COURSE MATERIAL

IV Year B. Tech I- Semester

MECHANICAL ENGINEERING

AY: 2025-26

PRODUCTION AND OPERATIONS MANAGEMENT

(R22A0332)

Prepared by:
Mrs. Indraja Bhadri
Assistant Professor

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

(Autonomous Institution - UGC, Govt.ofIndia)
Secunderabad 500100,
Telangana State, India. www.mrcet.ac.in

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

DEPARTMENT OF MECHANICAL ENGINEERING

CONTENTS

1. Vision, Mission & Quality Policy
2. Pos, PSOs & PEOs
3. Blooms Taxonomy
4. Course Syllabus
5. Lecture Notes (Unit wise)
    a. Objectives and outcomes
    b. Notes
    c. Presentation Material (PPT Slides/ Videos)
    d. Industry applications relevant to the concepts covered
    e. Question Bank for Assignments
    f. Tutorial Questions
6. Previous Question Papers

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

VISION

- To establish a pedestal for the integral innovation, team spirit, originality and competence in the students, expose them to face the global challenges and become technology leaders of Indian vision of modern society.

MISSION

- To become a model institution in the fields of Engineering, Technology and Management.
- To impart holistic education to the students to render them as industry ready engineers.
- To ensure synchronization of MRCET ideologies with challenging demands of International Pioneering Organizations.

QUALITY POLICY

- To implement best practices in Teaching and Learning process for both UG and PG courses meticulously.
- To provide state of art infrastructure and expertise to impart quality education.
- To groom the students to become intellectually creative and professionally competitive.
- To channelize the activities and tune them in heights of commitment and sincerity, the requisites to claim the never - ending ladder of **SUCCESS** year after year.

For more information: www.mrcet.ac.in

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

www.mrcet.ac.in

Department of Mechanical Engineering

VISION

To become an innovative knowledge center in mechanical engineering through state-of-the-art teaching-learning and research practices, promoting creative thinking professionals.

MISSION

The Department of Mechanical Engineering is dedicated for transforming the students into highly competent Mechanical engineers to meet the needs of the industry, in a changing and challenging technical environment, by strongly focusing in the fundamentals of engineering sciences for achieving excellent results in their professional pursuits.

Quality Policy

- ✓ To pursuit global Standards of excellence in all our endeavors namely teaching, research and continuing education and to remain accountable in our core and support functions, through processes of self-evaluation and continuous improvement.
- ✓ To create a midst of excellence for imparting state of art education, industry-oriented training research in the field of technical education.

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

www.mrcet.ac.in

Department of Mechanical Engineering

PROGRAM OUTCOMES

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and teamwork**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1 Ability to analyze, design and develop Mechanical systems to solve the Engineering problems by integrating thermal, design and manufacturing Domains.

PSO2 Ability to succeed in competitive examinations or to pursue higher studies or research.

PSO3 Ability to apply the learned Mechanical Engineering knowledge for the Development of society and self.

Program Educational Objectives (PEOs)

The Program Educational Objectives of the program offered by the department are broadly listed below:

PEO1: PREPARATION

To provide sound foundation in mathematical, scientific and engineering fundamentals necessary to analyze, formulate and solve engineering problems.

PEO2: CORE COMPETANCE

To provide thorough knowledge in Mechanical Engineering subjects including theoretical knowledge and practical training for preparing physical models pertaining to Thermodynamics, Hydraulics, Heat and Mass Transfer, Dynamics of Machinery, Jet Propulsion, Automobile Engineering, Element Analysis, Production Technology, Mechatronics etc.

PEO3: INVENTION, INNOVATION AND CREATIVITY

To make the students to design, experiment, analyze, interpret in the core field with the help of other inter disciplinary concepts wherever applicable.

PEO4: CAREER DEVELOPMENT

To inculcate the habit of lifelong learning for career development through successful completion of advanced degrees, professional development courses, industrial training etc.

PEO5: PROFESSIONALISM

To impart technical knowledge, ethical values for professional development of the student to solve complex problems and to work in multi-disciplinary ambience, whose solutions lead to significant societal benefits.

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

www.mrcet.ac.in

Department of Mechanical Engineering

Blooms Taxonomy

Bloom's Taxonomy is a classification of the different objectives and skills that educators set for their students (learning objectives). The terminology has been updated to include the following six levels of learning. These 6 levels can be used to structure the learning objectives, lessons, and assessments of a course.

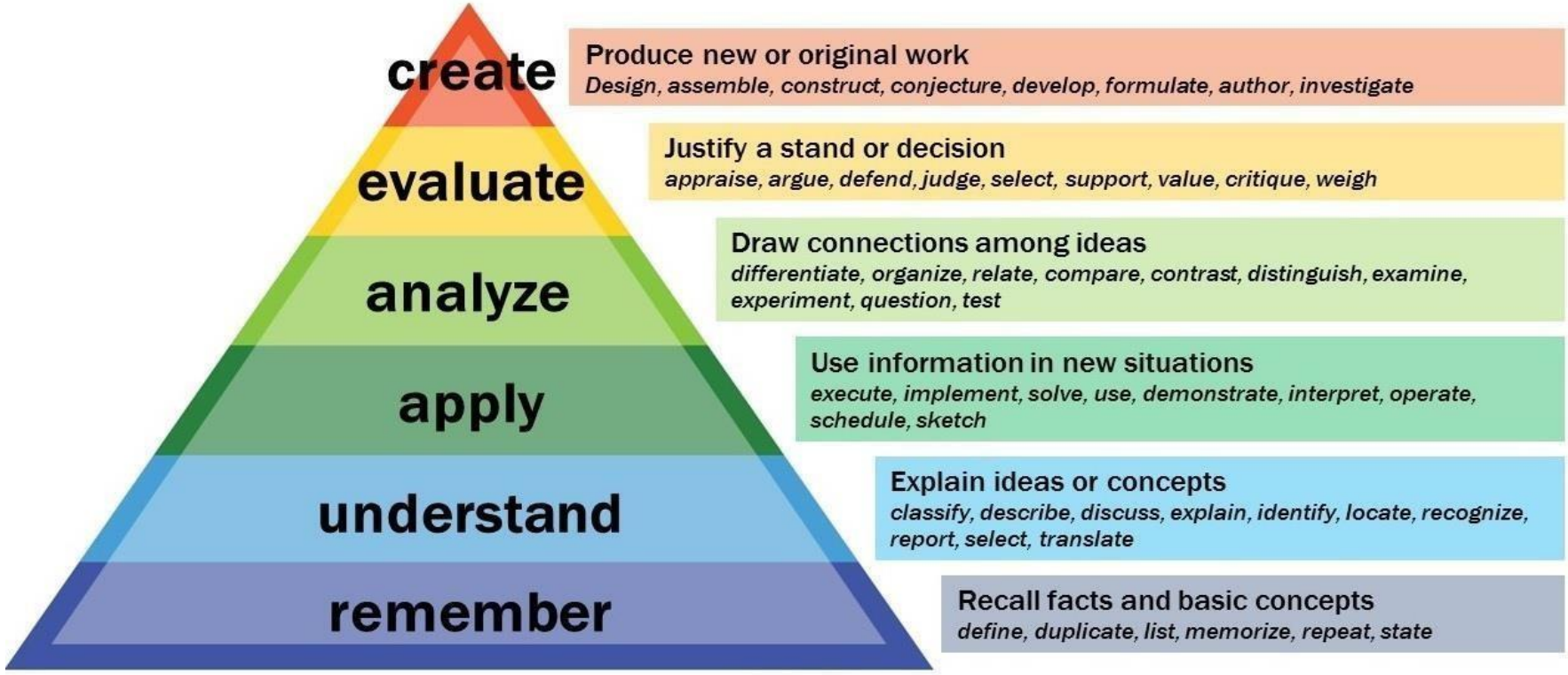
1. **Remembering**: Retrieving, recognizing, and recalling relevant knowledge from long- term memory.
2. **Understanding**: Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.
3. **Applying**: Carrying out or using a procedure for executing or implementing.
4. **Analyzing**: Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing, and attributing.
5. **Evaluating**: Making judgments based on criteria and standard through checking and critiquing.
6. **Creating**: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

www.mrcet.ac.in

Department of Mechanical Engineering



MALLA REDDY COLLEGE OF ENGINEERING AND TECHNOLOGY

IV Year B.Tech.ME-I Sem **L/T/P/C**
3/-/-/3

(R22A0332) Production and Operations Management
(PROFESSIONAL ELECTIVE VI)

COURSE OBJECTIVES:

1. To provide a comprehensive exposure to POM and its significance in Industries.
2. To understand different forecasting methods.
3. To analyze and apply techniques for scheduling.
4. To study the planning of resources required for a plant.
5. To learn the concept of stores management, stock control analysis and material handling techniques..

UNIT–I

Introduction: Overview of Production and Operations Management, Introduction, objectives, role and functions of Operations Management, Principles of Process planning and process design, Functions of Production Planning and Control, Production Cycle, Types of Production Systems - Job Shop, Assembly, Batch, Continuous and Project**.**

UNIT–II

Forecasting: Importance of forecasting, Types of forecasting, Objectives of forecasting, Importance, Process/Steps in forecasting, Advantages and Limitations, Factors affecting forecasting, Methods of forecasting.

UNIT–III

Facilities Management: Choice of site for location, Definition and objectives of Plant Layout Scheduling: Aggregate planning, Master Production schedule (MPS), Scheduling in Job shop, Mass, Continuous and project type production, Concept of PERT & CPM, Introduction and Terminology of Line balancing.

UNIT–IV

Resource requirement planning: Introduction to Resource requirement planning, Concept of Just-In-Time (JIT), General overview of material requirement planning (MRP), definitions of terms used in material requirement planning, outputs and inputs of material requirement planning, Manufacturing resource planning (MRP II), Enterprise Resource planning- scope, Benefits, applications.

UNIT–V

Stores Management and materials handling: Stores management - nature of stores, store lay out, stock verification, classification and codification, safety stock Inventory Control – ABC analysis, VED analysis Material handling: organization of material handling, factors affecting the selection of material handling equipment, types of material handling system, selection of handling system.

TEXTBOOKS:

1. Aswathappa K. andSridhara Bhat,"Production and Operations Management",2010, HPH.
2. Mahadevan.B,"OperationsManagement",2010,PearsonEducation.
3. PaneerSelvam-ProductionandOperationsManagement,PHI2006

REFERENCEBOOKS:

1. BuffaE,ModernProductionandOperationsManagement,Johnwiley2007
2. CharySN,ProductionandOperationsManagement,TMH,2009
3. RamaMurty-ProductionandOperationsManagement,NewAgeInternational,2005

COURSEOUTCOMES:

1. Understanding significance of POM, students able to illustrate production planning functions and manage manufacturing functions in a better way
2. Analyzing different forecasting methods.
3. Applying techniques for scheduling.
4. Studying the planning of resources required for a plant.
5. Learning the concept of stores management, stock control analysis and material handling techniques..



UNIT I
INTRODUCTION TO OPERATIONS MANAGEMENT



PRODUCTION MANAGEMENT

- Planning, organising, directing and controlling of production activities. Production management deals with converting **raw materials** into finished goods or products.
- It brings together the 6M's i.e. men, money, machines, materials, methods and markets to satisfy the wants of the people.

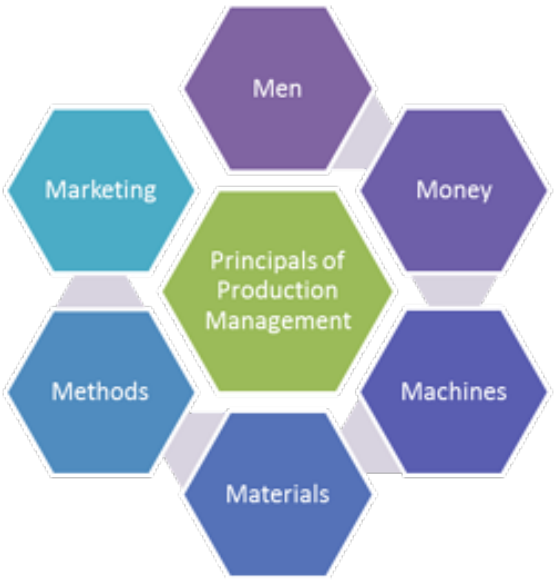


Fig 1.1 – 6M's for Production Management

OPERATIONS MANAGEMENT

- Operations management is chiefly concerned with planning, organizing and supervising in the contexts of production, manufacturing or the provision of services.
- As such, it is delivery-focused, ensuring that an organization successfully turns inputs to outputs in an efficient manner.
- The inputs themselves could represent anything from materials, equipment and technology to human resources such as staff or workers.
- Operation Management is understood as the process where by resources or inputs are converted in to more useful products.

Key Points

- Operations management is the administration of business practices to create the highest level of efficiency possible within an organization.
- Operations management is concerned with converting materials and labor into goods and services as efficiently as possible.
- Corporate operations management professionals try to balance costs with revenue to maximize net operating profit.

Difference between OM and PM

- It is accepted norm that OM includes techniques which enable the achievement of operational objectives in an operation system
- The operation system includes both manufacturing sector as well as service sector, but when you use the word PM, you should be careful to note that it refers to the manufacturing sector but not the service sector.
- Suppose, you are designing a layout for the hospital you should say that you are applying Operations Management Technique not the Production Management Technique

Two distinct points between PM and OM

1. The term PM is used for a system where tangible goods are produced whereas OM is frequently used where various inputs are transformed in to intangible services. That is OM cover service organizations such as banks, airlines, utilities, super bazars, educational institutions, consultancy firms, police department in addition to manufacturing enterprises.
2. The term OM is evolved from PM. OM is the term used now a days, PM precedes OM in the historical growth of the subject.
   So it can be concluded that PM is subset of OM

Components of Operations Management



Fig 1.2 – Foundational Components of Operations Management

Operation managers are concerned with planning, organizing, and controlling the activities which affect human behavior through models.

1. **Planning**
   - Activities that establishes a course of action and guide future decision-making is planning.

- The operations manager defines the objectives for the operations subsystem of the organization, And the policies, and procedures for achieving the objectives.
- This stage includes clarifying the Role and focus of operations in the organization's overall strategy.
- It also involves product Planning, facility designing and using the conversion process.

2. Organizing

- Activities that establishes a structure of tasks and authority.
- Operation managers establish a Structure of roles and the flow of information within the operations subsystem.
- They determine The activities required to achieve the goals and assign authority and responsibility for carrying Them out.

3. Controlling

- Activities that assure the actual performance in accordance with planned performance.
- To Ensure that the plans for the operations subsystems are accomplished, the operations manager Must exercise control by measuring actual outputs and comparing them to planned operations Management.
- Controlling costs, quality, and schedules are the important functions here.

4. Behavior

- Operation managers are concerned with how their efforts to plan, organize, and control affect Human behavior.
- They also want to know how the behavior of subordinates can affect Management's planning, organizing, and controlling actions.
- Their interest lies in decision- making behavior.

The combination of understanding and coordinating the work of a company are central to becoming a successful operations manager.

Objectives Of Operations Management

Objectives of operations management can be categorized into customer service and resource Utilization.

Customer service

- The first objective of operating systems is the customer service to the satisfaction of customer Wants.
- Therefore, customer service is a key objective of operations management.
- The operating System must provide something to a specification which can satisfy the customer in terms of cost And timing.
- Thus, primary objective can be satisfied by providing the 'right thing at a right price at the right time'.

Resource utilization

- Another major objective of operating systems is to utilize resources for the satisfaction of Customer wants effectively, i.e., customer service must be provided with the achievement of Effective operations through efficient use of resources.
- Inefficient use of resources or inadequate Customer service leads to commercial failure of an operating system.
- Operations management is concerned essentially with the utilization of resources, i.e., obtaining Maximum effect from resources or minimizing their loss, underutilization or waste.
- The extent Of the utilization of the resources' potential might be expressed in terms of the proportion of Available time used or occupied, space utilization, levels of activity, etc.
- Each measure indicates The extent to which the potential or capacity of such resources is utilized. This is referred as the Objective of resource utilization

Special Considerations

- A critical function of operations management relates to the management of inventory through the supply chain.
- To be an effective operations management professional, one must be able to understand the processes that are essential to what a company does and get them to flow and work together seamlessly.
- The coordination involved in setting up business processes in an efficient way requires a solid understanding of logistics.
- An operations management professional understands local and global trends, customer demand and the available resources for production.
- Operations management approaches the acquisition of materials and the use of labor in a timely, cost-effective manner to deliver customer expectations. Inventory levels are monitored to ensure excessive quantities are on hand.
- Operations management is responsible for finding vendors that supply the appropriate goods at reasonable prices and have the ability to deliver the product when needed.
- Another large facet of operations management involves the delivery of goods to customers. This includes ensuring products are delivered within the agreed time commitment. Operations management also typically follows up with customers to ensure the products meet quality and functionality needs.
- Finally, operations management takes the feedback received and distributes the relevant information to each department to use in process improvement.
- Operations managers are involved in coordinating and developing new processes while reevaluating current structures.
- Organization and productivity are two key drivers of being an operations manager, and the work often requires versatility and innovation.

ROLE OF OPERATIONS MANAGEMENT IN TOTAL MANAGEMENT SYSTEM

- Operations Management concern with the conversion of inputs into outputs, using physical resources, so as to provide the desired utilities to the customer while meeting the other organizational objectives of effectiveness, efficiency and adoptability.
- It distinguishes itself from other functions such as personnel, marketing, finance, etc. by its primary concern for 'conversion by using physical resources'.

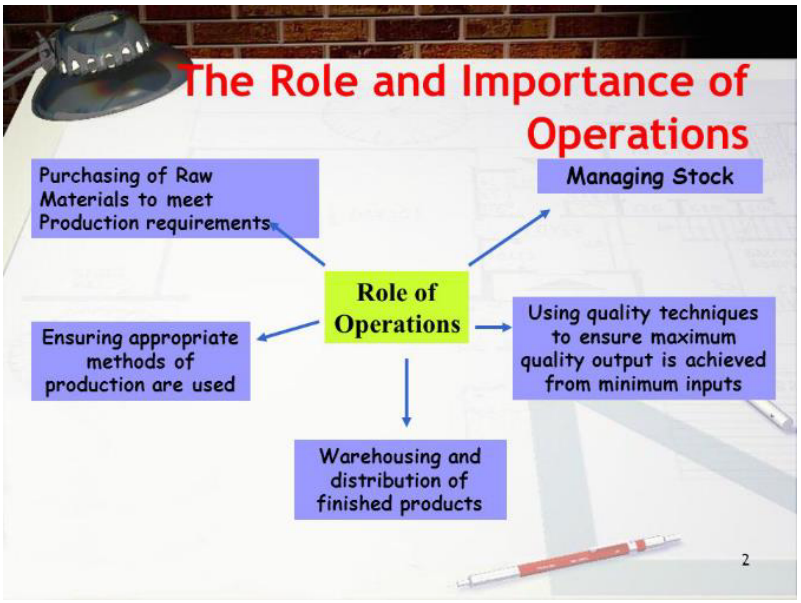


Fig 1.3 – Role of Operations

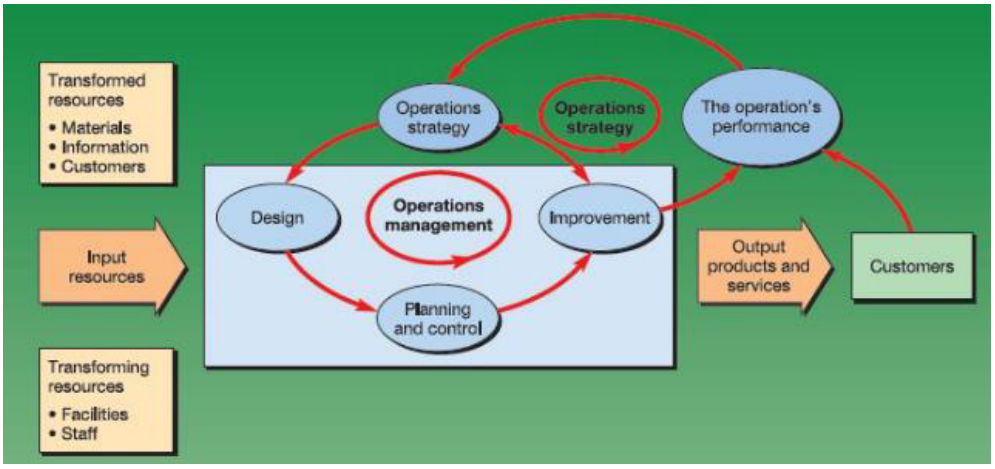


Fig 1.4 – Input and Output of Operations Management

Operations Management Functions:

1. Location of facilities
2. Plant layouts and material handling
3. Product design
4. Process design
5. Production and planning control
6. Quality control
7. Materials management
8. Maintenance management.



Fig 1.5 – Production and Operations Management

1. Location of facilities

- Location of facilities for operations is a long-term capacity decision which involves a long term Commitment about the geographically static factors that affect a business organization.
- It is an Important strategic level decision-making for an organization. It deals with the questions such as 'Where our main operations should be based?'
- The selection of location is a key-decision as large investment is made in building plant and Machinery.
- An improper location of plant may lead to waste of all the investments made in plant and machinery equipment's.
- Hence, location of plant should be based on the company's expansion.

2. Plant layout and material handling

- Plant layout refers to the physical arrangement of facilities.
- It is the configuration of departments, Work centres and equipment in the conversion process.
- The overall objective of the plant layout Is to design a physical arrangement that meets the required output quality and quantity most Economically.

3. Product design

- Product design deals with conversion of ideas into reality. Every business organization have to Design, develop and introduce new products as a survival and growth strategy.
- Developing New products and launching them in the market is the biggest challenge faced by the organizations.
- The entire process of need identification to physical manufactures of product involves three Functions: **marketing, product development, manufacturing.**
- Product development translates the Needs of customers given by marketing into technical specifications and designing the various Features into the product to these specifications.
- Manufacturing has the responsibility of selecting the processes by which the product can be manufactured.
- Product design and development provides link between marketing, customer needs and expectations and the activities required to manufacture the product.

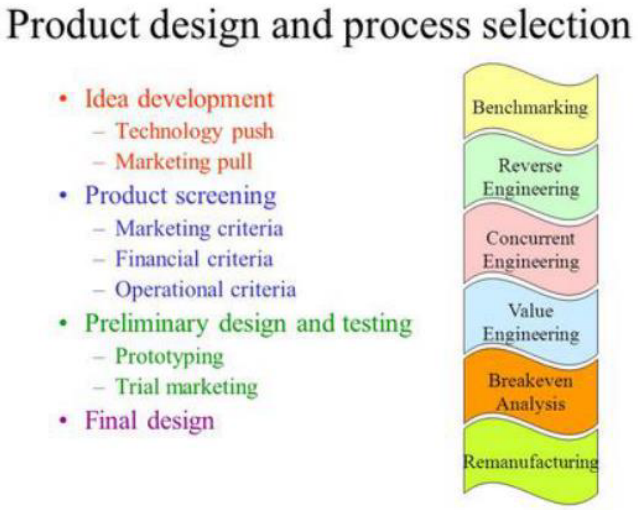


Fig 1.6 – Steps in Product Design

4. Process design

- Process design is a macroscopic decision-making of an overall process route for converting the Raw material into finished goods.
- These decisions encompass the selection of a process, choice of technology, process flow analysis and layout of the facilities.
- Hence, the important decisions In process design are to analyze the workflow for converting raw material into finished product and to select the workstation for each included in the workflow.

5. Production Planning And Control

- Production planning and control can be defined as the
  - process of planning the production in advance,
  - setting the exact route of each item,
  - fixing the starting and finishing dates for each item,
  - to give production orders to shops and to follow up the progress of products according to orders.
- The principle of production planning and control lies in the statement 'First Plan Your Work and then Work on Your Plan'.

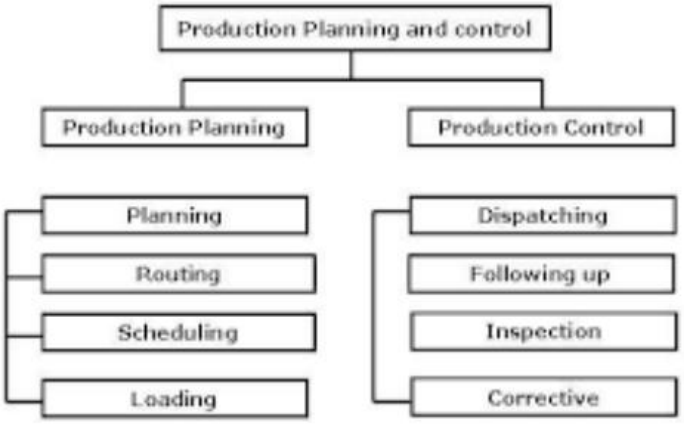


Fig 1.7 – Functions of PPC

Main functions of production planning and control includes Planning, routing, scheduling, dispatching and follow-up.

6. Quality Control

- Quality Control (QC) may be defined as 'a system that is used to maintain a desired level of Quality in a product or service'.
- It is a systematic control of various factors that affect the quality of the product.
- Quality control aims at prevention of defects at the source, relies on effective Feedback system and corrective action procedure.
- Quality control can also be defined as 'that industrial management technique by means of which Product of uniform acceptable quality is manufactured'.

- It is the entire collection of activities which ensures that the operation will produce the optimum quality products at minimum cost.

7. **Materials Management**

   Materials management is that aspect of management function which is primarily concerned with the acquisition, control and use of materials needed and flow of goods and services connected with the production process having some predetermined objectives in view.

   The main objectives of materials management are:

   - To minimize material cost.
   - To purchase, receive, transport and store materials efficiently and to reduce the related cost.
   - To cut down costs through simplification, standardization, value analysis, import substitution, etc.
   - To trace new sources of supply and to develop cordial relations with them in order to Ensure continuous supply at reasonable rates.
   - To reduce investment tied in the inventories for use in other productive purposes and to Develop high inventory turnover ratios.

8. **Maintenance Management**

   - In modern industry, equipment and machinery are a very important part of the total productive Effort.
   - Therefore, their idleness or downtime becomes are very expensive.
   - Hence, it is very Important that the plant machinery should be properly maintained.

   The main objectives of maintenance management are:

   - To achieve minimum breakdown and to keep the plant in good working condition at the Lowest possible cost.
   - To keep the machines and other facilities in such a condition that permits them to be used At their optimal capacity without interruption.
   - To ensure the availability of the machines, buildings and services required by other sections Of the factory for the performance of their functions at optimal return on investment.



Fig 1.8 – Functions of Operation Management

PROCESS PLANNING AND PROCESS DESIGN

PROCESS PLANNING

- In companies, planning processes can result in increased output, higher precision, and faster turnaround for vital business tasks.
- A process is described as a set of steps that result in a specific outcome. It converts input into output.
- Process planning is also called manufacturing planning, material processing, process engineering, and machine routing.
- It is the act of preparing detailed work instructions to produce a part. It is a complete description of specific stages in the production process.
- Process planning determines how the product will be produced or service will be provided.
- Process planning converts design information into the process steps and instructions to powerfully and effectively manufacture products.
- As the design process is supported by many computer-aided tools, computer-aided process planning (CAPP) has evolved to make simpler and improve process planning and realize more effectual use of manufacturing resources.

It has been documented that process planning is required for new product and services. It is the base for designing factory buildings, facility layout and selecting production equipment. It also affects the job design and quality control.

Objective of Process Planning:

- The chief of process planning is to augment and modernize the business methods of a company. Process planning is planned to renovate design specification into manufacturing instructions and to make products within the function and quality specification at the least possible costs.

- This will result in reduced costs, due to fewer staff required to complete the same process, higher competence, by eradicating process steps such as loops and bottlenecks, greater precision, by including checkpoints and success measures to make sure process steps are completed precisely, better understanding by all employees to fulfil their department objectives.
- Process planning deals with the selection of the processes and the determination of conditions of the processes.
- The particular operations and conditions have to be realised in order to change raw material into a specified shape.
- All the specifications and conditions of operations are included in the process plan.
- The process plan is a certificate such as engineering drawing. Both the engineering drawing and the process plan present the fundamental document for the manufacturing of products.
- Process planning influences time to market and productions cost.
- Consequently the planning activities have immense importance for competitive advantage.

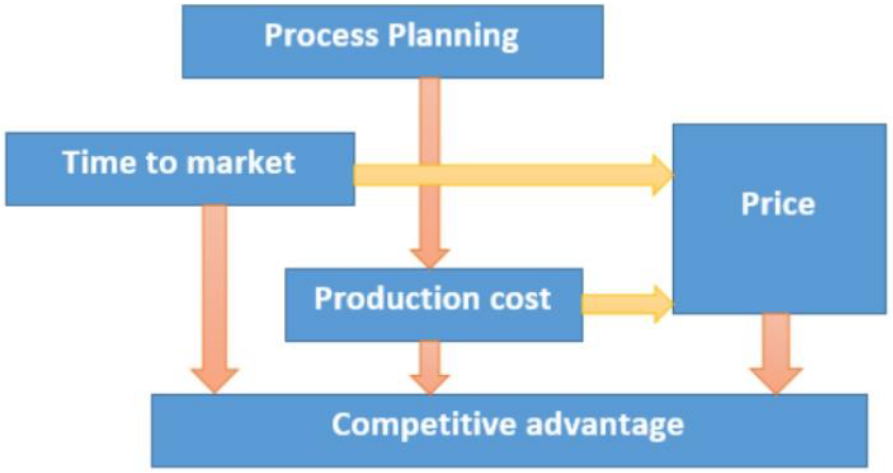


Fig 1.9 - Effect of process planning on competitive advantage

Principles of Process Planning

General principles for evaluating or enhancing processes are as follows:

1. First define the outputs, and then look toward the inputs needed to achieve those outputs.

2. Describe the goals of the process, and assess them frequently to make sure they are still appropriate. This would include specific measures like quality scores and turnaround times.

3. When mapped, the process should appear as a logical flow, without loops back to earlier steps or departments.

4. Any step executed needs to be included in the documentation. If not, it should be eliminated or documented, depending on whether or not it's necessary to the process.

5. People involved in the process should be consulted, as they often have the most current information.

Major steps in process planning:

Process planning has numerous steps to complete the project.

Process planning in manufacturing may include the following activities:

- Analysis of the product print and specifications
- Improvement of the specifications
- Make or buy decision
- Selection of the Basic Manufacturing Process
- Determine the sequence of operations
- Combine the operations
- Prepare the list or raw materials
- Selection of the Machine Tools and Equipment
- Inspection
- Requirement of Tools, Gauges etc
- Labour Requirements
- Time Standards
- Cost of Production
- Prepare the operation sheet and route sheet

PROCESS DESIGN

- Process design is concerned with the overall sequence of operations required to achieve the product specifications.
- It specifies the type of work stations that are to be used, the machines and equipment necessary and the quantities in which each are required.

The sequence of operations in the manufacturing process is determined by

1. The nature of the product
2. The materials used
3. The quantities being produced
4. The existing physical layout of the plant.

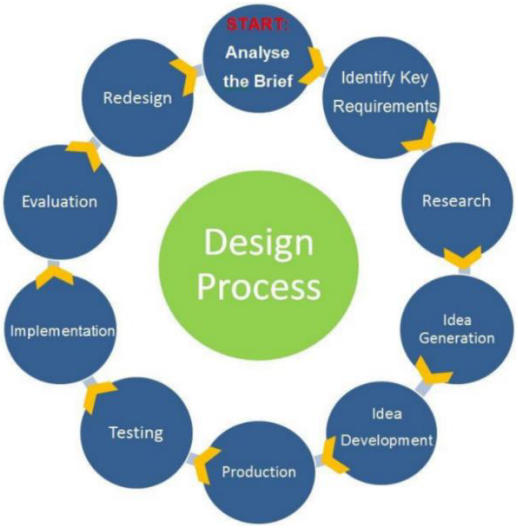


Fig 1.10– Steps in Design Process

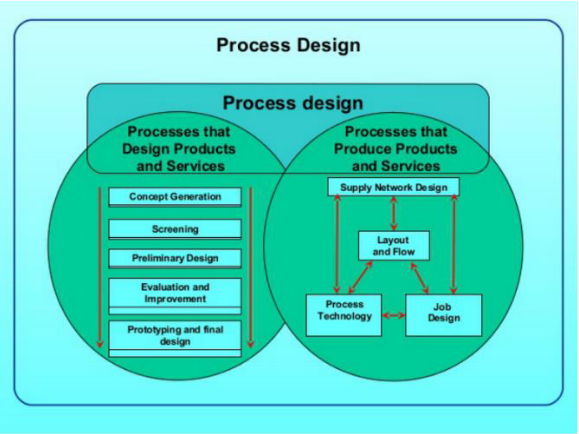
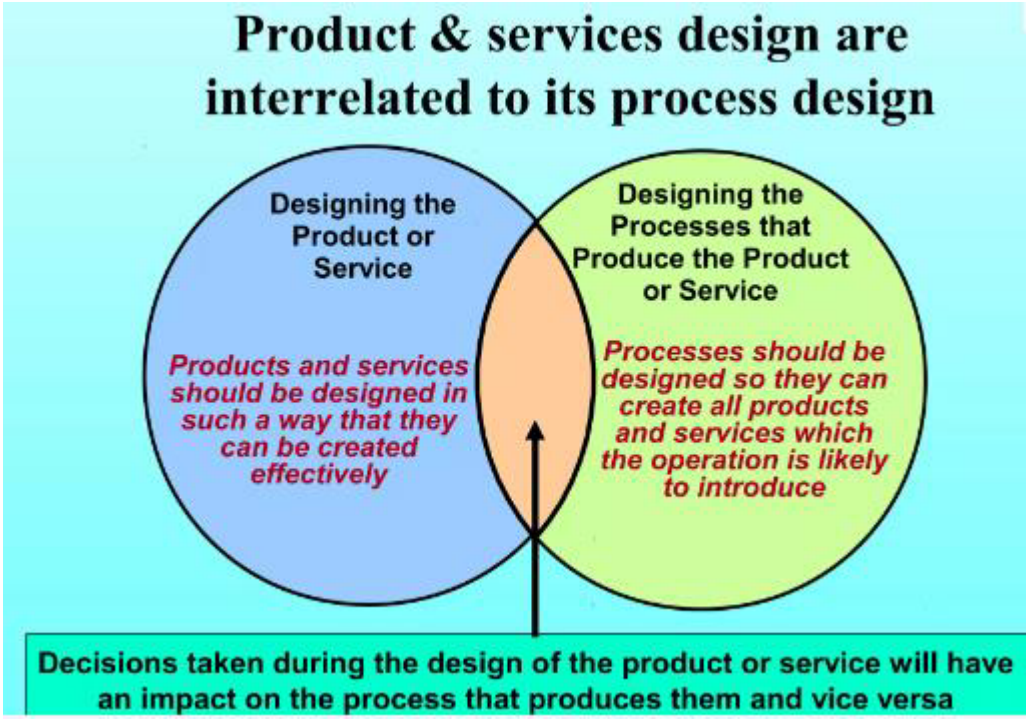


Fig 1.11 – Process Design

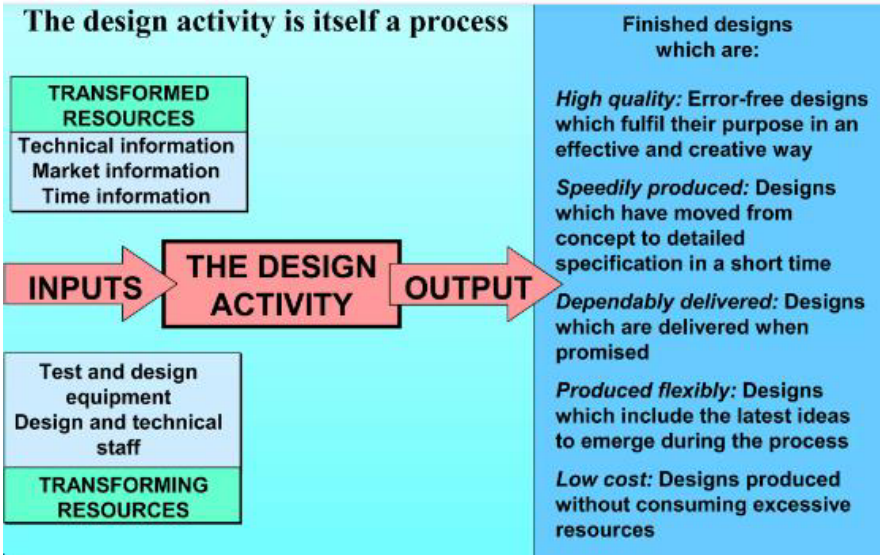
Nature of the design activity:

1) **Design is inevitable** – products, services and the processes which produce them all have to be designed.

