential goal conflicts have to be resolved.

1. High level of customer service/high service level versus low capital and inventory carrying costs.

2. High quality of materials versus low materials costs.
3. Low level of tied up capital/low liquidity burden versus continuous customer service.

Thus materials management is always as optimising function, comparable to a balancing act on a tight rope, as depicted in Figure 14.2.

The conflicting goals of Materials Management result in demands for measures which have to be taken and reconciled with one another, as detailed in Exhibit 14-A.

Exhibit 14-A: Goals and Objectives of Materials Management

Low costs	–	Minimisation of the cost of shortages
	–	optimal order levels
	–	high degree of standardisation in the purchasing programme
	–	low prices
	–	low costs on personnel, space and administration
	–	capacity usage of warehousing and transport facilities
	–	economic utilisation/disposal of obsolete and surplus material
High level of service/product availability	–	Exact calculation of requirements
	–	suppliers being consistently good at adhering to promised delivery dates and quantities
	–	preventing unilateral dependencies on suppliers
	–	smooth flow of materials
	–	high degree of flexibility on alterations in requirements
Quality assurance	–	optimal use of possible substitutes
	–	consistently good quality from suppliers
	–	optimal maintenance of stored goods
	–	preventing quality deterioration during storage periods.
Low level of tied-up capital	–	optimal inventory turnover
	–	low buffer stocks
	–	preventing obsolete inventories
	–	rapid throughout of orders
Support of other functions	–	Optimal liability planning
	–	comprehensive information of design/development and sales on technical and market developments
	–	smooth coordination with production (control)

In brief, the main objectives of materials management are as follows:

(i) To ensure continuous uninterrupted production or operation or project work by maintaining a steady flow of materials;

(ii) To achieve the above objective in an efficient and economical manner;

(iii) To effect economies in the cost of materials by purchasing materials of the right quality, in the right quantity, at the right time, from the right source, at the right price;

(iv) To effect economies in the costs incurred on materials after they have been purchased, through storage, processing and warehousing, till the finished goods ultimately reach the customer. These economies contribute towards cost thereby leading to higher profits;

(v) To reduce working capital requirements through proper and scientific inventory control;

(vi) To be alive to the changes in the market in respect of new products; and consequently;

(vii) To improve the quality of manufactured goods by use of better raw materials or components and thereby the increase the competitiveness on such goods put of sale;

(viii) To increase the competitiveness of manufactured goods by making it possible to reduce their prices through cost reduction, especially by value analysis;

(ix) To save foreign exchange through import substitution and economising on foreign purchases;

(x) to ensure cooperation among all departments of the enterprise to meet materials management objectives both at the corporate and functional levels and to ensure proper coordination in respect of such activities; and

(xi) To conserve materials resources within enterprise, thereby contributing to the conservation of national resources.

Importance of Materials Management to Business Management

Materials Management determines three cost categories within the company which, in most cases, have a substantial effect on company profits.

In team, these are:

1. *Materials Costs:* These are those costs which arise for the procurement of raw materials, indirect materials, fuels, semi-finished and finished products (goods), including delivery costs. In the manufacturing industry they constitute the largest percentage of the costs of Management of Materials.
2. *Capital Costs:* These cover primarily interest which accrues for the capital tied up in the stocks of materials, semi-finished and finished products (good), including depreciation for value adjustments which have to made.
3. *Overhead Expenses:* They cover the overhead expenses and/or cost centre expenses of all the separate areas within Materials Management, including the sometimes considerable costs of transport and packaging, electronic data processing and disposal.

Integrated Materials Management which is conceived as a comprehensive supply system can substantially contribute to a company's profits, via its systematic influence upon these cost categories.

The impact of the Materials Management department on company profits depends on the importance of materials costs, the degree of which Materials Management can control inventories of semi-finished products and work in process as well as finished goods, and the amount of personnel assigned to Materials Management.

Generally Integrated Materials Management offers substantial opportunities for influencing profitability as outlined in Figure 14.1.

Materials Management must now-a-days make an active contribution to improving profit by taking advantage of all opportunities for:

1. Reducing costs (materials costs, capital costs, overheads), and
2. Setting free the capital tied up in inventories and indeed in the whole pipeline from the suppliers to the consumers in the market.

This inevitably calls for an integrated approach to Materials Management in the interest of the company's profitability:

Purchasing must make its contribution to optimise the costs of materials:

1. Directly by making full use of its opportunities in the procurement markets, i.e., systematic procurement marketing, and

2. Indirectly by early introducing its market knowledge into design and development processes, i.e., even at the stage of determining the materials and parts to be used.

The cost of tied up capital and overheads must be reduced by an integrated approach to planning, controlling and handling of the flow of materials and goods in the entire supply system from the suppliers to the customers, namely:

1. Directly by making full use of every opportunity for reducing stocks at all stages, and
2. Indirectly by efficiently coordinating the processes from customer order processing to purchasing processing.

Market-oriented purchasing, on the one hand, and a comprehensive approach to planning, controlling, and handling the flow of materials and goods, using logistical instruments, on the other hand, are thus the two pillars of Integrated Materials Management.

The two of them used in combination have the power to make a substantial contribution in improving company profits.

Materials Management as Profit Centre

Materials Management has a considerable effect on profitability of an organisation. The materials management department enhances the profitability by:

(a) Reducing the cost of materials by buying the right quality of materials at the best possible prices by the use of modern purchasing techniques, etc., and

(b) Reducing the "cost on materials" by employing various modern techniques, materials management is able to directly contribute to the profits of a company. Every rupee saved in the price of materials or on their packaging, transportation, handling, storage, scrap, etc., add to the profits of a company.

Let us just take two examples by the way of illustration. There are three similar companies A, B and C whose performance are described below:

(₹ in lakhs)

	A	B	C
Sales Turnover	100	100	100
Gross Margin (10%)	10	10	10
Cost of Materials (50%)	50	50	50

All the companies desire that the profits should be ₹ 12.5 Lakh (or a 25 per cent increase). Company A decides to go all out and increase sales by 25 per cent, a real Herculean effort. It finds this an uphill task. Company B decides on a strategy of reducing its cost of materials by 5 per cent by the application of modern techniques of materials management (value analysis, negotiation, obtaining quantity discounts, vendor development, import substitution, make or buy, cost price analysis, etc.). Students will appreciate how company B can easily succeed if it went about this task in a scientific way, the company achieves the ₹ 2.5 lakh additional profit with the least effort and without any additional workforce in production, sales or elsewhere. One will appreciate that a reduction of 5 per cent of the cost of materials is equal to an increase of 25 per cent in sales. The third company C adopts both the strategies of companies A and B, an increase in sales and a reduction of the cost of materials. In companies like B and C, the materials management department is considered to be profit centre and not the traditional cost centre.

Functions of Materials Management

Materials Management as a company's supply system from the suppliers via all the stages adding value to the materials, right on to the customers, covers a broad spectrum of functions closely related to each other, regardless of whether or not they have been organisationally united in an equally comprehensive Materials Management organisation.

Even though a broad spectrum of function is listed here, one should not conclude from this that these functions have to be centralised in a Materials Management department under any circumstances whatsoever. The organisation of Materials Management is at all times dependent upon the circumstances in which an individual company finds itself. There is thus no universally valid patent formula to cover all circumstances and all companies.

Regardless of the organisational solution selected, the factual connections between the subfunction of the business supply system must be taken into account and resolved from a system view. This is ultimately the claim of Integrated Materials Management.

It is Integrated Materials Management's aim to achieve optimum supply by reconciling the conflicting goals of low materials cost and overhead, a high level of customer service and also a very low level of capital tied up in inventories by the use of EDP supported data systems and logistics/materials flow models, in close coordination with the other company function. It is the task here of the EDP supported data system and the logistics/materials flow models to resolve the interface problems between the individual functional elements of Materials Management.

"Planning and Control" Function

Planning and control give rise to purchasing, storing, allocating and disposal procedures within a company. In this respect we are dealing here with activities which control the flow of materials and goods. There are other activities to be found at the interface with marketing, design and development (and/or applied research) and production as well as with the suppliers (in the case of an extended production line) and these require the active cooperation of the departments within the company responsible for Materials Management.

Product requirement planning serves to ascertain the market requirement for the products to be sold. The product requirement plan indicates how much of which products a company is thinking of selling within a particular planning period. Materials Management has to ensure the appropriate availability.

It is already evident here that this is not only a pure marketing function with product requirement planning; the Materials Management function as supply system has to be involved just as much as the manufacturing function in producing a realistic product requirement plan, since only then can the appropriate customer service be guaranteed at the lower possible level of inventory investment.

Materials planing serves to ascertain the materials and parts by type and quality that are required for manufacturing a company's products.

Defining the materials and parts to be used a task for design and development alone. On the contrary, active cooperation is needed here too from Materials Management and in this case, specifically from purchasing, being responsible for providing materials which should be of a good a quality as is necessary and, at the same time as low in price as possible.

Production programme planning lays down the quantity and time schedule of the products to be produced within a given planning period. The production programme depends on the product requirement that has been prognosticated, the production capacities and the opportunities for procuring materials and parts from the outside the company. We are thus taking about a function right at the interface between sales, production and materials management, requiring the involvement of Materials

Management in every case. This is all the more important, the more the company is geared towards procurement from outside.

Materials requirements planning serves to break down a production programme into the materials and parts needed for it, by quantities and time schedules. Materials requirement planing in a modern industrial concern now-a-days has to cope with a large volume of data. As a rule this is only possible with the systematic use of EDP.

Materials requirement planing merges smoothly into materials scheduling as a further functional element of Materials Management. Materials scheduling is guided by production programme planning, materials requirement planning and capacity planning in production and serves to provide the production orders with the necessary materials. In details, the following tasks belong to materials scheduling:

1. Calculating net requirement given gross requirement;
2. Deciding about replenishment of inventories;
3. Aggregating demand according to lot size formulas of other processes and fixing quantities and schedule for the new production orders of purchasing orders;
4. Exploring the production requirement for the newly calculation production orders according to scheduling stages and fixing the availability of materials for capacity planing in production; and
5. Fixing delivery schedules, synchronising delivery cycles with suppliers and call-offs with suppliers.

Materials scheduling thus has interfaces both internally with the plants and externally with the suppliers.

It must, therefore, be viewed closely with production control and order control. Internally on the production plant, materials scheduling merges almost without any boundary line into materials control which, from an organisational standpoint, is a component of operations scheduling and production control but, functionally has to be assigned to Materials Management.

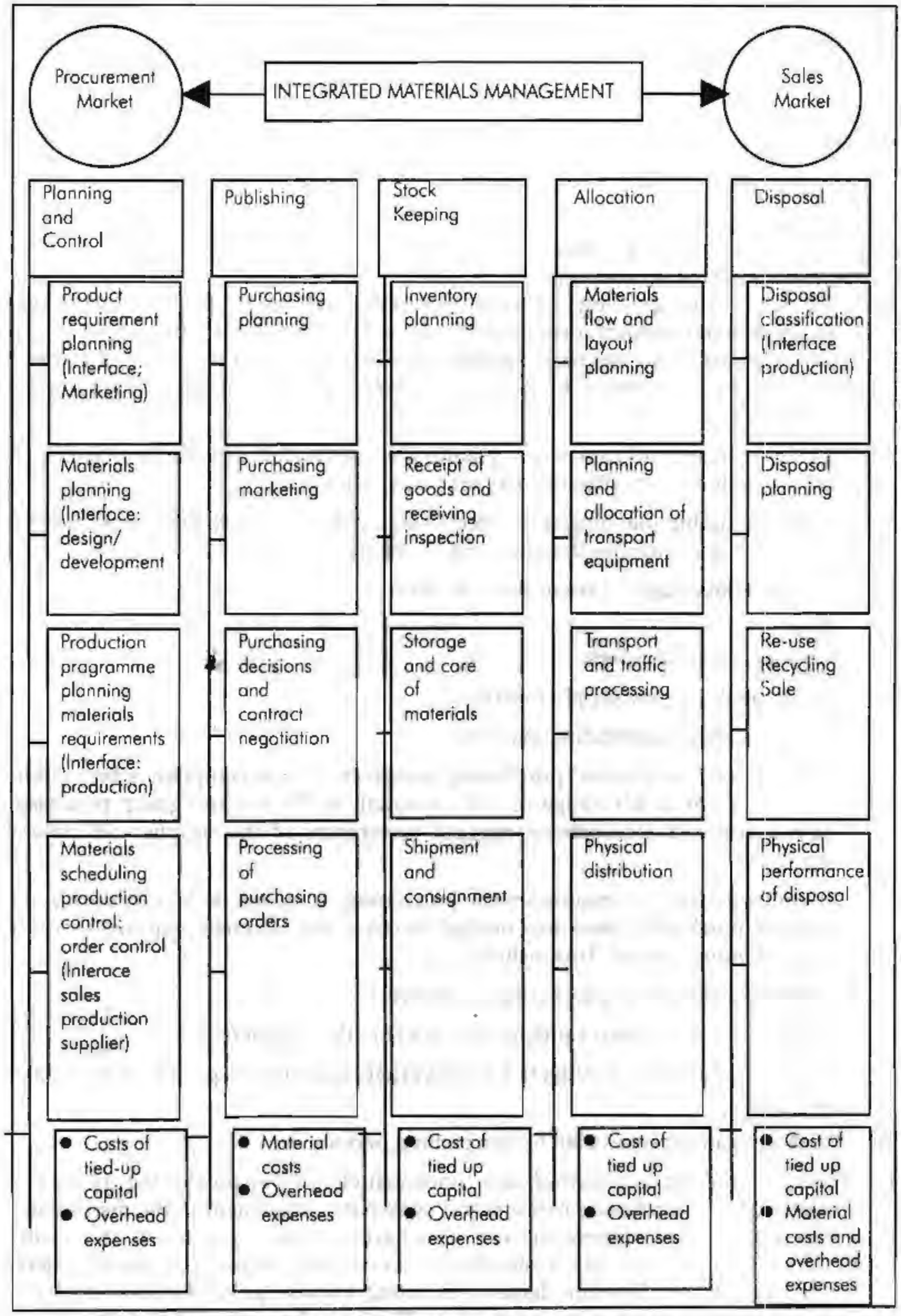
Materials scheduling is closely related to the administration of production purchasing – or customer orders. In conjunction with production control and order control, materials scheduling is, therefore, the central control function for the flow of materials and good within a company. Materials scheduling must therefore provide the essential contribution to the optimal fulfillment of the control functions named above.