2) **Product design influences process design** – decisions taken during the design of a product or service will have an impact on the decisions taken during the design of the process which produces those products or services and vice versa.



- Process designer customers satisfaction achieved through:
  - Layout
  - Location
  - Process technology
  - Human skills



PRODUCTION PLANNING AND CONTROL

- Production planning and control is the process of planning the production in advance.
- Setting the exact route of each item and fixing the starting and finishing date for each item is the key operation.
- Giving the production orders to different shops and observing the progress of products according to order.
- Main functions of production planning and control includes Planning, routing, scheduling, dispatching and follow-up.

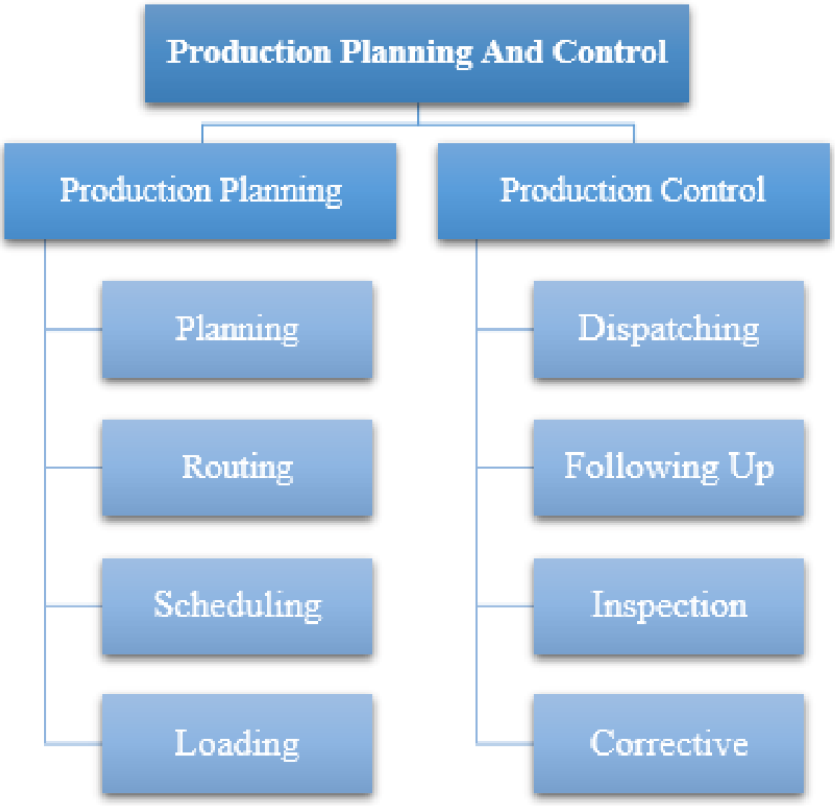


Fig 1.12 – Functions of Production Planning and Control



Fig 1.13 – PPC System

The Various Functions of PPC:

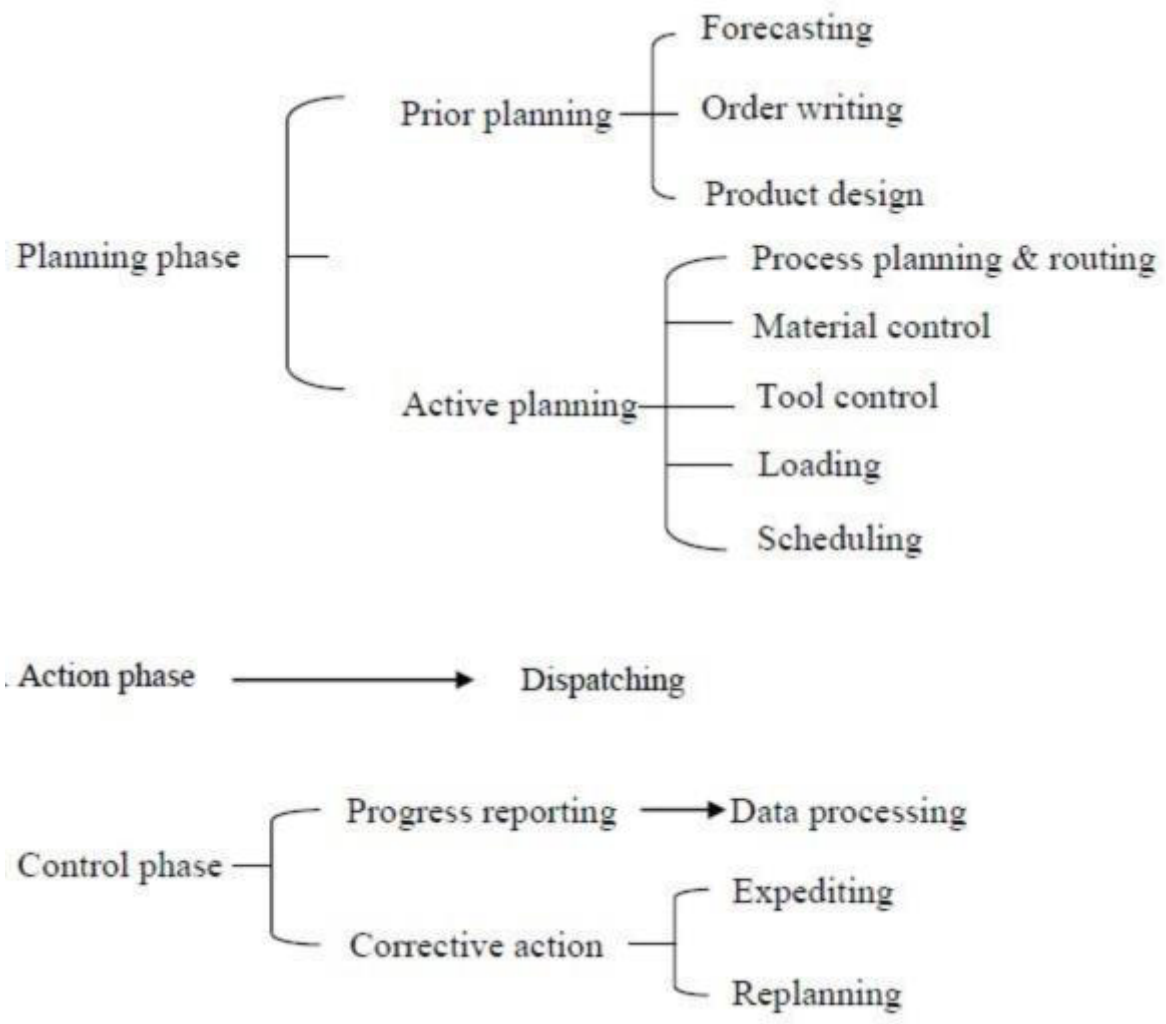


Fig 1.14 – Functions of Production Planning and Control

The main functions of PPC are the coordination of all the activities, which exist during production or manufacturing.

Some of the important functions of production planning and control are listed below:

1. Materials Function:

- Raw materials, finished parts and bought out components should be made available in required quantities and at required time to ensure the correct start and end for each operation resulting in uninterrupted production.

- The function includes the specification of materials (quality & quantity) delivery dates, variety reduction (standardisation) procurement and make or buy decisions.

2. Machines and Equipment:

- This function is related with the detailed analysis of available production facilities, equipment down time, maintenance policy procedure and schedules.
- Concerned with economy of jigs and fixtures, equipment availability.
- Thus the duties include the analysis of facilities and making their availability with minimum down time because of breakdowns.

3. Methods:

- This function is concerned with the analysis of alternatives and selection of the best method with due consideration to constraints imposed.
- Developing specifications for processes is an important aspect of PPC and determination of sequence of Operations.

4. Process Planning (Routing):

It is concerned with selection of path or route which the raw should follow to get transformed in to finished product.

The duties include:

(a) Fixation of path of travel giving due consideration to layout.

(b) Breaking done of operations to define each operation in detail.

(c) Deciding the set up time and process time for each operation.

5. Estimating:

- Once the overall method and sequence of operations is fixed and process sheet for each operation is available, then the operations times are estimated.
- This function is carried out using extensive analysis of operations along with methods and routing and standard times for operation are established using work measurement techniques.

6. Loading and Scheduling:

- Scheduling is concerned with preparation of machine loads and fixation of Starting and completion dates for each of the operations.
- Machines have to be loaded according to their capability of performing the given task and according to their capacity.

Thus, the duties include:

(a) Loading the machines as per their capability and capacity.

(b) Determining the start and completion times for each operation.

(c) To Co-ordinate with sales department regarding delivery schedules.

7. Dispatching:

- This is the execution phase of planning.
- It is the process of setting production activities in motion through release of orders and instructions.
- It authorises the start of Production activities by releasing materials, components, tools, fixtures and instruction sheets to the operator.

The activities involved are:
(a) To assign definite work to definite machines, work centres and men.

(b) To issue required materials from stores.

(c) To issue jigs, fixtures and make them available at correct point of use.

(d) Release necessary work orders, time tickets etc. to authorise timely start of operations.

(e) To record start and finish time of each job on each machine or by each man.

8. Expediting:

- This is the control tool that keeps a close observation on the progress of the work.
- It is a logical step after dispatching which is called "follow-up" or "Progress".
- It co-ordinates extensively to execute the production plan.
- Progressing function can be divided in to three parts, i.e. follow up of materials, follow up of work in process and follow up of assembly.

The duties include:

1. Identification of bottlenecks and delays and interruptions because of which the production schedule may be disrupted.

2. To devise action plans (remedies) for correct the errors.

3 To see that production rate is in line with schedule.

9. Inspection:

- It is a measure control tool.
- Though the aspects of quality control are the separate function, this is of very much important to PPC both for the execution of the current plans and in scope for future planning.
- This forms the basis for knowing the limitations with respects to methods, processes etc. which is very much useful for evaluation phase.

10. Evaluation:

- This stage though neglected is a crucial to the improvement of productive efficiency.
- A thorough analysis of all the factors influencing the production planning and control helps to identify the weak spots and the corrective action with respect to preplanning and planning will be effected by a feed back.
- The success of this step depends on the communication, Data and information gathering and analysis.

PRODUCTION CYCLE

- The **production cycle** is comprised of all activities related to the conversion of raw materials into finished goods.
- The **cycle** is comprised of several distinct components, involving the design of products, their incorporation into a **production** schedule, **manufacturing** activities, and a cost accounting feedback loop.

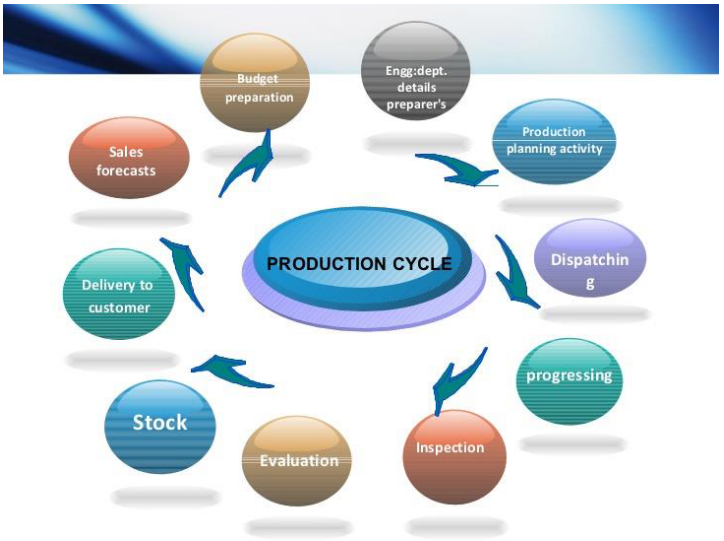


Fig 1.15 – Components of Production Cycle

Production Cycle Activities

- The four basic activities in the production cycle are: (1) product design; (2) planning and scheduling; (3) production operations; and (4) cost accounting.
- Accountants are primarily involved in the fourth activity (cost accounting) but must understand the other processes well enough to design an AIS (Accounting Information System) that provides needed information and supports these activities.

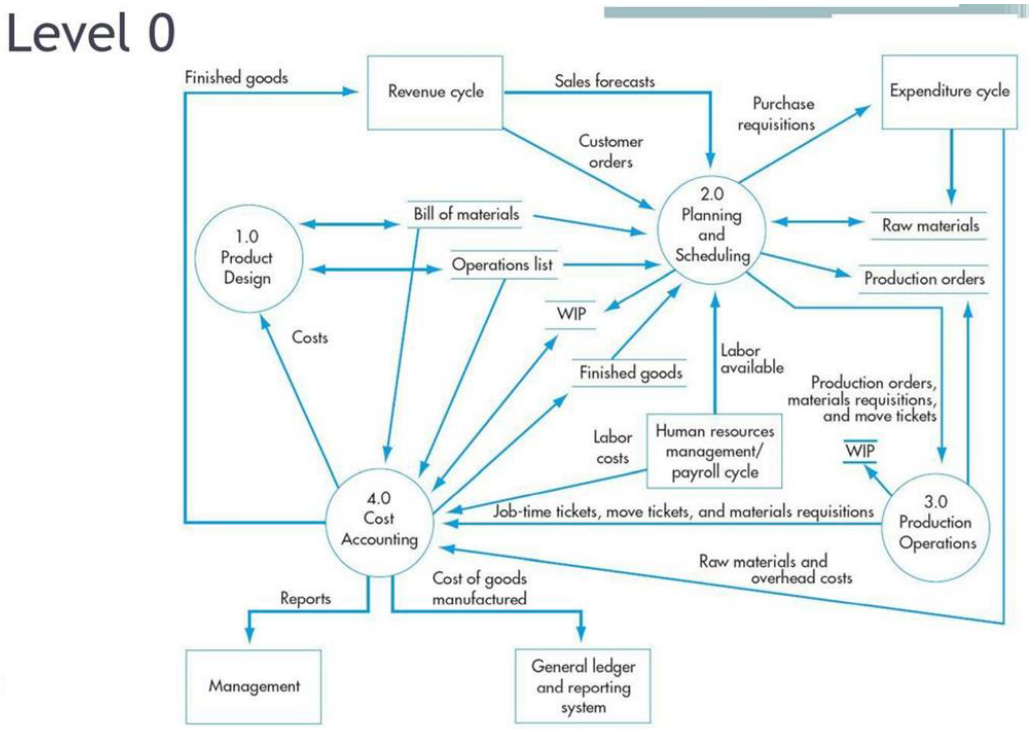


Fig 1.16 – Activities in Production Cycle

Product Design

- The objective of product design is to design a product that strikes the optimal balance of meeting customer requirements for quality, durability, and functionality; and minimizing production costs. Simulation software can improve the efficiency and effectiveness of product design.
- Key documents and forms in product design:
  - ***Bill of Materials:*** Lists the components that are required to build each product.
  - ***Operations List***: Lists the sequence of steps and the equipment and time required to produce each product.
- The accountant participates in product design, because 65-80% of product cost is determined at this stage. The accountant can add value by designing an AIS that measures and collects the needed data and by helping the design team use that data to improve profitability.

Planning and Scheduling

- The objective of the planning and scheduling activity is to develop a production plan that is efficient enough to meet existing orders and anticipated short-term demand while minimizing inventories of both raw materials and finished goods. There are two common approaches to production planning:
  - ***Manufacturing Resource Planning*** (MRP-II)--An extension of MRP inventory control systems. Seeks to balance existing production capacity and raw materials needs to meet forecasted sales demands. Often referred to as ***push*** manufacturing.

  - ***Lean Manufacturing***--An extension of just-in-time inventory systems. Seeks to minimize or eliminate inventories of raw materials, work in process, and finished goods. Theoretically produces only in response to customer orders, but in reality, there are short-run production plans. Often referred to as ***pull*** manufacturing.
- Key documents and forms:
  - ***Master production schedule***—specifies how much of each product is to be produced during each period and when.
  - ***Production order***—authorizes production of a specified quantity of a product.
  - ***Materials requisition***—authorizes movement of materials to the factory floor.
  - ***Move ticket***—documents transfer of parts and materials through the factory.
- Role of the accountant is to ensure the AIS collects and reports costs in a manner consistent with the company's production planning techniques.

Production Operations

- Production operations vary greatly across companies, depending on the type of product and the degree of automation. The use of various forms of IT, such as robots and computer-controlled machinery is called ***computer-integrated manufacturing (CIM)***. Accountants must understand how the CIM affects the AIS.
- In a lean manufacturing environment, a customer order triggers several actions. The system first checks inventory on hand for sufficiency, then calculates labor needs and determines whether overtime or temporary help will be needed. Based on the bill of materials, the system determines what components need to be ordered and transmits necessary purchase orders via EDI (Electronic Data Interchange). The master production schedule is adjusted to include the new order.
- Sharing information across cycles helps companies be more efficient by timing purchases to meet the actual demand.
- While the nature of production processes and the extent of CIM vary, all companies need data on: raw materials used; labor hours expended; machine operations performed; and other manufacturing overhead costs incurred.

Cost Accounting

- The objectives of cost accounting are: (1) to provide information for planning, controlling, and evaluating the performance of production operations; (2) to provide accurate cost data about products for use in pricing and product mix decisions; and (3) to collect and process information used to calculate inventory and COGS values for the financial statements.
- Types of cost accounting systems:
  - ***Job order costing***—assigns costs to a particular production batch or job.
  - ***Process costing***--assigns costs to each process or work center in the production cycle and calculates the average cost for all units produced.
- Accounting for Fixed Assets:
  - The AIS must collect and process information about the property, plant, and equipment used in the production cycle. These assets represent a significant

portion of total assets for many companies and need to be monitored as an investment. The purchase of fixed assets follows the same processes as other purchases in the expenditure cycle (order à receive à pay). But the amounts involved necessitate competitive bidding, involvement of more people, differences in payment approaches (e.g., installments), more elaborate controls, and formal approval for disposal.

- Both job-order and process costing systems require that data be accumulated about raw materials, direct labor, machinery and equipment usage, and manufacturing overhead. The choice of method does not affect how data are collected but does affect how costs are assigned to products.
- ***Raw Material Usage Data***--When production is initiated, the issuance of a materials requisition triggers a debit (increase) to work in process and a credit (decrease) to raw materials inventory. Work in process is credited and raw materials are debited for any amounts returned to inventory. Bar-coding of raw materials or RFID (radio frequency identification) tags can improve efficiency.
- ***Direct Labor Costs***--Historically, job time tickets were used to record the time a worker spent on each job task. Currently, workers may enter the data on online terminals or use coded ID badges swiped through a badge reader.
- ***Machinery and Equipment Usage***--Data about machinery and equipment are collected at each production step, often with data about labor costs.
- ***Manufacturing Overhead Costs***--Include costs that can't be easily traced to jobs or processes, such as utilities, depreciation, and supervisory salaries. Accountants help control overhead by assessing how product mix changes will affect overhead costs.

TYPES OF PRODUCTION PROCESSES

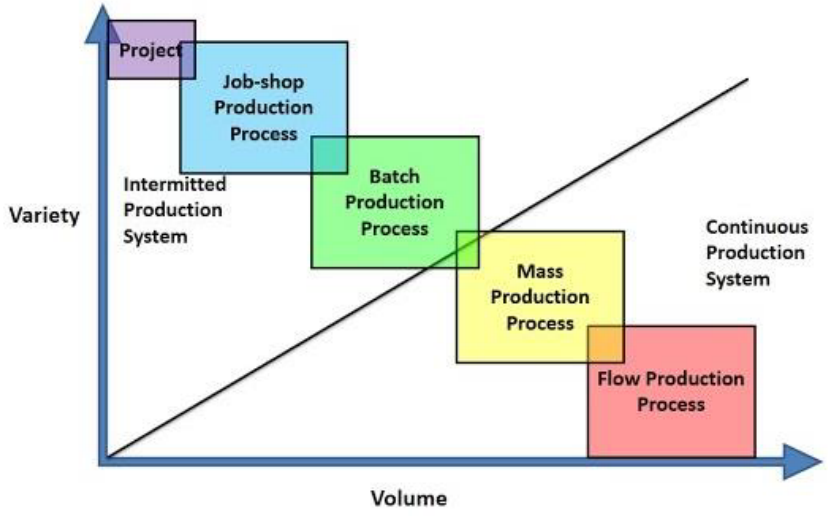


Fig 1.17 - Volume vs Variety for different Production Processes

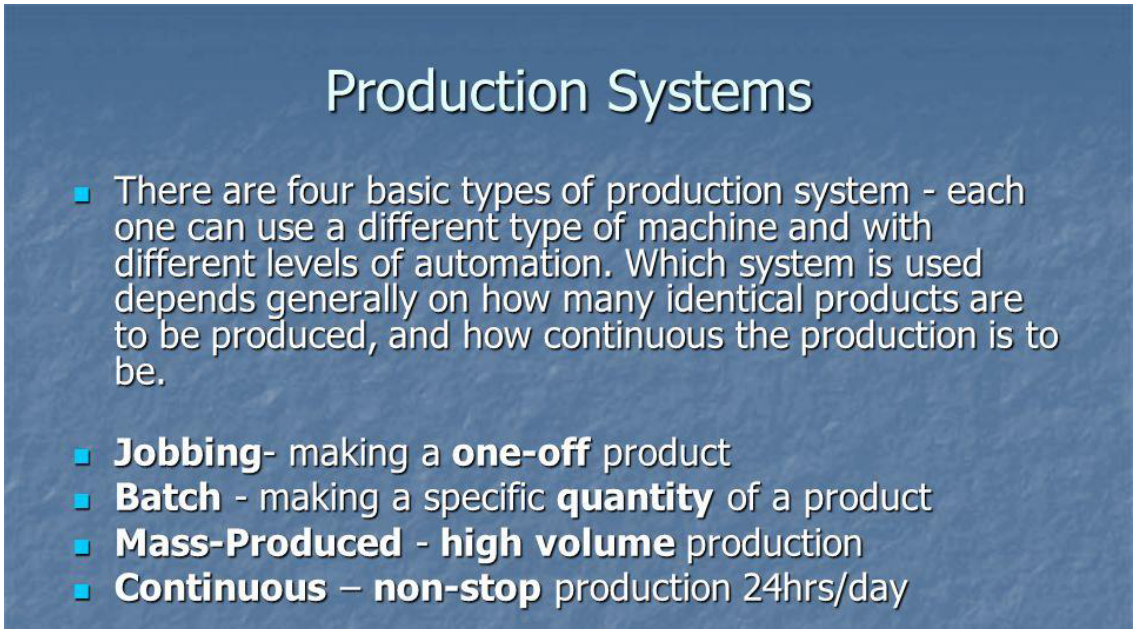


Fig 1.18 – Production Systems

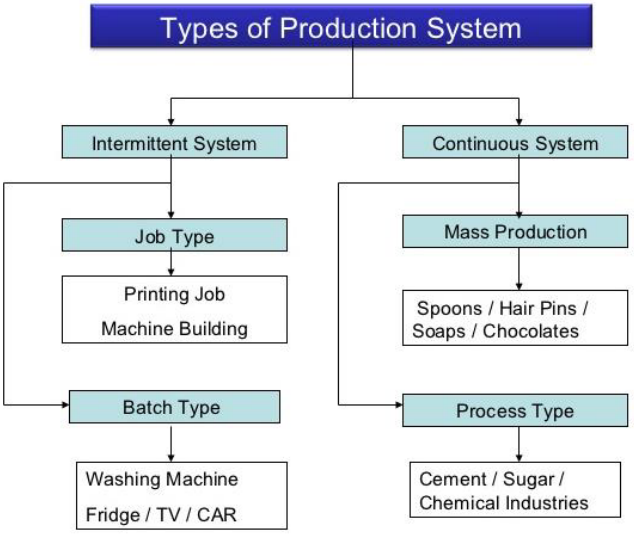


Fig 1.19 – Types of Production Systems

DIFFERENCE BETWEEN CONTINUOUS AND INTERMITTENT SYSTEMS

- **ON THE BASIS OF MACHINERY**

CONTINUOUS	INTERMITTENT
1.SPECIFIC MACHINERY	1.GENERALISED MACHINERY
2.PERMANENT MACHINE SETUP	2.FREQUENT CHANGES IN MACHINE SETUP
3.DUPLICATION OF MACHINES	3.LESS MACHINES REQUIRED

Fig 1.20 – Difference between Continuous and Intermittent Systems

PROJECT

- A Project is a temporary endeavour (attempt with lot of effort) undertaken to create a unique product, service or result.
- Temporary means having a definite beginning and end.
- The end is reached when the project's objectives have been achieved, or if the project is terminated for any reason.
- Temporary does not mean short in nature, and it could well be a mammoth project – like a 10 year project – for example, sending a man to moon, sending Curiosity to Mars, Building the Taj Mahal or the Pyramids
- Secondly, each project creates a unique product, service or result.
- Sure, there may be some repetitive elements present in each project, but the output must be unique – like similar housing projects in the same area with the same design may be similar, but each will have unique challenges, different contractors, issues, etc. that will make them each unique.

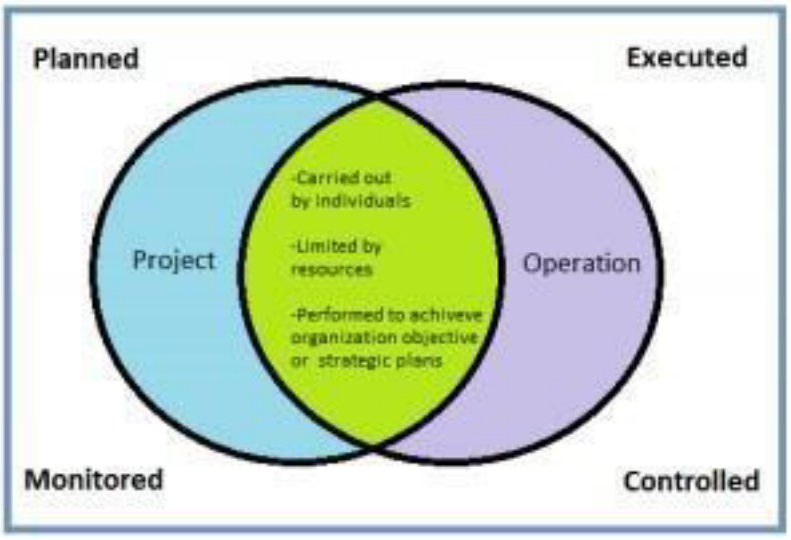


Fig 1.21 – Tasks in a Project

- Simply put, a project is a series of tasks that need to be completed in order to reach a specific outcome.
- A project can also be defined as a set of inputs and outputs required to achieve a particular goal.
- Projects can range from simple to complex and can be managed by one person or a hundred.
- Projects are often described and delegated by a manager or executive.
- They go over their expectations and goals and it's up to the team to manage logistics and execute the project in a timely manner.
- Sometimes deadlines can be given or a time limitation.
- For good project productivity, some teams break the project up into individual tasks so they can manage accountability and utilize team strengths.

JOB SHOP

- A job shop is a type of manufacturing process in which small batches of a variety of custom products are made.
- In the job shop process flow, most of the products produced require a unique set-up and sequencing of process steps.
- Examples of job shops include a wide range of businesses—a machine tool shop, a machining center, a paint shop, a commercial printing shop, and other manufacturers that make custom products in small lot sizes.
- Volume and standardization is low and products are often one of a kind.

Characteristics of a Job Shop

Layout

- In the job shop, similar equipment or functions are grouped together, such as all drill presses in one area and grinding machines in another in a process layout.

- The layout is designed to minimize material handling, cost, and work in process inventories.
- Job shops use general purpose equipment rather than specialty, dedicated product-specific equipment.
- Digital numerically controlled equipment is often used to give job shops the flexibility to change set-ups on the various machines very quickly.
- Job shops compete on quality, speed of product delivery, customization, and new product introduction, but are unlikely to compete on price as few scale economies exist.

Routing

- When an order arrives in the job shop, the part being worked on travels throughout the various areas according to a sequence of operations.
- Not all jobs will use every machine in the plant. Jobs often travel in a jumbled routing and may return to the same machine for processing several times.
- This type of layout is also seen in services like department stores or hospitals, where areas are dedicated to one particular product (men's clothing) or one type of service (maternity ward)

Employees

- Employees in a job shop are typically highly skilled craft employees who can operate several different classes of machinery.
- These workers are paid higher wages for their skill levels. Due to their high skill level, job shop employees need less supervision.
- Workers may be paid a standard hourly wage or by an incentive system.
- The role of management is to bid on jobs and to establish prices for customer orders. The key activity in a job shop is processing information.

Information

- Information is the most critical aspect of a job shop.
- Information is needed to quote a price, bid on a job, route an order through the shop, and specify the exact work to be done.
- Information begins with quoting, then a job sheet and blueprint are prepared before the job is released to the floor.
- Once on the production floor, employees complete job sheets and time cards for labor cost calculations and to update records for quoting future jobs when variances are present.
- While it is often easy to bid on jobs the shop has manufactured before, new jobs require accurate costing of labor, materials, and equipment as well as accurate assigning of overhead to the job.

- Tickets follow each job through the shop, where time and activities are recorded. Because the job shop makes specialty, custom items, it competes on quality and customer service and not on price.
- The job shop has little if any raw materials inventory because customers bring in the parts and materials to be worked on.
- The job shop has work-in-process inventory while jobs are being completed, but typically the customer is waiting on the order and expects prompt delivery, so there is no finished goods inventory in this make-to-order environment.
- Some job shops, like many small businesses, thrive on managing cash flow.
- They may work on small jobs to complete them by the end of the month so they can bill customers for the work.

Scheduling

- A job is characterized by its route, its processing requirements, and its priority.
- In a job shop the mix of products is a key issue in deciding how and when to schedule jobs.
- Jobs may not be completed based on their arrival pattern in order to minimize costly machine set-ups and change-overs.
- Work may also be scheduled based on the shortest processing time.

Capacity

- CAPACITY is difficult to measure in the job shop and depends on lot sizes, the complexity of jobs, the mix of jobs already scheduled, the ability to schedule work well, the number of machines and their condition, the quantity and quality of labor input, and any process improvements.

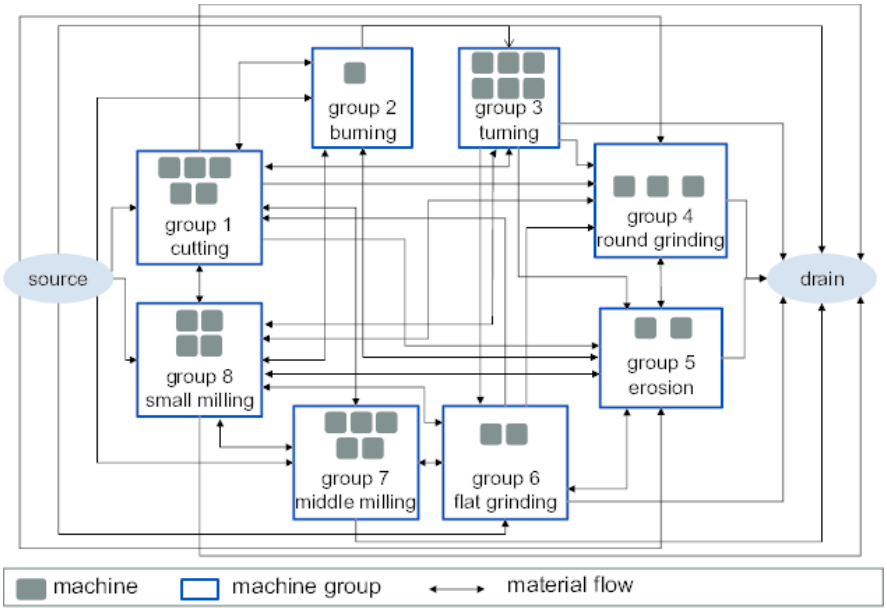


Fig 1.22 – Layout of a Job shop

BATCH PRODUCTION

- Batch production is a method of manufacturing where identical or similar items are produced together for different sized production runs.
- The method allows for products to be mass-produced in batches with small to major changes to the product, from car doors through to children's toys.
- Batch production is a method of manufacturing where the products are made as specified groups or amounts, within a time frame.
- A batch can go through a series of steps in a large manufacturing process to make the final desired product.

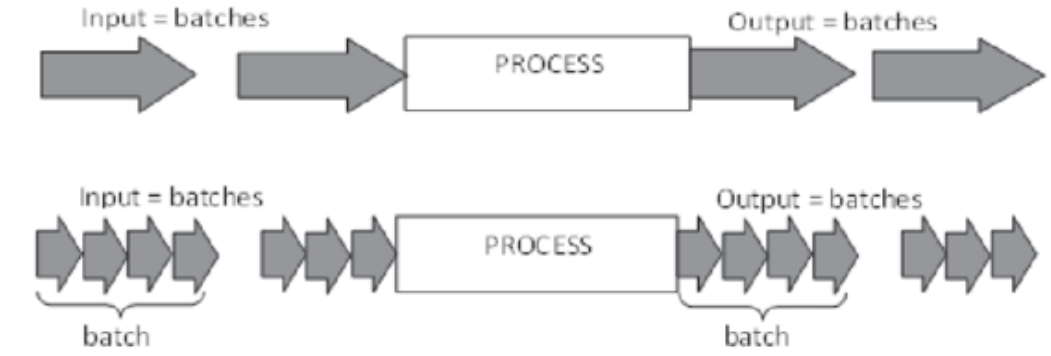


Fig 1.28 – Layout of Batch Production

- Batch production pertains to repetitive production. It refers to the production of goods, the quantity of which is known in advance. It is that form of production where identical products are produced in batches on the basis of demand of customers' or of expected demand for products.
- This method is generally similar to job production except the quantity of production. Instead of making one single product as in case of job production, a batch or group of products are produced at one time. It should be remembered here that one batch of products may not resemble with the next batch.
- Under batch system of production the work is divided into operations and one operation is done at a time. After completing the work on one operation it is passed on to the second operation and so on till the product is completed. Batch production can be explained with the help of an illustration.
- An enterprise wants to manufacture 20 electric motors. The work will be divided into different operations. The first operation on all the motors will be completed in the first batch and then it will pass on to the next operation. The second group of operators will complete the second operation before the next and so on. Under job production the same operators will manufacture full machine and not one operation only.

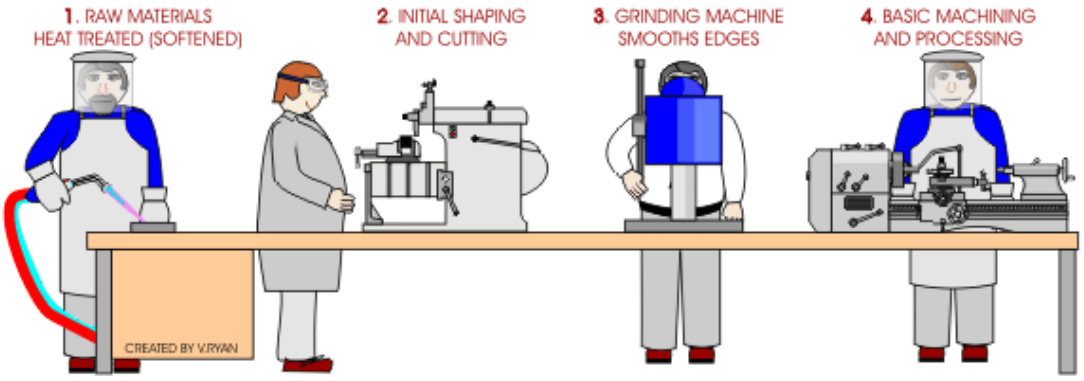


Fig 1.29 – Example of Batch Production

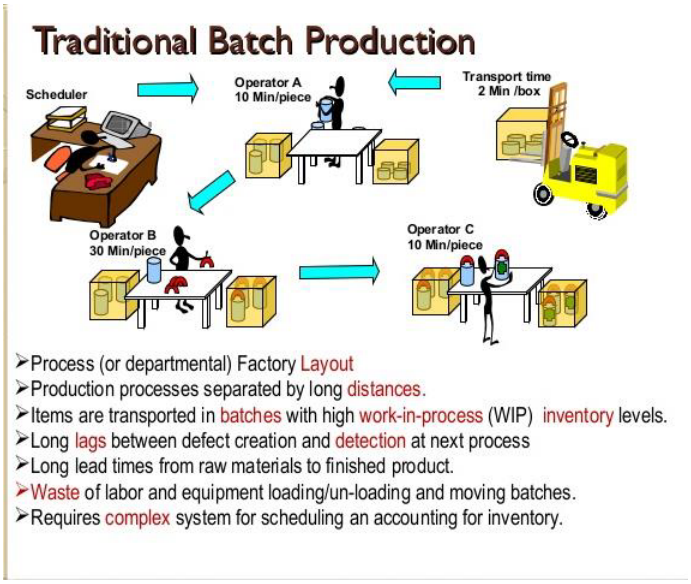


Fig 1.30 – Traditional Batch Production

Batch production can fetch the benefits of repetitive production to a large extent, if the batch is of a sufficient quantity. Thus batch production may be defined as the manufacture of a product in small or large batches or lots by series of operations, each operation being carried on the whole batch before any subsequent operation is operated. This method is generally adopted in case of biscuit and confectionery and motor manufacturing, medicines, tinned food and hardware's like nuts and bolts etc.

The batch production method possesses the following characteristics:

1. The work is of repetitive nature.

2. There is a functional layout of various manufacturing processes.

3. One operation is carried out on whole batch and then is passed on to the next operation and so on.

4. Same type of machines is arranged at one place.

5. It is generally chosen where trade is seasonal or there is a need to produce great variety of goods.

Changes may occur between different batches, such as products constructed in different colours, sizes, and styles. If a product needs to be altered, this variation can be changed as the production process switches from one batch style to the other.

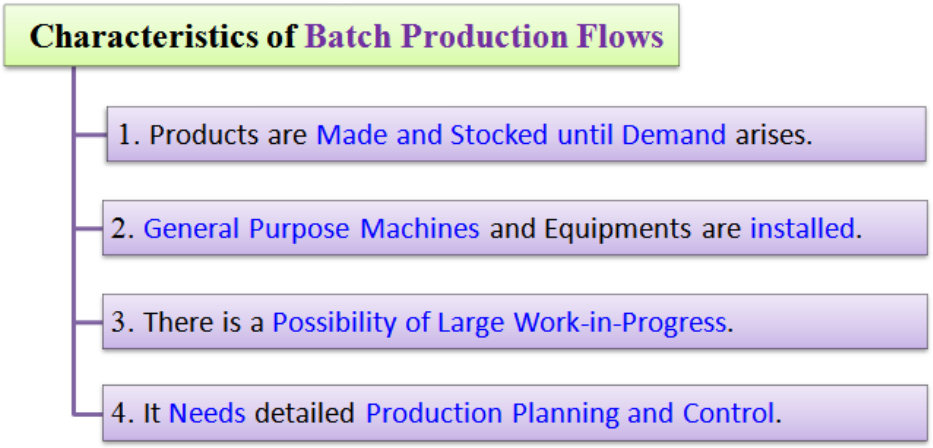


Fig 1.31 – Characteristics of Batch Production Flows

Working of Batch Production Methodology

- The process of batch production occurs where the manufacturing process channelizes as a whole in the form of batches.
- A particular batch which has been completed will be then moved from one production stage to the other one until the whole process of manufacturing is completed as a whole.
- The batch production process consists of the manufacturing of the identical items which are then used when there is a pretty high demand for a particular product, and the increase in the demand is consistent.
- The supplier needs to have products enough to supply to the growing demands of the customers and hence this process is used to improve the efficiency and also decrease the time needed for the whole manufacturing process to be completed.
- The products which are manufactured in the process of batch production are then kept as batches or groups. This group doesn't break and remains altogether as the processing keeps on happening on it.
- After the completion of the entire process of manufacturing, the batch is then dispatched and is ready to go into the stores. Don't understand what we are trying

to tell you in here? Let us give you an example so that you have the concept all cleared out

What makes this form of producing products different from larger types of manufacturing such as mass production or continuous production?

It's that the full process can be carefully quality controlled at different stages of the production process. This is a key benefit of the production process where a batch can be assessed to reduce the amount of wastage on a product.

Why do manufacturers use batch production?

- It's recommended to use this form of manufacturing when producing in smaller quantities because this can reduce waste and decrease lead times in production. As these products are not continuously made, manufacturers can charge a premium price for their product but still make them in some cases at relatively cheap prices thanks to mass production of that batch.
- The ability of these mass-production orientated machinery systems includes assembling product components, involving control and testing capabilities, and building in a 'no-faults forward' mechanism. This ensures the level of incorrect batches that might be pulled through to the next process are kept to a minimum.

What are examples of this manufacturing method?

Industries have used this type of manufacturing to make their overall process more efficient. Dependant on your desired output rate, engineering experts are able to create automated assembly systems to help meet the needs of your production process. Examples of products created within the batch production process include:

- Flatpack furniture
- Electrical goods
- Clothing
- Baked goods
- Books/ newspapers
- Pharmaceuticals
- Fast food

Advantages

When examining the most suitable manufacturing process, it's important to look at the advantages and disadvantages of batch production. The advantages include:

- Cheaper to produce a whole batch of a product than a single item at a time
- Machinery can be utilised more efficiently, therefore saving money for the business
- Reduces the risk of concentrating on one product and allows for flexibility
- The overall wastage is reduced by creating the correct number of products required
- Helps with contingency planning (if one batch has been spoiled, the cost is lower to discard that batch as opposed to thousands of products on a continuous cycle)
- Useful for seasonal items due to the ability to order more or less of a particular item
- The machinery isn't continually active, allowing running costs to be reduced

Disadvantages

Batch production is not suitable for all types of manufacturing, which means the disadvantages should be considered. The disadvantages include:

- Each batch can be subject to meticulous quality control and assurances, potentially causing increased employee downtime
- Increased storage costs for large quantities of produced products
- Errors with the batch produced will incur wasted time and cost
- Periods of downtime where the specialist machinery must be altered. I.e. workers sitting idle and can be considered inefficient if you're solely relying on the machines for this process
- The product cannot be personalised or unique to an individual customer due to being a batch production process

Overall, when a company is searching for solutions on how to manufacture uniform products that are made on-demand, batch production is a great solution. The manufacturing process can help keep your capital costs low and ensures quality is sustained through the production process.

CONTINUOUS FLOW PRODUCTION

- An important part of keeping your clients loyal is to deliver the right value at the right time to them.
- Looking for a way to achieve this, in the middle of the 20th century, Toyota developed a method called "continuous flow".
- It is an alternative to the commonly accepted way of batching work when managing a process.
- Continuous flow is a Lean method that allows you to move a single product through every step of your process instead of grouping work items into batches.
- The method is called this way because it allows you to continuously send goods to market.
- This provides you with the opportunity to deliver value more often to your customers.

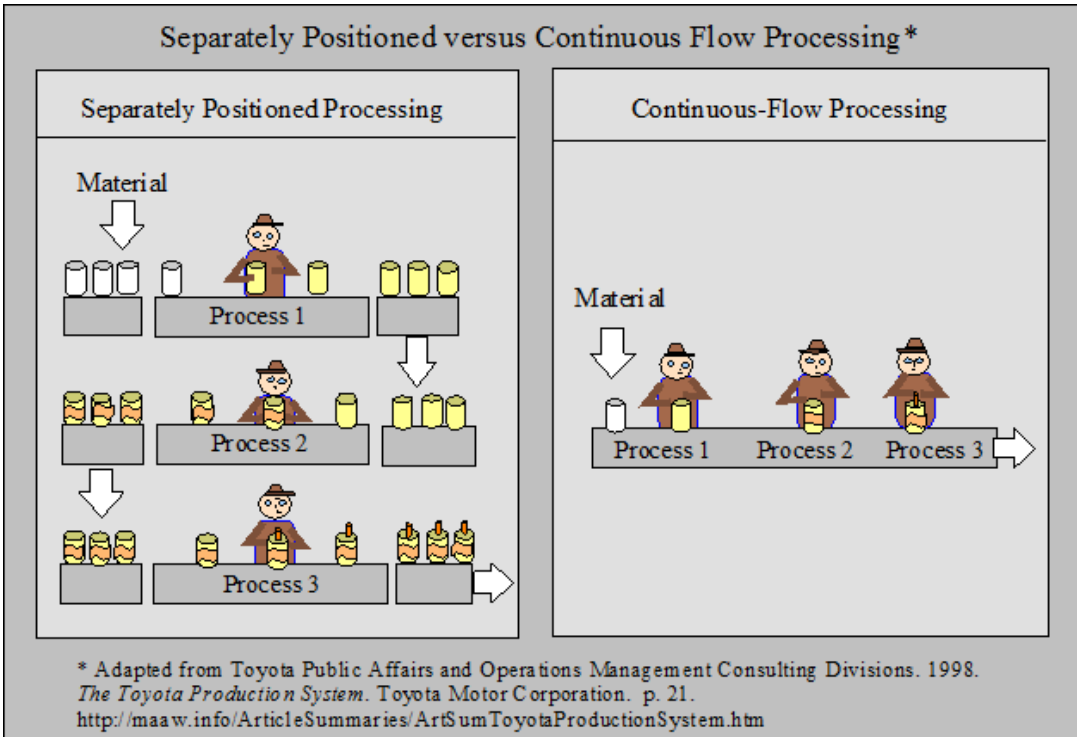


Fig 1.32 – Separately Positioned vs Continuous Flow Processing

- At first, the concept of continuous flow may sound less efficient than processing work in batches because, with it, you are delivering smaller amounts of value to the market at a time.
- However, it actually allows you to provide value to customers more often and reduce the time they spend waiting to receive their order.
- In addition, it is a fantastic way to minimize the waste of your process. Continuous flow is especially useful for reducing inventory costs and the wait time of your work items.
- The aim of the continuous manufacturing flow is to produce a flow production to manufacture, produce, or process materials uninterrupted.
- The reason it is called a continuous process is because the materials, which can also be fluids, are being perpetually processed.
- It makes use of special purpose machines and produces standardized items in large quantities. The examples are petrochemical, cement, steel, sugar and fertilizer industries, etc
- In a Continuous Production System, the items are produced for the stocks and not for specific orders.
- Before planning manufacturing to stock, a sales forecast is made to estimate the likely demand of the product and a master schedule is prepared to adjust the sales forecast based on past orders and level of inventory.
- Here, the inputs are standardized and a standard set of processes and sequence of processes can be adopted.
- Due to this, routing and scheduling for the whole processes can be standardized.

- After setting out a master production schedule, a detailed planning is carried out.
- Basic production information and bill of materials are recorded.
- Information for the machine load charts, equipment, personnel and material needs are tabulated.
- In continuous production, each production-run manufactures in lot sizes and the production process is carried out in a definite sequence of operations in a predetermined order.
- In process storage is not necessary, which in turn reduces material handling and transportation facilities.
- First-in-First-out method is followed in the system.

Characteristics of Continuous Production System

1. Standard products are manufactured, which have large demand throughout the year.
2. Standardized inputs and standardized sequence of operations, machine tools and equipment are used.
3. Division of labour is made more efficient.
4. Minimum and constant material handling.
5. Minimum flow of work at any point of time.
6. Small work in progress is involved.
7. Use of productivity techniques is feasible.
8. Minimum cost of production per unit is possible.
9. Rigid quality control is exercised.
10. More maintenance is required.

Types of Continuous Production

There are three types of continuous production viz., mass production, process production and assembly production.

1. **Mass Production**

- In this type of continuous production, only one type of product or a maximum of two or three types are manufactured in large quantities, as much emphasis is not given to orders of the consumers. Standardization of product, process, materials, machine and uninterrupted flow of materials are the main characteristics of this system.

- Mass production system is employed in several industries where the production is carried on without any interruption. Electronics, electrical, automobiles, bicycles and container industries are a few examples of mass production industries.

- Mass production system offers economies of scale as the volume of output is large. Quality of products tends to be uniform and high due to standardization and

mechanization. In a properly designed and equipped process; individual expertise plays a less prominent role. Of course, the exact quality level depends upon the quality control systems and management policy of the plant.

2. **Process Production**

- This system is used for the manufacture of those items whose demand is continuous and high. Here, single raw material can be transformed into different kinds of products at different stages of the production process e.g., processing of crude oil in refinery — we get kerosene, gasoline, etc., at different stages of production. On the basis of the nature of production process, flow of production may be classified into

i. Analytical process of production and
ii. Synthetic process of production.

- Analytical Process of Production: In analytical process of production, a raw material is broken into different products. For example, crude oil is analyzed into gas, naphtha, petrol, etc. Similarly, coal is processed to obtain coke, coal, gas, coal-tar, etc.
- Synthetic process of production: Synthetic process of production, on the other hand, involves the mixing of two or more materials to manufacture a product. For instance, lauric acid, myristic acid, plasmatic acid, stearic acid, linoleic acid, etc., are synthesized to manufacture soap.

3. ASSEMBLY LINE PRODUCTION

- An assembly line is a production process that breaks the manufacture of a good into steps that are completed in a pre-defined sequence.
- Assembly lines are the most commonly used method in the mass production of products.
- They are able to reduce labor costs because unskilled workers could be easily trained to perform specific tasks.
- Rather than hire a skilled craftsman to put together an entire piece of furniture or vehicle engine, companies would hire a worker to only add a leg to a stool or bolt to a machine.

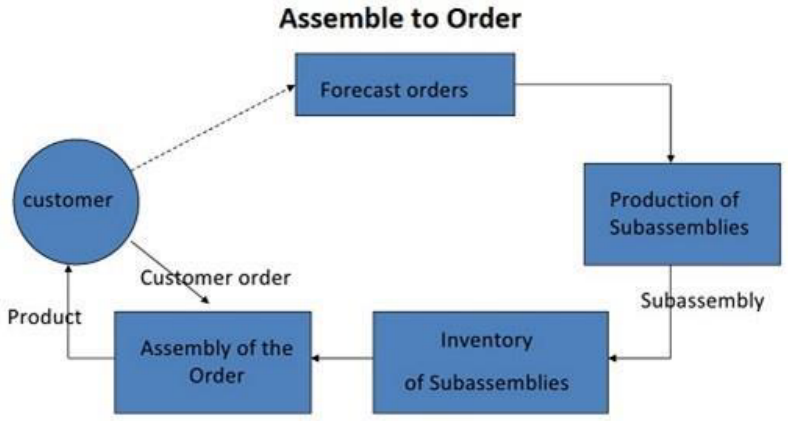


Fig 1.23 – Assembly of the order



Fig 1.24 – Example of an assembly

Principle of assembly line

The principle of an assembly line is that each worker is assigned one very specific task, which he or she simply repeats, and then the process moves to the next worker who does his or her task, until the task is completed and the product is made. It is a way to mass produce goods quickly and efficiently.

Interchangeable parts, continuous flow, division of labor, and reducing wasted effort. Using interchangeable parts meant making the individual pieces of the car the same every time.

Design for an assembly line

- The design for an assembly line is determined by analyzing the steps necessary to manufacture each product component as well as the final product.

- All movement of material is simplified, with no cross flow, backtracking, or repetitious procedure. Work assignments, numbers of machines, and production rates are programmed so that all operations along the line are compatible.
- An automotive assembly line starts with a bare chassis.
- Components are attached successively as the growing assemblage moves along a conveyor.
- Parts are matched into subassemblies on feeder lines that intersect the main line to deliver exterior and interior parts, engines, and other assemblies.
- As the units move by, each worker along the line performs a specific task, and every part and tool is delivered to its point of use in synchronization with the line.
- A number of different assemblies are on the line simultaneously, but an intricate system of scheduling and control ensures that the appropriate body type and colour, trim, engine, and optional equipment arrive together to make the desired combinations.

Assembly Line Methods

- In most cases, a manufacturing assembly line is a semi-automated system through which a product moves.
- At each station along the line some part of the production process takes place.
- The workers and machinery used to produce the item are stationary along the line and the product moves through the cycle, from start to finish.
- Assembly line methods were originally introduced to increase factory productivity and efficiency.
- Advances in assembly line methods are made regularly as new and more efficient ways of achieving the goal of increased throughput (the number of products produced in a given period of time) are found.
- While assembly line methods apply primarily to manufacturing processes, business experts have also been known to apply these principles to other areas of business, from product development to management.
- The introduction of the assembly line to American manufacturing floors in the early part of the twentieth century fundamentally transformed the character of production facilities and businesses throughout the nation.
- Thanks to the assembly line, production periods shortened, equipment costs accelerated, and labor and management alike endeavored to keep up with the changes.
- Today, using modern assembly line methods, manufacturing has become a highly refined process in which value is added to parts along the line.
- Increasingly, assembly line manufacturing is characterized by "concurrent processes"—multiple parallel activities that feed into a final assembly stage.

- These processes require sophisticated communications systems, material flow plans, and production schedules.
- The fact that the assembly line system is a single, large system means that failures at one point in the "line" cause slowdowns and repercussions from that point forward.
- Keeping the entire system running smoothly requires a great deal of coordination between the parts of the system.
- Computer power has enabled tracking systems to become more sophisticated and this, in turn, has made it possible to reduce the costs associated with holding inventories.
- Just-in-time (JIT) manufacturing methods have been developed to reduce the cost of carrying parts and supplies as inventory.
- Under a JIT system, manufacturing plants carry only one or a few days' worth of inventory in the plant, relying on suppliers to provide parts and materials on an "as needed" basis.
- Future developments in this area may include suppliers establishing operations within the manufacturing facility itself or increased electronic links between manufacturers and suppliers to provide for a more efficient supply of materials and parts.

Variations in assembly line methodologies

- The passage of years has brought numerous variations in assembly line methodologies.
- These new wrinkles can be traced back not only to general improvements in technology and planning, but to factors that are unique to each company or industry.
- Capital limitations, for example, can have a big impact on a small business's blueprint for introducing or improving assembly line production methods, while changes in international competition, operating regulations, and availability of materials can all influence the assembly line picture of entire industries.

Modular Assembly

- This is an advanced assembly line method that is designed to improve throughput by increasing the efficiency of parallel subassembly lines feeding into the final assembly line.
- As applied to automobile manufacturing, modular assembly would involve assembling separate modules—chassis, interior, body—on their own assembly lines, then joining them together on a final assembly line.

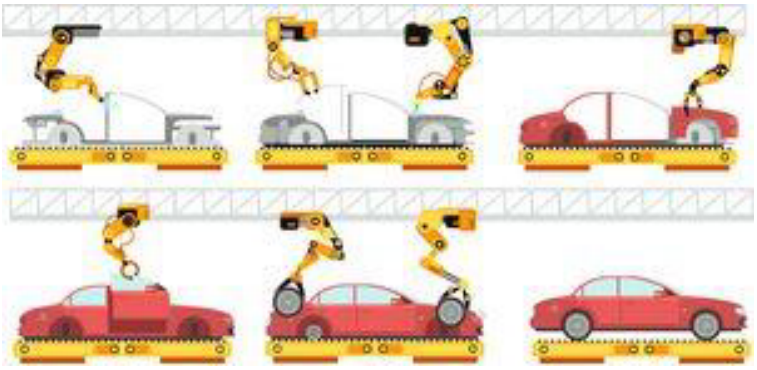


Fig 1.25 – Example of a Modular assembly

Team Production

- Team-oriented production is another development in assembly line methods.
- Where workers used to work at one- or two-person work stations and perform repetitive tasks, now teams of workers can follow a job down the assembly line through its final quality checks.
- The team production approach has been hailed by supporters as one that creates greater worker involvement in the manufacturing process and knowledge of the system.



Fig 1.26 – Example of a Team Production

U-shaped assembly "line"

- A line may not be the most efficient shape in which to organize an assembly line.
- On a U-shaped line, or curve, workers are collected on the inside of the curve and communication is easier than along the length of a straight line.
- Assemblers can see each process; what is coming and how fast; and one person can perform multiple operations.
- Also, workstations along the "line" are able to produce multiple product designs simultaneously, making the facility as a whole more flexible.
- Changeovers are easier in a U-shaped line as well and, with better communication between workers, cross-training is also simplified.
- The benefits of the U-shaped line have served to increase their use widely.

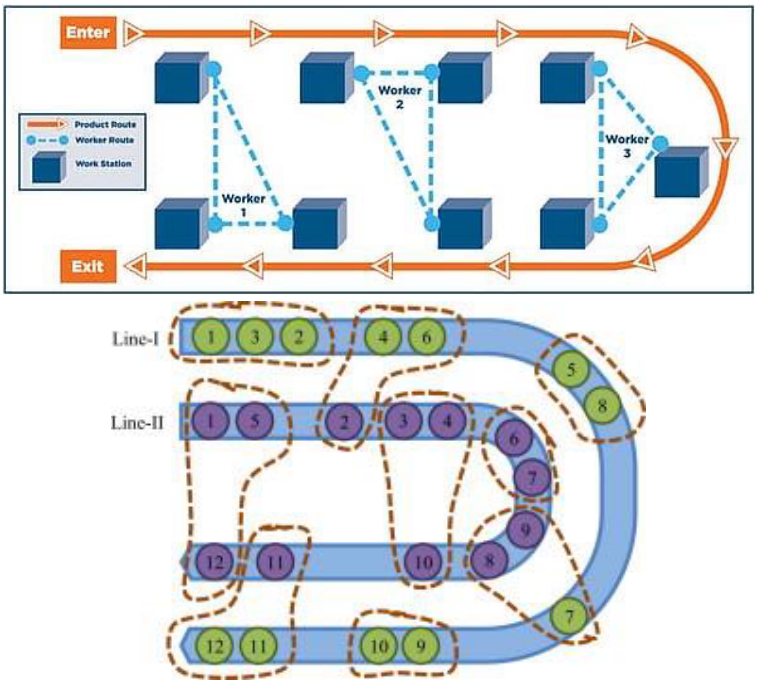


Fig 1.27 – Example of a U-shaped assembly "line"

Advantages

- Semi-finished products are reduced to a minimum, thereby, intermediate storage are avoided largely.
- The consistent arrangement of the workplaces also saves space, transport routes are shortened and transport costs are reduced
- Cost advantages through division of labor and specialization
- Low throughput times enable a reduction in the total production time

Disadvantages

- Low flexibility with fluctuations in employment, the adaptability of the company is reduced
- High susceptibility to failure of the entire production in the event of machine or work failures
- High system intensity
- Often little room for maneuver for workers
- Monotonous work creates alienation, dulling and motivation problems
- Lack of communication opportunities creates social problems for workers

Advantages of Continuous Production System

1. Reduced Labour cost,
2. High accuracy,
3. Reduced material handling,

4. Simple control process,
5. Minimum wastage,
6. Better materials /inventory control,
7. Higher return on investments.

Disadvantages of Continuous Production System

1. Heavy loss during slack demand period
2. Rigid maintenance and upkeep of machines
3. Customers' tastes cannot be met as only one standard product is manufactured.
4. Difficult to adjust to new situations and specifications.
5. Special purpose machine tools are required.

Suitability of Continuous Production System

- Continuous system is best suited to organizations which intend to produce a limited variety of products on a large scale. The heavy fixed costs of specialized equipment that are utilized for operating at low cost per unit can be distributed over a high volume of output.
- Continuous production system can be applied to those industries which satisfy the following requirements:

i. Uniform demand,
ii. High volume of production,
iii. product standardization, and
iv. Process balancing.

LIFECYCLE MANAGEMENT (LCM)

- Lifecycle management (LCM) is an integrated and flexible approach to business management that draws on the principles of lifecycle thinking (LCT) to help businesses of all kinds – manufacturers, retailers, financial, professional – understand their environmental impacts and where they occur within the lifecycle of their operation, from raw materials through to end-of-life.
- For manufacturers it is important to note that more than 70% of the environmental impacts, including resource use, of their products and of their operations have already been locked in at the design stage i.e. when the product was designed or the manufacturing process was designed.
- Therefore the most effective way to reduce impacts and resource use is the address these at the design stage. This is called design for sustainability (D4S).
- Lifecycle management (LCM) can benefit your business financially by helping to reduce resource (electricity, gas, water and materials) and waste costs, as well as boosting your reputation by reducing the negative environmental impacts of your business' operations.

PRODUCT LIFE CYCLE

Product life cycle (PLC) defines the stages that products moves through as they enter, get established in and ultimately leave the market place.

The life cycle of a product is associated with marketing and management decisions within businesses, and all products go through five primary stages: development, introduction, growth, maturity, and decline. Each stage has its costs, opportunities, and risks, and individual products differ in how long they remain at any of the life cycle stages.

1. Development

- The product development stage is often referred to as “the valley of death.”
- At this stage, costs are accumulating with no corresponding revenue.
- Some products require years and large capital investment to develop and then test their effectiveness.
- Since risk is high, outside funding sources are limited.
- While existing companies often fund research and development from revenue generated by current products, in startup businesses, this stage is typically funded by the entrepreneur from their own personal resources.

2. Introduction

- The introduction stage is about developing a market for the product and building product awareness.
- Marketing costs are high at this stage, as it is necessary to reach out to potential customers.
- This is also the stage where intellectual property rights protection is obtained.
- Product pricing may be high to recover costs associated with the development stage of the product life cycle, and funding for this stage is typically through investors or lenders.

3. Growth

- In the growth stage, the product has been accepted by customers, and companies are striving to increase market share.
- For innovative products there is limited competition at this stage, so pricing can remain at a higher level.
- Both product demand and profits are increasing, and marketing is aimed at a broad audience.
- Funding for this stage is generally still through lenders, or through increasing sales revenue.

4. Maturity

- At the mature stage, sales will level off.

- Competition increases, so product features may need to be enhanced to maintain market share.
- While unit sales are at their highest at this stage, prices tend to decline to stay competitive.
- Production costs also tend to decline at this stage because of more efficiency in the manufacturing process.
- Companies usually do not need additional funding at this stage.

5. Decline

- The decline stage of the product life cycle is associated with decreasing revenue due to market saturation, high competition, and changing customer needs.
- Companies at this stage have several options: They can choose to discontinue the product, sell the manufacturing rights to another business that can better compete or maintain the product by adding new features, finding new uses for the product, or tap into new markets through exporting.
- This is the stage where packaging will often announce “new and improved.”

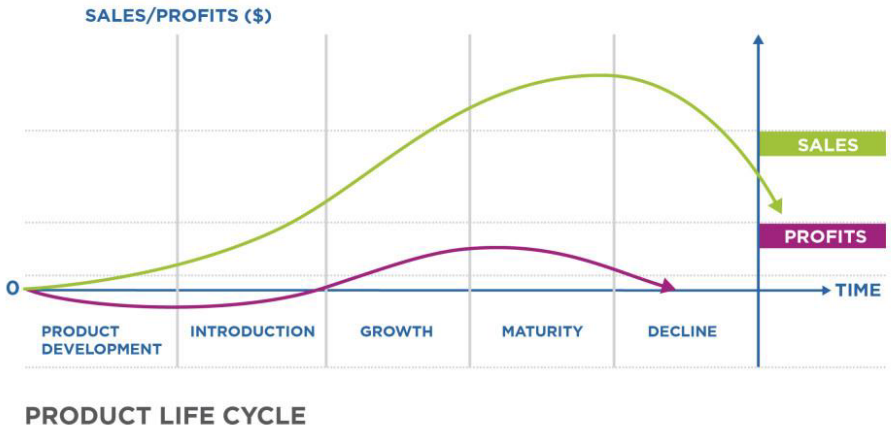


Fig 1.33 – Product Life Cycle

Product Life Cycle Examples

The traditional product life cycle curve is broken up into four key stages. Products first go through the Introduction stage, before passing into the Growth stage. Next comes Maturity until eventually the product will enter the Decline stage. These examples illustrate these stages for particular markets in more detail.

- 3D Televisions: 3D may have been around for a few decades, but only after considerable investment from broadcasters and technology companies are 3D TVs available for the home, providing a good example of a product that is in the Introduction Stage.

- Blue Ray Players: With advanced technology delivering the very best viewing experience, Blue Ray equipment is currently enjoying the steady increase in sales that's typical of the Growth Stage.
- DVD Players: Introduced a number of years ago, manufacturers that make DVDs, and the equipment needed to play them, have established a strong market share. However, they still have to deal with the challenges from other technologies that are characteristic of the Maturity Stage.
- Video Recorders: While it is still possible to purchase VCRs this is a product that is definitely in the Decline Stage, as it's become easier and cheaper for consumers to switch to the other, more modern formats.

Another example within the consumer electronics sector also shows the emergence and growth of new technologies, and what could be the beginning of the end for those that have been around for some time.

- Holographic Projection: Only recently introduced into the market, holographic projection technology allows consumers to turn any flat surface into a touchscreen interface. With a huge investment in research and development, and high prices that will only appeal to early adopters, this is another good example of the first stage of the cycle.
- Tablet PCs: There are a growing number of tablet PCs for consumers to choose from, as this product passes through the Growth stage of the cycle and more competitors start to come into a market that really developed after the launch of Apple's iPad.
- Laptops: Laptop computers have been around for a number of years, but more advanced components, as well as diverse features that appeal to different segments of the market, will help to sustain this product as it passes through the Maturity stage.
- Typewriters: Typewriters, and even electronic word processors, have very limited functionality. With consumers demanding a lot more from the electronic equipment they buy, typewriters are a product that is passing through the final stage of the product life cycle.

Inter Relationship between product life cycle and process life cycle

- A process life cycle normally refers only to the development process for developing and testing a product up to the point that the product is released to the market.
- Process Design is the act of transforming an organization's vision, goals, and available resources into a discernible, measureable means of achieving the organization's vision.
- Process design may start with process analysis; best practices from similar organizations; process reference models from industry-standards organizations (e.g., SCOR or eTOM) or third party consultants; or "green field" — ideas coupled with the experience and insights of the process design team. Process design focuses on defining what the organization will do to achieve its financial and other goals.

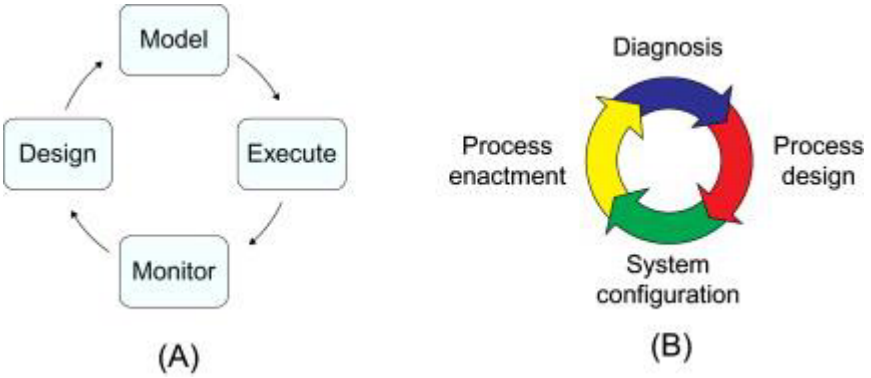


Fig 1.34– Process Life Cycle

➢ A product life cycle is much broader and covers the entire life of the product and all it's revisions and enhancements until the product is ultimately retired.

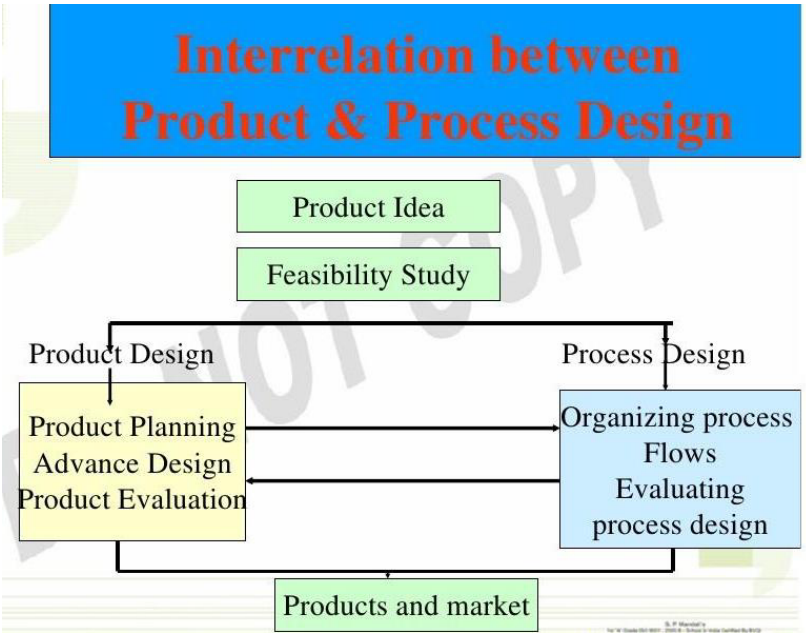


Fig 1.35– Interrelationship between Product & Process Design

The Product-Process Matrix

- The process life cycle has been attracting increasing attention from business managers and researchers over the past several years. Just as a product and market pass through a series of major stages, so does the production process used in the manufacture of that product.
- **The product-process matrix is a tool for analyzing the relationship between the product life cycle and the technological life cycle. It was introduced by Robert H. Hayes and Steven C. Wheelwright.**
- A company can be characterized as occupying a particular region on the matrix (see accompanying Figure).

- This region is determined by the firm's stage in the product life cycle and the firm's choice of production process.
- At the upper left extreme, firms are characterized as process oriented or focused while the lower right extreme holds firms that are said to be product focused.
- The decision of where a firm locates on the matrix is determined by whether the production system is organized by grouping resources around the process or the product.
- Note from the figure that the vertices of the matrix result in four distinct types of operations (described by the appropriate process choice) located on the diagonal of the matrix.