Externally, towards the suppliers, materials scheduling merges into the suppliers production programme planing and production control. There are interfaces for which now-a-days, with the installation of a new data and communications technology (teleprocessing, systems network) new types of solutions exist and which call for good cooperation with the suppliers. Purchasing is once again called upon to find suitable suppliers and to negotiate the contractual agreements that are necessary for successful cooperation in partnership.

Thus, in conjunction with customer order control, materials scheduling is the fulcrum and pivotal point between the demands of manufacturing on the one hand and the suppliers' capabilities on the other. It makes use of opportunities for procurement from outside, which purchasing has opened up, for the purposes of efficient production and optimal customer service.

"Purchasing" Function

The purchasing function covers all those planing, scheduling, handling and controlling activities which are aimed at making available to a company, under the most economic conditions, all the goods, energies and services needed for the fulfillment of its functions, from out of the national and international supply markets.



The optimum between the conflicting goals of Materials Management (Low costs on materials, logistics and overheads, high level of service; low level of inventory investment and low inventory carrying costs) as well as the optimum between the competing goals of the classical departments within a company – above all production and sales – can be achieved only with a total Materials Management system fully integrated in the company's decision-making procedures.

Figure 14.3: Functional Elements of Integrated Materials Management and its Effect on Costs

The objectives of purchasing are raw materials, indirect and fuels, semi-finished and finished products, capital goods and energies as well as services such as cleaning and security, maintenance work and transport facilities. It is of no consequence here to purchasing's function and responsibility whether or not the requirement to be covered occurs in design and development, production, marketing or administration.

Briefly, everything for which an invoice is submitted should be designated as "Purchasing".

Purchasing can these days no longer be understood to be a pure service function covering precisely specified materials requirements at the lowest possible prices. On the contrary, purchasing now-a-days has to be understood as a business function, taking into consideration its growing influence on profits, and one which ensures the full exploitation of market opportunities in technical and cost terms. With the proportion of materials costs further increasing as against manufacturing cost, purchasing ultimately secure manufacturing the room for play in its calculations which it needs in order to be competitive.

The functional element of purchasing planning is subdivided into the long-term and the short- to medium-term planning of purchasing activities.

Long-term purchasing planning is devoted to laying down a company's procurement policy. In detail, thus includes the following decisions.

1. The most important "Make or Buy" decision, which bind the company in the long run;
2. Supplier policy decisions;
3. Decisions about new supply markets;
4. Decisions about substituting materials;
5. Decisions on "qualitative" purchasing principles, such as competitive behaviour, not taking unfair advantage of one's strength in the market, group purchase, cooperation and countertrade regional preferences of the suppliers of certain origin, etc.
6. In contrast, short of medium-term purchasing, planning serves to decide on concrete purchasing measures needed to cover the materials requirement of a given planning period. This includes, e.g.
7. Planning cost optimal purchasing quantities;
8. Planning the allocation of purchasing orders to the suppliers;
9. Producing purchasing budgets for individuals materials or groups of materials; and
10. Producing an expenses plan for the planing period.

Purchasing marketing as a further new functional element of purchasing means the active formation of purchasing markets and systematic adjustment to the present and the future peculiarities of these markets. Purchasing marketing converts the results of the procurement policy into a set of incentives to and demand on the suppliers. Purchasing marketing therefore demands a sound knowledge of the state of affairs and developments in the purchasing markets. This knowledge about products, prices, suppliers, markets, etc. Has to be gained and refined via purchasing market research. Purchasing marketing is more than just bringing down the suppliers prices from a powerful position. On the contrary, it is concerned with creating incentives for the suppliers, such as, for instance, assistance in production and sales or research and development, which makes is very interesting for them to accept the demand from the inquiring company, for supply cycles, guarantee and price arrangements. Thus purchasing marketing aims at a fair partnership with the suppliers, in which both give as well as take.

Purchasing decisions and the negotiation of contracts have at all times been central function of purchasing. Numbered amongst these are, individually:

1. Carrying out inquiries and obtaining offers;
2. Selecting and evaluating suppliers with regard to price, quality reliability delivery time;
3. Carrying out purchasing negotiations;
4. Assuming legal and financial obligations towards the suppliers according to the criteria of quantity, price, time scale, data, quality, guarantees and delivery conditions; and
5. Placing orders with the suppliers.

The clerical activities involved in purchasing are closely connected with scheduling and cover the following activities.

1. Writing out and dispatching orders;
2. Transmitting call-offs to suppliers, possibly using paperless communication;
3. Checking order confirmations;
4. Follow-up of orders; and
5. monitoring contract fulfillment.

"Stock-keeping" Function

The stock-keeping function covers all the activities of carrying inventories of the goods (materials, semi-finished and finished products) handled by a company, ensuring optimal supply and customer service. This function has a decisive influence on the level of capital tied up in inventories which is thus withheld from any other possible profitable uses.

The stock-keeping is inventory planning. It is a component of a company's planning of customer service and production responsiveness.

The following tasks are parts of the stock-keeping function.

1. Planning the materials and parts to be stored;
2. Planning inventory quota (ratio of stocks to turnover);
3. Planning the stock coverage times A, B and C materials;
4. Planning inventory turns;
5. Planning safety stocks; and
6. Planning maximum and minimum inventory levels for the different warehouses.

Receiving and inspection of incoming goods cover all the operational activities of taking receipt of, testing and putting into storage deliveries of materials and goods from the suppliers, along with advising colleagues in sales, scheduling and the warehouse as well as, if need be, the consumer requiring them about the arrival of the materials of goods. Inspection included quantity and quality supervision.

Maintenance of warehouses and materials covers:

(a) Warehouse administration with updating of stock status;

(b) Performing of all of the physical and administrative warehouse movements and their supervision;

(c) Maintaining the values of goods in storage by means of preservation; and

(d) Shipment and consignment include:

- Carrying out removals from the warehouse;

- Preparing the relevant papers; and
- Assembling the materials of goods according to requests or customer orders, ready for releasing to the in-house user or dispatching to the customer.

"Allocation" Function

The "allocation" function covers a company's handling and transport activities for materials and goods.

1. From the suppliers to the company;
2. From warehouse to production;
3. Between the company's different plants; and
4. From the company into the sales market, either directly to the customer or to the point where the company's sales organisation or sales subsidiaries take charge of them.

The above handling and transport tasks have to e carried out at the lowest possible costs (logistics costs in their strictest sense) and aiming at having the lowest possible level of materials and goods held in stock. In determining the costs one has to take into account the costs for the transport itself and the cost of capital that is tied up during transport as well as packaging costs. According to one well-known rule of thumb: low transport costs; long transit time, high level of capital tied up (e.g., in sea freight) or, high transport costs; short transit time, low level of capital tied up.

In details, the following tasks are included under the allocation functions:

1. Planning the flowing of materials and layout, in which the Materials Management department should be involved;
2. Further transport planing tasks, such as planing transport and conveying equipment, planning the use of the means of transport available, choosing between different modes of transport (road, rail, sea, air) and choosing between works traffic or carriers, etc.;
3. Ensuring the functioning of the transport and carrying facilities;
4. Carrying out transport and traffic processing with carriers and authorities, including questions of custom clearance, etc.; and
5. Delivering materials and goods on time to the customer including packing and also loading and unloading the means of transport.

"Disposal" Function

The "disposal" function covers planning and operational activities for making use of removal of waste and surplus materials, harmful substances and materials and equipment that are not needed, along with obsolete spare and reserve parts. In details, this includes the following activities:

1. Disposal classification according to whether some thing can be re-used, any hazard it represents and the possibility of environmental pollution. The assignment of responsibility for carrying out the disposal depends upon the result of this classification. As a result of legal requirements, technical conditions, the hazard represented by some waste products and increased awareness of the environment amongst the public, this task might have to be allocated to a special location (department) within the company and only part of the responsibility resting with Materials Management.
2. Disposal planning decides which form of disposal should be used and takes into consideration the alternatives of reuse, recycling with the aim of appropriate reprocessing, selling or disposal.

3. Recording, collecting, converting, selecting, processing, regenerating, destruction, realisation and selling of the goods to be disposed of.
4. Physical performance of disposal by recycling reusable materials into the production process, transporting away goods that are no longer needed, removing unusable materials and harmful substance in accordance with legal and official instructions and technical conditions and scrapping of obsolete equipment and square as well as reserve parts.

Originally disposals was a scarcely recognised incidental task. During the last few years it has substantially gained in importance, thought, partly as a results of increased public awareness of the environment and more stringent legislation but also due to better recognition of the opportunities it offers for returns.

Depending on the branch of industry involved, the "disposal" function is to a varying extent capable of influencing the level of materials costs and overhead expenses on the one hand and the level of capital tied up in obsolete materials in stock, in worn out equipment and in spares and reserves that can no longer be used, on the other. It can be altogether cheaper for a company to dispose of equipment, spares and reserves that are no longer needed instead of keeping them and hence continuing to make allowance for their maintenance care and insurance costs.

Interdependencies between Materials Management and other Allied Functions

Materials Management as a company's supply system has manifold interdependencies with its neighbour function and is thus of great importance in industrial management. It must therefore be the business maxim of Materials Management to make as optimum contribution of the company's profits by goods cooperation with its neighbouring departments. Costs for materials and overheads can be effectively reduced just as much inventories by means of cooperation and sufficiently intensive communication. Only in this way can the interface problems between Materials Management and its neighbour functions be solved, which exist in a company regardless of how responsibilities are divided up. This of course pre-supposes a climate of mutual trust, understanding, recognition of the achievements of the other functions and also consensus as to common goals instead of departmental egoism.

Materials Management and Design/Development

Good cooperation is absolutely necessary between Materials Management and design development in the interest of advantageous materials costs and low level of capital being tied up in inventories. Measures taken by design and development determine the structure of a company's materials and parts requirements and hence materials and parts requirements and hence material costs as well to a quite considerable extent. Cooperation between Materials Management and design/development is therefore necessary in several respect:

- To coordinate product development and supply;
- In alteration service;
- In buying new assembly parts;
- In carrying out value analysis;
- In the setting of norms, standardisation and analysis of the materials and part purchases;
- In quality control;
- In determining component parts to be used;
- In formulating enquiries to suppliers;

- In making or buying decisions; and
- In updating the bills of materials.

Materials Management and Production

The task of Materials Management and production are closely related. Derived from marketing, it is in production where materials requirements originate and it is up to Materials Management to cover the requirements.

The two functions overlap within the spheres of scheduling, production programme planning and production control i.e. in those sub-functions which are also assigned in different ways organisationally within the company to Materials Management and production.

Close cooperation is required above all in:

- Planing production and materials requirements;
- Coordinating production control and materials scheduling;
- Solving bottleneck problems by subcontracting measures; and
- Deciding about call-off inventories to be held by suppliers and consignment inventories kept in-house.

By means of effective cooperation between Materials Management and production, one can succeed in reducing the level of capital tied up in inventories as well as reducing materials costs. This sort of cooperation is an imperative prerequisite for total control of the flow of materials from the suppliers to the user within the company and via the processing points in production to the users within allocation for marketing and thus for fast order processing.