Process structure Process life cycle stage ↓	Product structure Product life cycle stage →	Low volume Unique (one of a kind)	Low volume Multiple Products	Higher volume Standardized product	Very high volume Commodity product
	(Project)				
Jumbled flow (job shop)		Job shop			
Disconnected line flow (batch)			Batch		
Connected line flow (assembly line)				Assembly line	
Continuous flow (continuous)					Continuous

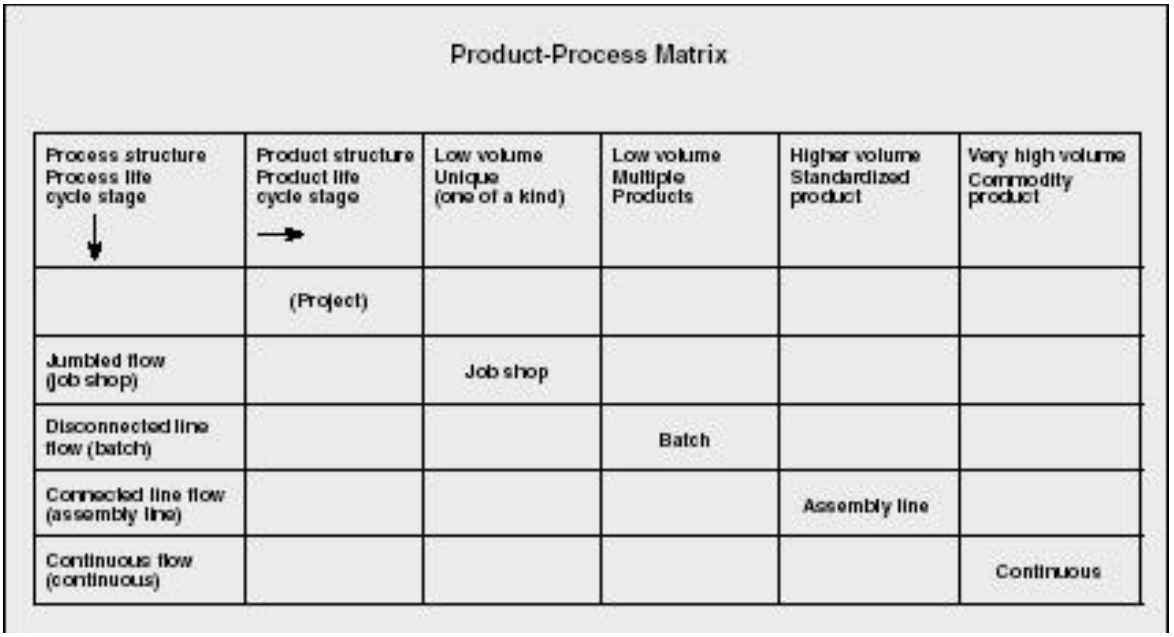


Fig 1.36– Product Process Matrix

Using The Matrix

- The product-process matrix can facilitate the understanding of the strategic options available to a company, particularly with regard to its manufacturing function.
- A firm may be characterized as occupying a particular region in the matrix, determined by the stages of the product life cycle and its choice of production process(es) for each individual product.
- By incorporating this dimension into its strategic planning process, the firm encourages more creative thinking about organizational competence and competitive advantage.
- Also, use of the matrix provides a natural way to involve manufacturing managers in the planning process so they can relate their opportunities and decisions more effectively with those of marketing and of the corporation itself, all the while leading to more informed predictions about changes in industry and the firm's appropriate strategic responses.
- Each process choice on the matrix has a unique set of characteristics.
- Those in the upper-left quadrant of the matrix (job shop and batch) share a number of characteristics, as do those in the lower-right quadrant (assembly line and continuous).
- Upper-left firms employ highly skilled craftsmen (machinists, printers, tool and die makers, musical instrument craftsmen) and professionals (lawyers, doctors, CPAs, consultants).
- Hence upper-left firms can be characterized as labor intensive.
- Since upper-left firms tend to utilize general-purpose equipment, are seldom at 100 percent capacity, and employ workers with a wide range of skills, they can be very flexible.
- However, there is a difficult trade-off between efficiency and flexibility of operations.
- Most job shops tend to emphasize flexibility over efficiency.
- Since efficiency is not a strong point of upper-left firms, neither is low-cost production.
- Also, the low volume of production does not allow upper-left firms to spread their fixed costs over a wide enough base to provide for reduced costs.
- Finally, upper-left firms are also more likely to serve local markets.
- Lower-right firms require production facilities that are highly specialized, capital intensive, and interrelated (therefore, inflexible).
- Labor requirements are generally unskilled or semi-skilled at most.
- Much of the labor requirement deals with merely monitoring and maintaining equipment.

- Lower-right firms are also more likely to serve national markets and can be vertically integrated.

Hayes and Wheelwright relate three areas affected by the use of the product-process matrix: distinctive competence, management, and organization.

- Distinctive competence
  Distinctive competence is defined as the resources, skills, and organizational characteristics that give a firm a comparative advantage over its competitors. Simply put, a distinctive competence is the characteristic of a given product that causes the buyer to purchase it rather than the similar product of a competitor. It is generally accepted that the distinctive competencies are cost/price, quality, flexibility and service/time.
- Management
  In general, the economics of production processes favor positions along the diagonal of the product-process matrix. That is, firms operating on or close to the diagonal are expected to outperform firms choosing extreme off-diagonal positions. Hayes and Wheelwright provide the example of a firm positioned in the upper-right corner of the matrix. This would appear to be a commodity produced by a job shop, an option that is economically unfeasible. A firm positioned in the lower-left corner would represent a unique one-time product produced by a continuous process, again not a feasible option. Both examples are too far off the diagonal. Firms that find themselves too far off the diagonal invite trouble by impairing their ability to compete effectively. While firms operating in the near vicinity, but not exactly on the diagonal, can be niche players, positions farther away from the diagonal are difficult to justify. Rolls Royce makes automobiles in a job shop environment but they understand the implications involved. Companies off the diagonal must be aware of traps it can fall into and implications presented by their position.
- Organization

  Firms organize different operating units so that they can specialize on separate portions of the total manufacturing task while still maintaining overall coordination. Most firms will select two or more processes for the products or services they produce. For example, a firm may use a batch process to make components for products, which are constructed on assembly lines. This would be especially true if the work content for component production or the volume needed was not sufficient for the creation of a dedicated line process. Also, firms may need separate facilities for different products or parts, or they may simply separate their production within the same facility. It may even be that a firm can produce the similar products through two different process options. For example, Fender Musical Instruments not only mass produces electric guitars (assembly line) but also offers customized versions of the same product through the Fender Custom Shop (job

shop). Again, the matrix provides a valuable framework for diagnostic use in these situations.

Other uses of the product-process matrix

Additional uses of the matrix include:

1. Analyzing the product entry and exit.
2. Determining the appropriate mix of manufacturing facilities, identifying the key manufacturing objectives for each plant, and monitoring progress on those objectives at the corporate level.
3. Reviewing investment decisions for plants and equipment in terms of their consistency with product and process plans.
4. Determining the direction and timing of major changes in a company's production processes.
5. Evaluating product and market opportunities in light of the company's manufacturing capabilities.
6. Selecting an appropriate process and product structure for entry into a new market.

UNIT II

FORECASTING

INTRODUCTION

Forecastingstands as a systematic effortto anticipate futureevents based on the patterns and information available from past data. Within the domain of operations management, forecasting takes asignificant role, acting as anaiding tool for decision-making, strategic planning,andefficientresourceallocation.Properforecastingcansignificantlyreducecosts, optimize processes, and pave the way for better organizational performance.

Forecasting the technique by which past and present data is analysedto plan for future. There are varioustypes andways of carrying out business forecasts depending on the objectivesanddesiredoutcome.Itcanbedonetoarriveatageneralbusinessforecastorcan be applied to forecast specifically to predict departmental outcomes. It canvary from forecasting sales for a consecutive monthto predicting the rate of demand during festive seasons.

Companiesuseawiderangeoftechniquesandmethodstoforbusinessforecasting.Itcanbe predictions relatedto sales, expenses incurred, revenue or profits. These scientific predictions will help the companies takestrategic decisions on time and prevent losses in advance.

Forecasting Defined : Forecasting is the first step in planning. It is defined as *estimating the future demand for products and services and the resources necessary to produce these outputs.* Estimates of the future demand for products or services are commonly referred to as **sales forecasts.** The sales forecasts or demand forecasts are the starting point for the entire planning in production and operations management. *For example,* material planning, capacity planning, manpower planning, financial planning and production scheduling, all depend on sales forecasting.

ImportanceofForecasting:

Importanceofforecastinginvolvesthefollowingkeypoints:

- Forecastingprovidesrelevantandreliableinformationaboutthepastandpresent events and the likely future events. This is necessary for sound planning.
- Itgivesconfidenceto themanagersformakingimportantdecisions.
- Itisthebasisformakingplanningpremises,and.
- Itkeepsmanagersactiveandalerttoface thechallengesoffutureeventsandthe changes in the environment.

Theimportanceisdirectlyproportionalto:

- [Resultsofanactionbasedonforecast]-[Results ofanactionforthesamesituation without any forecast].
- Ifthedifference inpositiveandlargethentheimportance ismore,otherwiseitisnot important.
- Importanceofforecastandofabilityofusedstatisticalforecastingtechniquesto generate reliable/accurate forecasts, are directly related.
- Ifingeneralforecastsarenotaccurate i.e.quantumofforecasterrorismore;then difference of results of actions as discussed above may not be relevant.
- Becausebothbecome unreliable.
- ForecastErrorcanbeexplainedas:ForecastError=[valueforecast -value actually happening]
- Themoresophisticatedmodelsof forecastoften provide forecastwithsmaller error butcostofdevelopmentofthemodel,forecasting andmaintainingtendstobehigh. There has to be a trade off between choice of model and the cost. The following figure clearly explains this trade off

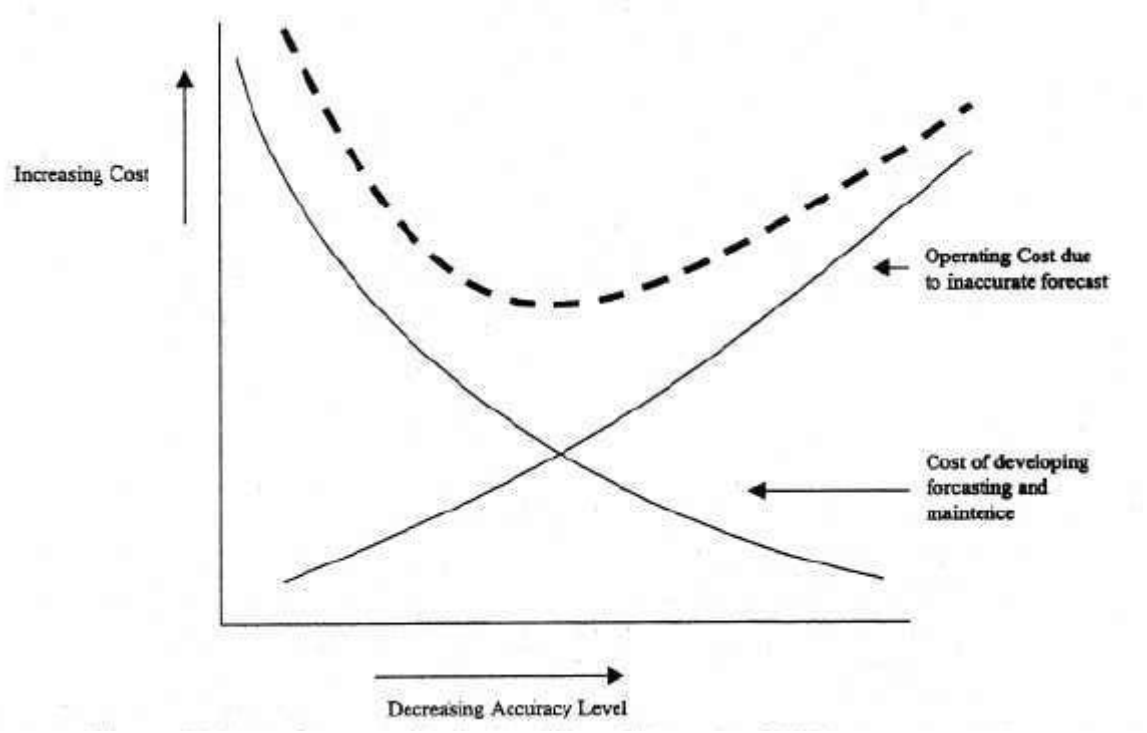


Fig3.1–CostandAccuracyTradeoffinChoiceofForecasting Models

Table1.1:SometypicalapplicationsofforecastinginProduction/Operations Management

Application	Some Indicators	Time Span
1. New Plant for Production expansion	Long term Demand Long term production Capacity of all producers etc.	5 or more years some times may be less
2. Seasonal Production Planning.	Demand Cycles, preferable from one peak to another peak	Usually 6 months-2 years
3. Capital Planning	Long term money market trends. Interest rate trends	Usually one or more years
4. Intermediate Operations Planning	Intermediate demand shift in preferences	Upto about 2 years
5. Short run production Adjustment	short-term demand short term material/input protections	about 6 weeks.
6. Scheduling Production	Order position, Emergency orders	Usually 1 week
7. Product Development	Long term sales trend specifically decline Stage. Technological Developments in related fields	2 years and more depends on usual time taken in product development

NeedOfForecastinProduction/operationsManagement

Thereare twobasic reasonsforthe needforthe forecastinanyfieldmoresoinproduction/ operation management.

1) Purpose–

Any action/plan is contemplated/devised in the PRESENT to take care of some contingency accruing out-of a situation/condition or set of conditions set in the future. These future conditions offer a purpose/target to be achieved so as to take advantage of or to minimize the impact of (if the foreseen conditions are adverse in nature) these fixture conditions. An actionoraplancannotbetaken/devised invoid-withoutanypurpose/objective/target.Any plan of action is to achieve something This `something' is a derived function of future condition (s).

Example:

The action/plan to set up an additional plant to increase production capacity. How much increased production and what should be the size of the new plant is dependent on the futuredemand-supplygap.Totakeadvantageofthisfuturedemand-supplygap,atargetof increased production is arrived at. To achieve this target a plan is prepared and put into action.

2) Time–

Toprepareaplan,organize resourcesforitsimplementation,implement;andcompletethe plan; all these need time as a resource. Some situations need very little time; some other situations needseveralyears oftime. Therefore,thefuture forecast is availableinadvance, appropriate actions can be planned and implemented 'in time'.

Example:Considerthe sameexamplediscussedearlier-totakeadvantageofafuture demand-supply gap;

LimitationsofForecasting

Demerits,criticismorlimitationsofforecastinginvolvesfollowingpoints:-

1. Thecollectionandanalysisofdataaboutthepast,presentandfutureinvolvesalot of time and money. Therefore, managers have to balance the cost of forecasting with its benefits. Many small firms don't do forecasting because of the high cost.
2. Forecastingcanonlyestimatethefutureevents.Itcannotguaranteethatthese eventswilltakeplace inthe future.Long-termforecastswillbelessaccurateas compared to short-term forecast.
3. Forecasting is based on certain assumptions. If these assumptions are wrong, the forecastingwillbewrong.Forecastingisbasedonpastevents.However,historymay not repeat itself at all times.
4. Forecastingrequires properjudgementandskills onthepartofmanagers.Forecasts maygowrongduetobadjudgementandskillsonthepartofsomeofthemanagers. Therefore, forecasts are subject to human error.

TYPESOFFORECASTS

- **BYTIMEHORIZON**

Business forecasts are classified according to period, time and use. There are **long term forecasts**as well as **short term forecasts**. Operation managers need long rangeforecasts to make strategic-decisionsabout products,processes andfacilities. They also needshort term forecasts to assist them in making decisionsdecisionsabout production issues that span, only few weeks. Forecasting forms an integral part of planning and decision making, production managers must be clear about the horizon of forecasts.
The three divisions of forecast are short range forecast, medium range forecast and long range forecast.

1. **Shortrange forecast:** It is typically less than3 months but has a time span of up-to 1 year.Itisused inplanning,purchasingforjobschedules,jobassignments,work force levels, product levels.
2. **Medium range forecast:** It is typically 3 months to 1 year but has a time span from one to three years. It is used for sales planning, production planning, cash budgeting and so on.
3. **Long range forecast:** This has a time span of three or more years. It is used for designing and installing new plants, facility location,capital expenditures,research and development, etc.

Medium and Long range Forecasts deal with more comprehensive issues and support managementdecisions regarding design and the development of new products, plants and processes. Short range forecasts tend to be more accurate than the long range forecasts.

ApplicationofShortRangeforecasts

Short range forecasts provide operations managers with the information to makeimportantdecisions such as the following:

- Howmuchinventoryofaparticularproductshouldbecarriednextmonth?
- Howmuch ofeachproductshouldbescheduledforproductionnextweek
- Howmuch ofeachrawmaterialshouldbeorderedfordeliverynextweek?
- Howmuchworkersshouldbescheduledtoworkonregulartimebasisandon overtime basis next week?
- Howmanymaintenance workersshouldbescheduledtoworknextweek?

ApplicationofLongRangeforecasts

Longrangeforecastsprovide,operationsmanagerswithinformationtomake importantdecisions such as the following:

- Selectingaproductdesign.Thefinaldesignisdependentonexpectedsalesvolume.If thedemandishigh,thedesignshouldbesuchthattheproductcanbemassproduced ton ensuring low costs manufacture.
- Selectingaproductionprocessingscheme
- Selectingaplantosupplyscarcematerials
- Selectingalongrangeproductioncapacityplan
- SelectingalongrangeFinancialPlanforacquiringfundsforcapitalinvestment
- Tobuildnewbuildingsandtopurchasenew materials
- Todevelopnewsourcesof materialsandnewsourceof capitalfunds(finance)

Table 3.1 : Types and characteristics of forecasts based on time horizon

Forecast Horizon	Applications	Characteristics	Forecast Methods
Long-range (3 to 5 yrs. or more)	Business planning, Product planning, Capital planning, Facility planning Location planning	Broad, general, often only qualitative	Technological, Economic, Demographic Marketing studies, Judgement
Medium or intermediate (3 months to 3 years)	Aggregate planning Capital and cash budgets, Production planning and budgeting, inventory planning and budgeting	Numerical, not necessarily at the item level. Estimate of reliability needed	Collective opinion, Time series/Regression analysis, Judgement
Short-range (1 week to 3 months)	Short run adjustment of production and personnel levels, purchasing, job scheduling, capacity changes by over time, lay offs etc.	May be at item level for planning of activity level, should be at item level for purchasing and inventory control.	Extrapolation of trends, Judgement, Exponential-Smoothing

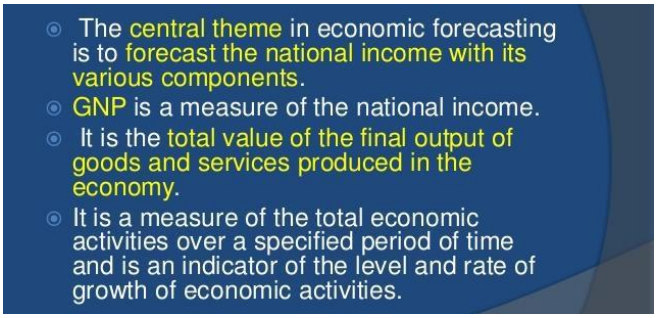
- **ECONOMICFORECASTS**
  - Addressbusinesscycle
  - e.g.,inflationrate,moneysupplyetc.

Economistsattempttomakeforecastsforleadingeconomicvariablessuch as

- Inflation
- Economicgrowth
- Houseprices
- Exchangerates
- Populationgrowth

Themainimportanceofeconomicforecastsistohelppolicymakersmakebetterdecisions. Forexample,ifthe economy was forecast toenter intoa recession,the government could consider implementing expansionary fiscalpolicy (higherspending financed by borrowing) to maintain demand in the economy and prevent a sharp downturn in the economy.

Forecastsareimportantbecausepolicychangestaketime.Ifyouwishtoincreasedemand inthe economy. There could be atime lag ofup to1 or 2years forthe change tohave the full effect. If you wait untilafterthe event,the policy willbe delayed and it willtake up to two years to have an effect.



Therearethreetypesofforecastingbasedontheeconomy:

i. **Macro-levelforecasting:**Itdealswiththegeneraleconomicenvironmentrelatingtothe economy as measured by the Index of Industrial Production(IIP), national income and general level of employment, etc.

ii. **Industry level forecasting:** Industry level forecasting deals with the demand for the industry'sproductsasawhole.Forexampledemandforcementin India,demandfor clothes in India, etc.

iii. **Firm-levelforecasting:**Itmeansforecastingthedemandforaparticularfirm'sproduct. Forexample,demandforBirlacement,demandforRaymondclothes,etc.

- **TECHNOLOGICALFORECASTS**
  - Predicttechnologicalchange
  - Predict*new*productsales

  Technology forecasting is

  - Agroupoftechniquesthatpredictthedirection,character,rate, implication and impact of technological advances.
  - ItisIndispensable.
  - ItimprovestheQualityofDecisionMaking
  - Scanningthetechnologicalenvironment
  - Anticipatingemergingtechnologicalchanges
  - Identifyingsuitabletechnologiesbyevaluatingvariousalternatives
  - Planningforfuturetechnologicalneeds

- **DEMANDFORECASTS**

  Predict*existing*productsales

- Itisatechniqueforestimationofprobabledemandforaproductorservicesinthe future.
- Itisbasedontheanalysisofpastdemandforthatproductorserviceinthepresent market condition.
- Demandforecastingshouldbedoneonascientificbasisandfactsandeventsrelatedto forecasting should be considered.
- Therefore,insimplewords,wecansaythataftergatheringinformationaboutvarious aspectofthemarketanddemandbasedonthepast,anattemptmaybemadeto estimatefuturedemand.Thisconceptiscalledforecastingofdemand.
- Forexample,supposewesold200,250,300unitsofproductXinthemonthofJanuary, February,andMarchrespectively.Nowwecansaythattherewillbeademandfor250 unitsapprox.ofproductXinthemonthofApril,ifthemarketconditionremainsthe same.

  UsefulnessofDemand Forecasting

- Demandplaysavitalroleinthedecisionmakingofabusiness.
- Incompetitivemarketconditions,thereisaneedtotakecorrectdecisionandmake planningforfutureeventsrelatedtobusinesslikeasale,production,etc.
- Theeffectivenessofadecisiontakenbybusinessmanagersdependsupontheaccuracy of the decision taken by them.
- Demandisthemostimportantaspectforbusinessforachievingitsobjectives.
- Manydecisionsofbusinessdependondemandlikeproduction,sales,staff requirement,etc.
- Forecastingisthenecessityofbusinessataninternationallevelaswellasdomestic level.

SignificanceofDemandForecasting:

- Fulfillingobjectivesof thebusiness
- Preparingthebudget
- Takingmanagementdecision
- Evaluatingperformanceetc.

Moreover,forecastingisnotcompletelyfullofproofandcorrect.Itthushelpsinevaluating variousfactorswhichaffectdemandandenablesmanagementstafftoknowaboutvarious forces relevant tothe study ofdemandbehavior.

The Scope of Demand Forecasting

- Thescopeofdemandforecastingdependsupontheoperatedareaofthefirm,presentas wellaswhatisproposedinthefuture.Forecastingcanbeataninternationallevelifthe areaofoperationisinternational.Ifthefirmsuppliesitsproductsandservicesinthe localmarket thenforecastingwillbeat locallevel.

- Thescopeshouldbedecidedconsideringthetimeandcostinvolvedinrelationtothe benefitoftheinformationacquiredthroughthestudyofdemand.Costofforecastingand benefitflowsfromsuchforecastingshouldbeinabalancedmanner.

I TYPES OF FORECASTS

Technological forecasts: Concerned with rates of technological progress

Economic forecasts: Statements of expected future business conditions.

Demand forecasts: Projections of demand for a company's products or services throughout some future period.

1. **Technological forecasts** are concerned with rates of technological progress. Technological changes will provide many companies with new products and materials to offer for sale. Even if the products remain unchanged, a new process for producing the products can be developed with a new or improved technology using new machinery and equipment.
2. **Economic forecasts** are statements of expected future business conditions published by governmental agencies. These forecasts address the business cycle by predicting inflation rates, money supplies, housing starts and other economic indicators such as tax revenues, levels of employment, gross national product etc. These forecasts give ideas about long range and intermediate range business growth to business organisations.
3. **Demand forecasts** are projections of demand for a company's products or services. These forecasts, also called *sales forecasts* give the expected level of demand for a company's goods or services throughout some future period and usually provide the basis for the company's planning and control decisions. These forecasts drive a company's production capacity and scheduling systems and serve as inputs to financial, marketing and human resource (manpower) planning. Economic and technological forecasting are specialised techniques which fall outside the scope of production and operations managers and

GENERALPRINCIPLESOFFORECASTING

Settheforecastingtaskclearlyandconcisely

- Care is needed when setting the forecasting challenges and expressing the forecasting tasks.

- Itisimportantthateveryonebeclearaboutwhatthetaskis.

- All definitions should be clear and comprehensive, avoiding ambiguous and vague expressions.

- Also, it is important to avoid incorporating emotive terms and irrelevant information that may distract the forecaster.

Implementasystematicapproach

- Forecast accuracy and consistency can be improved by using a systematic approach to judgmental forecasting involving checklists of categories of information which are relevant to the forecasting task.

- For example, it is helpful to identify what information is important and how this information is to be weighted.

- When forecasting the demand for a new product, what factors should we account for and how should we account for them?

- Should it be the price, the quality and/or quantity of the competition, the economic environment atthe time, the targetpopulation of the product?

- It is worthwhile to devote significant effort and resources to put together decision rules that will lead to the best possible systematic approach.

Documentandjustify

- Formalising and documenting the decision rules and assumptions implemented in the systematic approach can promote consistency, as the same rules can be implemented repeatedly.

- Also, requesting a forecaster to document and justify their forecasts leads to accountability, which can lead to reduced bias.

- Furthermore, formal documentation aids significantly in the systematic evaluation process.

Systematicallyevaluateforecasts

- Systematically monitoring the forecasting process can identify unforeseen irregularities.

- In particular, keep records of forecasts and use them to obtain feedback when the corresponding observations become available.

- Theenvironmentaforecasteroperateshouldbedynamic.

- Changes occur, and forecaster need to monitor these in order to evaluate the decision rules and assumptions.
- Feedback and evaluation help forecasters learn and improve their forecast accuracy.

Segregateforecastersandusers

- Forecast accuracy may be impeded if the forecasting task is carried out by users of the forecasts, such as those responsible for implementing plans of action about which the forecast is concerned.
- The forecasting is about predicting the future as accurately as possible, given all ofthe information available, including historical data and knowledge of any future events that may impact the forecasts.
- Forecastersandusersshouldbeclearlysegregated.
- Aclassiccaseisthatofanewproductbeinglaunched.
- The forecast should be a reasonable estimate of the sales volume of a newproduct, which may differ considerably from what management expects or hopes the sales will be in order to meet company financial objectives.
- Inthiscase,aforecastermaybedeliveringarealitychecktotheuser.
- It is important that forecasters communicate forecasts to potential users thoroughly.
- Users may feel distant and disconnected from forecasts, and may not have full confidence in them.
- Explaining and clarifying the process and justifying the basic assumptions that ledto the forecasts will provide some assurance to users.
- The way in which forecasts may then be used and implemented will clearly depend on managerial decision making.
- For example, management may decide to adjust a forecast upwards (be over-optimistic), as the forecast may be used to guide purchasing and stock keeping levels.
- Such a decision may be taken after a cost-benefit analysis reveals that the cost of holding excess stock is much lower than that oflost sales.

- This type of adjustment should be part of setting goals or planning supply, rather than part of the forecasting process.
- In contrast, if forecasts are used as targets, they may be set low so that they can be exceeded more easily.
- Again, setting targets is different from producing forecasts, and the two should not be confused.

GeneralStepsintheForecastingprocess
Thegeneralstepsintheforecastingprocessareasfollows:

1) IdentifytheGeneralNeed.

For example: in the present manufacturing business, unfulfilled demand might have been observed.Themanufacturermayhaveafeeling,"Whynotexpandproduction?"Thisshould constitute the identification of general need. Still, the manufacturer does not know for certain whether expansion is really a wise decision? How much to expand? When to expand?

2)SelectthePeriod(TimeHorizon)of Forecast:

Considering the same example: General estimate regarding time taken to erect the plant. And beyond that the usual plant life. Thus, in this case long term forecast is needed. The long term' can be defined appropriately for each situation. In this case, if we consider time forplanterectiontobe roughly3years-thenweneedaforecastspanning5-10yearsbeyond 3 years. That means a forecast covering a period of 5 years starting three years from now.

3)Selectthe IndicatorsRelevantto theNeed:

Dependinguponthe product orproduct line,one ormoreofthefollowingmaybe identified:

i) IndustrySales

ii) Competitors(collective)presentandprojected capacity.

iii).Populationprojection(incaseproductisdirectlyrelatedtothepopulation)

iv) Incomelevels

v) Economicdevelopmentetc.

4)SelecttheForecastModeltobeUsed:

For this, knowledge of various forecasting models, in which situations these are applicable, howreliableeachoneofthem iswhattypeofdataisrequired.Ontheseconsiderations;one or more models can be

5)DataCollection:

with reference to various indicators identified –collect data from various appropriate sources–datawhichiscompatiblewiththe model(s)selectedinsteps(4).Datashouldalsogo back that much in past , which meets the requirements of the model.

6) Prepare Forecast:

Applythemodelusingthedatacollectedthevalueoftheforecast.

7)Evaluate:

The forecast obtained through any of the models should not be used, as it is, blindly. It shouldbeevaluated intermsof'confidenceinterval'–usually,allgood forecastmodelshave methods of calculating upper value within which the given forecast is expected to remain with a certain specified level of probability. It can also be evaluated from a logical point of view whether the value obtained in logically feasible? It can also be evaluated against some related variables or phenomena. Thus, it is possible, some times advisable to modify thestatisticallyforecasted'valuebasedontheevaluation.

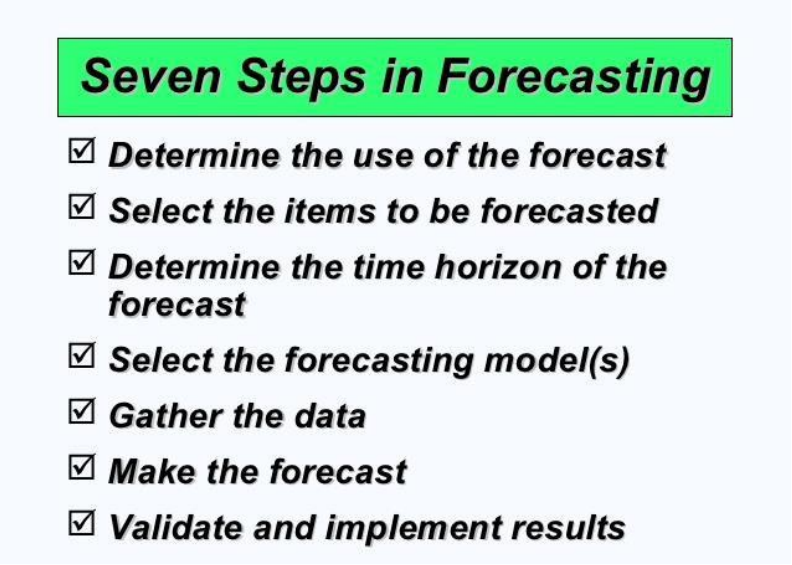
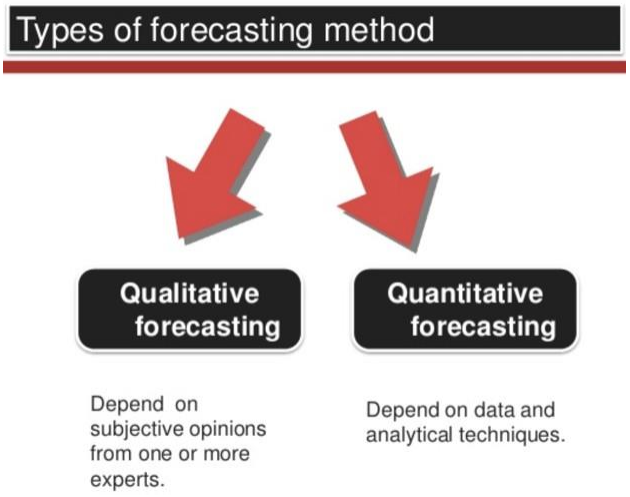


Fig3.2–StepsinForecasting

FORECASTINGTECHNIQUES/METHODS



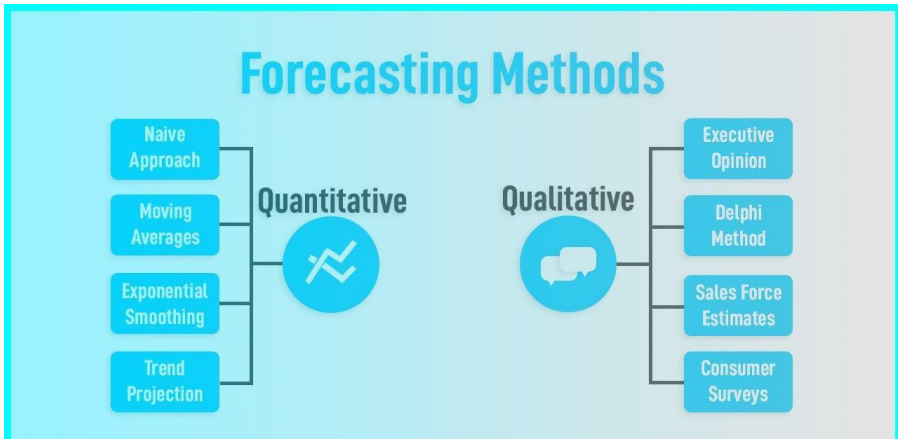


Fig3.3–TypesofForecasting Methods

- **Quantitativemethodofforecasting**usesnumericalfactsandhistoricaldatato predict upcoming events.
  The two main types of quantitative forecasting used by business analysts are the explanatorymethodthatattemptstocorrelatetwoormorevariablesandthetime series method that uses past trends to make forecasts.
- **Qualitative method of forecasting** is often employed where the key trends or developmentsarehardtocapture orwheresuch dataisnotavailable.Insuchacase business analysts used subjective information such as intuition or informed opinion for forecasting the future results. This type of forecast is essential for new products where no historical information is available and primarily used for medium & long term planning.

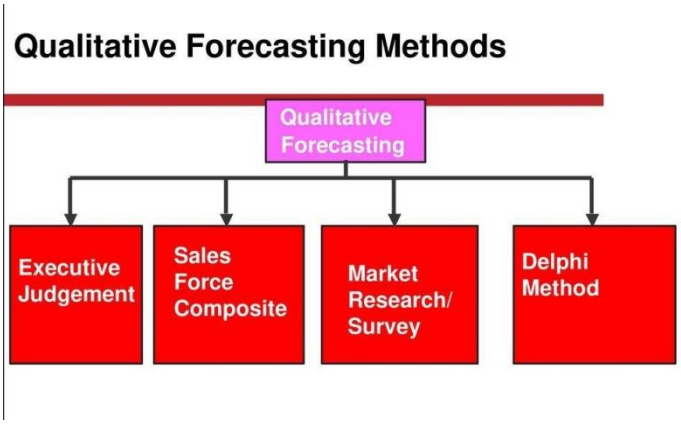


Fig3.4–QualitativeForecastingMethods

1. **DelphiMethod**:TheDelphimethodinvolvescollectingopinionsfromapanelof experts individually. This helps to prevent bias and ensures that any consensus about business predictions stems from expert opinions on their own. Other employees analyze the experts' responses and return them with additional questions until settling on a prediction that makes sense for the company.

2. **Jury of Executive Opinion:** This approach relies on judgments from experts in sales, finance, purchasing, administration or production teams. Forecasting by executive opinion can ensure that a team completes a forecast quickly and considers multiple perspectives from different departments to inform their forecast.Somecompaniesmightuseexecutiveopinionforecastingalongwitha quantitative method.

3. **Market Research:** Market research evaluates the success of a company's services or products by introducing them to potential customers and recording details about how they react. Companies canconduct market researchwiththe help of their own employees or by hiring outside agencies that specialize in marketresearchactivities.Somewaystoconductmarketresearchincludefocus groups, consumer surveys or blind product testing, where a customer tries a product without having heard of it before. Based on the reactions of participants, companies can decide which products or services to continue producing and which might need revision in the production stage.

4. **Consumer Surveys:** Consumersurveys ask customers ofa business about their experience as a consumer. Companies might send consumer surveys to customers through mail-in questionnaires or forms sent through email. Other optionsforconductingconsumersurveysincludecold-callingcustomersonthe phone and inviting customers into the office for personal interviews. After collecting information from consumer surveys, employees can use the details

theylearntohelpinformtheirpredictionsaboutacompany'sfuturebasedon the experience of their existing customers.

5. **Sales Force Polling:** Sales force polling involves speaking with sales staff who work closely with customers and might have thorough information about their satisfaction and experiences with the company. One advantage of sales force polling is that it uses information from employees who are most frequently involvedintheactualbusinessoperations,which canensurethatthedetailsare correct and relevant. Sales force polling is also simple to conduct since it only requires meeting with salespeople and focusing on the information they provide.

QUANTITATIVEMETHODSOFFORECASTING

- Itisastatisticaltechniquetomakepredictionsaboutthefuturewhichuses numerical measures and prior effects to predict future events.

- Thesetechniquesarebasedonmodelsofmathematics andinnaturearemostly objective. They are highly dependent on mathematical calculations.

  Thereare twotypesofquantitativeforecastingmethodswhicharelistedbelow:

  1. Time-seriesmodels– Thesemodelsexaminethepastdatapatternsandforecast the future on the basis of underlying patterns that are obtained from those data. There are many types of time series models like Naïve Approach, Simple moving average, trend projections, and exponential smoothing.

  2. Associative models – are also known as casual models. The model assumes that the variable that is being forecasted is associated with other variables. The predictionsaremadebasedontheseassociations.Thelinearregressionisoneofthe simplest forms of an associative model of forecasting. This regression line forecasts the dependent variable based on the selected value of the independent variable.

- Quantitativeforecastingmethodsareveryeasytopredictbasedontheunderlying information.

- Thedatacanbeusedtoforecastautomatically withoutmanycomplications.Any person can easily forecast on the basis of available data.

- Oneofthemaindisadvantagesofthismethodisitsdependenceonthedata.

- Theentireforecastingdependsonthedataoftheunderlyingmodel.

- An error in the available data can lead to wrong forecasting. These methods can alsobeusedonly iftheproperdataisavailable.Thismethodcannotalsoevaluate the effect of changes in the other variables involved

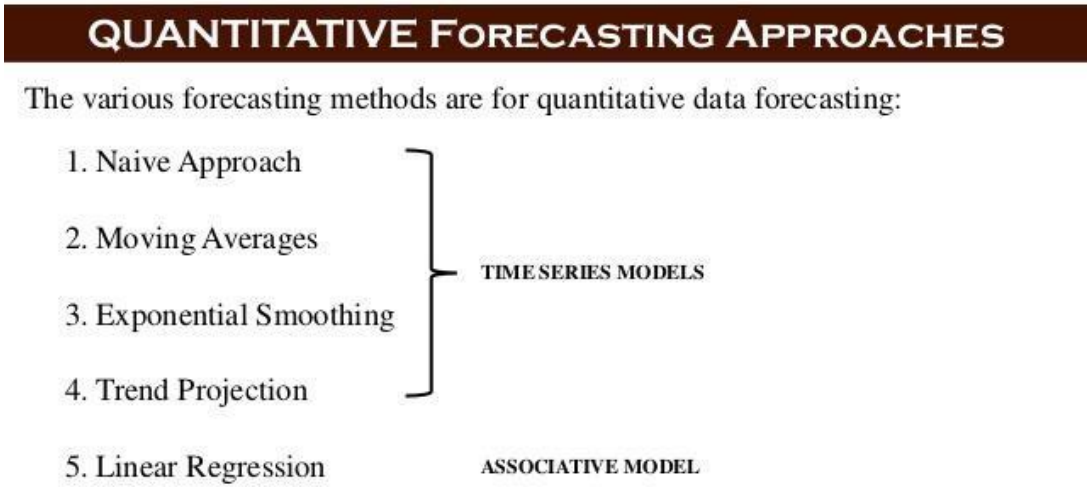


Fig3.5–QuantitativeForecastingMethods

Time Series Forecasting Methods

A **time series** is a time-ordered sequence of observations taken at regular intervals over a period of time (e.g., hourly, daily, weekly, monthly, quarterly or annually). The data may be measurement of demand, earnings, profits, outputs, productivity, consumer price index etc.

Decomposition of a Time Series

Analysis of time series data requires the analyst to identify the underlying behaviour of the series. This can be done by plotting the data with time on the 'X' axis and data on 'Y' axis and visually examining the plot. One or more patterns might appear. They are **trends, seasonal variations, cycles** and **random** or **irregular variations** (error).

Trend refers to gradual, long term, upward or downward movement in the data over time. Changes in income, population, age distribution or cultural views may account for such movements.

Seasonality refers to short-term, fairly regular variations related to factors such as weather, holidays, vacation etc. Seasonal variations can be daily, weekly or monthly.

Cycles are wavelike variations of more than one year's duration or which occur every several years. They are usually tied with business cycle related to a variety of economic, political or agricultural conditions.

Techniques for Averaging

Historical data contain a certain amount of random variation, or **noise** which tends to observe systematic movement in the data. It is desirable to completely remove any randomness from the data and leave only "real" variation such as changes in demand.

Averaging techniques smooth fluctuations in a time series so that the forecast can be based on an average, to exhibit less variability than the original data. Averaging techniques generate forecasts to reflect recent values of a time series. Three techniques for averaging are:

(i) Naive forecasts or Naive approach, *(ii)* Moving averages (Simple and weighted) and *(iii)* Exponential smoothing.

1. **Naive Approach :** The simplest way to forecast is to assume that forecast of demand in the next period is equal to the actual demand in the most recent period (*i.e.,* the current period). *For example,* if the actual sales for a product in January 2003 is 100 units, the forecast demand for February 2003 will also be 100 units.
2. **Moving Averages Method :** A moving average forecast uses a number of most recent historical actual data values to generate a forecast. The moving average for 'n' number of periods in the moving average is calculated as :

$$\text{Moving average} = \frac{\sum \text{demand in previous n periods}}{n}$$

n may be 3, 4, 5 or 6 periods for 3, 4, 5 or 6 period moving average.

The "simple moving average method" is used to estimate the average of a demand time series and remove the effects of random fluctuation. It is most useful when demand has no pronounced trend or seasonal fluctuations. In this method, if we use 'n' period moving averages, the average demand for the 'n' most recent time periods is calculated and used as forecast for the next time period. For the next period, after the demand is known, the older demand from the previous average is replaced with the most recent demand and the average is recalculated. *For example,* We use a 3 month simple moving average method and the demand data is as below :

Month (period)	Actual Demand	Forecast Based on Simple Moving Average
1	d_1	
2	d_2	
3	d_3	
4	d_4	$\frac{d_1+d_2+d_3}{3}$ (forecast for month 4)
5	d_5	$\frac{d_2+d_3+d_4}{3}$ (forecast for month 5)
6	d_6	$\frac{d_3+d_4+d_5}{3}$ (forecast for month 6)
7	?	$\frac{d_4+d_5+d_6}{3}$ (forecast for month 7)

In the **weighted moving average method** each historical demand in the moving average can have its own weight and the sum of the weight equals one. *For example,* in a 3 period weighted moving average model, the most recent period might be assigned a weight of 0.50, the second most recent period might be assigned a weight of 0.30 and the third most recent period with a weight of 0.20.

$$\text{Then forecast, } F_{t+1} = \frac{0.50\ D_t + 0.30(D_{t-1}) + 0.20\ D_{t-2}}{\text{Sum of the weights (}i.e.,\ 0.5+0.3+0.2\text{)}}$$

(*i.e.,* the average is obtained by multiplying the weight of each period by the value for that period and by adding the products together).

The advantage of a weighted moving average method is that it allows to emphasise recent demand over earlier demand.

3. **Exponential Smoothing Method :** It is a sophisticated weighted moving average method that is still relatively easy to understand and use. It requires only three items of data : this period's forecast, the actual demand for this period and α which is referred to as *smoothing constant* and having a value between 0 and 1. The formula used is

$$\text{Next period's forecast} = \text{This period's forecast} + \alpha\left(\begin{matrix}\text{This period's}\\ \text{actual demand}\end{matrix} - \begin{matrix}\text{This period's}\\ \text{forecast}\end{matrix}\right)$$

or $$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$$

Where
F_t = Forecast for the this period (t)
F_{t-1} = Forecast for the previous period $(t-1)$
A_{t-1} = Actual demand for the previous period $(t-1)$
α = Smoothing constant (value varies from 0 to 1)

Selecting a smoothing constant is basically a matter of judgement or trial and error. Commonly used values of α range from 0.05 to 0.5. Detailed discussion of causal models is

ILLUSTRATION OF THE NAÏVE METHOD

Naïve method: The forecast for next period (period t+1) will be equal to this period's actual demand (A_t).

In this illustration we assume that each year (beginning with year 2) we made a forecast, then waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

Year	Actual Demand (A_t)	Forecast (F_t)	Notes
1	310	--	There was no prior demand data on which to base a forecast for period 1
2	365	310	From this point forward, these forecasts were made on a year-by-year basis.
3	395	365	
4	415	395	
5	450	415	
6	465	450	
7		465	

MEAN (SIMPLE AVERAGE) METHOD

Mean (simple average) method: The forecast for next period (period t+1) will be equal to the average of all past historical demands.

In this illustration we assume that a simple average method is being used. We will also assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). At the end of year 1 we could start using this forecasting method. In this illustration we assume that each year (beginning with year 2) we made a forecast, then waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

Year	Actual Demand (A_t)	Forecast (F_t)	Notes
1	310	300	This forecast was a guess at the beginning.
2	365	310.000	From this point forward, these forecasts were made on a year-by-year basis using a simple average approach.
3	395	337.500	
4	415	356.667	
5	450	371.250	
6	465	387.000	
7		400.000	

SIMPLE MOVING AVERAGE METHOD

Simple moving average method: The forecast for next period (period t+1) will be equal to the average of a specified number of the most recent observations, with each observation receiving the same emphasis (weight).

In this illustration we assume that a 2-year simple moving average is being used. We will also assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). Then, after year 1 elapsed, we made a forecast for year 2 using a naïve method (310). Beyond that point we had sufficient data to let our 2-year simple moving average forecasts unfold throughout the years.

Year	Actual Demand (A_t)	Forecast (F_t)	Notes
1	310	300	This forecast was a guess at the beginning.
2	365	310	This forecast was made using a naïve approach.
3	395	337.500	From this point forward, these forecasts were made on a year-by-year basis using a 2-yr moving average approach.
4	415	380.000	
5	450	405.000	
6	465	432.500	
7		457.500	

EXPONENTIAL SMOOTHING METHOD

Exponential smoothing method: The new forecast for next period (period t) will be calculated as follows:

New forecast = Last period's forecast + α(Last period's actual demand – Last period's forecast)

(this box contains all you need to know to apply exponential smoothing)

$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$ (equation 1)

$F_t = \alpha A_{t-1} + (1-\alpha)F_{t-1}$ (alternate equation 1 – a bit more user friendly)

Where α is a smoothing coefficient whose value is between 0 and 1.

The exponential smoothing method only requires that you dig up two pieces of data to apply it (the most recent actual demand and the most recent forecast).

An attractive feature of this method is that forecasts made with this model will include a portion of every piece of historical demand. Furthermore, there will be different weights placed on these historical demand values, with older data receiving lower weights. At first glance this may not be obvious, however, this property is illustrated on the following page.

EXPONENTIAL SMOOTHING ILLUSTRATION

In this illustration we assume that, in the absence of data at startup, we made a guess for the ye 1 forecast (300). Then, for each subsequent year (beginning with year 2) we made a forecast using the exponential smoothing model. After the forecast was made, we waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

This set of forecasts was made using an α value of .1

Year	Actual Demand (A)	Forecast (F)	Notes
1	310	300	This was a guess, since there was no prior demand data.
2	365	301	From this point forward, these forecasts were made on a year-by-year basis using exponential smoothing with α=.1
3	395	307.4	
4	415	316.16	
5	450	326.044	
6	465	338.4396	
7		351.09564	

TREND PROJECTION

Trend projection method: This method is a version of the linear regression technique. It attempts to draw a straight line through the historical data points in a fashion that comes as close to the points as possible. (Technically, the approach attempts to reduce the vertical deviations of the points from the trend line, and does this by minimizing the squared values of the deviations of the points from the line). Ultimately, the statistical formulas compute a slope for the trend line (b) and the point where the line crosses the y-axis (a). This results in the straight line equation

$Y = a + bX$

Where X represents the values on the horizontal axis (time), and Y represents the values on the vertical axis (demand).

For the demonstration data, computations for b and a reveal the following ***(NOTE: I will not require you to make the statistical calculations for b and a; these would be given to you. However, you do need to know what to do with these values when given to you.)***

$b = 30$

$a = 295$

$Y = 295 + 30X$

This equation can be used to forecast for any year into the future. For example:

Year 7: Forecast = $295 + 30(7) = 505$

Year 8: Forecast = $295 + 30(8) = 535$

Year 9: Forecast = $295 + 30(9) = 565$

Year 10: Forecast = $295 + 30(10) = 595$

Factors to be considered in the selection of a forecasting method are : *(i)* cost, *(ii)* accuracy, *(iii)* data available, *(iv)* time span, *(v)* nature of products and services and *(vi)* impulse response and noise dampening.

These factors are discussed below :

Factors to be considered in selectioin of a forecasting method are:
- **Cost and Accuracy**
- **Data available**
- **Time span**
- **Nature of products and Services**
- **Impulse response and Noise dampening.**

(i) **Cost and Accuracy :** A trade-off may result between cost and accuracy in choosing a forecasting method. This means high forecast accuracy can be obtained at a high cost. High accuracy approaches use more data, which are more difficult to obtain and the models are costly to design, implement and operate. Examples of high cost models are complex econometric models, Delphi and market research methods. Statistical models based on historical data and jury of executive opinion method are of low or moderate cost.

(ii) **Data Available :** The availability of relevant data for forecasts is an important factor in the choice of forecasting method. *For example,* if the attitudes and intentions of customers are relevant for the forecasts and if the data can be economically obtained from customers about their attitudes and intentions, then a survey of customers (market research method) may be an appropriate method for forecasting the demand.

(iii) **Time Span :** The choice of an appropriate forecasting method is affected by the nature of the production resource to be forecasted. Workforce, cash, inventories and machine schedules are short range in nature and can be forecasted using moving average or exponential smoothing models. Long-range production resources such as plant capacities and capital funds can be forecasted by regression analysis, executive committee consensus (*i.e.,* jury of executive opinion) or market research methods.

(iv) **Nature of Products and Services :** Different forecasting models have to be used for different products. The choice of the forecasting method is affected by factors such as volume of production, cost of the product, nature of the products (*i.e.,* goods or services), whether product demand has seasonal fluctuations or growth or decline and whether the product is in its life cycle etc.

(v) **Impulse Response and Noise Dampening :** How responsive we want the forecasting model to be to changes in the actual demand data must be balanced against our desire to suppress undesirable chance variation or noise in the data. Each model differs in its impulse response and noise dampening abilities and the model selected must fit the forecasting situation.

Some Reasons for Ineffective Forecasting

1. Not involving a broad cross section of people in forecasting.
2. Not recognising the fact that forecasting is integral to business planning.
3. Not recognising that forecasts will never be correct or accurate.
4. Not forecasting the right things. *For example,* forecasting the demand for raw materials that go into the products is not necessary as it can be computed based on the demand for products.
5. Not selecting an appropriate forecasting method.
6. Not tracing the performance of the forecasting models so that forecast accuracy can be improved and the forecasting model can be modified if needed.

	Qualitative Methods	Quantitative Methods
1. Characteristics	Based on human judgment, opinions; subjective and nonmathematical.	Based on mathematics; quantitative in nature.
2. Strengths	Can incorporate latest changes in the environment and "inside information."	Consistent and objective; able to consider much information and data at one time.
3. Weaknesses	Can bias the forecast and reduce forecast accuracy.	Often quantifiable data are not available. Only as good as the data on which they are based.

Fig3.6–DifferencebetweenQualitativeandQuantitativeForecasting Methods

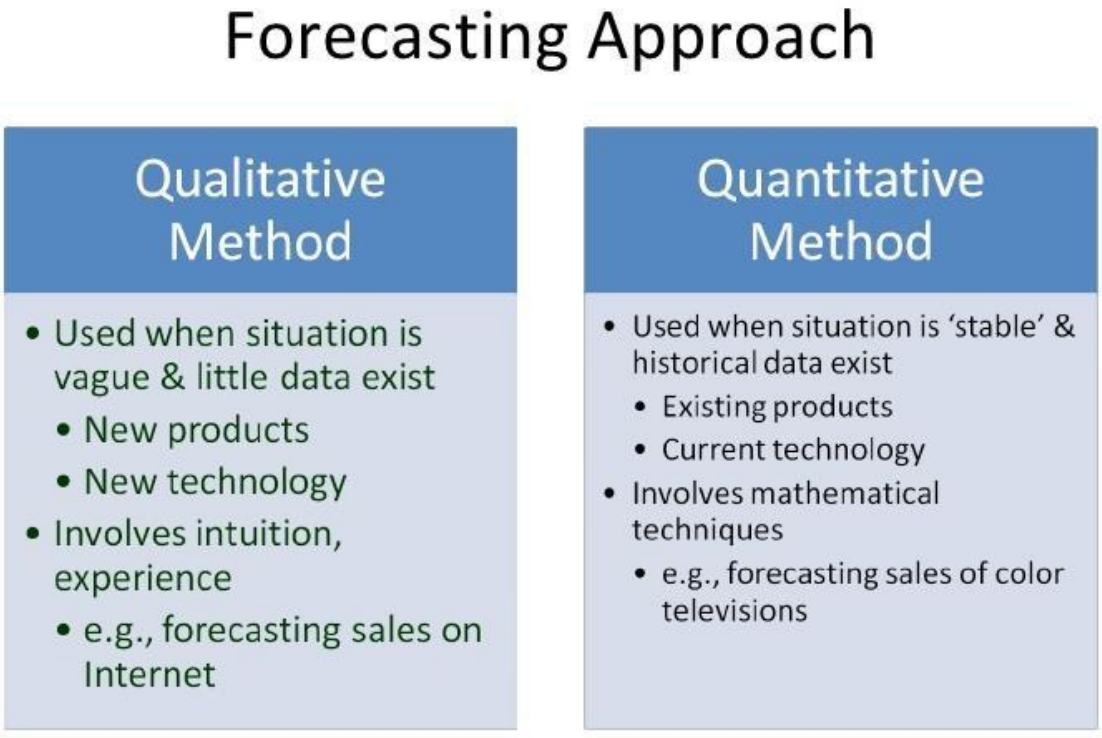


Fig3.7–ApproachesofQualitativeandQuantitativeForecastingMethods

UNIT III
SCHEDULINGANDCONTROLOF PRODUCTIONOPERATIONS

TYPESOFPLANNINGLEVELS

1. Short– range plans
2. Intermediate–rangeplans
3. Long–rangeplans

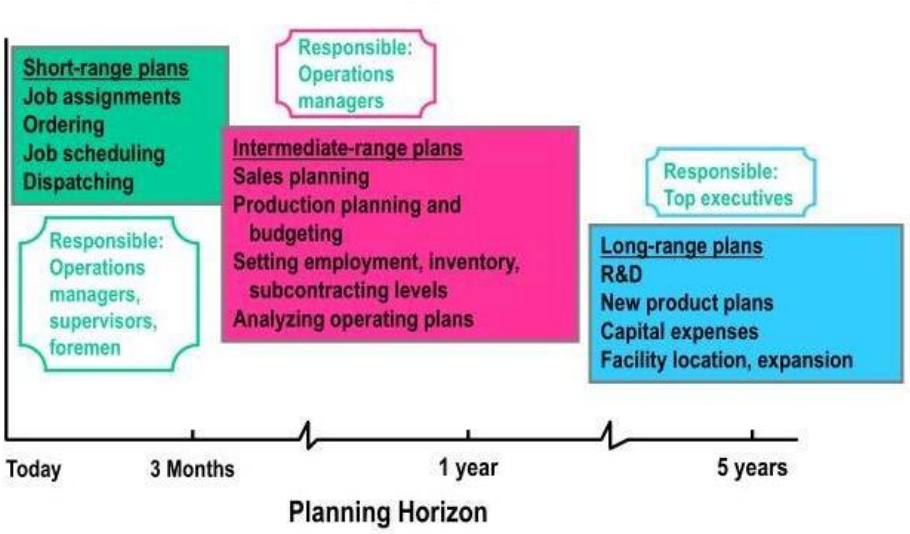


Fig2.1–PlanningHorizons

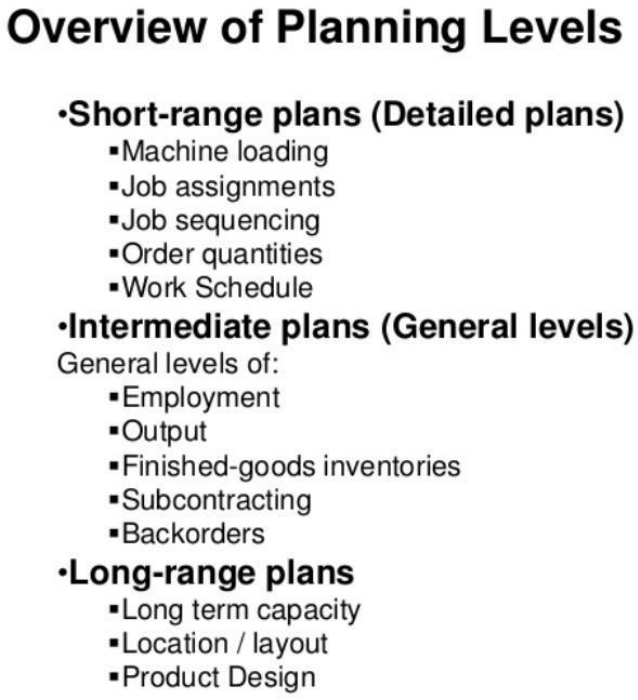


Fig2.2–OverviewofPlanningLevels

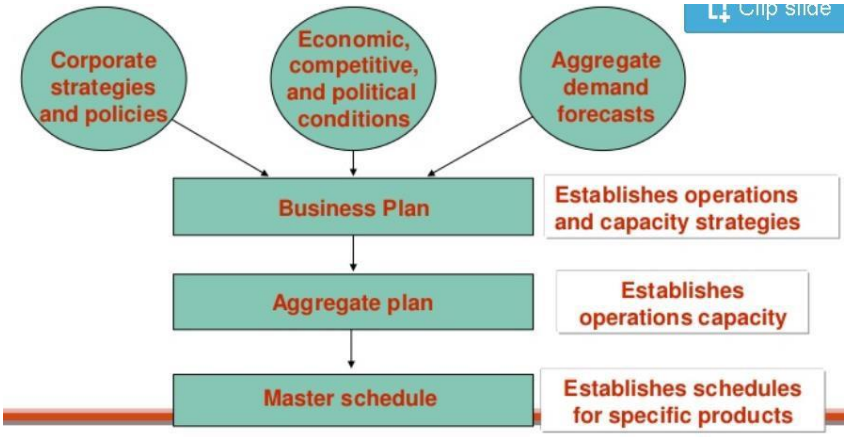


Fig2.3–PlanningSequence

AGGREGATEPLANNING

- Aggregateproductionplanningisconcerned withthedeterminationofproduction, inventory, and work force levels to meet fluctuating demand requirements over a planning horizon that ranges from six months to one year
- Aggregate planning is a planning method in the production process which is also consideredamarketingactivityusedtodeterminetherequiredresourcecapacityto meet expected demand.
- The aggregate planning is done in advance of 6 – 18 months and includes a combinationofsub-contracting,sourcing,outsourcing,employment,laborovertime, amount of inventory and planned output to match demand and supply cost-effectively.
- Aggregate planning is critical to an organization which wants to optimize its operationalactivitybecauseithelpsinbalancingshorttermproductionplansand long term strategic plans.

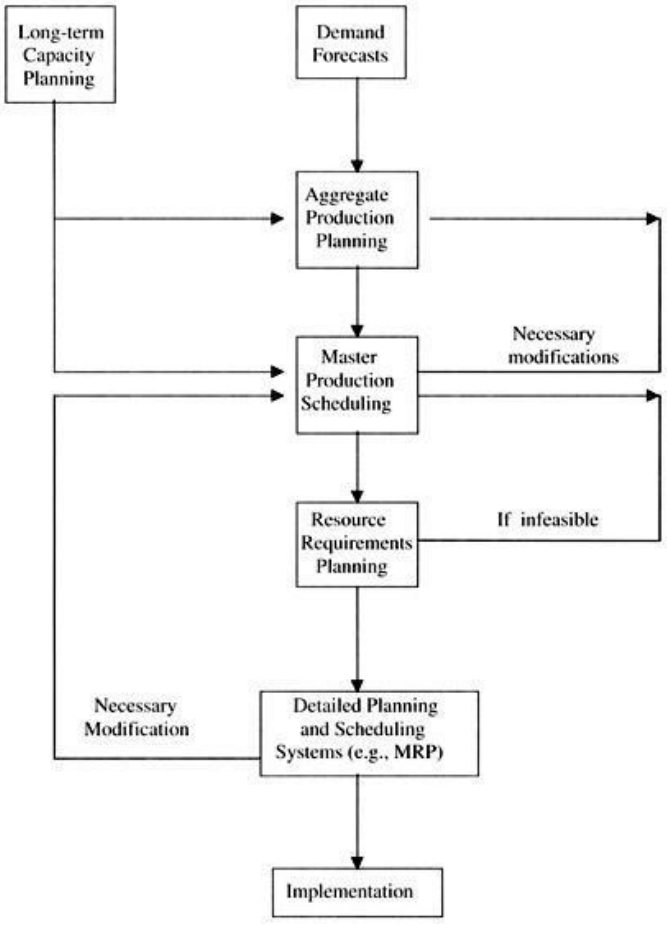


Fig2.4–SequenceforAggregate Planning

Aggregate Planning Inputs and Outputs

Input	Output
Resources -Workforce/production rates -Facilities and equipment	Total cost of plan
Cost -Inventory carrying cost -Backorders -Hiring/firing -Overtime -Inventory changes -Subcontracting	Projected levels of: Inventory Output Employment Subcontracting Backordering
Demand forecast	
Policies on workforce changes	
Subcontracting	
Overtime	
Inventory levels/changes	
Backorders	

Fig2.5–AggregatePlanningInputsandOutputs

Importanceofaggregateplanning

Aggregateplanningisaproventechnique thatbringsanelementofforesightandstability into manufacturing. It helps the management to achieve the long-term objectives of a company. The importance of aggregate planning include-

- Createsasatisfiedandhappy workforce
- Reducechangesinthelevelsoftheworkforce
- Helpstodetermineresourcesfortheshort-term
- Helpsinmaximumutilizationofspace
- Meetstheoverallgoalsandobjectivesofacompany
- Helpstoadjustcapacitytomeet demand
- Minimizescostsassociatedwithinventorystocking
- Reduceinvestmentsrelatedtovariousinventories
- Matchingdemandwithsupplyandminimizingthewaitingtimeforthecustomersto maximize customer service
- Offersbettercustomer value
- Properutilizationofproductionfacilities
- Maximumusageofvarioustypesofequipment
- Reducingthechangesinproduction rates
- Removesvariablecostandimprovesthebottomlineofthefinancialstatementfor achieving the business goals of an organization

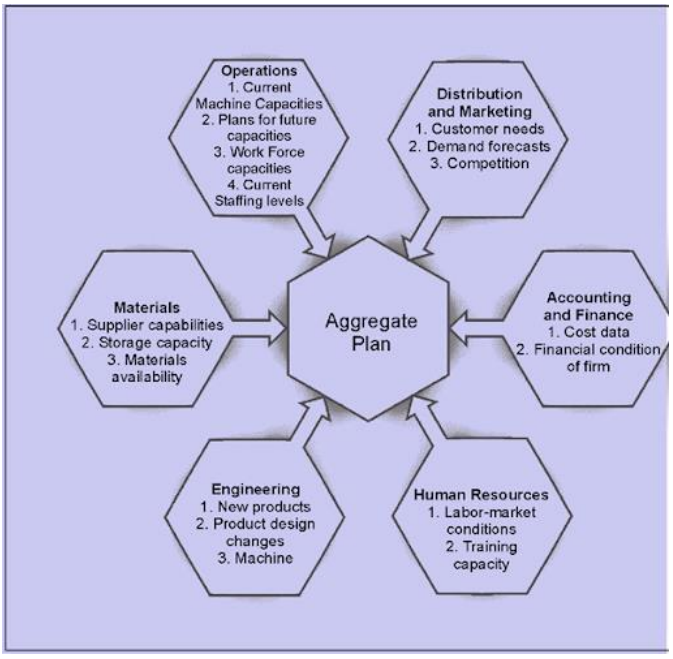


Fig2.6–Various ElementsofAggregatePlanning

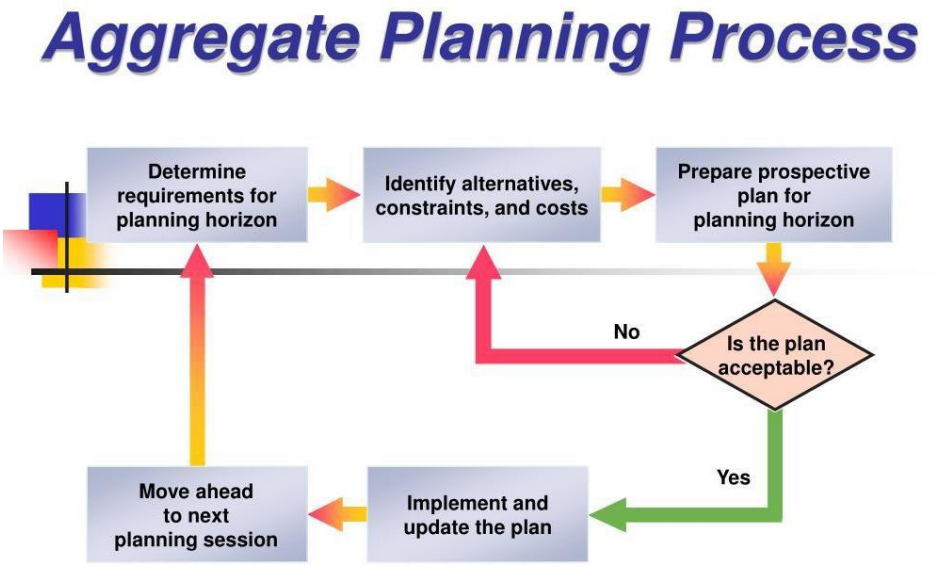


Fig2.7–AggregatePlanningProcess

AggregatePlanningStrategies

Thereare twopureplanningstrategiesavailabletotheaggregateplanner:alevelstrategy andachasestrategy.Firmsmaychoosetoutilize oneofthepurestrategiesinisolation,or they may opt for a strategy that combines the two.

Levelstrategy.

- Alevelstrategyseekstoproduceanaggregateplanthatmaintainsasteady production rate and/or a steady employment level.
- In order to satisfy changes in customer demand, the firm must raise or lower inventorylevels inanticipationofincreasedordecreasedlevelsofforecastdemand.
- Thefirmmaintainsalevelworkforceandasteadyrateofoutputwhendemandis somewhat low.
- Thisallowsthefirmtoestablishhigherinventory levelsthanarecurrently needed.
- Asdemandincreases,thefirm isable tocontinue asteadyproductionrate/steady employment level, while allowing the inventory surplus to absorb the increased demand.
- Asecondalternativewouldbetouseabacklogor backorder.
- Abackorder is simply a promise to deliver the product at a later date when it is morereadilyavailable,usuallywhencapacitybeginstocatchupwithdiminishing demand.
- In essence, the backorder is a device for moving demand from one period to another,preferablyoneinwhichdemandislower,therebysmoothingdemand requirements over time.

- Alevelstrategyallowsafirmtomaintainaconstantlevelofoutputandstillmeet demand.
- Thisis desirablefromanemployee relationsstandpoint.
- Negative results of the level strategy would include the cost of excess inventory, subcontractingorovertimecosts,andbackordercosts,whichtypicallyarethecostof expediting orders and the loss of customer goodwill.

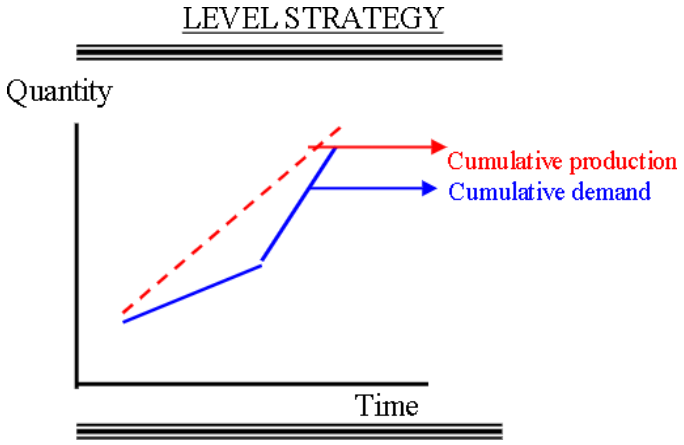


Fig2.8–LevelStrategy

Chasestrategy

- Achasestrategyimpliesmatchingdemandandcapacityperiodby period.
- Thiscouldresult ina considerableamountofhiring,firingorlayingoffofemployees; insecureandunhappyemployees;increasedinventorycarryingcosts;problems with labor unions; and erratic utilization of plant and equipment.
- Italsoimpliesagreatdealof flexibilityon thefirm'spart.
- Themajoradvantageofachasestrategyisthatitallowsinventorytobe heldtothe lowest level possible, and for some firms this is a considerable savings.
- Mostfirmsembracingthejust-in-timeproductionconceptutilizeachasestrategy approach to aggregate planning.
- Mostfirmsfinditadvantageoustoutilizeacombinationofthe levelandchase strategy.
- A combination strategy (sometimes calledahybridor mixedstrategy)canbe found tobettermeetorganizationalgoalsandpoliciesandachievelowercoststhaneither of the pure strategies used independently.