Materials Management and Sales

Integrated Materials Management is not least of all a supply system for sales. It is oriented towards fulfilling the customer orders obtained by the sales department, at the lowest possible cost. If one regards Materials Management in this light, then it in fact exhibits manifold connections with sales which necessitate close cooperation here as well, indeed in several respects:

- In deciding on customer service towards the market;
- In formulating the sales plan and pursuing fulfillment of the plan;
- In deciding about transport facilities and also transport and traffic processing;
- In the administration of customer orders which must be linked with Materials Management; and
- In deciding about commissioning, packaging and dispatching to the customers.

Effective cooperation between Materials Management and sales is a prerequisite on the one hand for the lowest possible level of capital tied up in stock, and on the other hand, for high customer services in the face of a now-a-days volatile market demand and for flexibility in supplying customers. Examples from practical experience show that close cooperation between sales and Materials Management and the latter being geared towards the company's marketing strategy can provide a company with important competitive advantages.

Materials Management, Finance and Accounting

Connections between Materials Management and the finance and accounting departments arise as a result of the fact that Materials Management is mostly responsible for the greatest bulk of costs within a company and has a considerable influence on the level of its current assets. From this importance of Materials Management to the company profitability and liquidity and hence to the key factors of finance and accounting, comes the necessity for coordination with both departments. In details, this involves:

- Planning justifiable levels of inventory investments for the purpose of annual budgeting;
- Controlling inventory status during the course of the years;
- Implementing inventory reduction projects;
- Carrying out analysis for Make or Buy decisions;
- Deciding on investments in transport and storage facilities;
- Implementing plans for the reduction of overhead expenses;
- Routine coordination between invoice checking and credit control; and
- Exchanging information and data for the purpose of planning and control.

Integrated Materials Management Function

The considerable influence that a comprehensive Materials Management has on profits calls for total control on the flow of materials and goods from the suppliers to the company, via the processing stages within the company through to handing over finished goods to the consumers. Integrated Materials Management can do justice to this demand.

Integrated Materials Management is a cross-sectional function within the company, penetrating mere functional thinking in purchasing, production, sales and design/ development and overlaying it with resource oriented thinking. Its main objective is to make a substantial contribution to profit by optimising the procurement, the management and the allocation of materials as a productive resource.

As far as that goes, with regard to its range of tasks, Integrated Materials Management is compatible with two other cross-sectionals functions which have already been established within the company for a long time, namely, finance and personnel management, administration and allocation of the resources capital and personnel.

Integrated Materials Management is on par with finance and personnel Management and is a partner to production, sales, and design/development in all spheres of materials supply. It must constantly cooperate effectively with these in the manner prescribed above.

Advantage of Integrated Materials Management Concept

Organisations with integrated materials Management enjoy the following advantages:

(i) ***Better Accountability:*** A centralised authority and responsibility establish a clear cut accountability. Various department can direct their problems to one control point so that action can be taken immediately. The creates an atmosphere of trust and allows management to work in an objectives manner.

(ii) ***Better Coordination:*** Centralisation of control of activities ensure better support and cooperation in the accomplishment of the materials function. This creates an atmosphere of trust and better relations between the user departments and the materials management department.

(iii) ***Better Performance:*** Integrated approach ensures greater speed and accuracy results in communication. Need for materials is promptly brought to notice by materials planning purchase department, is fed with stock levels and order status by stores and inventory control department.

(iv) ***Adaptability to Electronic Data Processing:*** The centralisation of the materials function makes it possible to design data processing systems. Even advanced and efficient electronic data processing systems can be economically introduced under an integrated set-up.

(v) ***Other Advantages:*** Under the system a team spirit is inculcated resulting in better morale and cooperation. This ensures better opportunities for growth and development.

Integrated Materials Management Organisation

Integrated Materials Management is responsible for the entire flow of materials ad goods from the suppliers right through the company to the consumers in the sales market. It covers a correspondingly large range of functions.

This modern organisation's materials management is subdivided for example into three areas:

(i) Purchasing and vendor development,

(ii) Planning, scheduling and control, and

(iii) Order processing, storage, and inplant distribution.

Figure 14.4 illustrates an example of Integrated Materials Management organisation.

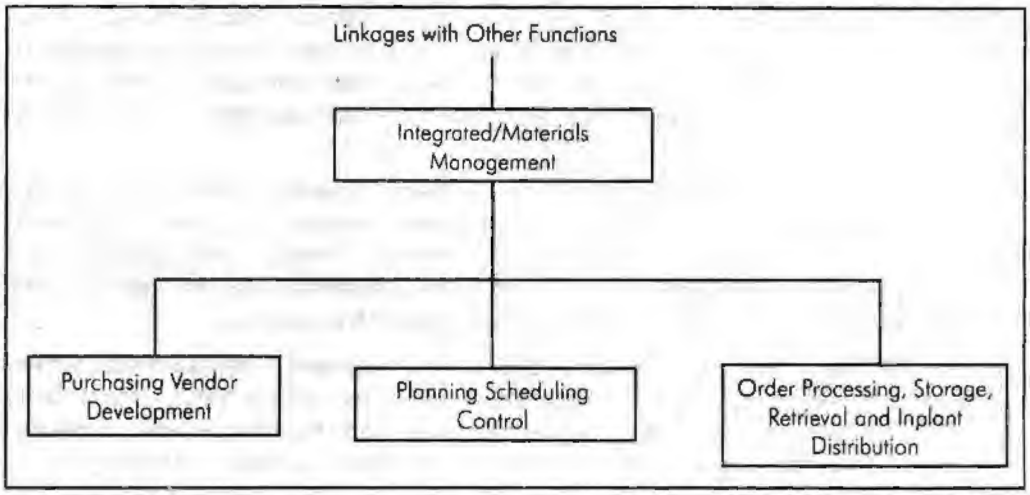


Figure 14.4: Organisation of Integrated Materials Management

An Integrated Materials Management organisation of this type is characterised by:

(i) A good balance between market-oriented purchasing logistics planning and control function as well as operational functions such as storage, transport, distributions and order processing.

(ii) Good opportunities for smooth synchronisation between the influx of order and materials supply.

(iii) Favourable pre-conditions for balancing sales market requirements, production and procurement capacities.

(iv) Comprehensive planing and control of the flow of materials and goods via all the stages of the supply system.

(v) Clear responsibility for materials costs and capital tied up in inventories of purchased material, semi-finished products and finished products.

(vi) Clear responsibility for customer service vis á vis the sales market, total responsibility for the overhead expenses for all Materials Management functions.

Integrated Materials Management is a modern type of organisation which offers Materials Management extensive opportunities to provide its essential contribution to the company's profit. Its effect can only be fully developmental if it can fall back upon both technically and commercially experienced personnel, on the one hand, on integrated EDP supported planing, control and processing systems, on the other.

Prerequisites for Integrated Materials Management

The successful realisation of Integrated of Integrated Materials Management is not least a question of personnel, organisation appropriate introduction.

(i) *Personnel Requirements:* The materials manager required for the purpose of Integrated Materials Management must posses both high personal and high professional qualities.

Of particular not amongst the personal qualities are the following:

- Leadership qualities,
- Integrity,
- Flexibility and initiative,
- Negotiating skills, and
- Readiness to make contacts and make decisions.

The most important professional qualities are:

- Business management expertise,
- Familiarity with the materials and goods and knowledge of technical production processes,
- Familiarity with supply markets and suppliers,
- Legal knowledge,
- Knowledge of the possibilities for applying EDP and also the potential of modern information technology,
- Knowledge of modern transport methods,
- Knowledge of materials flow technology,
- Familiarity with regulations and possibilities for disposal,

(ii) *Organisational Requirements:* Implementation of the concept of Integrated Materials Management has the following organisational requirements.

- Organisational concentration of the separate functions of Materials Management,
- linking Materials Management with its neighbour functions, and
- Exploiting the potential of modern information technology and the available software.

(iii) *Implementation Process:* Integrated Materials Management can only be implemented in several steps requiring persuasion processes. It must have as its starting point directive from top management which must support the project in all of its phases.

Parallel with the step-by-step introduction of this concept, the systematic personal development of employees in planning and control, purchasing, scheduling and warehousing is required, preparing them for new and demanding tasks. Both in-company and external training and further development facilities should be used to this end.

A System Approach

What we mean by a systems approach is to take an overall integrated view of the total system instead of looking at each function as a compartmentalised of autonomous entity. In a company there is always a tendency to consider one's Department as independent without hardly realising, far less appreciating, the effect of one's decisions on other departments or on the overall functioning of the company.

Take inventories as an example. There are several types of the inventories lying in several parts of the company—raw materials, spares, WIP, finished goods, scrap and so on. Each Department looks at inventories in a different way. The Production Department is not accountable for inventories as it concerns itself with production costs and wants maximum possible stocks so that production does not stop. So is sales who like to have variety of products in stock for possible customers. The Accounts Department looks at inventories as working capital but in most cases is unable to convince either sales or production to reduce them. Maintenance Department similarly is concerned about breakdowns and readily available spares, rather than inventories. When we speak of an integrated system, each realises the significance of the problem of inventories and its overall role in the company's working, plus the kind of linkage that exists between one department and another. For example, Production Department assumes the Materials Department will not be able to procure materials in an emergency so excess materials should be stocked. If each understood each other, this kind of wrong belief might not have existed.

Take again the problem of physical distribution and materials handling.

There is a strong relationship between physical distribution and packaging, different type of transportation, speed of transport, transit inventory, insurance and a host of other cost. When we talk of transportation, therefore, we should not just think of moving goods by road rail or sea but we should consider the transportation as a part of a total system where so many other factors are involved.

The same case applies to materials management. It is total system consisting of several subsystems – designing, purchasing, storage, inventory control, standardisation, quality specifications, production, physical distribution, packaging, insurance and a host of other factors. It is necessary for us to take an overall or system view rather than think of production or inventory control of purchasing, etc., in isolation. This is what is known as the systems approach.

Overall Responsibility of Materials Department

The overall responsibility of the Materials Department in regard to the materials function is twofold:

(i) As a coordinating agency, to make every department conscious of the needs for materials management and coordinate the effort of the each department to achieve the optimum overall efficiency and effectiveness in respect of the materials function.

(ii) To provide know-how in regard to Materials costs to various department so that the maximum results can be obtained.

The second functions is easily understood. The first function is rather difficult and has to be handled with care. The main reason is that each department has a big sense of pride and does not usually appreciate others "interfering" in their affairs. For example, it will take a lot of convincing to make Sales Department realise that it has several lakhs of excess, surplus and obsolete inventories in their depots even if the fact glares on in the face. The Production Manager will not easily accept the "excessive cost" of materials handling nor will the Distribution Manager accept the view that the distribution costs can be reduce to half. If a materials manager is to achieve results he should be first class Public Relations man and have an infinite capacity for convincing and influencing his colleagues. Actually the convincing should start at the Top Management level. The Chief Executive should be convinced first—the rest may not pose much difficulties.

Student Activity

Fill in the blanks:

1. Materials management is a specialised area of ....
2. "The Materials Management is a total concept involving ....
3. Areas of materials management can be described as ....
4. Materials Management determines ....

Summary

Materials management is a specialised area of management which concerns itself with the management of Material Resources. The objectives of Materials Management is to contribute to increased profitability by coordinated achievement of least materials cost. This is done through optimising capital investment, capacity and personnel, consistent with the appropriate customer service level."

Materials Management as a company's supply system from the suppliers via all the stages adding value to the materials, right on to the customers, covers a broad spectrum of functions closely related to each other, regardless of whether or not they have been organisationally united in an equally comprehensive Materials Management organisation.

Keywords

Materials management: Materials management is a specialised area of management which concerns itself with the management of Material Resources.

Materials Costs: These are those costs which arise for the procurement of raw materials, indirect materials, fuels, semi-finished and finished products (goods), including delivery costs.

Capital Costs: These cover primarily interest which accrues for the capital tied up in the stocks of materials, semi-finished and finished products (good), including depreciation for value adjustments which have to made.

Overhead Expenses: They cover the overhead expenses and/or cost centre expenses of all the separate areas within Materials Management, including the sometimes considerable costs of transport and packaging, electronic data processing and disposal.

Review Questions

1. Explain the meaning and objectives of Materials Management and also explain its importance and functions.
2. Describe the "Integrated concept of Materials Management" and state how it is important in managing a big manufacturing company.
3. What do you understand by "A System Approach" to materials management? Give illustrative examples.
4. Write short notes: (a) Materials Management as a profit centre, (b) Scope of Materials Management.
5. State overall responsibility of Materials Department.

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see*, Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management*, John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage*, Tata McGraw Hill, Delhi, 2004.

Krajewski and Ritzman, *Operations Management, Strategy and Analysis*, Pearson Education, 2002.

Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach*, McGraw Hill, 1996.

Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies*, John Wiley & Sons, 2004.

Unit 15 Inventory Control

Unit Structure

- Introduction
- Inventory Defined
- Characteristics of Inventory
- Inventory Control Fundamentals
- Basic Concepts of Inventory Related Costs
- Perpetual Inventory System
- Economic Order Quantity
- Selective Inventory Control
- Summary
- Keywords
- Review Questions
- Further Readings

Learning Objectives

At the conclusion of this unit, you should be able to understand:

- Inventory Control Fundamentals
- Basic Concepts of Inventory Related Costs
- Economic Order Quantity
- Selective Inventory Control

Introduction

Recent industry reports show that inventory costs as a per cent of total logistics costs are increasing. Despite this rise, many organizations have not taken full advantage of ways to lower inventory costs. There are a number of proven strategies that will provide payoff in the inventory area, both in customer service and in financial terms.

Some of these strategies involve having fewer inventories while others involve owning less of the inventory. ERP and information technology solutions have been able to provide solutions, not only for inventory management but also for aggregate planning, material requirement planning and operations scheduling.

Regardless of which technique or solution one employs, proactive inventory management practices make a measurable difference in operations. In this supplement, we will cover some of the important inventory models and their characteristics, which are used in many of these ERP solutions.

Inventory Defined

Inventory is the physical stock of items that a business or production organisation keeps in hand for efficient running of affairs of its production. Inventories consist of raw materials. Component parts supplies and finished assemblies which an organisation purchases from an outside source and parts, assemblies and finished products which the company manufactures itself. In simple words inventory means 'stock items' or 'items in stock'.

Characteristics of Inventory

The concept of inventory and its relation with performance of any system can be explained by the following statements:

(i) ***Inventories serve as cushions to absorb shocks:*** An organisation has to deal with several customers and vendors who are not necessarily close to their works. But due to their unpredictable behaviour there are always fluctuations in demand or supply of the items which disturbs the schedule of an organisation. Inventories absorb these fluctuations and help in maintaining undisturbed production and stable employment rates, i.e., we decouple the manufacturing operation from the customer and the vendor successfully by cushions of stocks.

(ii) ***Inventory for any organisation is a necessary evil:*** Inventories require valuable space and consume taxation and insurance charges. This leads to considerable investment and causes considerable opportunity loss. This capital invested in inventories remains idle till items present in stocks are not used. On the other hand, no organisation can work without maintaining some inventory, i.e., it is a necessity. It is observed that costs of not having inventories are usually greater than the costs of having them. Thus inventories are necessary evil.

(iii) ***Inventories are the result of many interrelated decisions and policies within an organisation:*** The behaviour of inventories is the direct result of diverse policies and decisions within a company. Marketing, production, finance and purchasing decisions directly influence the level of inventory.

(iv) ***Inventory provides production economies:*** Stocks bring economy in purchase of various inputs due to discounts on bulk purchase. This also minimises ordering, transportation and other costs. They also reduce the number or set-ups.

Types of Inventories

The various types of inventories for a manufacturing organisation are classified as under:

(i) ***Raw Materials and Supplies Inventories:*** These consist of raw materials, parts, sub-assemblies and supplies which the company purchases from outside sources, namely suppliers-dealers or manufacturers. These items are to be purchased and kept in stock before and during production of goods.

(ii) ***Production Inventories:*** Raw materials, parts and components which become part of the product during the production process are called production inventories. These may consist of:

(a) Raw materials or other items purchased from outside;

(b) Non-standard purchased items or supplies; and

(c) Special items manufactured in the factory itself.

(iii) ***M.R.O. Inventories:*** Maintenance, repair and operation supplies or in short M.R.O. inventories. Which are assumed in the production process but do not become part of the product, for example, oil, spare parts, etc.

(iv) ***In Process Inventories:*** These are processed or semi-finished products, manufactured at various stages during the production cycle (process). In bicycle factory frames, pedals, rims, axles, etc. These are also called in-process inventories or work-in-progress inventories.

(v) ***Finished Product Inventories:*** Finished goods or stocks are completed products ready to be sent away to the market or customers. These products have been fabricated or manufactured or assembled from production and in-process inventories, i.e., a complete bicycle in case of a cycle manufacturing factory or a car in case of a car manufacturing factory.

(vi) ***Material in Transit inventories:*** These are raw material and supplies inventories which are in transit and have already been received at the factory.

(vii) ***Dealers Stock:*** In case a company owns a showroom or distribution centre, inventories of finished goods or products kept there have also to be considered.

(viii) ***Total Inventories:*** Total inventories of an organisation should consist of all the above categories of inventories as capital is locked up in these.

Functions of Inventory

Inventories are essential for keeping the production wheels moving. Inventories keep the market going and distribution system intact. They serve as lubrication and spring for production-distribution system.

The following are the important functions of inventories:

(i) Inventories gear up production.

(ii) Inventories force consumption to adopt itself to the necessities of production.

(iii) Inventories activise the market.

(iv) Inventories provide a cushion to prevent stockouts.

(v) Inventories help in stabilising employment in the enterprise.

(vi) Inventories help in utilising the existing skilled labour and help in making a utilisation plan for future.

(vii) Inventories strike a balance between the objectives of the stores department and those of the enterprise as a whole.

(viii) Inventories help in avoiding unnecessary wastage and blocking up of valuable working capital.

(ix) Inventories act as an insurance against errors in demand forecasts.

(x) A well planned inventory scheme helps in efficient, smooth and effective service to customers at a lesser cost with the help of lower investment through planned but reduced inventories.

Difference between Inventory and Stores

In simple words inventory means stock items. However, the two words inventories and stores should not be confused. Where as stores means all those articles (materials, supplies and products) which are kept in a store. Inventory comprises stores as well as materials in transit, materials in process (i.e., semi-finished and finished parts), finished products, stock and stock laying at company's showrooms and distribution centres which have not been sold out.

In spite of these differences it may not be surprising to discover that the terms inventory and stores are being used interchangeably.

Advantages of Inventory

In a large manufacturing concern it is always advantageous to order some type of raw materials and purchase parts in advance and hold them in stock to be used when required to meet the customer's orders. The main advantages of purchasing materials well in advance are the following:

(i) Sometimes in competition with other manufacturers, delivery requirements (dates) are very tight and if orders for raw materials or parts are placed after receiving customer's orders it may not be possible to meet the demand and the required delivery date. It is, therefore, advantageous to hold inventories.

(ii) Buying and producing material in large quantities is profitable as discounts and concessions are available on a large quantity purchases. There is reduced cost per item of selling up machines and plant. There is also reduced clerical work and cost for placing orders less frequently.

(iii) A good industry keeps a ready stock of its product for immediate sale. Inventory of raw materials and parts helps to replace these products faster once they are sold and disposed of.

(iv) There can be difficulties in procurement of raw materials and parts due to unexpected strikes, shortages, power breakdowns or periods of high demands in relation to supply. In this case, inventories may come to rescue.

(v) Building up a big inventory will be profitable as later on there may be a rise in prices of various items due to various reasons.

(vi) More products can be manufactured rapidly when raw material or parts are held in stock.

(vii) Inventories reduce the risk of closing down the plant or keeping workers and machines idle.

Disadvantages of Large Inventories

(i) Working capital is tied up with excess inventories. Interest has to be paid on capital. This increases the cost of production. At the same time there is less available cash for income producing investment.

(ii) They occupy valuable space and may require added storage space for which rent has to be paid.

(iii) Bigger the inventories more the insurance charges to be paid for their security.

(iv) There will be an increased cost of handling stores and maintaining their record.

(v) Inventories or 'goods in stock' are subject to damage, deterioration and spoilage with passage of time. With change in design or availability of better type of material, long lying inventories may be considerable.

(vi) There is greater risk of loss due to devaluation through changes in price of manufacturing cost. Therefore, it is important that strict control be exercised over the inventory so that cost of purchasing and storing are lowest possible, while at the same time material is available as and when required.

Inventory Control Fundamentals

Definition

Inventory control is a system which ensures the provision of the required quantity of inventories of required quality at the required time with the minimum amount of capital investment. Thus the function of inventory control is to obtain the maximum inventory turnover with sufficient stock to meet all requirements.

In the words of John L. Burbridge, "Inventory control is concerned with the control of the quantities and/or monetary values of these items at predetermined level or within safe limits."

Scope of Inventory Control

The inventory control management includes the following aspects:

(i) Size of inventory—determining maximum and minimum levels, establishing time schedules, procedures and lot of sizes for new orders ascertaining minimum safety levels, coordinating sales, production and inventory policies.

(ii) Providing proper storage facilities arranging the receipts, disbursements and procurement of materials, developing the forms of recording these transactions.

(iii) Assigning responsibilities for carrying out inventory control functions.

(iv) Providing for the reports necessary for supervising the overall activity.

Objectives and Importance of Inventory Management

Inventory control now-a-days has become unavoidable in any manufacturing process. The basic managerial objectives of inventory control are twofold: (i) to avoid over and under investment in inventories; and (ii) to provide the right quality in the goods of right quantity at the proper time and at reasonable price. The objectives and importance of inventory control may be discussed as follows:

(i) ***Availability of materials:*** The first and foremost objective of inventory control management is to make all types of materials available at all times whenever it is required by the production department.

(ii) ***Minimising the wastage:*** Inventory control aims at minimising the wastage of inventory at all levels, i.e., during its storage in godown or at work in the factory. Normal wastage or uncontrollable wastage should strictly be controlled. Wastage of materials by leakage, theft, embezzlement and spoilage due to dust, rust or dirt should be avoided.

(iii) ***Better services to customers:*** In order to meet the demand of quality goods, it is the responsibility of the concern to produce sufficient stock of finished goods at proper time to execute the orders of customers. It means a flow of production should be kept on.

(iv) ***Promotion of manufacturing efficiency:*** Inventory control promotes the manufacturing efficiency of the enterprise by providing right type of materials production because it will improve the morale of workers.

(v) ***Control of production level:*** Proper inventory control helps in creating and maintaining buffer stock of raw materials to meet any eventuality in difficult times. Production variations can also be avoided through proper control of inventories.

(vi) ***Optimum level of inventories:*** The management can procure the inventory in time in order to run the plan efficiently if regular and prompt information about the availability of materials is provided to it. It, thus, helps the management in maintaining the inventory at optimum level keeping in view operational requirements. It also avoids the out of stock danger.

(vii) ***Economy in purchasing:*** A proper inventory control brings several advantages and economies in purchasing. Management makes every attempt to purchase the inventories in bulk and to take the advantages of favourable market conditions.

(viii) ***Optimum investment and efficient use of capital:*** From financial point of view, the prime objective of inventory control is to have an optimum level of investment in inventories. There should neither be any deficiency of stock which may obstruct the production flow nor should there be any excessive investment in inventories so that it may block the funds of the concern that may otherwise be utilised fruitfully in other activities. So the management must control the quantum of inventories by fixing the minimum and maximum levels and to avoid the deficiency or surplus stock positions.

Essentials of a Good Inventory Control System

For an efficient and successful inventory control system, the following elements or essentials are necessary:

(i) ***Classification and identification of inventories:*** The inventory includes stock of raw materials, semi-finished goods, finished goods and components, etc., of several description. In order to facilitate prompt recording, locating and dealing each item of inventory should be assigned a particular code for proper identification and then must be divided or subdivided in groups on any basis (location, nature of item, plant, etc.) feasible. Specific efforts should be made to establish an effective control of high value items. ABC analysis is very much helpful in this regard.

(ii) ***Standardisation and simplification of inventories:*** For proper inventory control standardisation of materials and products as well as simplification of the production line is necessary. Standardisation refers to limiting of a production line to definite types, sizes and characteristics which are considered to be standard by which a comparison on evaluation can be made. Specification for components should also be fixed. It will ensure the quality of products manufactured. Simplification of inventories refers to the elimination of excess types and sizes of items. It leads to reduction in inventories and carrying cost.

(iii) ***Adequate storage facilities:*** Adequate and well organised warehouse facilities with well-equipped proper handling must be there. It need not necessarily be elaborate and expensive. Such facilities will reduce the wastages due to leakage, wear and tear, rust and dust and mishandling of materials.

(iv) ***Setting different levels and re-order points:*** Just to avoid the chances of over and under investment as well as running short of an item during the course of production, minimum and maximum limits for each item of inventory should be fixed. While fixing the minimum and maximum levels, reorder point should also be fixed in advance.

(v) ***Fixing economic reorder quantity:*** It is also a basic inventory problem to determine as to how much quantity of a particular item should be ordered at a time considering various costs. In determining the economic order quantity (EOQ) the two opposing costs, ordering cost and carrying cost should be balanced.

(vi) ***Adequate inventory records and reports:*** An efficient inventory control necessitates maintenance of proper inventory records because various inventory records contain information to meet the needs of purchasing, production, sales and financial staff. Any typical information regarding any particular item of inventory may be had at hand from such records. Such information may be about quantity in hand or in transit or on plants, location, unit cost, EOW, re-ordering points, safety level, etc., for each item of inventory. Statements, forms, reports, etc., should be designed in such a way that the clerical cost of maintaining these records must be kept at a minimum.