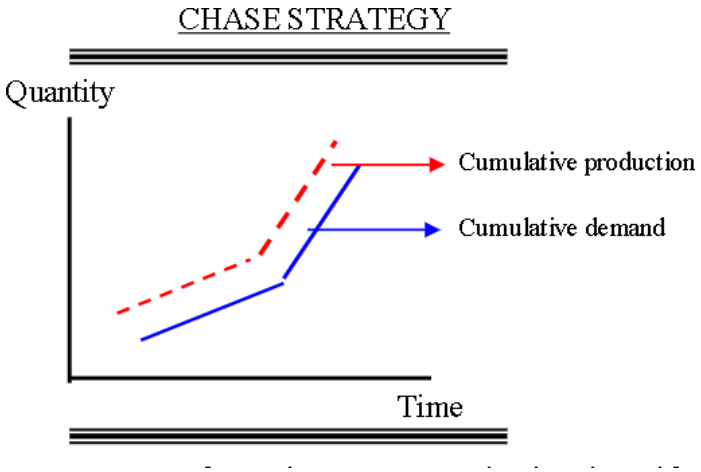


Fig2.9–ChaseStrategy

Hybrid strategy

Asthenameindicates,theHybridstrategyisanintegrationofbothlevelandchase strategies to get a better result.

- Itmaintainsasufficientbalancebetweenstocklevel,recruiting,terminationand production rate.
- Inthehybridstrategyofaggregateplanning,theorganizationsbuildupinventory before rising demands. It uses backorders to level with high peak periods.
- Itcaneasilycovershort-termpeaksbyhiringworkerstemporarilyorby subcontracting production.
- Hiring,lay-offandreassigningworkersisanormalpartofthehybridstrategy.

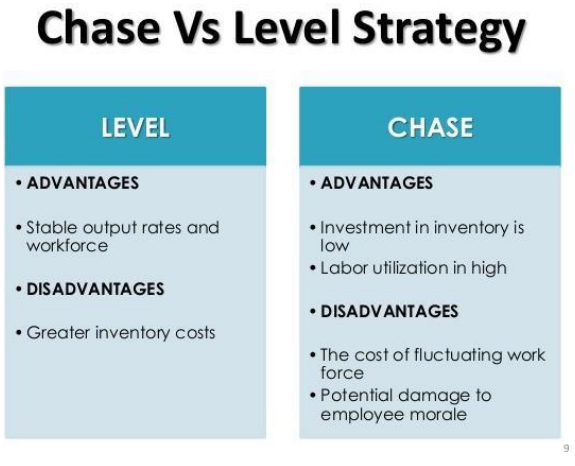


Fig2.10–Levelvs ChaseStrategy

TechniquesForAggregatePlanning

Techniques for aggregate planning range from informal trial-and-error approaches, which usually utilize simple tables or graphs, to more formalized and advanced mathematical techniques. William Stevenson's textbook Production/Operations Management contains an informalbutusefultrial-and-errorprocessforaggregateplanningpresentedinoutlineform. This general procedure consists of the following steps:

- **Determinedemandforeachperiod.**

  Determinecapacityforeachperiod.Thiscapacity shouldmatchdemand,which means it may require the inclusion of overtime or subcontracting.

  Identify company, departmental, or union policies that are pertinent. For example, maintaining acertainsafety stocklevel,maintaining areasonably stable workforce, backorderpolicies,overtimepolicies,inventorylevelpolicies,andotherlessexplicit rules suchas the nature ofemployment withthe individual industry,the possibility of a bad image, and the loss of goodwill.

- **Determineunitcostsforunitsproduced.**
  These costs typically include the basic production costs (fixed and variable costs as well as direct and indirect labor costs). Also included are the costs associated with making changes in capacity. Inventory holding costs must also be considered, as shouldstorage,insurance,taxes,spoilage,andobsolescencecosts.Finally,backorder costs must be computed. While difficult to measure, this generally includes expediting costs, loss of customer goodwill, and revenue loss from cancelled orders.
- **Developalternativeplansandcomputethecostfor each.**

  Ifsatisfactoryplansemerge,selecttheonethat bestsatisfiesobjectives.Frequently, this is the plan with the least cost. Otherwise, return to step 5.

Advantages

AdvantagesforManagementandUsers

Theadvantagesassociatedwithaggregateplanning include-

1. It helps the organization in dealing with production facilities in a lean manner. If a manufacturingfacilityhasanexcessoffinishedproducts,thenit isnotsuitableforit. The chance of product damage before reaching the end target is higher and this means loss. Moreover, excess inventory costs mean additional expense for the company. The only way to minimize these costs is by implementing a proper aggregate planning process.
2. Theprocesshelpstodevelopeffectivestrategicplansaswellasrelationshipswith distributors and suppliers. It also assists in making developing accurate market research

3. Theplanninghelps intheoptimizationofinventory.Carryingexcessiveinventorywill mean additional expenses for a manufacturing company. It also results in more storage space to keep it properly because the chances of damage increase if the storage space is not proper. The organization will also have to invest in more resources, laborandequipment tomanagetheinventory andfor its movement. The process makes an adequate estimation for the anticipated inventory that will be sufficiently able to meet projected demands.
4. An essential advantage is that it serves as a useful tool for making viable forecasts aboutproductdemand.Abusinessentityisnowabletomakepredictionsaboutstaff requirements, for instance, the number of additional workers it will needtemporarily or the number of employees it will need to lay-off. Proper forecasting helps the company tofillthe positions withtemporary stafffromagencies. The need foradditionalhires iseasilymetwithoutotherexpensesthatarepartofthefull-time workforce. The aggregate planning method helps the organization to make considerable savings in terms of both money and time that would have to be spent on the hiring and training process.
5. Ithelpstoadjustcapacitysothatitcanmeetdemands
6. Theaggregateplanning processhelpstocalculatecapacity,forinstance,howmany units can be produced daily or in a week or a month.
7. Production orders cannot be constant throughout the year. It will vary and this makes it difficult for the business entities to keep up with a similar production plan for all times. The aggregate planning process takes this thought into consideration and allows for contingency measures. These are put in place so that the manufacturing facilities can accommodate the changes that occur in production as wellasordersfromthecustomers.Theorganizationkeepsshiftingbetween thelevel strategy, chase strategy and hybrid strategy to keep up with the changes.
8. Ithelpstheorganizationtoidentifythe bestoptionssothatitcanmeetthedemands easily.
9. Itassistsinknowingaboutthe inefficienciesthatexistwithinthe organization
10. It helps to determine resources for instance amount of raw materials on hand, availability of total machine hours and the total number of workers along with productsinprogress,packagingmaterials,andtoolsrequiredformanufacturing finished goods
11. Anadvantageoftheplanningprocessisthatithelpstoprojectdemandandfigure out the units in need for the short-term by factoring in advertising campaigns, special pricing, and promotions.
12. It encourages the optimized utilization of space. The facilities that are used by organizationsformanufacturingpurposesaretoo costlyanditisnotfeasibletoown or rent it at all times. Besides paying for space, an organization also has to pay for maintenance and utilities. The aggregate planning helps the company to avoid any

scenariowherethespace isunusedforanextendedperiodandithastobear unnecessary expenses

13. It helps to offer optimized value to both the direct buyers from which it is getting rawmaterialsetc.and endcustomerstowhichit willsellthe products.Theprocess reducestheproductioncostsandthishelpsthem topassonsavings.Ultimatelythe end consumer gets the best quality products at the minimum price levels

DisadvantagesofAggregatePlanning

DataandBias

Likewithallplans,they areonly as goodas the peoplewhomakethem. Planners oftenhave biases,prejudicesandhabituationthatderivefromtheirexperienceandeducation. These,if unchecked, can leadto a planthat misreads economic indicators or relies onfaulty data like economic forecasting models. A production plan cannot take shocks into consideration,such as a spike in oil prices, Federal Reserve policies, interest rate hikes or changes in consumerconfidence. As the name suggests,these plans can only deal with“aggregates” or averages that are only a partially successful tool to predict fluctuations in demand.

LaborandUncertainty

Labor remains one of the most serious problems of aggregate production planning. For example,acompany plans to increase overtime hours and hire part-time workers forpeak demand seasons. It will then cut hours and give unpaid furloughs during poor demand seasons. This implies that workers, especially long-term ones, will become increasingly dissatisfiedand cynicalaboutcompany policy and will notworkup tocapacity. Evenmore, well-qualified workers will choose other companies because of the constant insecurity of such a production policy. As most aggregate models forecast alternations in labor conditions,thiscancauseproblemsamongfull-timeworkers.Itintroducesinsecuritiesand uncertainty into the workplace.

MASTERPRODUCTIONSCHEDULE

- MasterProductionSchedulingistheprocessthathelpsmanufacturersplanwhich products and related quantities to produce during certain periods.
- MPSisproactiveinthat itdrivestheproductionprocessintermsofwhatis manufactured and what materials are procured.

MasterProduction Schedule

- Asthenameimplies,theMPSdecideswhatproductsaremanufacturedand when.
- The required raw materials are then identified by the finished goods BOM,the data fromwhichisthenintegratedwithcurrentinventorydatatocreatetheMRPforraw materials procurement.

- TheMasterProductionScheduleformsthebasisofcommunicationbetweensales and manufacturing.
- Using the MPS as a contract between sales and production means that sales can makevalidorderpromises.TheMPSisnotarigidplan.MPSisadynamicplanand can be changed when there are changes in demand or capacity.

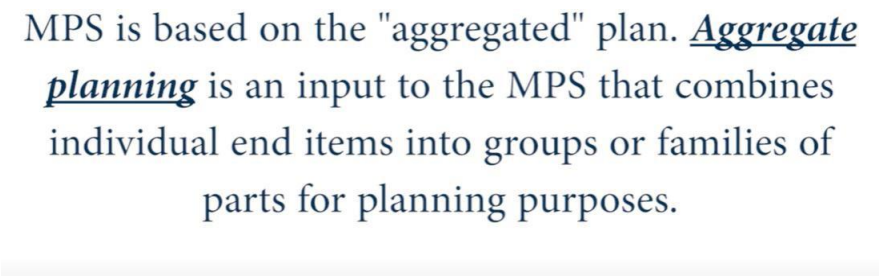


Fig2.11–InputtoMPS



Fig2.12–MPS Inputs

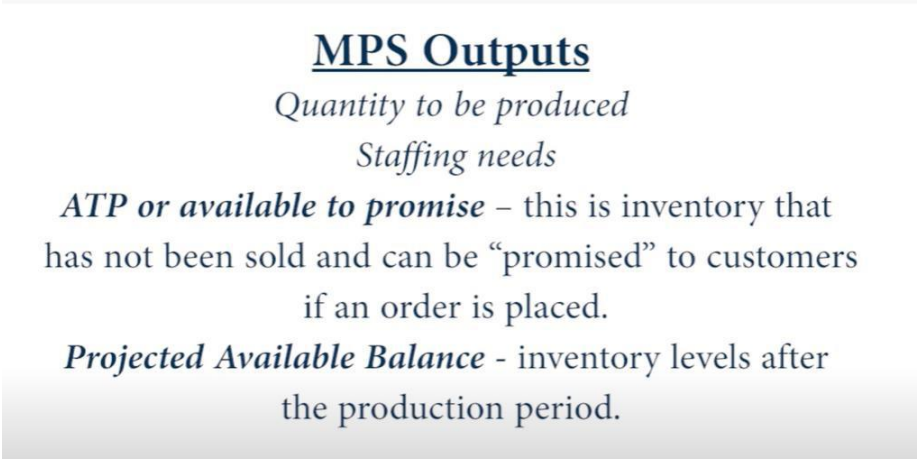


Fig2.13–MPS Outputs

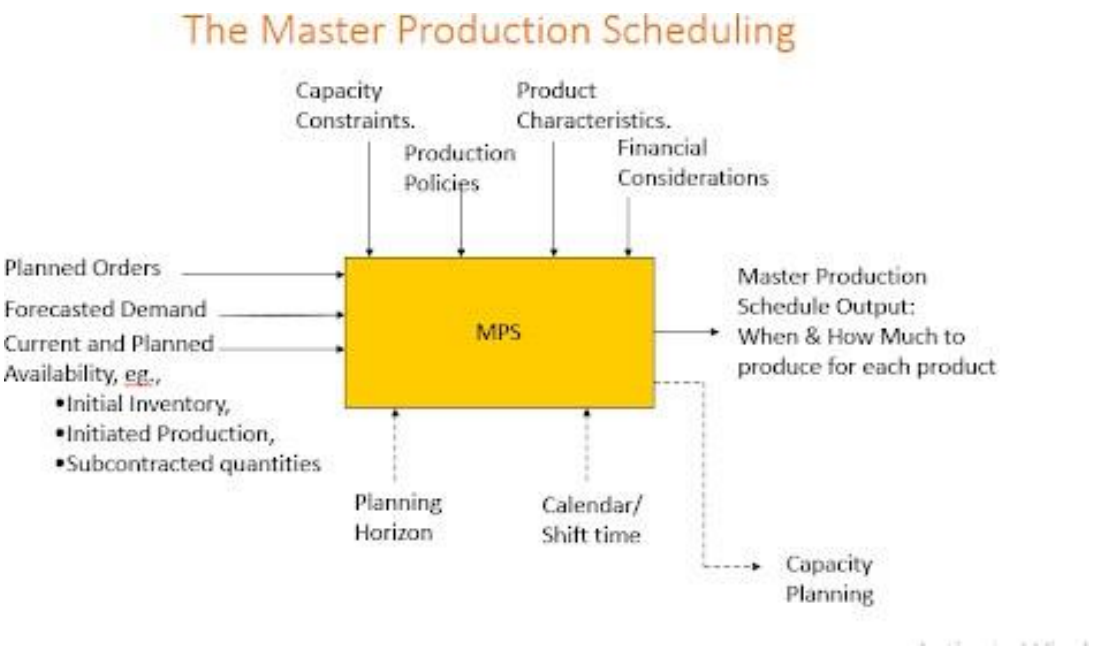


Fig2.14–MasterProductionScheduling

Apple

A	B	C	D	E
	IPad Aggregate Plan	Jan	Feb	Mar
	Product / Ipad Family	1000	1000	1000
	TOTALS	1000	1000	1000

A	B	C	D	E	F	G	H	I	J	K	L	M	N
MPS		Jan				Feb				Mar			
Week		1	2	3	4	5	6	7	8	9	10	11	12
Product	Ipad	100		150	100	100		150	100	100		150	100
	Ipad Mini	150	100	100		150	100	100		150	100	100	
	Ipad Pro		150		150		150		150		150		150
	TOTALS	1000				1000				1000			

Fig2.15–ExampleofMPSfromAggregatePlan

MainFunctionsofMasterProduction Scheduling

TheMPSstrivestoformadetailedplanthatfulfilsthefollowing objectives:

- Achievedesiredcustomerservicelevels
- Makethemostefficientuseofresources
- Maintaina desirablelevelof inventory

ObjectivesofMasterProductionScheduling(MPS)

ThemainobjectivesofMasterProductionScheduling(MPS)includethefollowing:

- InventoryControl -MPSoverseesinventoryandattemptstokeepadesiredlevelof inventory available within the company. This is completed through making perfect use of the resources available and minimizing overall cost and waste within the operation. Inventory control is one of the main objectives of MPS and can benefit the manufacturing operation immensely.
- Setting Up Due Dates - This objective pertains to setting up the due dates for availabilityofenditemsandalsoproviding informationpertainingtoresourcesand materials. This objective acts as the foundation of aggregate planning within the production facility.
- Customer Service - Delivery time is extremely important in ensuring for customer servicesatisfaction-whichMPScanhelpwith.Masterproductionschedulinghelps keep customer delivery promises through delivering in a timely and cost-effective manner.
- Scheduling - MPS sets up particular schedules for production of parts and components that are utilized as inputs to materials requirements planning. This ensuresforanoptimizedandefficientproduction schedulethatwillensureforon- time delivery and for the product to be completed in the time that it is given with the available resources.

PartsofaMasterProductionSchedule

Thecorrectprocedurefordevelopingamasterproductionscheduleistoincludethe following elements:

— Product List — All product models you produce. After you have completed your ABC analysis,youcanorderthem bypopularity,sothe items youproduce themostareatthe top of the list;

— Variation Sub-Lists for Each Product — Have a field for each product variation. One foreachSKU(Stockkeepingunit).Forexample,youcansplitbackpacks intoS,M,andL for size. You can further split these into other variations like color;

— Year, month, and week — This is useful for planning and keeping records, which is necessary for accurate demand forecasting. Split up your schedule into months and weeks.Theaim istohaveasolidplanofwhatyouwillproduce forthenextfewmonths. You can reassess your projected demand every few months. Don't be afraid to make adjustments sooner if the demand calls for it; and

— Productionquantities — This is the number of units youdecide to manufacture each week. Say, after analyzing your demand plan, you decide to manufacture 200 units of productinaweek.Youthenaddthenumber200 tothebottom ofeachweeklycolumn. But don't stop there, as you now need to allocate how many of each product variation will make up the 200 total. This depends on what you already have in stock, and what the projected demand is. For example, one week all 200 units could be of on e SKU, whereasthenextweektheproductioncouldbemoreevenlydistributedacrossproduct models.

DifferentMasterProductionSchedulingtechniques

TheMPSneedstoplan forwhatwillbemanufacturedatthemostefficientlevel.IftheMPS coverstoomany items,itwillbedifficult toput theplanintoaction,effectively.Whereas,if the plan is not detailed enough, the production will suffer. As a general rule, master scheduling should happen where the smallest number of product alternatives exists.

- In **make-to-stock** environments, a limited number of items are assembled from a larger numberofcomponents,forexample,videorecordersorcomputers.TheMPSshouldinthis case be a schedule of finished goods items.
- In a **make-to-order** environment, many different finished goods can be produced from a relativelysmallnumberofrawmaterials.Agreat exampleofthisprocesswould behowcars are manufactured. The subassemblies for many cars will be the same but the different models of cars manufactured differ in specific options such as color, stereo, sunroof, and electric windows. The MPS in a make-to-order environment is a schedule of the actual customer orders.
- **Assembletoorder**environmentsmakeuseofraw materialstoformbasiccomponentsand complete subassemblies. These components and subassemblies make up a variety of finished products. The Master Production Schedule should therefore take place at the subassembly level.

TheMasterProductionSchedulerequiresaslightlydifferentfocusforeachoftheseoptions. In each case, it will base the schedule on the smallest number of product options, as illustrated below:

Supply-Demand Options	MPS Focus
✓ Make-to-Stock (MTO)	✓ Schedule finished goods
✓ Make-to-Order (MTO)	✓ Schedule raw materials
✓ Assemble-to-Order (ATO)	✓ Schedule module production

Fig2.15– Techniquesof MPS

TheBenefitsofMPS

FivekeybenefitsofMasterProductionScheduling

1. Canhelptosmoothdemandsignal

- Mostcustomerdemandsignalswillcontainpeaks andtroughsofdemand – this profile can result in planning problems and inefficiency for manufacturers.
- AsignificantbenefitofMPSisthatsinceitdecouplesthecustomerdemand from what is manufactured – batch sizes can be tuned to optimize the production process.
- Where demand is particularly spiky (ie. Peeks and troughs of demand) this canbeofenormousassistanceproducingasteadydrumbeatofmanufacture (taking advantage of batch sizes and minimal setup times) which can then ripple through the supply chain.

2. Protectsleadtimeandhelpsbookfuturedeliveries

- Acommon complaint formanyorganizations isthatdemandis loaded withinlead time – i.e. if a part takes 100 days to manufacture it's no good taking a customer demandfordelivery in50dayswherethereisnostock –youarestruggling before you've even started the manufacturing process.
- This can create panic amongst the staff – throwing existing priorities into disarray. Whilst there are a variety of methods that can be used to stop this – MPS can be a veryeffectivemethodasitistheproductionschedulethatdrivesthemanufacturing not the customer demand.

- This enables the organization to protect its lead time but also assists planning in lookingatwhenfuturecustomerrequirementisbestsupportedbymanufacturing output.

3. Actsasasinglecommunicationtoolto the business

- AmajorbenefittoanyorganizationthatadoptsMPSisthatitactsasasingle communication tool for the business regarding its manufacturing plans.
- The MPS schedule is typically available via the MRP system however whatever the methodit'simperativethatitscommunicatedinaneasilyunderstandableformthat can be used throughout the organization.

4. HelpstheSupplychainprioritizerequirement

- Having a fixed schedule enables the supply chain team – in particular the procurementfunctiontocommunicateprioritiesandrequirementseffectively.
- Oneofthekeyproblemsmanymanufacturingorganizationsfacewheretheyareled by changing customer requirement is where the supply chain gets reprioritized depending on the "problem of the week".
- Its no surprise that suppliers work best to regular smoothed demand – where that demandinunstable itcan often leadtomisseddeliveries(ofwhatwasplanned) let alonethedetrimentalaffecttorelationshipswithsuppliersthatstruggletokeepup with what's really required.

5. Helpsstabilizeproduction

- Masterproductionschedulesare bestreviewedaspartofaformalbusinessprocess whichincludestherelevantstakeholdersandoftenrequiresseniorsignoffbeforeit is either loaded into the MRP system or is passed to production for action.
- It'scommontheproductionscheduletobeoutputtedfroma formalSIOPreview.
- Typically master production schedules do not allow "planning in arrears" so where failureshavehappenedandproducthasnotbeen manufacturedasplanned–these items are re-planned to a relevant point in the future.

OPERATIONSCHEDULING

- In the past, manufacturing operations struggled with the concept of keeping productionontimeandefficient.Asthisproblem becameprevalentandtechnology improved, operations scheduling became a viable option for manufacturers that were seeking efficiency improvement.
- **Operations scheduling** pertains to establishing both timing and utilization of resourceswithinanorganization.Withinoperationsscheduling,schedulingcoincides with the utilization of equipment, scheduling of human labor, and materials receipt.
- Operations scheduling can enable production to have a schedule to follow and ensureforaccuratedeliverytimeswhilealsokeepinganeyeoninventorylevels

PRODUCTSEQUENCING

- Theorderinwhichjobspassthroughthemachinesorworkstationsis called **sequencing.**
- **Sequencing** means grouping production operations into production batches and arranging them by priority..... Byutilizingtheleanphilosophy,smallquantitiesare producedinchronologicordertoreducetheinventories.
- **Sequencing gives the idea of the order in which things happen or come in event. Supposethereare'n'jobs(1,2,3,……n)eachofwhichhastobeprocessedoneata time at 'm' machine (A,B,C.....). The arrangement of these flows is called job sequencing.**

PrioritySequencingRules

Priority sales are used to decide which job will be processed next at work centre, whereseveral jobs are waiting to be processed. The jobs waiting for processing are sequencedusing one of many priority sequencing rules. It is assumed that the work centre canprocess only one job at a time. A large number of sequencing rules are used in researchand in practice to sequence the jobs waiting for processing at a work centre.

Therelativeprioritiesare basedoncertainrulesasdiscussedinthefollowing:

1. First Come, First Served (FCFS) rule: This is a fair approach particularly applicable to people.Incaseofinventorymanagement,it isFirstIn FirstOut(FIFO).Thatmeansthe1st piece of inventory at a storage area is the 1st one to be used.

2. Theshortestprocessingtime(SPT)rule:SPTrulesequencesjobsinincreasingorder of their processing times (including set up).

3. TheEarliestDueDate(EDD)rule:Sequences jobsinorder oftheir duedates,earliest first.

4. Thecriticalratio(CR)rule:Sequencesjobsinincreasingorderoftheircritical ratio.

$$CR = \frac{DueDate - Today^{F}sDate}{RemainingProcessingTime}$$

IfCR>1Thejobisaheadofschedule. If

CR<1 The job is behind schedule.

IfCR=1Thejob isexactlyonschedule.

5. TheSlackTime Remaining(STR)rule:Itemploysthatthenextjobprocessedisthe one that has the least amount of slack time.

Slack=(Duedate–Today'sdate)–Remainingprocessingtime

Thejob'sprioritysdeterminedbydividingtheslackbythenumberoftheoperations that remain including the operation which is being scheduled.

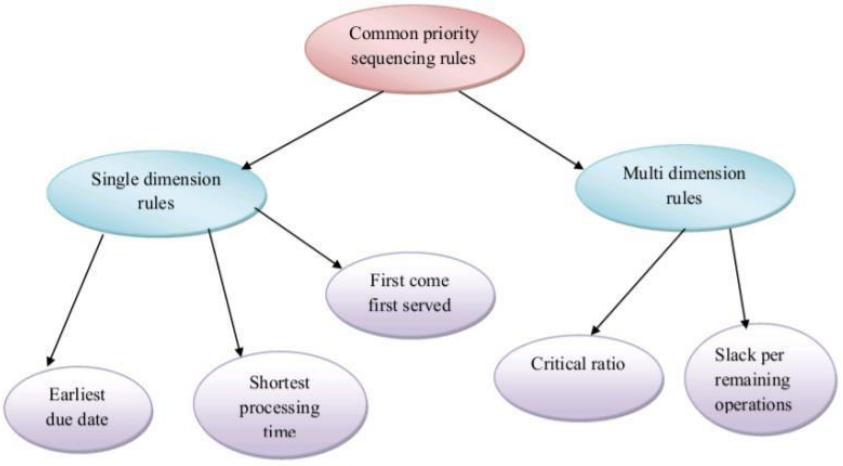


Fig2.16–Sequencing Rules

SEQUENCINGOFPRODUCTSINMULTI-PRODUCTMULTI-STAGE

Consider a problem with five jobs (A, B, C, D, and E) and two machines M1 and M2. All five jobsconsistoftwooperationseach.The firstoperationofeachjobisprocessedonmachine M1; and the second operation is processed on machine M2.

Table 2.1givesthemachines requiredforeachjobandtheprocessingtimesforeach operation of each job

Table 2.1-Datafora5-Job2-MachineFlowShop Problem

Job	*Operation #1*	*Operation #2*	*Machine for Operation #1*	*Machine for Operation #2*	*Time for Operation #1 (Days)*	*Time for Operation #2 (Days)*
A	A1	A2	M1	M2	8	3
B	B1	B2	M1	M2	5	7
C	C1	C2	M1	M2	6	9
D	D1	D2	M1	M2	7	1
E	E1	E2	M1	M2	4	6

Thescheduling objectiveistofindanoptimalsequencethatgivestheorderinwhichthe five jobs will be processed on the two machines to minimize make-span.

Let us find the make-spanfor one ofthe sequences,say,A–B–C–D–E,before attempting to find theoptimalanswer.We willdrawaGanttcharttofindmake-span. ThesequenceA–B– C–D–Etells us that A is the first jobto be processed,B is the secondjob,andso on. E is the

lastjobto beprocessed.TheGanttchartforthesequenceA–B–C–D–Eisgiven inFigure 2.17. We must assume that the sequence is the same on both machines. This is also called “nopassing”inthescheduling literature.Thevalueofmake-span(timetocompletealljobs) is 36 days. Ourobjective is to identify the sequence that minimizes the value of make-span.

Position 1	Position 2	Position 3	Position 4	Position 5

Gantt chart for sequence A–B–C–D–E

Time (days)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
M1	A1	A1	A1	A1	A1	A1	A1	A1	B1	B1	B1	B1	B1	C1	C1	C1	C1	C1	C1	D1	D1	D1	D1	D1	D1	D1	E1	E1	E1	E1						
M2									A2	A2	A2			B2	B2	B2	B2	B2	B2	B2	C2	C2	C2	C2	C2	C2	C2	C2	C2	D2	E2	E2	E2	E2	E2	E2

Fig2.17–GanttchartforsequenceA–B–C–D–E

Johnson’s Rule

Johnson’s rule is a proven method to give an optimal solution. There are five sequence positions 1–5. Johnson’s rule assigns each job to one of these positions in an optimal manner. This rulealso requires thatthesameoptimalsequence is usedon both machines. Therulealsoassumesthatnopreemption(nopassing)isallowedwhichmeansthatoncea job is started it cannot be interrupted.

Weusethefollowing four-stepprocesstofindthe optimalsequence.

Step1:Findthe minimumprocessingtimeconsideringtimesonboth machines.

Step2:Identifythecorrespondingjobandthecorrespondingmachinefortheminimum time identified at Step 1.

Step3:Schedulingrule

a. Ifthemachine identified inStep2ismachineM1,then thejobidentifiedinStep2willbe scheduled in the first available schedule position.

b. IfthemachineidentifiedinStep 2ismachineM2,then thejobidentifiedinStep2willbe scheduled in the last available schedule position.

Step4:Removethejobfrom considerationwhose positionhasbeenfixedinStep3andgo to Step 1.

Continuethisprocessuntilalljobshavebeen scheduled.

Job	Operation #1	Operation #2	Machine for Operation #1	Machine for Operation #2	Time for Operation #1 (Days)	Time for Operation #2 (Days)
A	A1	A2	M1	M2	8	3
B	B1	B2	M1	M2	5	7
C	C1	C2	M1	M2	6	9
D	D1	D2	M1	M2	7	1
E	E1	E2	M1	M2	4	6

Fig2.18–Iteration1

Iteration1(seeFigure 2.18)

Step1:Theminimumtimeis1.

Step2: ThejobisDandthemachineisM2.

Step 3: Since the machine identified at Step 2 is machine M2, the job D will be assigned to thelastavailablesequencepositionwhichisposition5;andtheresultingpartial sequenceis given below.

Step4:DeletejobDfromconsideration.

Position 1	Position 2	Position 3	Position 4	D

Job	Oper-ation #1	Oper-ation #2	Machine for Oper-ation #1	Machine for Oper-ation #2	Time for Oper-ation #1 (Days)	Time for Oper-ation #2 (Days)	
A	A1	A2	M1	M2	8	3	
B	B1	B2	M1	M2	5	7	
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~1~~	Scheduled
E	E1	E2	M1	M2	4	6	

Fig2.19–Iteration2

Iteration2(seeFigure2.19)

Step1: Thenextminimumtimeis3.

Step2: ThejobisAandthemachineisM2.

Step3:ThejobAwillbeassignedtothe last availablescheduleposition,whichisposition4. After assigning job A to position 4, the partial sequence is given below.

Step4:DeletejobAfromconsideration

Position 1	Position 2	Position 3	A	D

Job	*Oper-ation #1*	*Oper-ation #2*	*Machine for Oper-ation #1*	*Machine for Oper-ation #2*	*Time for Oper-ation #1 (Days)*	*Time for Oper-ation #2 (Days)*	
~~A~~	~~A1~~	~~A2~~	~~M1~~	~~M2~~	~~8~~	~~3~~	Scheduled
B	B1	B2	M1	M2	5	7	
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~4~~	Scheduled
E	E1	E2	M1	M2	4	6	

Fig2.20–Iteration3

Iteration3(seeFigure 2.20)

Step1:Theminimumtimeis4.

Step2: ThejobisEandmachineisM1.

Step3:ThejobEwillbeassignedtothefirstavailablescheduleposition,whichis

position 1. The partial sequence after assigning job E to position 1 is givenbelow.

Step4:DeletejobEfromconsideration.

E	Position 2	Position 3	A	D

Job	Operation #1	Operation #2	Machine for Operation #1	Machine for Operation #2	Time for Operation #1 (Days)	Time for Operation #2 (Days)	
~~A~~	~~A1~~	~~A2~~	~~M1~~	~~M2~~	~~8~~	~~3~~	Scheduled
B	B1	B2	M1	M2	5	7	
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~1~~	Scheduled
~~E~~	~~E1~~	~~E2~~	~~M1~~	~~M2~~	~~4~~	~~6~~	Scheduled

Fig2.21–Iteration4

Iteration4(seeFigure 2.21)

Step1:Theminimumtimeis5.

Step2: ThejobisBandmachineisM1.

Step3:ThejobBwillbeassignedtothe firstavailablescheduleposition,whichisposition2. The partial sequence after assigning job B to position 2 is given below.

Step4:DeletejobBfrom consideration

E	B	Position 3	A	D

Job	Operation #1	Operation #2	Machine for Operation #1	Machine for Operation #2	Time for Operation #1 (Days)	Time for Operation #2 (Days)	
~~A~~	~~A1~~	~~A2~~	~~M1~~	~~M2~~	~~8~~	~~3~~	Scheduled
~~B~~	~~B1~~	~~B2~~	~~M1~~	~~M2~~	~~5~~	~~7~~	Scheduled
C	C1	C2	M1	M2	6	9	
~~D~~	~~D1~~	~~D2~~	~~M1~~	~~M2~~	~~7~~	~~1~~	Scheduled
E	~~E1~~	~~E2~~	~~M1~~	~~M2~~	~~4~~	6	Scheduled

Fig2.22–Iteration5

Iteration5(seeFigure 2.22)

Theonlyunscheduledjobatthisstageis Candit willbeassignedtotheremaining unassigned position 3.

Thefinalsequenceisgiven below.

E	B	C	A	D

FindingMake-Span

The sequence E–B–C–A–D identified by Johnson's rule guarantees the minimum value of make-span.However,Johnson'sruledoesnotgivethevalueofmake-span.Itonly identifies thebestsequence.Thevalue ofmake-spanisobtainedeitherby drawingtheGanttchartor acomputerizedalgorithm canbe used.TheGantt chartforthisoptimalsequence isgivenin Figure 2.23. The value of make-span is 31 days.

Thisisthe optimalanswer.

Gantt chart for sequence E–B–C–A–D

Time (days)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
M1	E1	E1	E1	E1	B1	B1	B1	B1	B1	C1	C1	C1	C1	C1	C1	A1	A1	A1	A1	A1	A1	A1	A1	D1	D1	D1	D1	D1	D1	D1						
M2					E2	E2	E2	E2	E2	E2	B2	B2	B2	B2	B2	B2	B2	C2	C2	C2	C2	C2	C2	C2	C2	C2	A2	A2	A2		D2					

Fig2.23–GanttchartforsequenceE–B–C–A–D.

PLANTCAPACITY

Plantcapacity(productioncapacity)referstothe volumeornumberofunitsthatcanbe manufactured during a given period.

- FactorsaffectingdeterminationofPlantCapacity
  a. Marketdemandforaproduct/service.
  b. Theamountofcapitalthatcanbe invested.
  c. Levelofintegration(i.e.vertical integration).
  d. Typeoftechnologyselected.
  e. Dynamicnatureofallfactorsaffectingdeterminationofplantcapacity,viz., changes intheproduct design,process technology,market conditions and product life cycle, etc.
  f. Difficultyinforecastingfuturedemandandfuture technology.
  g. Obsolescenceofproductandtechnologyoveraperiodoftime.

h. Presentdemandandfuturedemandbothovershort-range,intermediate-range and long-rangetime horizons.
i. Flexibilityforcapacityadditions.

Severalfactorshaveabearingonthecapacity decision.

1. **Technologicalrequirement**
   Formany industrialprojects,particularlyinprocesstypeindustries,thereiscertain minimum economic size determined by the technological factor.

2. **Inputconstraints**
   InadevelopingcountrylikeIndia,theremay beconstraintsontheavailabilityof certaininputs.Powersupplymaybe limited;basic rawmaterialsmaybescarce; foreignexchange available forimports may be inadequate. Constraints ofthese kinds should be borne in mind while choosing the plant capacity.

3. **Investmentcost**
   Whenseriousinputconstrainsdoesnotobtaintherelationshipbetweencapacity andinvestmentcostisanimportantconsideration.Typically,the investmentcost per unit of capacity decreases as the plant capacity increases. This relationship may be expressed as follows:

   Examples suppose the known investment cost for 5,000 units of capacity for the manufactureofacertainitem isRs10,00,000.Whatwillbetheinvestmentcostfor 10,000 units of capacity if the capacity – cost factor is 0.6.