(vii) ***Experienced personnel:*** The last but not the least important requirement of a successful inventory control system is the appointment of intelligent and experienced personnel in purchasing, production and sales department. Mere maintenance or records and procedures would not give the desired results because there is no substitute for efficient, sincere and honest personnel. Hence the whole inventory control structure should be manned with trained, qualified, experienced and devoted employees.

Factors Affecting Inventory Control Policy

The inventory policy of an organisation has an impact on the whole system. There are a number of factors which can affect the inventory decisions. These can be broadly divided into the following categories:

(a) *Characteristics of the Manufacturing System:* The nature of the production process, the product design, production planning and plant layout have significant effect on inventory policy. Some of these factors are:

   (i) *Degree of Specialisation and Differentiation of the Product at Various Stages:* The degree of change in the nature of the product from raw material to final product at various stages of transformation, viz., final assembly and packaging determines the nature of inventory control operation, e.g., if nature of product remains more or less same at various stages of production then economies can be achieved by keeping the right balance of stock of semi-finished product.

(ii) *Process Capability and Flexibility:* Process capability is characterised by processing time of various operations, e.g., the replenishment lead time (length of delay in execution after issuance of a replenishment order) directly influences the size of inventory.

Similarly how rapidly and economically a system can adjust its production rate, shift product facilities from one operation to another determines the magnitude of flexibility. Inventory policy should aim towards balancing the production flexibility, capability, inventory levels and customer service needs.

(iii) *Production Capacity and Storage Facility:* The capacity of production system as well as the nature of storage facilities considerably affects the inventory policy of an organisation, e.g., capacity for heating oil production in an oil refinery is governed in part by its through-put capacity and in part by its distribution system. Similarly if for any product the cost of storage facility is high then it sets a limit on the storage capacity.

(iv) Quality requirements, shelf-life and obsolescence risks.

(v) *The Nature of the Production System:* It is characterised by the number of manufacturing stages and the interrelationship between various production operations, e.g., in product-line system inventory control is simpler than in Job-type system. Similarly when there are many operational stages then the inventory control system must provide smooth adjustment of early operating stages and inventories to fluctuations in finished stock.

(b) ***Amount of Protection against Shortages:*** There is always variation in demand and supply of the product. The protection against such unpredictable variations can be done by means of buffer stocks. The factors responsible for such variations are:

(i) *Changes in Size and Frequency of Orders:* The amount of product sold in a large number of orders of small size can be operated with less inventory.

(ii) *Unpredictability of Sales:* If there are too much fluctuations in demand of a product then these can be handled only by flexible and large capacity of inventory operations.

(iii) *Physical and Economic Structure of Distribution Pattern:* Longer the channel of distribution the more is the inventory requirement. Field inventories basically improve service to retailers by removing some of the burden of keeping stocks.

(iv) *Costs Associated with Failure to Meet Demand:* When there is heavy penalty on any delay in fulfillments of any order then inventory should be large.

(v) *The Accuracy, Frequency and Detail of Demand Forecasts:* Fluctuations in stock exist when forecasts are not exact. The responsibility of forecast errors for inventory needs should be clearly recognised.

(vi) Protection Against Breakdown or Other Interruptions in Production.

(c) ***Organisational Factors:*** There are certain factors which are related to the policies, traditions and environment of any enterprise. Some of these are:

(i) Labour relations policies of the organisation.

(ii) Amount of capital available for stock.

(iii) Rate of return on capital available if invested elsewhere.

(d) *Other Factors:* These are related to the overall business environment of the region, viz.,

(i) Inflation.

(ii) Strike situation in communication facilities.

(iii) Wars or some other natural calamities like famines, floods, etc.

(iv) Difference between input and output.

Measures of Inventory Performance

Every inventory is a link in chain of inventories stretching from the point of raw-material extraction to the point of consumption. No single index serves to describe the performance of an inventory. There interrelated factors must be considered in rating the performance, namely:

(i) The size of inventory in money or unit amounts, averaged over the period.

(ii) Cost of replenishment, i.e., the total re-order cost for purchased goods or set up costs for manufactured goods over the period.

(iii) The degree to which it provides stock when demanded, i.e., service level-average stock available in money/unit expressed as a fraction of amount demanded.

Limitations of Inventory Control

(i) Efficient inventory control methods can reduce but cannot eliminate business risk.

(ii) The objectives of better sales through improved service to customer; reduction in inventories to reduce size of investment and reducing cost of production by smoother production operations are conflicting with each other.

(iii) The control of inventories is complex because of the many functions it performs. It should be viewed as a shared responsibility.

Basic Concepts of Inventory Related Costs

In general inventory related costs can be classified into four categories:

(a) Ordering cost/Acquisition cost.

(b) Inventory carrying cost.

(c) Understocking costs.

(d) Overstocking costs.

(a) *Ordering Costs:* Ordering costs or procurement costs are those costs which are incurred on procurement (buying) process. Ordering costs include all the annual expenditure of the purchase section or department. Small items should be ordered in significantly large quantities to avoid unreasonable expense in preparing large numbers of small orders.

Ordering costs cover the following expenditure:

(i) Costs of calling quotation.

(ii) Costs of processing tenders.

(iii) Costs of placing the purchase order.

(iv) Costs of inspecting the shipment.

(v) Rent for the office accommodation of inspecting staff.

(vi) Salary and wages of the purchasing department staff.

(vii) Stationery used.

(viii) Postage.

(ix) Telephone and telegram expenses.

(x) Travelling expenses.

(xi) Entertainment and refreshment expenses.

(xii) Legal expenses in case of purchase disputes.

Ordering costs are usually expressed as cost per order which is obtained by dividing the total of the costs mentioned above by the number of orders placed during a given period. This works out to be roughly between ₹ 10 and ₹ 50 per order depending upon the purchase procedure adopted by a company. Ordering costs naturally depend upon the number of orders placed during a given time, say, a year. More the number of orders to be placed, more will be the expenditure on the above factors particularly salaries, stationery and travelling expenses. The ordering cost may vary dependent upon the type of items: raw material, like steel against production components like casting.

If the level of purchasing increases, the extra load will be tackled by paying overtime to existing staff or by recruiting new personnel. This additional cost can be viewed as the marginal cost of orders. The ordering cost in a typical Indian firm is around ₹ 100 per order. Best experience shows that this cost varies considerably depending upon the purchasing department.

(b) ***Inventory Carrying Costs:*** Thus cost is measured as a percentage of the unit cost of the item. This measure gives a basis for estimating what it actually costs a firm to carry stock. This cost includes:

(i) Interest on capital;

(ii) Insurance and Tax chargers;

(iii) Storage costs – any labour excluding handing or receipts of new orders-the costs of provision of storage area and facilities like bins, ranks, etc.;

(iv) Allowance for deterioration or spoilage;

(v) Salaries of stores staff; and

(vi) Obsolescence.

The inventory carrying cost varies in a typical Indian industry is about 30 per cent. A major portion of this is accounted for by the interest on capital which depends on the fiscal policies of the government. A few firms differentiate the costs as fixed and variable. In the analysis of and used of mathematical formula, only the variable cost of ordering should be considered as the fixed costs will be constant irrespective of the number of orders placed or the inventory carried.

(c) ***Understocking Cost:*** This cost is the cost incurred when an item is out of stock. It indicates the cost of lost production during the period of stockout and the extra cost per unit which might have to be paid for an emergency purchase.

(d) ***Overstocking Cost:*** This cost is the inventory carrying cost (which is calculated per year) for a specific period of time. The time varies in different contexts–it could be the lead time of procurement or the entire life time of a machine. In the case of one time purchases, overstocking cost would be: Purchase price – Scrap price.

Example 1

(a) How will you calculate ordering cost and inventory carrying costs. What is their significance?

(b) Following details are known of a company:

Purchase Department Expenses	:	₹ 2,00,000
Stores Personnel Expenses	:	₹ 2,00,000
Obsolescence	:	₹ 60,000

Hire Charges of Warehouse	:	₹ 1,40,000
Collection Cost	:	₹ 40,000
Receiving Cost	:	₹ 35,000
Inspection Cost	:	₹ 50,000
Material Handling in the Stores	:	₹ 1,60,000
Bill Payment Expenses	:	₹ 75,000
Interest Charges	:	₹ 14.5%
Insurance Charges	:	₹ 2%

Calculate Costs of Ordering and of Carrying Inventory.

The Company places 5000 orders per year and has an average total of ₹ 100 lakh.

Solution

(i) Ordering Costs:

Purchase Department Expenses	:	₹ 2,00,000
Collection Cost	:	₹ 40,000
Receiving Cost	:	₹ 35,000
Inspection Cost	:	₹ 50,000
Bill Payment Expenses	:	₹ 75,000
	Total =	₹ 4,00,000

No. of orders/year = 5,000

$$Cost\,/\,order = \frac{4,00,000}{500} = 80\,/-$$

Inventory Carrying Cost

Stores Personnel Expenses	:	₹	2,00,000
Obsolescence	:	₹	60,000
Hire Charge to Warehouse	:	₹	1,40,000
Material Handling in the Stores	:	₹	1,60,000
		₹	5,60,000
Insurance	:	₹	2,00,000
Interest charge @ 14.5% of ₹ 100 lakh	:	₹	14,50,000
Total	:	₹	22,00,000

$$= \frac{Total\ Inventory\ Cost}{Average\ inventory} \times 100$$

$$= \frac{22,10,000 \times 100}{1,00,00,000}$$

$$= 22.1\%$$

Factors affecting Stock Levels

The extent of stock holdings in a particular organisation is influenced by four main considerations. These are:

(a) ***Operational Needs:*** The user's desire is for immediate availability of all materials, stores and spares which may be required under any circumstances with no risk whatever of failure of supply. From an operational point of view the efficiency of the stores department is judged by whether material is forthcoming or not when it is required. In the event of a run out the consequences may be very serious. Failure to supply some stores may result merely in an irritating delay but if there is a runout of a vital production material the whole of a production line may be stopped and great expense incurred.

(b) *Delivery Time:* As regards time of delivery some goods can be obtained ex-stock from suppliers but in many cases weeks or months must elapse between the date of order and receipt. The effect of this delay can be overcome by phasing deliveries commensurate with operational requirements in advance hut it will still be necessary to hold sufficient stock to avoid shortages in case suppliers fail to deliver on time and also to cater for unexpected variations in production schedule.

(c) *Availability of Capital:* Goods in stock represent working capital and the business will have to provide this capital either out of its own resources or by borrowing from a bank or elsewhere. Capital is never unlimited and from a financial point of view, it is most desirable to restrict the amount tied upon stock as far as circumstances will permit. Efficiency in this respect is normally judged by the rate of turnover. The turnover of stock is the value of stores issued in any given period divided by the average value of stock in hand during that period. It is expressed as a ratio; for example, if the turnover of steel is ₹ 10,00,000/2,50,000, i.e., four and the investment of a working capital of ₹ 2,50,000 in stock has supported consumption of a value of ₹ 10,00,000. It will be clear that the higher the rate of turnover, the more active and economical is the use of capital.

(d) *Cost of Storages:* The factors comprising the cost of storage are as follows:

(i) Interest on the value of stores in stock (i.e., loss of interest on capital tied up);

(ii) Operating expenses of store houses including wages, depreciation, rent, rates repairs, heating, lighting, etc.;

(iii) Deterioration of stock;

(iv) Obsolescence;

(v) Insurance;

(vi) Stock Checking; and

(vii) Recording and Accounting.

These costs are substantial and investigations made in various industries have shown that the annual cost of storage may be of the order ₹ 200-300 per ₹ 2,000 stock held.

Control of Stock of Quantity and Value

It is usual to have to methods of control, the first by quantity and the second by value. The quantity control system is designed to supervise the input and output of each individual stock item and must, therefore, be very detailed and meticulous. The purpose of the value control is to provide a means of verifying that the detailed quantity control is operating effectively and also to produce information about the value of stock for financial purposes.

Control of Stock by Quantity: The main point about the control of stock by quantity is that by the very nature of operation every item of stores receives individual attention. Detailed information about each item is required. This can be taken by stock records.

The stock controller regulates the input of material which is entirely within his jurisdiction. Following points must be considered in connection with the stock holdings:

(i) *Unit of Issue*: To control by quantity the first step is to establish the units of quantity. For example kilograms for weight, litres for liquids, metres for length, etc. A suitable unit of issue is fixed for each item of stock held and this unit should be employed consistently in all receipt, issue, recording and procedures.

(ii) ***Probable Requirements:*** Past performance as indicated by the records is a very good guide. The stock controller must see that he has as much reliable information as he can get about future changes in production levels or alternations in technique. He needs regular and effective contact with all user departments.

(iii) ***Availability of Supplies:*** To regulate the input of materials effectively the stock controller must know what delivery period is likely to be required by the suppliers.

(iv) ***Frequency of Delivery:*** The geographical location of the source of supply or the nature or bulk of the material affects the size and frequency of deliveries.

(v) ***Price Discounts for Quantities:*** Price is naturally very important and if substantial supplies are regularly required the buyer will seek to make bulk purchases wherever possible to get the cheapest unit price. Before placing orders the amount of discount available should be compared with the extra costs of storage which may be incurred to make sure that it is, in fact, advantageous to make bulk purchases.

(vi) ***Cost of Ordering:*** The clerical and administrative cost of placing orders is not negligible and with items of low units value may be significant factor. Such items should be ordered in sufficiently large quantities to avoid the reasonable expenses.

(vii) ***Rate or Issue:*** If the store house is supplying an overseas depot it may be necessary to make up major consignments of substantial quantities or in process or engineering factories there may be a minimum quantity of materials suitable for economic batches in the production process.

(viii) ***Seasonal Fluctuations:*** In some business production is related to harvest time or weather. In fruit canning or textile manufacture the input of materials has to be arranged at appropriate time.

(ix) ***Standard Ordering Quantities:*** Some articles are purchased in standard quantities, i.e., by the tonne, the hundred, the litre and so on. It is for the stock controller to see that his demands are expressed in the standard ordering quantities.

(x) ***Allocation:*** Where specific quantities are set aside for special jobs or capital projects, this must be taken into account when controlling the amount in stock if the materials are also used for other purposes.

(xi) ***Obsolescence:*** Particularly in the case of specially prepared production materials or machine spares, regard should be had to the possibility of the item becoming obsolete and stores should be maintained at a sufficiently low level to avoid under risk in this respect.

(xii) ***High Value Items:*** It is obvious that the greatest attention should be paid to the items of the highest value but this common sense approach is sometimes overlooked. Very frequently a large production of the value of stock is represented by a comparatively small number of expensive articles or materials with a very high rate of consumption, and the effect of fluctuations in these stock holdings is a major factor in the total stock investment.

Various Control Levels

For acting judiciously, systematically and scientifically on this score, the materials manager, first of all, fixes the following different levels (points):

1. ***Maximum Level:*** Maximum level represents the level beyond which the stock in hand is not allowed to exceed. This is because:

   (a) If stock exceeds this level it will: (i) involve more investment, (ii) require more space, (iii) amount to more wastage because of more handling, more chances of damage, spoilage, obsolescence, and (iv) involve more carrying cost.

(b) Excess stock will involve unnecessary locking up of capital and prevent its availability for a more profitable use.

(c) Excess stock will increase the cost of storage, thereby increasing production/selling cost and thus defeating the very purpose of efficient store-keeping.

(d) Stock in excess will prevent the management from taking advantage of price fluctuations and favourable market conditions.

The fixation of maximum level depends on the following factors:

(i) Rate of consumption of the materials;

(ii) Time necessary to obtain the deliveries;

(iii) Amount of money available;

(iv) Storage space available;

(v) Possibility of loss due to evaporation, deterioration, etc.;

(vi) Market condition, seasonal and price fluctuation;

(vii) Economic ordering quantity;

(viii) Government restrictions as in the case of explosive materials, etc.;

(ix) Staff and other facilities available of the maintenance of stores and the maintenance cost involved; and

(x) Need of buffer stock (safety stock) in relation to active stock.

Formula: Maximum Level = Reorder Level + Reorder Quantity – (Minimum Consumption x Minimum Reorder Period).

2. ***Minimum Level:*** Minimum level points to the level below which the stock in hand shall not be allowed to fall. This limit is fixed in order to avoid the possibility of the suspension of production due to shortage of materials. It is necessary that the stock on hand shall always be kept a little above this level to be on the safe side but never to fall below this level. This is usually fixed, taking into account two important factors among others, namely, the time required to obtain fresh stock, i.e., lead time and the rate of consumption material. Minimum level gives an element of safety in production as materials can always be kept in reserve for emergencies. This is why sometimes the stock at this level is known as Emergency Reserve Stock. The level in any case is not allowed to touch the zero level.

Formula: Minimum Stock Level = Reorder Level – (Average Rate of Consumption × Lead Time).

3. ***Order Level:*** This is the quantity of stock (level) fixed between the maximum and minimum levels of stock. When this level is reached, it becomes the duty of the stores incharge to initiate purchase so as to replenish the stock within reasonable time. This level is usually a little higher than the minimum in order to be prepared for such emergencies as abnormal usage of materials, unexpected delay in delivery of new supplies, etc. While fixing this level we ordinarily take the following points into consideration:

(a) Time required for obtaining fresh supplies;

(b) Quantity required to be ensured of a certain level of production at a given time;

(c) Possible unexpected requirement which cannot be avoided; and

(d) Possible unexpected delays in getting the fresh supplies because of rains, political situation, war, labour trouble, transport inadequacy, etc.

The objective of fixing up the order level is to restock the materials at the lowest cost ensuring the uninterrupted operation of the manufacturing unit/business organisation.

It may, however, be pointed out that the order quantity is determined by taking into account the supplier's discount, rate of consumption, price of the material, storage cost, danger of deterioration and obsolescence besides the availability of funds, space available for storage and preservation facilities. The loss due to interruption of operation will also have to be examined. These factors taken together will determine the order quantity, which in turn affects the point at which the order level has to be fixed. It is necessary to be definite about the order quantity because the supplier has also to be given sufficient time for making arrangements of the supply. The larger the consignment, the greater will be the time taken by the supplier. Thus the order quantity has its own say in fixing the points of order (or re-order) level.

4. *Danger Level:* This level below the minimum level and represents the stage at which emergency and immediate steps have to be taken for getting the stock replenished. It is fixed taking into account the time required to get the materials by the quickest possible means of transport, i.e., the minimum time required for obtaining supplies from any possible source. Danger level of any item in the store gives red signal to the stores incharge that the materials have touched the lowest point and if no emergency steps are taken to restock them, they will completely be exhausted, i.e., the closure of operation is in the offing.

   The job of the stores incharge is not over with the fixing up of these levels. These levels are subject to change. Hence they should be reviewed from time to time. This is important because these levels are fixed in relation to two factors, the procurement time and the rate of consumption. Since these are themselves not static, the different levels can also not remain static. Hence a periodic review makes them more realistic and reliable.

Perpetual Inventory System

The perpetual inventory system is a system of maintaining records of physical movement of stock (a record of every purchase and issue) and their current balance to facilitate regular checking and to obviate closing down of books for stock taking. The system has been defined by ICMA, London as "A system of records maintained by the controlling department which reflects the physical movement of stocks and their current balance." Store balances are recorded after every receipt and issue.

The basic object of this system is to make available the details of quantity and value of stock of each individual item of store at all times so that a potential inventory may be checked at any time by a programme of continuous stock-taking. The system thus provides a rigid control over the stock of materials as 'physical verification' of stock of materials is possible with the help of stock records maintained under this system.

It should be clear here that perpetual inventory system is a system or records of materials received and issued and their current balances and differs from continuous stock taking which is the physical checking of those records with actual stocks in the bin or store.

Step Necessary for Introducing Perpetual Inventory System

In order to introduce a perpetual inventory system in a large manufacturing industrial undertaking the following two steps are necessary:

(i) *Maintenance of Bin Cards and Stores Ledger:* In introducing perpetual inventory system, bin cards and stores ledger are to be maintained regularly. Bin cards and provide quantitative perpetual inventory while stores ledger provides quantitative-cum-valued perpetual inventory.

   (a) *Bin Cards:* Bin means a rack, container or space where materials are kept. The store is fitted with a number of bins, each meant for a particular type of material. A card is placed outside each meant for a particular type of material.

A card is placed outside each bin, generally known as bin or stone card. Every receipt and issue from the bin is recorded on the bin card immediately and thus it shows a record of materials received, material issued and material in stock. The card, inter alia, contains particulars regarding maximum, minimum and ordering levels, code number, description, etc., of the materials kept in the bin. It assists the storekeeper in controlling the stock.

(b) *Stores Ledger*: Maintenance of stores ledger is also necessary for perpetual inventory system. It is a ledger containing a separate account for each kind of materials and spare parts stocked in store. Entries in the ledger are made for materials received, materials issued and a balance of materials returned notes. These entries are identical to those on the bin card. The store ledger also maintains a record of money value of materials received, materials issued (by any one method of pricing materials issue from store to the job) and materials in stock.

The store ledger is maintained by the cost department in order to have an internal check over the receipts, and issues of materials. The store staff is in no way associated in writing up the ledger otherwise it will lose its importance.

(ii) *Adoption of Continuous Stock Taking:* In order to make the perpetual inventory system effective, a system of continuous stock taking is a system effective, a system of continuous stock taking is a system where an independent internal audit staff is empowered to verify the physical quantity of materials of components in the store with the quantities shown in the bin card and stores ledger. Discrepancies which may be there due to certain avoidable and unavoidable reasons should be located and steps taken to remove them and to prevent the discrepancies in future.

Advantages of Perpetual Inventory System

The advantages of perpetual inventory system may be summed up as follows:

(i) *Counting without Interruption:* The stock of raw materials can be counted at any time without interrupting the production or the regular working of the stores department.

(ii) *Distribution of Work Load:* The work load can also be distributed in such a way among the working staff that no extra man is necessary. It will facilitate the counting programme in a more orderly and relaxed way and thus the chances of errors may be reduced to the minimum.

(iii) *Steps to Correct Discrepancies:* The quantity and value of individual item of store as shown on the bin card must tally with the physical stock in the bin. If there is any discrepancy or malpractice, it is discovered immediately and steps should be taken to prevent such recurrence in future.

(iv) *Interim Accounts*: Easy to Prepare. Since stock figures are instantly available the interim trading, profit and loss account and balance sheet can be prepared easily if such accounts are necessary for taking any interim decision.

(v) *Maintenance of Stock Limit Possible:* It is the duty of storekeeper always to maintain the adequate stock of raw materials within the limits (maximum, minimum and reorder levels) prescribed by the management in order to have a better control over inventory and finance. A comparison between actual stock and authorised limit can be made at any time. In this way, these limits can be maintained effectively.

(vi) *Avoids Excessive Stock:* The perpetual inventory system avoids the disadvantages of carrying excessive stocks because of strict enforcement of various stock levels and thus over-investment in materials can be avoided.

(vii) ***Moral Check on Stores Staff:*** The system serves as a moral check on the stores staff. They will try to their level best to keep the records up-to-date and will avoid committing dishonesty.

(viii) ***Easy Settlement of Claims:*** Unfortunately if materials are destroyed by fire, the system helps in settling the insurance claims satisfactorily. Correct loss figure of stock can be ascertained easily from the complete stock.

Economic Order Quantity

Economic Order Quantity (EOQ) is the most economical purchase order quantity or lot size which keeps a balance inventory carrying costs and ordering costs. These two types of costs are opposed to one another. Inventory costs increase, ordering costs decrease with quantity of purchase order. These tendencies have been shown in the diagram below. These requirements are conflicting and there is a particular quantity at which the sum of both the ordering and inventory carrying costs are minimum. This quantity is called as the Economic Order Quantity (EOQ).

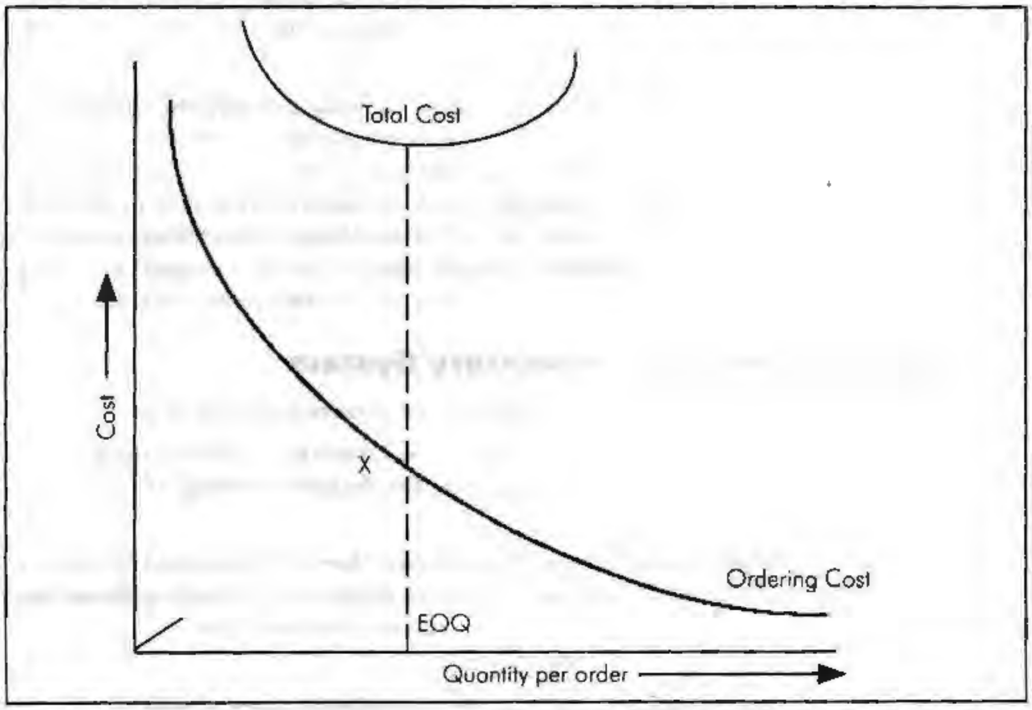


Figure 15.1: Graphic Description of EOQ Concept

It has also been called "Economic purchase quantity, or Economic lot size or Optimum lot size or Minimum Cost Inventory."