   Thederivedinvestmentcostfor10,000unitsofcapacitymaybeobtainedasfollows:

   - C1=10,00,000*(10,000/5,000)0.6=Rs15,16,000

4. **Market conditions**
   Theanticipatedmarketfortheproductorservicehasanimportantbearingonplant capacity. If the market for the product is likely to be very strong, a plant of higher capacity is preferable. If the market is likely to be uncertain, it might be advantageous to start with a smaller capacity. If the market, starting from a small base, is expected to grow rapidly, the initial capacity may be higher than the initial level of demand- further additions to capacity may be affected with the growth of market.

5. **Resourcesofthe firm**
   The resources, managerial and financial, available to a firm define a limit on its capacitydecision.Obviously,afirmcannotchooseascaleofoperations beyondits financial resources and managerial capacity.

6. **Governmentpolicy**

Thecapacitylevelmaybe influencedbythepolicyofthegovernment.

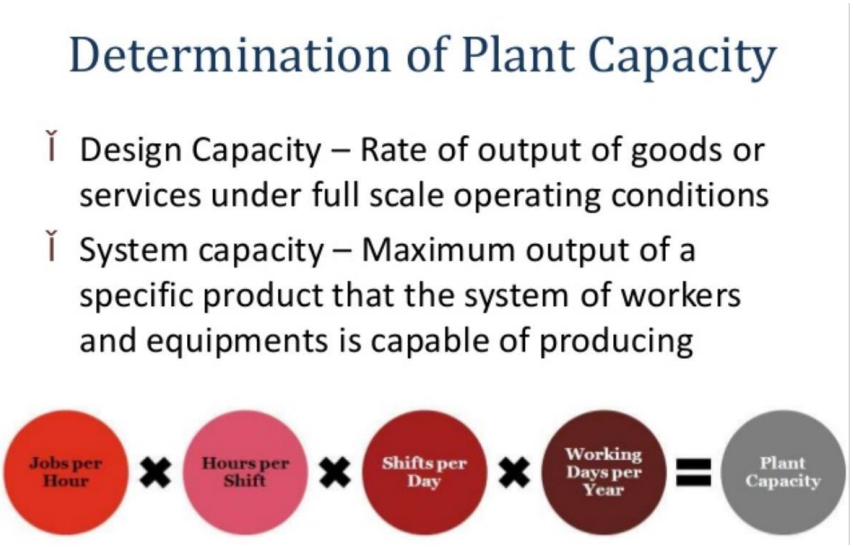


Fig2.24–DeterminationofPlantCapacity

LINEBALANCING

- **Aproductionlineissaidtobeinbalancewheneveryworker'stasktakesthe same amountoftime.**
- **Line balancing is a manufacturing-engineering function in which whole collection ofproduction-linetasksaredividedinto equalportions.Well-balancedlinesavoid labour idealness and improve productivity.**

ProductionLine Balancing

Line-balancingstrategyistomakeproductionlinesflexibleenoughtoabsorbexternaland internalirregularities.Therearetwotypesofline balancing,whichwehaveexplainedas –

- StaticBalance–Referstolong-termdifferencesincapacityoveraperiodofseveral hours or longer. Static imbalance results in underutilization of workstations, machines and people.
- DynamicBalance –Referstoshort-term differencesincapacity,like,overaperiodof minutes, hours at most. Dynamic imbalance arises from product mix changes and variations in work time unrelated to product mix.

Exampleoflinebalancing:

- Everyoneisdoingthesameamountofwork
- Doingthesameamountofworktocustomerrequirement
- Variationis'smoothed'

- Noone overburdened
- Noone waiting
- Everyoneworkingtogetherina**BALANCED**fashion

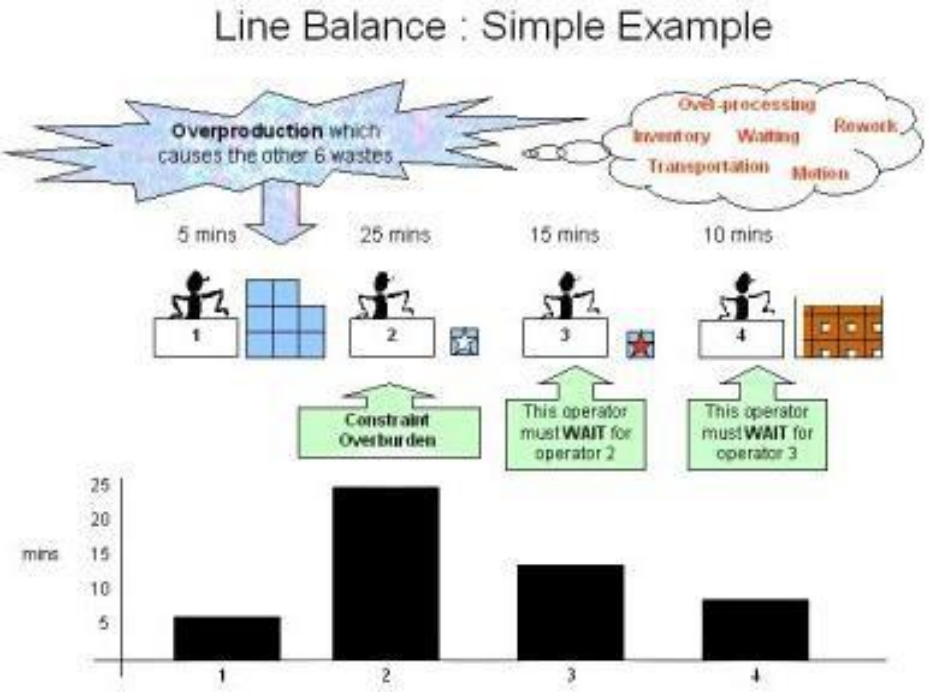


Fig2.25–Line Balance:SimpleExample

- Hereweseeoperatornumber1over-producing,thuscreatingthe other6wastes.
- Re-balancetheworkcontent(Redistributesomeofthework),usingaYamazumi board as it is often known

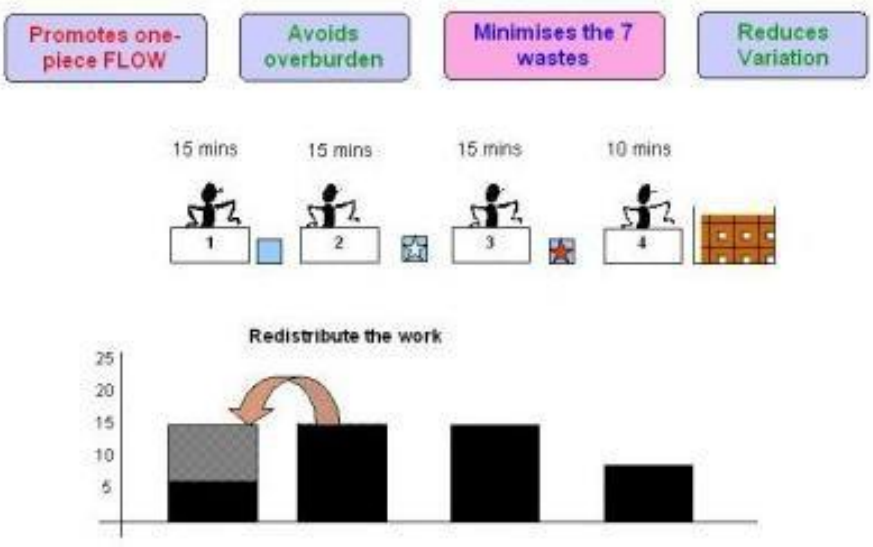
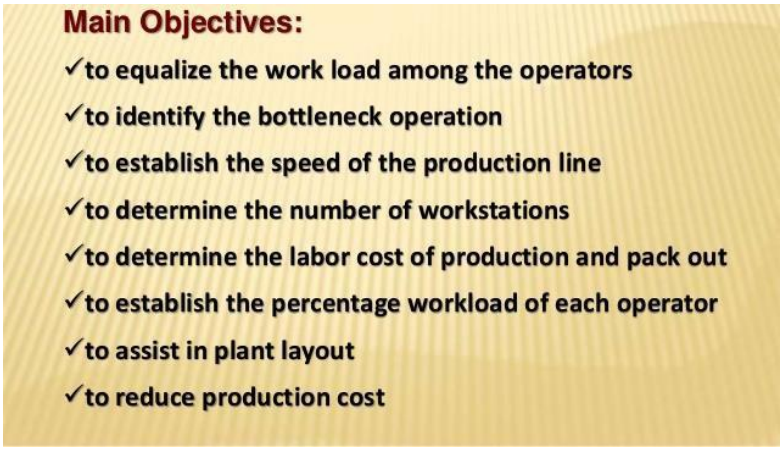


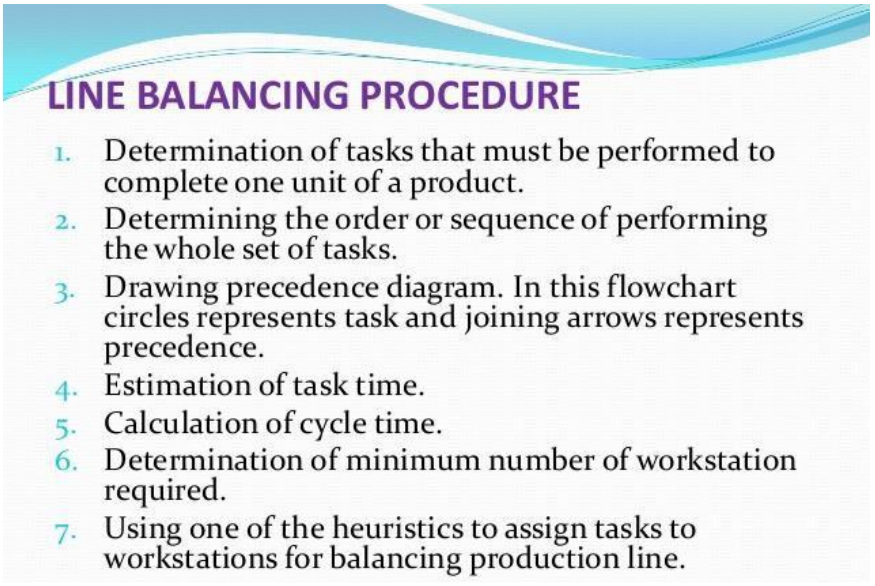
Fig2.26–Line Balance:SimpleExample



- Linebalancingtechniquewasusednormallyinassemblylineoftheautomotive industry which is called ALB.
- MostoftheSmallandMediumIndustriesdonot uselinebalancingmethodinthe production line.

Linebalancingoperatesundertwocircumstances:

1. **Precedence Constraint:**Products cannot progress to other station if it doesn't complete necessarytaskatthatstation.Itshouldnotacrossotherstationbecausecertainpartneeds to be performed before other activities.
2. **Cycle time Restriction:** Cycle time is maximum time for products spend in every workstation. Different workstation has different cycle time.



TermsinLineBalancingTechnique

Thereisrangeoftermsusedinassemblylinebalancingsystem.Eachofthemhastheir meaning and purposes.

I. **Cycle Time:**Maximum amount of time allowed at each station. This can be found by dividing required units to production time available per day. This is the time expressed in minutes between two simultaneous products coming of the end of production line.
II. **LeadTime:**Summationofproductiontimesalongtheassembly line.
III. **Bottleneck:**Delay in transmission that slow down the production rate. This can be overcome by balancing the line.
IV. **Task Precedence:**It is the sequence by which tasks are carried out. It can be represented bynodesorgraph.Inassemblylinetheproductshavetoobeythisrule.Theproductcannot be moved to the next station if it doesn't complete at the previous station.
V. **Idletime:**Aperiodwhensystemisnotinusedbutisavailable.
VI. **Productivity:**Definedasratioofoutputoverinput.Productivitydependsonseveralfactors such as workers skills, jobs method and machine used.
VII. **Takt times:**The time needed by competent worker or unattended machine to perform a task.Thisisusuallyexpressedinminutes.Takttimeispre-requisiteprocedureindoingline balancing task. Takt time is the swiftness of production that aligns production with client demand. It shows how fast the need to manufacture product in order to fill the customer orders. Producing fasterthantakt time results in overproductionwhich is a type of waste whereasproducingslowerthantakttimeresultsinbottleneckswherethecustomerorders maynotbefulfilledintime.Therearenumerousbenefitsofusingtakttime.Theseinclude,
    i. Achieveasteadyandcontinuousflowofproduction.
    ii. Eliminatethewasteofoverproductionbyproducingactualcustomer demand.
    iii. Improvesaccuracyofplanning.
    iv. Encourage thedevelopmentofstandardize workinstructions, promotingquality and efficiency.
    v. Setrealtimetargetsforproductionthatshowsoperatorsexactlywheretheirwork output should be at any given point of time.
    vi. Establishwhat-ifscenarioforcustomerdemandbasedonflexible manning.

TheTAKTTimeFormula=(NetTimeAvailableforProduction)/(Customer'sDaily Demand).

VIII. **Workstation:**Aphysicalareawhereaworkerwithtools/oneormoremachinesor unattended machines such as robot perform specific task in a production line.
IX. **Downtime:**Downtimeexplainedasthetimethatisnonvalueadded.Itis oftenassociated with the seven wastes as under:
    a. Defects:Defectisdirectcostsofacompany.
    b. Overproduction:Oneoftheseverewastesdiscouragesasmoothflowofgoodsand services,whichmayleadtounnecessaryleadandstoragetime.Itwillleadtothedefects

whichcannotbedetectedearlierandthentheproductsmaydeteriorate.Itwillalsolead to excess work-in-progress stocks.

c. Waiting: It occur when the goods are not moving or being worked on. It affects both goods and workforce where the waiting time should be used for some value added activities such as training and maintenance.
d. Transportation:Any movement infactory canbe consideredas waste. Doublehandling and excessive movements are likely to cause damage and deterioration with the distance of communication between processes proportional to time taken. It takes to feedback reports of poor quality and needs corrective action.
e. Unnecessaryinventory:Thereisaproblemwithextrainventory.Inventorywillincrease the lead time, preventing quick identification of problems and increasing space. Significant storage costs are wasted which absolutely lower the competitiveness ofthe organization of value stream.
f. Unnecessarymotion:Involvetheergonomicsofproductionwhereoperationmighthave to stretch, bend and pick up when these actions actually could be avoided. It not only tires the workers but also leads to poor productivity.
g. Inappropriate processing: Over-complexity of a process discourages ownership and encourages the employees to over produce to recover the large investment in the complex machines. It encourages poor quality and takes corrective action.

StepsinSolvingLineBalancing

Thereare fourstepsinsolvinglinebalancingdescribedbyG.Andrew(2006).

I. Drawing Precedence Diagram: Precedence diagram needs to be drawn to demonstrate a relationship between workstations. Certain process begins when previous process was done.
II. Determining Cycle Time: Cycle time is longest time allowed at each station. This can be expressed by this formula:

$$\text{Cycle time} = \frac{\text{Available time}}{\text{Desired output}}$$

Thismeanstheproductsneedstoleavetheworkstationsbeforeitreachesitscycletime.

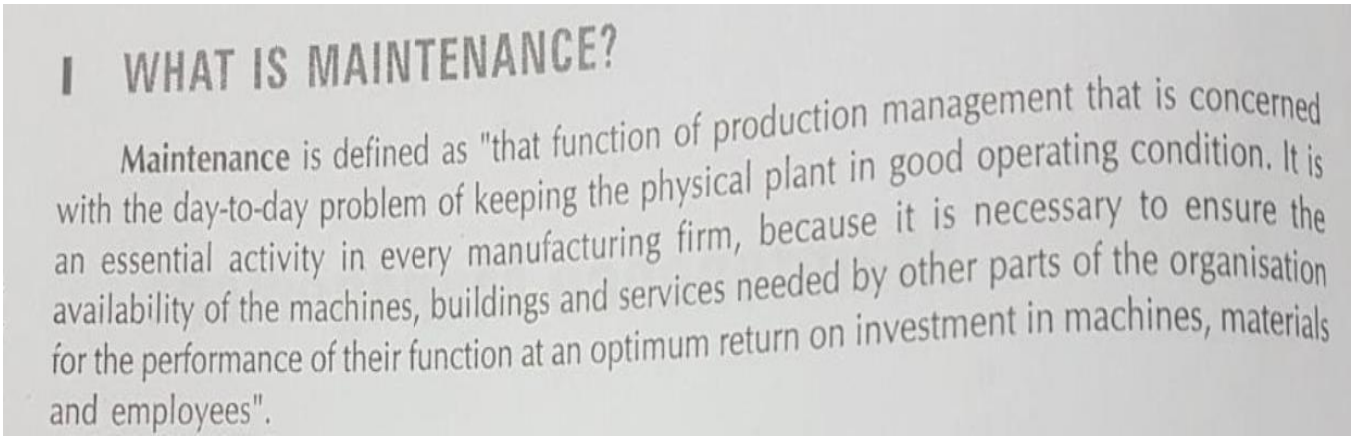
III. Assigningtaskstoworkstation:Thetasksdistributionsshouldbetakenaftercompletinga timecycle.It'sgoodtoallocatetaskstoworkstationintheorderoflongesttask times.

$$\text{Number of work Stations} = \frac{\sum \text{Task Time}}{\text{Desired Actual Time}}$$

IV. Calculating an Efficiency Line: This is done to find effectiveness of the line. The formula is given by:

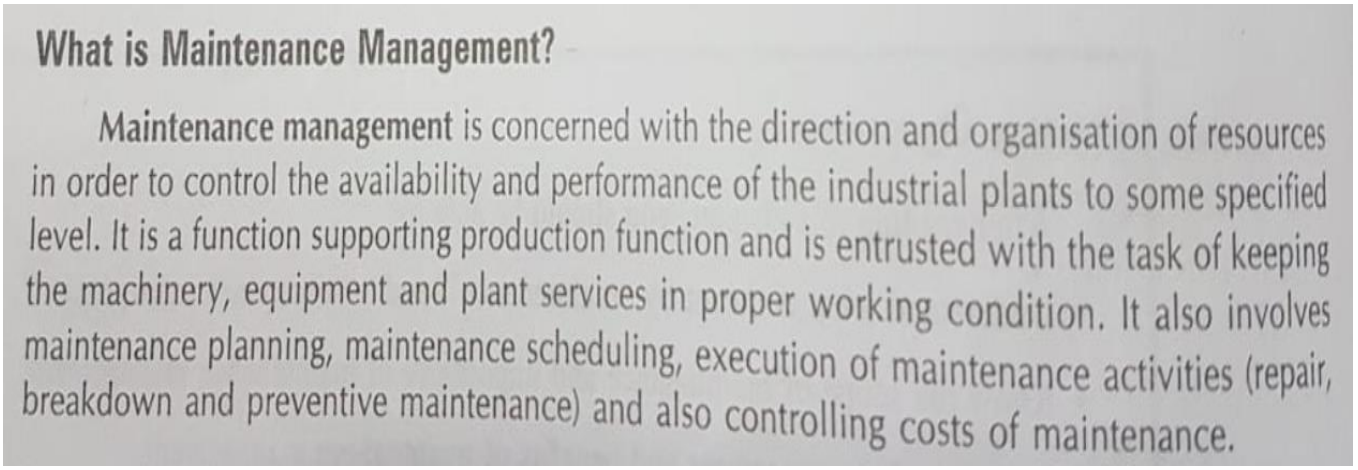
$$\text{Line Efficiency} = \frac{\text{Sum of task times}}{\text{Number of workstation X Desired cycle time}}$$

MAINTENANCEMANAGEMENT



I WHAT IS MAINTENANCE?

Maintenance is defined as "that function of production management that is concerned with the day-to-day problem of keeping the physical plant in good operating condition. It is an essential activity in every manufacturing firm, because it is necessary to ensure the availability of the machines, buildings and services needed by other parts of the organisation for the performance of their function at an optimum return on investment in machines, materials and employees".



What is Maintenance Management?

Maintenance management is concerned with the direction and organisation of resources in order to control the availability and performance of the industrial plants to some specified level. It is a function supporting production function and is entrusted with the task of keeping the machinery, equipment and plant services in proper working condition. It also involves maintenance planning, maintenance scheduling, execution of maintenance activities (repair, breakdown and preventive maintenance) and also controlling costs of maintenance.

MaintenanceManagementistheprocessofmaintainingacompany'sassetsandresources while controlling time and costs, ensuring maximum efficiency of the manufacturing process.

UseofMaintenance Management

- Themainaimofequipmentmaintenanceistomaintainthefunctionalityofthe equipment and to minimize its breakdowns.
- Formechanicalequipment,themaintenancemanagementwillinvolverepair, replacement, and serving of tools.
- Italsoensurestheproperworkingandtointerceptfluctuationsthatoccurinthe duration of the production process.
- Thefactremainsthat,anykindofchangeevenaminordowntimecouldreducethe overall efficiency of machines which would lead to major production losses.
- Therefore,itis importantfororganizationstodaytogetandimplementagood maintenance strategy.

Withoutorintheabsence ofequipmentmanagement,itmightbepossibletofacesome consequences in revert of careless decisions. Some of them are:

- Productionloss
- Reschedulingofwholeprojects
- Materialwastagefromresourcesthathavenotbeenused yet
- Overtimeof labor becauseof downtime
- Disposalofmachineryandequipmentbeforetheendofitsusefullife

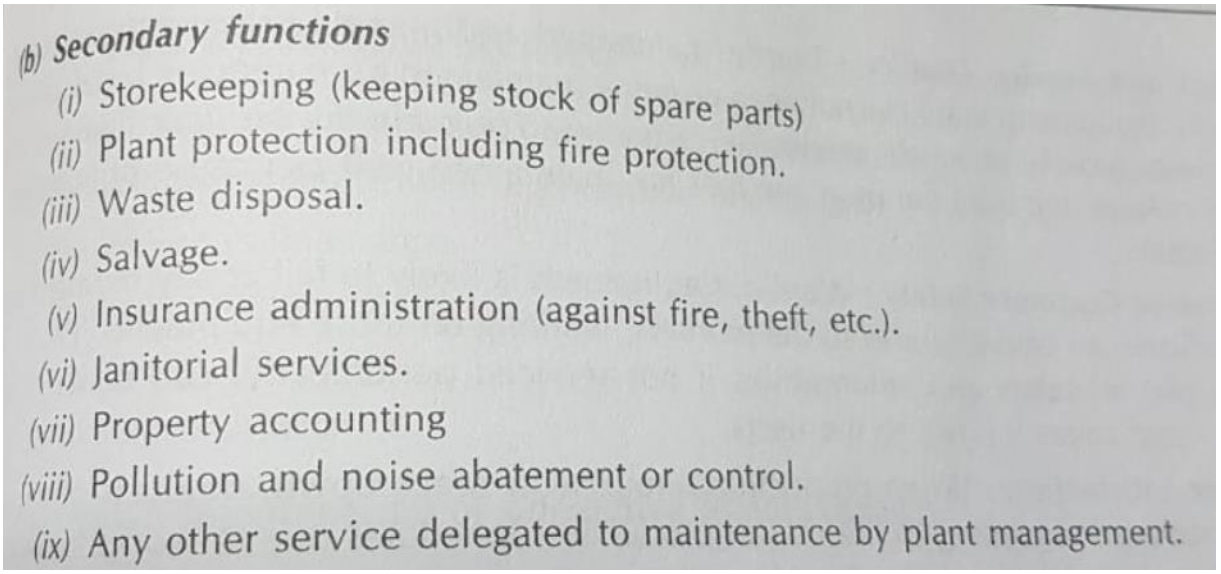
Scope of Maintenance

Every manufacturing organisation needs maintenance because machines break down, parts wear out and buildings deteriorate over a period of time of use. All segments of a factory – buildings, machinery, equipments, tools, cranes, jigs and fixtures, heating and generating equipments, waste disposal systems, air-conditioning equipments, wash rooms, dispensaries and so on need attention.

Maintenance covers two broad categories of functions as outlined below.

(a) Primary functions

(i) Maintenance of existing plant and equipments.
(ii) Maintenance of existing plant buildings and grounds.
(iii) Equipment inspection and lubrication.
(iv) Utilities generation and distribution.
(v) Alterations to existing equipments and buildings.
(vi) New installations of equipments and buildings.


(b) Secondary functions
(i) Storekeeping (keeping stock of spare parts)
(ii) Plant protection including fire protection.
(iii) Waste disposal.
(iv) Salvage.
(v) Insurance administration (against fire, theft, etc.).
(vi) Janitorial services.
(vii) Property accounting
(viii) Pollution and noise abatement or control.
(ix) Any other service delegated to maintenance by plant management.

ImportanceofMaintenance Management

Manyorganizationsstillbelieveinthe oldmethodologieswhichsuggesttonottofix anything unless it's broken. But breaking this myth, we will suggest you, to go for preventive maintenance management as it has many benefits:

- OperatorandMachineSafety

  Byperforming regularpreventivemaintenance,youwillalwaysbeassuredthatyour equipment will operate under safe conditions, both for the machine and the operators.Possibleissuescanbe cutoffbefore it tendstocauseanyharm,withouttaking any chance.

- MachineEfficiency

  Withnormalwearandtear,machinescancauselowerefficiency.Properpreventive maintenance management willassure you of the optimal working conditions ofthe equipment and moreover, conserves its life span.

- TimeSavings

  Planned preventive maintenance management will reduce the actual downtime caused by the breakdownandfurther enhance the products that tooinless time,thereby,saving a lot oftime.Preventativemaintenancewillconsumelesstimethanthetimetakeninemergency repairs and replacements.

...maintenance by plant management.

Importance of Maintenance Management

1. Dependability of service is one of the performance measures by which a company can distinguish itself from others. To establish a competitive edge and to provide good customer service, companies must have reliable equipments that will respond to customer demand when needed. Equipments must be kept in reliable condition without costly work stoppage and down time due to repairs if the company is to remain productive and competitive.
2. Maintenance is an important factor in *quality assurance* which is another basis for successful competitive edge. Inconsistencies in equipments lead to variability in product characteristics and result in defective parts that fail to meet the established specifications. Beyond just preventing break downs, it is necessary to keep equipments operating within specifications (*i.e.*, process capability) that will produce high level of quality.
3. Many manufacturing organizations, particularly those with JIT (Just-In-Time) programs are operating with inventories so low that they offer no protection in the event of a lengthy equipment failure. Beyond the cost of idle equipment, idle labour and lost sales that can result from a breakdown, there is a danger of permanently losing market shares to companies that are more reliable. Maintenance function can help prevent such an occurrence.
4. Good maintenance management is important for the company's cost control. As companies go in for automation to become more competitive, they increasingly rely on equipments to produce a greater percentage of their output. It becomes more important that equipments operate reliably within specifications. The cost of idle time is higher as equipment becomes more high-tech and expensive, e.g., NC/CNC machines and robots.
5. Organisations like airlines and oil refineries have huge investment in equipment. Equipment failure will be disastrous for such companies. They need proper maintenance to maintain equipment in good condition.

Objectives of Maintenance Management

The following are some of the objectives of maintenance management.

1. Minimizing the loss of productive time because of equipment failure (*i.e.*, minimizing idle time of equipment due to break down).
2. Minimizing the repair time and repair cost.
3. Minimizing the loss due to production stoppages.
4. Efficient use of maintenance personnel and equipments.
5. Prolonging the life of capital assets by minimizing the rate of wear and tear.
6. To keep all productive assets in good working condition.
7. To maximize efficiency and economy in production through optimum use of facilities.
8. To minimize accidents through regular inspection and repair of safety devices.
9. To minimize the total maintenance cost which includes the cost of repair, cost of preventive maintenance and inventory carrying costs due to spare parts inventory.
10. To improve the quality of products and to improve productivity.

FAILURECONCEPT

- Eventinwhichanypart ofanequipmentormachinedoesnot performaccordingto its operational specifications.
- Failureistheterminationoftheability ofequipmenttoperforma requiredfunction (function or combination of functions which are considered necessary for the equipment to provide a given service).
- Afterafailuretheequipmenthasafaultwhich maybecompleteorpartial.
- Failures can occur for different reasons. A cause of failure can be one, or a combination,ofthefollowing:designfailure,manufacturingfailure,installation failure, mishandling failure and/or maintenance related failure.
- Inadditiontothecause,everyfailurehasamechanism,i.e.aphysical,chemicalor other type of process which leads to the failure occurrence.
- Notethatwhilethecauseoffailureshows"why"theequipmentfails,the failure mechanism shows "how" the equipment fails to perform the required function.

Failurescanbediscussedundertwocategories viz.,GradualFailures,andSuddenFailures.

Gradual failure

Themechanismunderthiscategory isprogressive.Thatis,asthe lifeofanitemincreases, its efficiency deteriorates, causing:

- Increasedexpenditureforoperatingcosts
- Decreasedequipments"productivity
- Decreaseinthevalue oftheequipment

Example:bearings,pistons,pistonrings,„AutomobileTyres",mechanicalsystemslike machines,machinetools,flexiblemanufacturingequipmentetc.fallunderthis category.

Suddenfailure

This type of failure is applicable to those items that do not deteriorate markedly with service, but which ultimately fail after some period of using. For any particular type of equipmenttheperiodfrominstallationtofailureisnotequalbutwillfollowsomefrequency distribution which may be progressive, retrogressive, or random in nature".

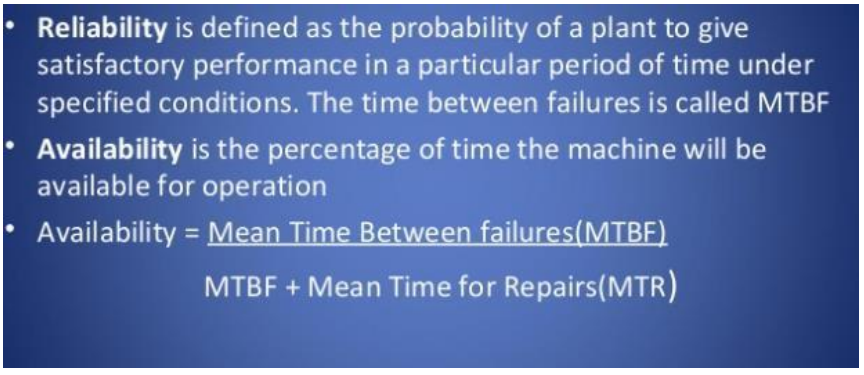
a) Progressivefailures:Inthismechanism,probabilityoffailureincreasesasthelifeof equipment increases. Examples include: electric light bulbs, automobile tubes etc.,

b) Retrogressive failures:Some equipment may prone tofailure with high probability inthe beginning of their life, and as the time progresses the probability of failure falls down. i.e., thecapabilityoftheequipmenttosurviveinthebeginningoflifeenhancesitsprobablelife. Industrial equipments with this type of distribution of life span is exemplified by aircraft engines.

c) Random failures: Under this failure, constant probability of failure is associated with the equipmentthat fails fromrandomcausessuchas physicalshocks,not relatedtoage.Insuch a case, virtually all equipments fail prior to their expected life. Example: Electronic components like transistors, semi conductor elements, glass made items, delicate or brittle items, perishable items like fruits and vegetables‟ have been shown to fail at a rate independent of the age.

RELIABILITY

- **The ability of an apparatus, machine, or system to consistently perform its intendedorrequiredfunctionormission,ondemandandwithoutdegradationor failure.**
- Themostknownconcepttodefine reliabilityis:“Probabilitythatanassetorsystem operates without failing during a given period of time under some operation conditions previously established.”
- Reliabilityandmaintenanceimprovementinitiativescandeliversubstantialfinancial as well as other benefits to a company.





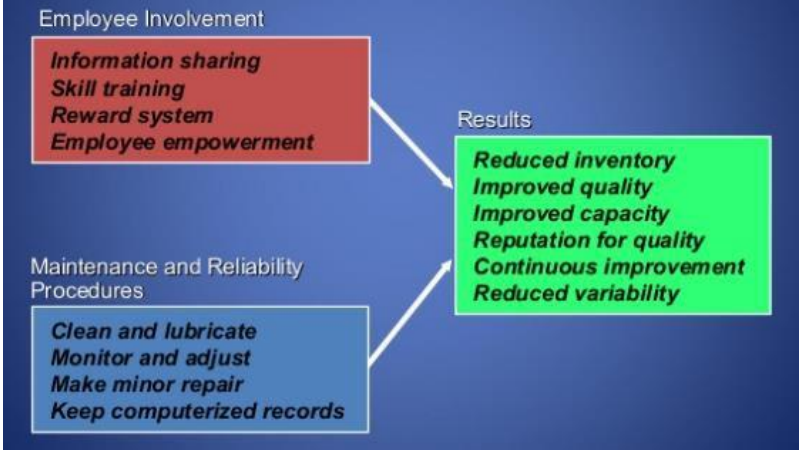
Maintenance and Reliability

- ☑ The objective of maintenance and reliability is to maintain the capability of the system while controlling costs
  - ☑ Maintenance is all activities involved in keeping a system's equipment in working order
  - ☑ Reliability is the probability that a machine will function properly for a specified time

Strategic Importance of Maintenance and Reliability

- ☑ Failure has far reaching effects on a firm's
  - ☑ Operation
  - ☑ Reputation
  - ☑ Profitability
  - ☑ Dissatisfied customers
  - ☑ Idle employees
  - ☑ Profits becoming losses
  - ☑ Reduced value of investment in plant and equipment

Maintenance Strategy



TYPESOFMAINTENANCE

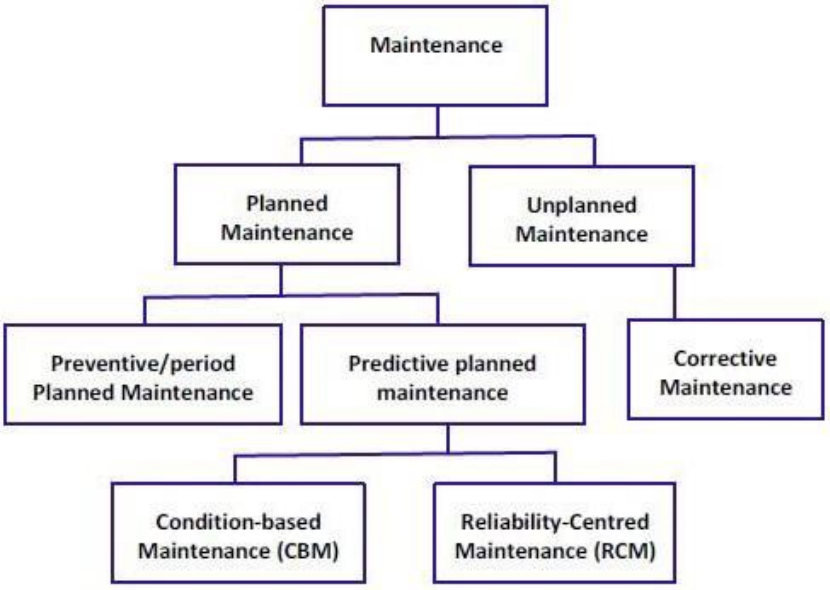


Fig2.27–MaintenanceTypes

1. **BreakDownMaintenanceorCorrectiveMaintenance**

Break Down Maintenance or Corrective Maintenance

As the name suggests, corrective maintenance occurs when there is a work stoppage because of machine breakdown. In this sense, maintenance becomes repair work. Repairs are made after the equipment is out of order – an electric motor will not start, a conveyor belt is ripped, or a shaft has broken. In cases such as these, the maintenance department checks into the difficulty and makes the necessary repairs. Role of the department is almost passive.