It will be seen from the Figure 15.1 that when these two opposing costs are the same, their graphs intersect each other at X where the Economic Order Quantity occurs. The total cost of inventory at this point is minimum. The total inventory cost graph curves downward due to decreasing ordering costs as the order quantity increases but at X it starts rising further due to increasing inventory carrying costs. The total cost curve is obtained by adding the ordinates of inventory carrying costs and ordering costs.

Let 'A' be annual consumption in units

'U' = Ordering cost/order

'C' = Unit cost

'I' = Inventory carrying cost

'Q' = Quantity/order

(i) Calculation of ordering cost.

$$\text{No of orders} = \frac{\textit{Annual consumption}}{\textit{Quantity / order}}$$

$$= \frac{A}{Q}$$

Ordering Cost = No. of orders × ordering card / order

(ii) Calculation of inventory carrying cost.

$$= \frac{Q}{2} \times C \times I$$

Cost of carrying Inventory = Average Inventory × unit cost × Inventory carrying cost.

Average Inventory = $\frac{Q}{2}$

At optimum condition these costs are equal. Equaling these two we get,

$$\frac{A}{Q} \times U = \frac{Q}{2} \times C \times I$$

$$2 = \frac{2AU}{CI}$$

$$Q = \sqrt{\frac{2AU}{CI}}$$

Practical Considerations in the Application of EOQ

Order Quantity

To enable quick calculation of EOQ, ready made reference tables are available where the EOQ for various consumption value procurement costs and inventory carrying costs have been worked out.

Some of the usual objection that one hears about EOQ are as follows:

(i) Often the inventory holding cost and the ordering cost cannot be identified accurately and sometimes cannot be even identified properly.

(ii) The FOQ calculated is often an inconvenient number.

(iii) The use of EOQ usually leads to orders at random points in time, so that suppliers receive an irregular stream of orders.

(iv) EOQ may not be applicable when the requirements are irregular, or where there is an impending price rise.

This is where the human judgement comes in. Techniques in management do not always give results which are 100 per cent correct. Every decision will depend upon the environmental conditions, i.e., those relating technology, imports and exports, consumer tastes and myriads of other items, all of which play a very vital role in taking decision. As such, every decision is to be taken on the merits of the problems and the EOQ formula should not be treated as gospel.

Limitations of EOQ

1. Ordering to the nearest trade quantities or packing. Say instead of ordering 11 dozens, the order may be for one gross.

2. Modifying an order quantity to get a better freight may more than compensate the extra inventory carrying cost.
3. Simplification of routine. Instead of ordering 14 times a year, one may order once a month.
4. In the case of perishable, or bulky items with diminishing consumption or for items whose market prices are likely to decline, it may be better to order less than the theoretically worked out order quantities.
5. Seasonal supply factors, market conditions, availability of transport facilities, etc., may indicate larger or smaller purchase quantities. In these situations, judgement should be given more weight.
6. Liberal discounts or concessional freight rates may suggest larger quantities. The 'pros' and 'cons' of such purchase should be weight carefully before a decision is taken.

EOQ and Quantity Discounts

At EOQ both ordering cost and inventory carrying cost are at optimum. However, we get discounts if we buy more quantities than EOQ. One would ask the question as to whether to go in for the discount and buy more than EOQ or do not accept the discounts.

Let us look at the case in detail.

There are two important costs while we buy:

(i) Cost of Materials;

(ii) Cost of Ordering;

(i) Cost of materials go down when we get discounts. This will result in saving;

(ii) Cost of Ordering are:

- (a) Ordering cost, and
- (b) Inventory cost.

While we get discounts we buy more quantities, i.e., quantity/order is more and subsequently number of orders/year are less. If number of orders are less then we get a saving in ordering cost.

Contrary to it when number of orders are less and quantity ordered is more average inventory is more. Subsequently inventory carrying cost increases so we have the following phenomenon while taking discounts.

Saving in		Saving in ordering		Loss in inventory
Discount	+	cost	–	carrying cost

Example 2

For a given item there is a constant demand rate. Yearly demand is 6,000 units. The price of the item is ₹ 60 per unit. The ordering cost is ₹ 150 and inventory carrying cost is 20 per cent. What is the optimal ordering policy?

The manufacturer of the item offers a 1 per cent discount if 1200 units are ordered. Should the discounts be taken?

Solution

$$\text{Optimal ordering} = \frac{2AU}{CI}$$

Where A = 6000 units

C = ₹ 60/-

U = ₹ 150/-

1 = 20%

$$EOQ = \sqrt{\frac{2 \times 6000 \times 150}{60 \times 0.2}}$$

= 387.29

= 388

No. of orders $= \frac{6000}{388} = 15.46 = 16$

As we have seen while we buy at quantities of 1200 units more than EOQ quantity, i.e., units we have following situation.

(a) No. of orders are less, ordering costs are less.

(b) Average Inventory is more, so inventory carrying costs are more.

(c) Saving in special discounts.

Saving in ordering cost + Saving in discount – Loss in inventory Carrying cost

(a) Saving in ordering costs equation

$$= \left[\frac{6000}{388} - \frac{6000}{1200}\right] \times 150$$

$$= (15.46 - 5) \times 150$$

$$= 1569$$

(b) Saving in discount

$$= \frac{6000 \times 60 \times 1}{100} = 3600$$

(c) Loss in inventory carrying costs

$$= \left[\frac{1200}{2} - \frac{388}{2}\right] \times 60 \times \frac{20}{100}$$

$$= (600 - 194) \times 60 \times \frac{20}{100}$$

$$= 4872$$

i.e.

saving in order cost + saving discount – Loss in I.C.C.

1569 + 3600 – 4872

Since we are gaining ₹ 297 it is better to take discounts and buy in quantities of 1200 units instead of 388 units.

Example 3

A worked example is given below to illustrate the technique:

The following information is available about ABC Company which manufactures Electric Fans.

The company has an average total inventory of ₹ 100 lakh and places 4000 orders every year.

Purchase Department Expenses	:	₹	2,00,000
Stores Warehouse Personnel Salary	:	₹	2,00,000
Obsolescence, Spoilage, etc.	:	₹	60,000
Floor Space Charge Related to			
Stores Activities (Warehousing)	:	₹	1,40,000
Cost of Collecting Material	:	₹	40,000
Cost of Receiving Material	:	₹	35,000
Cost of Inspection	:	₹	50,000
Cost of Material Handling for			
Warehousing Activities	-	₹	1,50,000
Cost of Bill Payment	-	₹	75,000
Interest	:	₹	12.5%
Insurance Charges	:	₹	2%

The company wants to buy a certain component, whose price is: ₹ 12 each and the annual requirement is 17280 Nos. Calculate cost of placing an order, cost of carrying inventory as a per cent of inventory and EOQ.

Solution

Procurement	:	₹ 2,00,000
Purchase Department Expenses	:	₹ 2,00,000
Cost of Collecting Material	:	₹ 40,000
Cost of Receiving Material	:	₹ 35,000
Cost of Inspection	:	₹ 50,000
Cost of Bill Payment	:	₹ 75,000
		₹ 4,00,000
No. of Order placed	:	4,000
Purchasing Cost per Order	:	₹ 100 (i.e.)
		₹ 4,00,000
Inventory Carrying Cost	:	4,000
Stores/WH Personnel Salary	:	₹ 2,00,000
Obsolescence Spoilage etc.	:	₹ 60,000
Floor Space Charges	:	₹ 1,40,000
Materials Handling	.	₹ 1,50,000
Interest Charges @ 12.5% for average inventory of ₹ 100 lakhs.		12,50,000
Insurance Charges @ 16% of Average inventory.	-	₹ 2,00,000
		₹ 20,00,000

Inventory Carrying Charges $= \frac{20 \text{ lakhs}}{100 \text{ lakhs}} \times 100$

$= 20\%$

Price of Component = ₹ 12

Annual Requirement = 17280

$EOQ = \sqrt{\frac{2AU}{IC}}$

$= EOQ = \sqrt{\frac{2AU}{IC}}$

$= \sqrt{\frac{2 \times 17280 \times 100 \times 100}{12 \times 20}}$

$= \sqrt{144 \times 100 \times 100}$

= 1200

EOQ = 1200 units per order.

Selective Inventory Control

As its name implies, selective control means that we have variations in the methods of inventory control from item to item and this differentiation should be on a selective basis.

Classification of Selective Inventory Control Technique

Very broadly, selective control technique can be classified as follows:

(i) A-B-C- analysis

(ii) H-M-L analysis

(iii) V-E-D analysis

(iv) S-D-E analysis

(v) G-O-L-F analysis

(vi) F-S-N analysis

(vii) S-O-S analysis

(viii) X-Y-Z analysis

	Classification	Criteria
1.	A-B-C (sometimes nicknamed Always Better Control) he unit value of the items).	Annual value of consumption of the items concerned. (It has nothing to do with
2.	H-M-L (High, Medium, Low)	Unit price of material. (This is the opposite of A-B-C and Does not take consumption into account)
3.	V-E-D (Vital, Essential and Desirable)	By the critical nature of the component or material with respect to production.
4.	S-D-E (Scarce, Difficult to obtain, Easy to obtain)	Purchasing problems in regard to availability.
5.	G-O-L-F (Government, Open market, Local, Foreign)	Source from which the material is obtained.
6.	F-S-N (Fast moving, Slow moving and Non-moving)	Issues from stores.
7.	S-O-S (Seasonal, Off-Seasonal)	Seasonality. This applies specially to commodities.
8.	X-Y-Z	The inventory value of items stored.

A-B-C Technique of Inventory Control

Where there are a large number of items in the inventory it becomes essential to have an efficient control over all items of stores. However, comparatively greater care should be given to items of higher value. The movements of certain manufacturing concerns may consist of a small number of items representing a major portion of inventory value and a large number of items may represent a major portion of inventory value. In such cases, a selective approach for inventory control should be followed.

The most modern technique for controlling the inventory is a value item analysis popularly known as ABC analysis which attempts to relate how the inventory value is concentrated among the individual items. This analysis is based on Pareto's Law. Pareto's Law states that a fewer items having high usage value having high investment value should be paid more attention than a bulk of items having low usage value and having a low investment in capital.

Under this analysis, all items of stores are divided into three main categories—A, B and C. Category A includes the most important items which represent about 60 and 70 per cent of the value of stores but constitute only 10 to 15 per cent items. These items are recognised for special attention. Category B includes lesser important items representing an investment value of 20 to 25 per cent and constitute a similar percentage of items of stores. Category C consists of the least important items of stores and constitute 60 to 70 per cent of stores items representing only a capital investment between 10 to 15 per cent. Close attention is paid to items falling in Category A and the best items of Category C. This classification of items into A, B and C categories is based upon value, usage rate and criticality of items and these variables are given due weightage in categorising the items. The term ABC implies Always Better Control.

Steps in ABC Analysis

Though no definite procedure can be laid down for classifying the inventories into A,B and C categories as this will depend upon a number of factors such as nature and varieties of items, specific requirements of the business, place of items in the production, etc. These factors vary from business to business and item to item. However, the following procedure may be recommended:

(i) First, the quality of each material expected to be used in a given period should be estimated.

(ii) Secondly, the money value of the items of materials so chosen should be calculated by multiplying the quantity of each item with the price.

(iii) Thirdly, the items should be rearranged in the descending order of their values irrespective of their quantities.

(iv) Fourthly, a running total of all the values and items will be taken and then the figure so obtained should be converted into percentages of the gross total.

(v) Fifthly and lastly, it will be found that a small number of a first few items may amount to a large percentage of the total value of the items. The management, then, will have to take a decision as to the percentage of the total value or the total number of items which have to be covered by A, B, and C categories.

ABC Analysis on Graph

The two percentages, so calculated (percentage of items and percentage of values) may be plotted on graph paper by taking the percentages of total items on X-axis and the corresponding usage values on Y-axis. Points then shall be marked where the curve sharply changes its shape. This will give three segments as A, B and C. ABC graph can be drawn as follows:

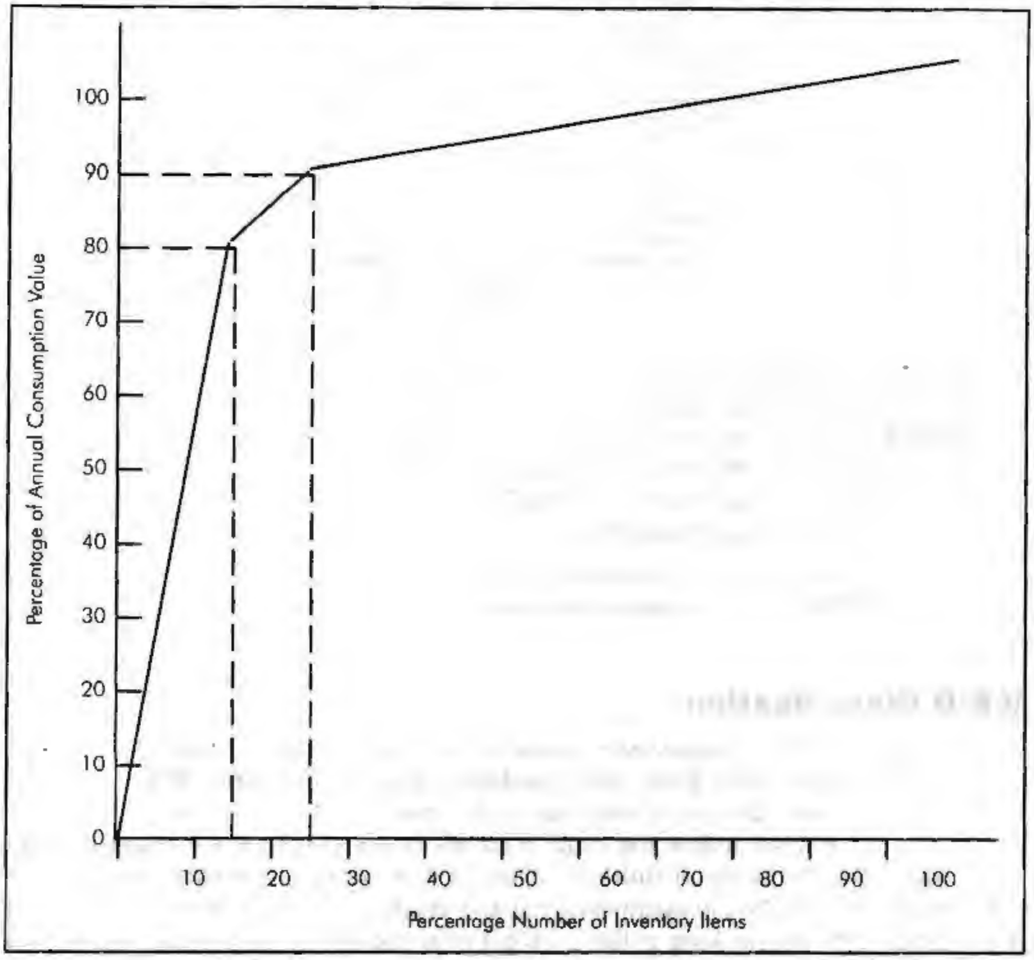


Figure 15.2: Graphical Representation of ABC Analysis

Advantages of ABC Analysis

The advantages of ABC Analysis are as follows:

(i) It ensures closer control on costly items in which a large amount of capital is invested.

(ii) It helps in developing a scientific method of controlling inventories. Clerical costs are reduced and stock is maintained at optimum level.

(iii) It helps in achieving the main objectives of inventory control at minimum cost. The stock turnover rate can be maintained at comparatively higher level through scientific control of inventories.

(iv) The technique of ABC Analysis is based on the principle of management by exception and can be used in areas other than the inventory control.

H-M-L Classification

More or less the same procedure as for A-B-C classification can be adopted here, the only difference being that unit value is the criterion and not the annual consumption value.

Class	Nature of Materials		No. of Items	% of Total Number	% of Consumption Value
A.	Chemicals and costly engineering items:		1452	6.80	82.70
	(a) Unit price greater than ₹ 5000 (H item)	494			
	(b) Unit price ₹1000 ₹ 5000 (M item)	692			
	(c) Unit price below ₹ 1000 (L Item)	266			
B.	Consumables less expensive spares, etc.		5692	26.47	11.00
C.	All other items which do not fall into the		13346	66.73	6.30
	Above categories.		21500	100	100

The items should be listed out in descending order of unit value and management may fix limits for deciding the three categories. For example, it may decide that all items of all unit value above ₹ 5000 will be H items, between ₹ 1000 to ₹ 5000 will be M items and below ₹ 1000 will be L items. On this basis, Management may delegate authority to various subordinate officers to purchase petty cash items. The top management may decide that items of value above a unit of ₹ 5000 are H items and may decide that all such items will only be sanctioned by it.

It is desirable to combine ABC and HML classifications. For example, A items above the unit value of ₹ 5000 can be treated in a different way than A items whose value is only ₹ 10.

V-E-D Classification

V-E-D stands for vital, essential and desirable. This type of classification is applicable mostly in the case of spare parts. This peculiarity about spare parts is that it does not follow a predictable demand pattern as in the case of raw materials, for example. The result is that if we follow the usual methods outlined earlier, we might get into difficulties when the demand suddenly changes. For example, the older the machine gets, the greater may be the maintenance spares required. As such, past trends cannot throw much light on stocking policies. To get over this difficulty, V-E-D classification is used. Here, the categories are made in terms of the importance or criticality of the part to the operation of the plant. If it is very vital, it is given a V classification. If it is not so important, it is given a D classification. How such a classification is done will purely depend upon the machinery or equipment involved and one's own experience, ease of availability of the items, etc. For example, if the item was available off the shelf from the supplier's showroom, there would be no purpose in categorising it as V. But, on the other hand, a minor imported item might automatically get a V classification. In other words, the classification is not purely in terms of the criticality of the item for proper working of the machine but it is a combination of several factors including price, availability, etc.

For V items a reasonably large quantum of stocks might be necessary, while for D items, no stocks need, perhaps, be kept. Especially, if that item also happens to be in the A or B classification, close control should be kept on stock levels, but if it is a C item, large quantities may be stored (see table).

Classes	V items	E items	D items
A items	Constant control and regular follow-up	Moderate stocks	Nil stocks
B items	Moderate stocks	Moderate stocks	Very low stocks
C items	High stocks	Moderate stocks	Low stocks

S-D-E Classification

These letters stand for scarce items, those which are difficult to obtain and those which are fairly easy to obtain. It is quite obvious that where an item is scarce and it is an

A item, we cannot apply the same procedure or yardstick for its stocking. Take, for example, an item which is imported. It would be quite absurd for anyone to say that it should be procured once in six weeks. It would be best to obtain it once in a year, considering the time, effort and expenditure involved in the procedures for import.

A scarce item might be an item which is not easily available in the market and might require source development, or else it might be an item which is very difficult to manufacture or there are only one or two manufacturers who have to be given orders several months in advance, and so on.

G-O-L-F Classification

This word stands for Government-Open Market-Local or Foreign.

There are many items of imports which are channelised through the State Trading Corporation, Indian Drugs and Pharmaceuticals Ltd., Minerals and Metals Trading Corporation, etc. There are special procedures to be followed for procuring such items. As such, ordinary procedures of inventory control may not work with respect to these materials and they would require special treatment.

Similarly items which are available within the country could be treated differently if they were available locally, compared to them being available only in very distant towns or where they have to be specially manufactured.

Imported items would be a special class by themselves and have to be accorded a treatment quite unique.

F-S-N Classification

This classification takes into account the pattern of issues from stores. The three letters stand for fast moving, slow moving and non-moving. This classification comes in very handy when we desire to control obsolescence. Items classified as S and N require very great attention, especially N items. There may be several reasons why an item has got into the N category. There might have been a change in technology or change in the specification of a particular spare part or the item might no longer be in use. When an FSN classification is made all such information stand out prominently enabling managers to act on the information in the best interests of the organisation.

S-O-S Classification

Some of the items required are seasonal in nature and require special purchasing and stocking strategies. We had discussed the purchasing aspects at some length in Paper II in relation to the purchase of commodities. Many commodities especially of agricultural origin and seasonal in character have to be purchased at the best time. One cannot apply EOQ here for example. Inventories at the point of procurement will be extremely will be extremely high but this cannot be helped.

A buying and stocking strategy for seasonal items would depend on a large number of factors, and more on a high degree of sophistication taking place in this matter. Operational research techniques would have to be used to obtain optimum result.

X-Y-Z Classification

This is the last type and is based on the value of inventory stored. If the values are high, special efforts should be made to reduce them. This exercise can be done once a year.

X items are those whose inventory values are high while Z items are those whose inventory values are low. This type of classification helps us to identify those items which are extensively stocked.

XYZ and ABC can be used in conjunction and the method of control will be as follows:

Class of Item	X Items	Y Items	Z Items
A items	A critical analysis must be done in such a case.	Attempts must be made to convert class	Items are within control
B items	Consumption and stock should be reviewed frequently	Further action in control may not be necessary	Can be reviewed annually.
C items	Step should be taken to dispose of surplus stocks	Control should be tightened	Can be reviewed annually.

We can also merge FSN and XYZ classifications as given below:

Class of Items	F Items	S Items	N Items
X items	Tight inventory control.	Reduce Stock to very low level.	Quick disposal of items at optimum price.
Y items	Normal inventory control.	Low level of stocks.	Should be disposed as early as possible.
Z items	Can reduce clerical labour by increasing stocks.	Low level of stocks.	Can afford to dispose of at lower prices.

Student Activity

Fill in the blanks:

1. Inventory is the physical stock of ....
2. Stocks bring economy in purchase of various inputs due to discounts on ....
3. Inventories are essential for keeping the ....
4. Working capital is ....

Summary

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. Formulating inventory policy requires understanding the inventory's role in the firm. Though inventory is an idle resource and adds to the risk of the firm, it is almost essential to keep some inventory in order to promote smooth and efficient running of business.

The different types of inventories have different risks depending upon the firm's position in the distribution channel. If an individual enterprise plans to operate at more than one level of the distribution channel, it must be prepared to assume additional inventory risk. In light of all quality, customer service and economic factors—from the viewpoints of purchasing, manufacturing, sales and finance—effective inventory management is essential to organizational competitiveness.

The heart of inventory decisions lies in the identification of inventory costs and optimizing the costs relative to the operations of the organization: When items should be ordered, how large the order should be, and "when" and "how many to deliver." The following costs are generally associated with inventories: Holding (or carrying) costs, Cost of ordering, Setup (or production change) costs, and Shortage or Stock-out Costs.

Many selective inventory management techniques are used. The most common is the ABC Classification. The ABC classification is based on focusing efforts where the payoff is highest; i.e. high-value, high-usage items are tracked carefully and continuously, while the level of control for other items tapers off. Other similar types of classifications are the XYZ Classification, VED Classification, and the HML classification of inventory. All these techniques are used to focus management attention in deciding on the degree of control necessary for different items in the inventory.

Keywords

Economic Order Quantity (EOQ) Models: The basic approach to determining fixed order sizes—are the Economic Order Quantity (EOQ) models. The basic EOQ model is concerned primarily with the cost of ordering and the cost of holding inventory.

Fixed Order Quantity Systems: These are multiple period inventory models that are "event triggered", at an identified level of the stock the fixed-order quantity model initiates an order.

Fixed Time Quantity Systems: These systems are "time triggered", at an identified fixed time the fixed-time quantity model initiates an order to replenish the stock.

Price-Break Models: When item cost varies with volume ordered, the result is a modified simple lot size situation called the quantity volume case or price break model.

Re-order Level: The inventory level at which the order is released is known as the reorder level.

Review Questions

1. Define the term Inventory and state its characteristics.
2. State the types and functions of inventories.
3. State the difference between Inventory and Stores.
4. Explain the advantages and disadvantages of Large Inventories.
5. Define the term Inventory Control and state its scope, objectives and importance.
6. Explain the essentials of Inventory Control.
7. State the factors affecting Inventory Control and also explain the limitations of Inventory Control.
8. Write short notes on:
   (a) Ordering cost
   (b) Inventory carrying cost
   (c) Under-stocking cost
   (d) Over-stocking cost
   (e) Safety stock
   (f) Factors governing the Safety Stock Level.
9. What are the factors that influence the extent of stock-holding?

Further Readings

Adam & Ebert, *Production and Operations Management – Concepts, Models and Behavior,* Prentice Hall of India, 1992.

Bradley Gale, *Managing Customer Value: Creating Quality and Service that Customers can see,* Free Press, NY, 1994.

Buffa and Sarin, *Modern Production/Operations Management*, John Wiley & Sons, 1994.

Clayton Christensen, *"The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail"*, HBS Press, 1997.

Chase, Jacobs, *Aquilano, Operations Management for Competitive Advantage,* Tata McGraw Hill, Delhi, 2004.

Production & Operation Management	Krajewski and Ritzman, *Operations Management, Strategy and Analysis*, Pearson Education, 2002. Melnyk, S. and D. Denzler, *Operations Management: A Value Driven Approach*, McGraw Hill, 1996. Vonderembse, Mark, White, Gregory, *Operations Management, Concepts, Methods and Strategies*, John Wiley & Sons, 2004.