Break-down-Maintenance: Corrective or remedial maintenance that occurs when equipments or machines fail and must be repaired on an urgent basis.

Nevertheless, corrective maintenance seeks to achieve the following objectives :

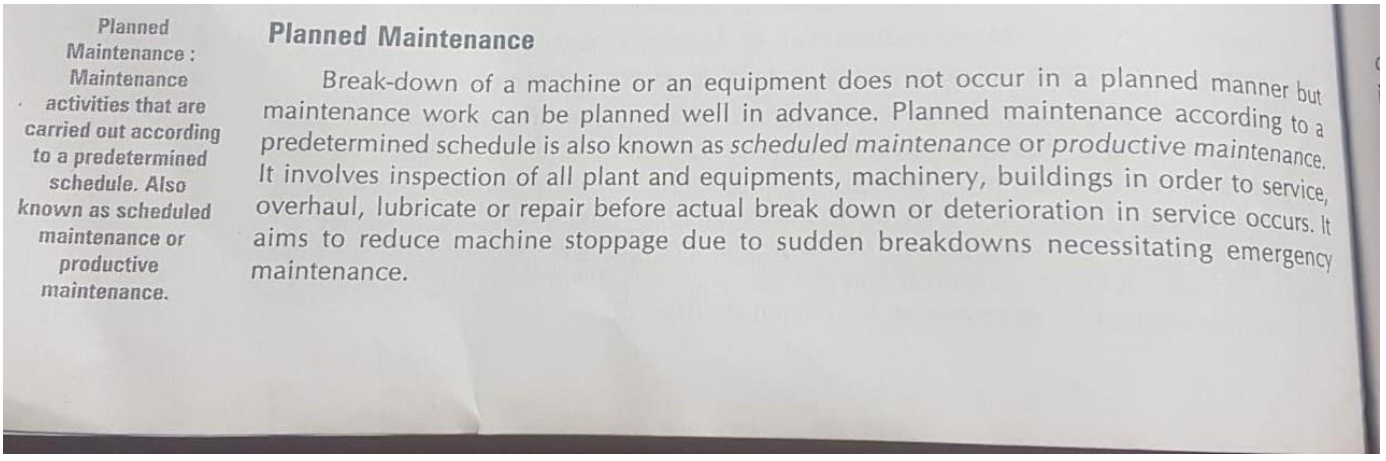
1. To get equipment back into operation as quickly as possible in order to minimise interruption to production. This objective can directly affect production capacity, production costs, product quality and customer satisfaction.
2. To control the cost of repair crews, including regular time and overtime labour costs.
3. To control the cost of the operation of repair shops.
4. To control the investment in replacement spare parts that are used when machines are repaired.
5. To control the investment in replacement spare machines which are also called standup or backup machines, These replace manufacturing machines until the needed repairs are completed.
6. To perform the appropriate amount of repairs at each malfunction. The decision about how far to go with a repair ranges from a band-aid and bubble gum fix to a complete overhaul. Some parts can be replaced early to extend the time until the next repair is required.

DrawbacksofBreakdownMaintenance:

1. Equipment'soperationalavailabilitywillbe less.
2. Componentsforrepairorreplacementmightbeunavailablesometimeswith maintenance stores.
3. Majorlossofproductivetimeofboth machinesandtheworkmen,ifthereisany delayinrestoringtheequipment'stoworkingcondition.
4. Focusisonrepairingandrestoringtheequipmenttoworkingconditionbutnot on knowing the reason for failure
5. Dangerofrecurrenceoffailures

This type of maintenance is economical for that equipment, whose breakdown time and repaircostsareless.However,thereareseverallimitationswithBreakdownmaintainedin case of high cost production systems.

2. PlannedMaintenance



Planned Maintenance

Break-down of a machine or an equipment does not occur in a planned manner but maintenance work can be planned well in advance. Planned maintenance according to a predetermined schedule is also known as *scheduled maintenance* or *productive maintenance*. It involves inspection of all plant and equipments, machinery, buildings in order to service, overhaul, lubricate or repair before actual break down or deterioration in service occurs. It aims to reduce machine stoppage due to sudden breakdowns necessitating emergency maintenance.

Planned Maintenance : Maintenance activities that are carried out according to a predetermined schedule. Also known as scheduled maintenance or productive maintenance.

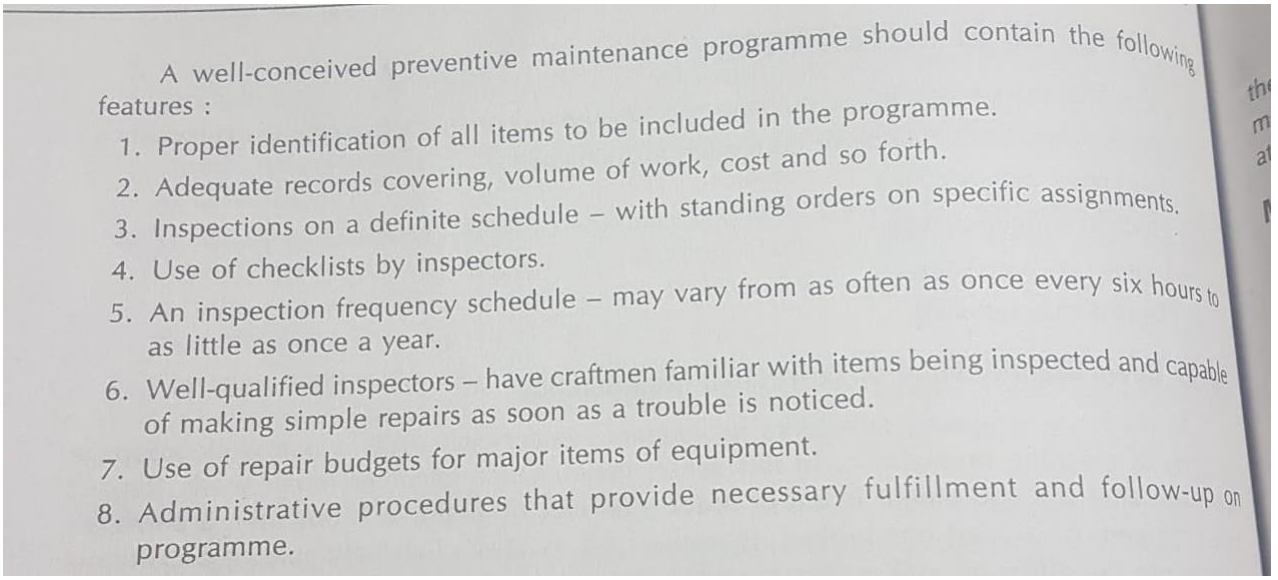
Plannedapproachto maintenance reducesthemaintenanceorequipment downtime, reducesthecostofmaintenanceandincreasesproductivityascomparedtounplanned maintenance.

3. PreventiveMaintenance

- Preventive maintenance attempts to prevent any probable failures/breakdowns resultinginproductionstoppages.ItissaidthatPreventivemaintenanceisastichin time that saves time. So it follows a slogan that "prevention is better than cure".
- Preventivemaintenancereferstomaintenanceactionperformedto keeporretaina machine/equipment or asset in a satisfactory operating condition through periodic inspections, lubrication, calibration, replacements and overhauls.
- PreventiveMaintenanceInvolves:
  (i) Periodicinspectionofequipment/machinerytouncoverconditionthat leadto productionbreakdownandharmfuldepreciation.Upkeepsofplantmachineryto correct such conditions while they are still in a minor stage.
  (ii) Thekeytoallgoodpreventivemaintenanceprogrammes,howeverisinspection.

(iii) Regularcleaning,greasingandoilingofmoving parts.
(iv) Replacementofworn outpartsbeforetheyfailto operate,
(v) Periodicoverhaulingoftheentiremachine.
(vi) Machinesorequipment'swhichareliabletosuddenfailuresshouldbeinstalled induplicatee.g.motors,pumps,transformersandcompressorsetc.

- Preventivemaintenanceissubdividedintofollowingtwocategories:
  (i) Running.
  (ii) Shutdown.
  Runningmaintenancemeansthatmaintenanceworkcarriedoutevenwhenmachine or equipment is in service, while shut down maintenance is concerned with maintenance work carried out only when the machine/equipment is not inoperation.



A well-conceived preventive maintenance programme should contain the following features :

1. Proper identification of all items to be included in the programme.
2. Adequate records covering, volume of work, cost and so forth.
3. Inspections on a definite schedule – with standing orders on specific assignments.
4. Use of checklists by inspectors.
5. An inspection frequency schedule – may vary from as often as once every six hours to as little as once a year.
6. Well-qualified inspectors – have craftmen familiar with items being inspected and capable of making simple repairs as soon as a trouble is noticed.
7. Use of repair budgets for major items of equipment.
8. Administrative procedures that provide necessary fulfillment and follow-up on programme.

AdvantagesofPreventive Maintenance:
(1) Reductioninbreakdowntimeandassociatedbreakdownelements.
(2) Reducestheoddtimerepairsandovertimetothemaintenancestaff.
(3) Fewerlargescaleandrepetitive repairs.
(4) Lessmemberofstandbyequipmentad sparepartsrequired.
(5) Greatersafetytoworkforce/employeesduetoreducedbreakdowns.
(6) Increasedlife ofequipmentandmachines.
(7) Theworkloadofthemaintenancestaffcanbe properly planned.
(8) Itimprovestheavailabilityoffacilities.
(9) Optimumproductionefficiencycanbeachievedbyemployingpreventive maintenance.
(10) Maintenanceandrepaircostreduce heavily.
(11) Itimprovesthequalityofproductandreducesrejections.
(12) ProductioncostgoesdownbyadoptingRM.
(13) Regularplannedservicingandadjustmentmaintainsandprovidesahighlevelof plant output, better equipment performance and better product quality.

(14) Healthy,hygienic,safeandanaccidentfreeworkenvironmentcanbeachieved with the application of scientific preventive maintenance. This would promote industrial relations since workers do not loose any type of incentive due to breakdowns or accidents.
(15) Reductionininventoryofspareparts.
Limitations of Preventive Maintenance:
(1) Whenthecostoffailure preventionisalwaysgreaterthancostoffailure rectification the process of P.M is very costly e.g., batch production-bridge construction.
(2) Thetypeofmaintenance requiresextrafacilitiesandleadtounder/poor utilization of basic facilities for RM.
(3) Forsmallscalemanufacturingunitswhicharemainlyundertakingjobandbatch production, the P.M system is not suited and economically justified.

4. **PredictiveMaintenance**
Predictive maintenance (PdM) is a type of condition-based maintenance that monitorstheconditionofassetsusingsensordevices.Thesesensordevicessupply datainreal-time,whichisusedtopredictwhentheassetwillrequiremaintenance and prevent equipment failure.

- Predictivemaintenanceworkflow
Thegraphicbelow outlinesthepredictivemaintenanceworkflowfromstarttofinish. The ultimate goal with predictive maintenance is to catch breakdowns before they happen by monitoring equipment conditions.

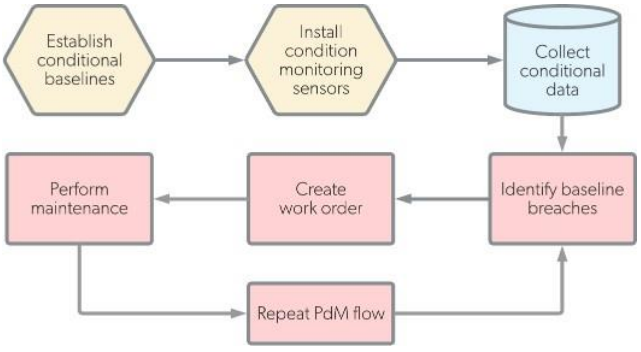


Fig2.28–Predictivemaintenanceworkflow

The goal of predictive maintenance is the ability to first predict when equipment failure couldoccur(basedoncertainfactors), followedbypreventingthefailurethroughregularly scheduled and corrective maintenance.

Predictivemaintenancecannotexistwithout conditionmonitoring,whichisdefinedasthe continuousmonitoring ofmachinesduringprocessconditionstoensurethe optimaluseof machines. There are three facets of condition monitoring: online, periodic and remote.

Online condition monitoring is defined as the continuous monitoring of machines or productionprocesses,withdatacollectedoncriticalspeedsandchangingspindle positions.

Periodicconditionmonitoring,whichisachievedthroughvibrationanalysis,“givesinsight into changing vibration behavior of installations” with a trend analysis. Lastly, remote condition monitoring, as its name suggests, allows equipment to be monitored from a remote location, with data transmitted for analysis.

Technologies

- InfraredThermography
- AcousticMonitoring
- VibrationAnalysis
- OilAnalysis
- OtherTechnologies

  Along with these techniques, facilities may use other technologies such as motor condition analysis,which details the operating andrunning conditionofmotors;and eddy current analysis, which identifies changes in tube wall thickness within centrifugal chillers and boiler systems. Borescope inspections, CMMS, data integrationandconditionmonitoringcanalsohelpfacilitatepredictivemaintenance. While there are severaldifferent technologies toaid inyourPdM efforts, it is vitalto choose the right one to ensure success.

  AdvantagesandDisadvantagesofPredictiveMaintenance

  - The advantages of predictive maintenance are tremendous from a cost-savingsperspectiveandincludeminimizingplanneddowntime,maximizing equipment lifespan, optimizing employee productivity and increasing revenue.
  - Anotheradvantageof predictivemaintenanceis its ability to transformboth amaintenanceteamandanorganization,asimplementingPdMallowsasset managers to improve outcomes and better balance priorities such as profitability and reliability.
  - Oneofthemaindisadvantagesofpredictivemaintenanceistheamountof time it takes to assess and implement a PdM schedule.
  - Withpredictivemaintenancebeingacomplexinitiative,plantpersonnelmust be trained on how to not only use the equipment but also how to interpret the analytics (or data).

  While many organizations choose to train existing employees on predictive maintenance, there are condition-monitoring contractors who specialize in performingtherequiredlaborandanalyzingtheresultsforafacility.Inadditionto

the training costs, predictive maintenance involves an investment in maintenance toolsandsystems.Thiscosthasdecreasedovertimewiththeintroductionofcloud- based technology.

REPLACEMENTPOLICIES

The replacement problems deal with deal with the situation that arise when some components (men or machinery) requires replacement because of reduced efficiency, or breakdownorcompletefailure.Suchdecreasedefficiencyorcompletefailure maybeeither gradual or all of a sudden.

Objectivesofreplacement

The primary objective of replacement is to direct the organization towards profit maximization or cost minimization. Deciding the replacement policy thatdeterminestheoptimalreplacementage ofequipment,insteadofusing with higher maintenance costs for long time, is the main objective of replacement problem. For instance, in order to replace an:

- itemwhethertowaittillitsfailureorreplacingat anearlyagewith higher cost.
- equipmentwhethertoreplacetheinefficientequipmentwitha similar type of equipment or with a modern one.

Replacementproblemsfallintothefollowingcategoriesdependinguponthelifepatternof the equipment involved.

- Replacementoftheequipmentthatwearsoutorbecomesobsoletewithtime (because of constant use or new technological developments)
- Replacementoftheequipmentthatfailscompletely.

1. IndividualReplacementPolicy:MortalityTheorem
2. GroupReplacementofitemsthatfailcompletely

- Otherreplacement problems

1. RecruitmentandPromotionProblems
2. EquipmentRenewalProblems

- Miscellaneousproblems

For items that wear out, the problem is to balance the cost of new equipment againstthecostofmaintainingtheefficiencyontheoldand/orcostdueto thelossof efficiency.Though,generalsolutionisnotpossible,modelshavebeenconstructedand solutions have been derived using simplified assumptions about the conditions of the problem.



UNIT IV
RESOURCE REQUIREMENT PLANNING



RESOURCE REQUIEMENT PLANNING

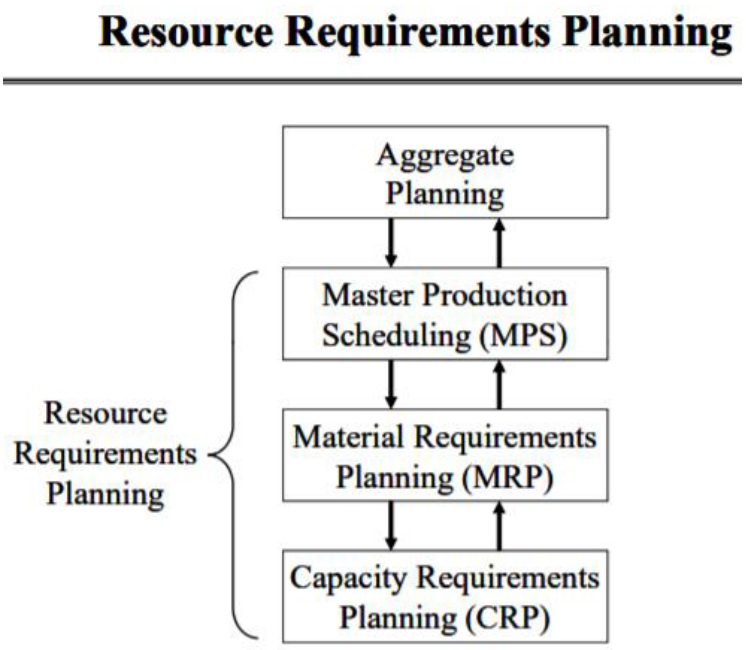


Fig 4.1 – Resource Requirement Planning

Aggregate Planning

- Aggregate production planning is concerned with the determination of production, inventory, and work force levels to meet fluctuating demand requirements over a planning horizon that ranges from six months to one year
- Aggregate planning is a planning method in the production process which is also considered a marketing activity used to determine the required resource capacity to meet expected demand.

Master Production Schedule

- Master Production Scheduling is the process that helps manufacturers plan which products and related quantities to produce during certain periods.

MPS is based on the "aggregated" plan. ***Aggregate planning*** is an input to the MPS that combines individual end items into groups or families of parts for planning purposes.

RESOURCE REQUIREMENT PLANNING

The process of converting the production plan or the master production schedule into the impact on key resources, e.g., man hours, machine hours, storage, standard cost dollars, shipping dollars and inventory levels.

- Resource requirement planning is directed at the determination of the amount and timing of production resources such as personnel, materials, cash and production capacity needed to produce the finished products or end items as per the master production schedule.
- Resource requirements planning is also known as rough-cut capacity planning.
- It can be used to evaluate the feasibility of a trial master production schedule.
- It is an aggregate planning tool that is used to sum up and evaluate the workload that a production plan (MPS) imposes either on all work centres or on only selected key work centres where resources are limited, expensive or difficult to obtain from outside sources (sub-contractors).
- This step ensures that a proposed MPS does not overload any key work centres or departments or machines thus making the MPS unworkable.
- Rough-cut capacity planning is usually applied to the critical work centres which are most likely to be bottlenecks.

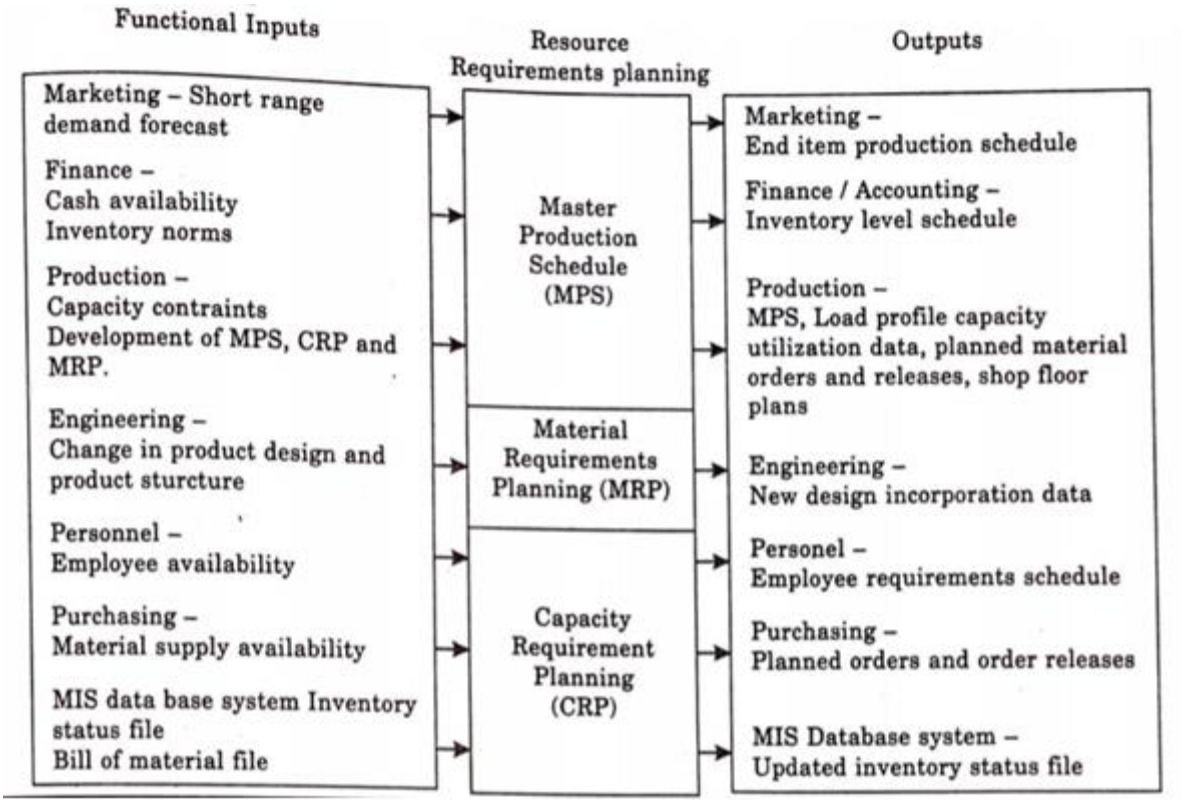


Fig 4.2 – Resource Requirements Planning System Inputs and Outputs

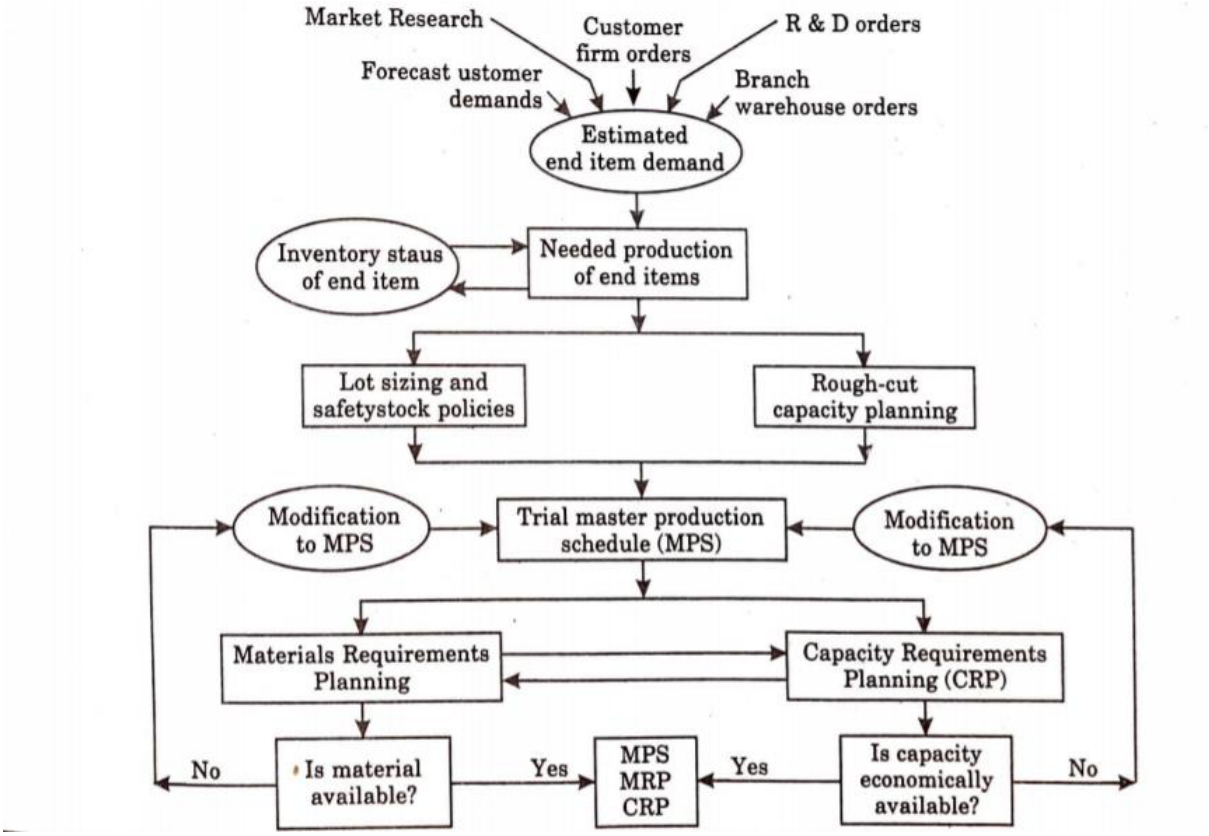


Fig 4.3 – Flow Chart of Resource Requirements Planning System or Rough-cut Capacity Planning Process

Steps involved in rough-cut capacity planning are:

1. Developing a trial production plan (or trial master production schedule) that indicates the company's products that are planned for production during each week or month of the planning horizon.
2. Computing the work load that this production plan will impose on each key work centre and key subcontractors for each period (week or month) of the planning horizon. The load profile i.e., the load on each work centre over time, is evaluated for feasibility, by comparing the load with the available capacity in each of the key work centres or key sub-contractors.
3. If the trial production plan does not appear to be feasible or does not make optimal use of the resources in the key work centres, the plan may be revised.
4. The capacity requirements of the revised production plan (revised MPS) can then be evaluated to determine the feasibility of the plan.
5. Step No. 4 and 5 are repeated until a plan considered to be satisfactory is developed.

There are two main elements of resource requirements planning systems namely
(a) Material requirements planning (MRP)
(b) Capacity requirements planning (CRP)

- **Resource Requirements Planning is a long-run planning strategy.** Resource Requirements Planning is typically a long-term approach to capacity planning and management – an early stage assessment of whether or not the company's production resources are up to the tasks prescribed by the business plan. At this stage of the planning process, the focus is primarily on labor, equipment, and other resources that require a little time to acquire.
- Resource acquisition. If Resource Requirements Planning demonstrates that the company has adequate resources to achieve the Sales & Operation Plan, no additional action is required, at least at this stage of the capacity planning process. If RRP shows that the company is under resourced, one possible response is to acquire additional facilities, capital, equipment, or workers to achieve the necessary capacity. Since the individuals involved with both Sales & Operation Planning and RRP are senior-level staff, it's assumed they have the ability to approve the necessary resource acquisitions.
- Scaling back. If capital acquisition is not a possibility, another response to a resource shortfall is to scale back the Sales & Operations Plan or Aggregate Production Plan to a level that can be achieved with current or prorated levels of resources.

MATERIAL REQUIREMENT PLANNING

"Materials Requirement Planning (MRP) is a technique for determining the quantity and timing for the acquisition of dependent demand items needed to satisfy master production schedule requirements."

- For a manufacturing company to produce end items to meet demands, the availability of sufficient production capacity must be co-ordinate with the availability of all raw materials and purchased items from which, the end items are to be produced.
- In other words, there is a need to manage the availability of dependent demand items from which the products are made.
- Dependent-demand items are the components i.e. materials or purchased items, fabricated parts or sub-assemblies that make up the end product.
- One approach to manage the availability of dependent-demand items is to keep a high stock of all the items that might be needed to produce the end items and when the on-hand stock dropped below a present re-order level, the items are produced or bought as the case may be to replenish the stock to the maximum level.
- However, this approach is costly due to the excessive inventory of components, fabricated parts and sub-assemblies to ensure high service level (i.e. availability of dependent demand items at a short notice)
- An alternative approach to managing dependent-demand items is to plan for procurement or manufacture of the specific components that will be required to produce the required quantities of end products as per the production schedule indicated by the master production schedule (MPS).

- The technique is known as material requirements planning (MRP) technique.

Objectives of MRP

1. ***Inventory reduction:*** MRP determines how many components are required when they are required in order to meet the master schedule. It helps to procure the materials/ components as and when needed and thus avoid excessive build up of inventory.
2. ***Reduction in the manufacturing and delivery lead times:*** MRP identifies materials and component quantities, timings when they are needed, availabilities and procurements and actions required to meet delivery deadlines. MRP helps to avoid delays in production and priorities production activities by putting due dates on customer job order.
3. ***Realistic delivery commitments:*** By using MRP, production can give marketing timely information about likely delivery times to prospective customers.
4. ***Increased efficiency:***
   MRP provides a close coordination among various work centers and hence help to achieve uninterrupted flow of materials through the production line. This increases the efficiency of production system.

Why is MRP important?

- MRP helps ensure that the right inventory is available for the production process exactly when it is needed and at the lowest possible cost.
- As such, MRP improves the efficiency, flexibility and profitability of manufacturing operations. It can make factory workers more productive, improve product quality and minimize material and labor costs.
- MRP also helps manufacturers respond more quickly to increased demand for their products and avoid production delays and inventory stockouts that can result in lost customers, which in turn contributes to revenue growth and stability.
- MRP is widely used by manufacturers and has undeniably been one of the key enablers in the growth and wide availability of affordable consumer goods and, consequently, has raised the standard of living in most countries.
- Without a way to automate the complex calculations and data management of MRP processes, it is unlikely that individual manufacturers could have scaled up operations as rapidly as they have in the half century since MRP software arrived.

It consists of three primary steps:

- taking inventory of the materials and components on hand,
- identifying which additional ones are needed
- and then scheduling their production or purchase.

MRP objectives

- The main theme of MRP is "getting the right materials to the right place at the right time".
- Specific organizational objectives often associated with MRP design and implementation may be identified among three main dimensions, namely: inventory, priorities and capacity:

Table 4.1: Three main dimensions of MRP design and implementation

Dimension	Objective specifics
Inventory	- Order the right part - Order the right quantity - Order at the right time
Priorities	- Order with the right due date - Keep the due date valid
Capacity	- Plan for a complete load - Plan for an accurate load - Plan for an adequate time to view future load

- Objectives of MRP should be identified with regard to inputs and outputs associated with it.
- Inputs are delineated with master production schedule, bill of materials, etc.
- Therefore, a clear specification of MRP objectives should be associated with a respectively clear description of objectives of MRP inputs as well as MRP outputs.

Benefits of MRP

The primary objective of MRP is to make sure that materials and components are available when needed in the production process and that manufacturing takes place on schedule. Additional benefits of MRP are as follows:

- Reduced customer lead times to improve customer satisfaction.
- Reduced inventory costs.
- Effective inventory management and optimization -- by acquiring or manufacturing the optimal amount and type of inventory, companies can minimize the risk of stock-outs, and their negative impact on customer satisfaction, sales and revenue, without spending more than necessary on inventory.

- Improved manufacturing efficiency by using accurate production planning and scheduling to optimize the use of labor and equipment.
- Improved labor productivity.
- More competitive product pricing.

Disadvantages of MRP

MRP has drawbacks, including the following:

- Oversupply of inventory. While MRP is designed to ensure adequate inventory levels at the required times, companies can be tempted to hold more inventory than is necessary, thereby driving up inventory costs. An MRP system anticipates shortages sooner, which can lead to overestimating inventory lot sizes and lead times, especially in the early days of deployment before users gain the experience to know the actual amounts needed.
- Lack of flexibility. MRP is also somewhat rigid and simplistic in how it accounts for lead times or details that affect the master production schedule, such as the efficiency of factory workers or issues that can delay delivery of materials.
- Data integrity requirements. MRP is highly dependent on having accurate information about key inputs, especially demand, inventory and production. If one or two inputs are inaccurate, errors can be magnified at later stages. Data integrity and data management are thus essential to effective use of MRP systems.

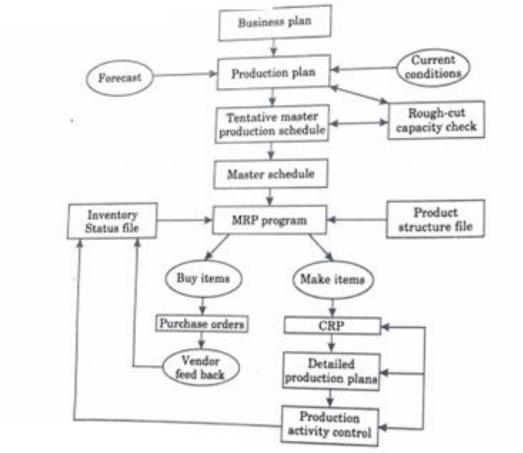


Fig 4.4 – Information flow for Planning and Controlling with MRP

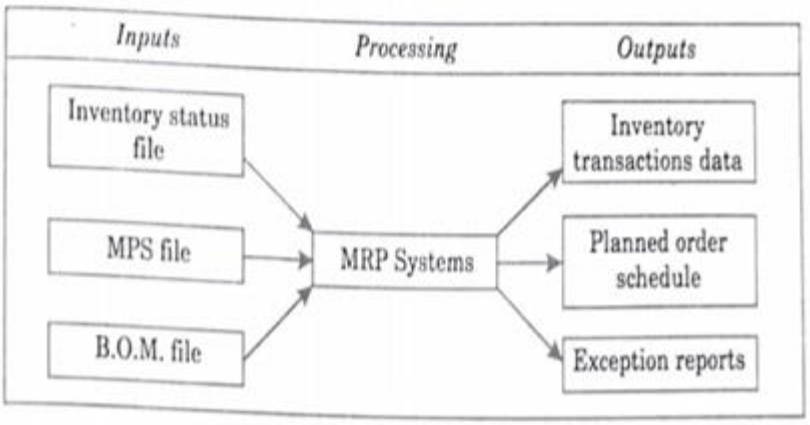


Fig 4.5 – Operation of MRP System

The entire MRP system is driven by the MPS. The bill of materials file and inventory status file are fed to the MRP computer program to generate the outputs.

How does MRP work?

- MRP uses information from the bill of materials (BOM), inventory data and the master production schedule to calculate the required materials and when they will be needed during the manufacturing process.

- The BOM is a hierarchical list of all the materials, subassemblies and other components needed to make a product, along with their quantities, each usually shown in a parent-child relationship. The finished good is the parent at the top of the hierarchy.

- The inventory items in the BOM are classified as either *independent demand* or *dependent demand*.

- An independent demand item is the finished good at the top of the hierarchy.

- Manufacturers determine its amount by considering confirmed orders and examining market conditions, past sales and other indicators to create a forecast, then decide how many to make to meet the expected demand.

- Dependent demand items, in contrast, are the raw materials and components needed to make the finished product.

- For each of these items, demand depends on how many are needed to make the next-highest component in the BOM hierarchy.

- MRP is the system most companies use to track and manage all of these dependencies and to calculate the number of items needed by the dates specified in the master production schedule.

- To put it another way, MRP is an inventory management and control system for ordering and tracking the items needed to make a product.

- Lead time -- the period from when an order is placed and the item delivered -- is another key concept in MRP.
- There are many types of lead times. Two of the most common are material lead time (the time it takes to order materials and receive them) and factory or production lead time (how long it takes to make and ship the product after all materials are in).
- Customer lead time denotes the time between the customer order and final delivery. The MRP system calculates many of these lead times, but some are chosen by the operations managers and entered manually.

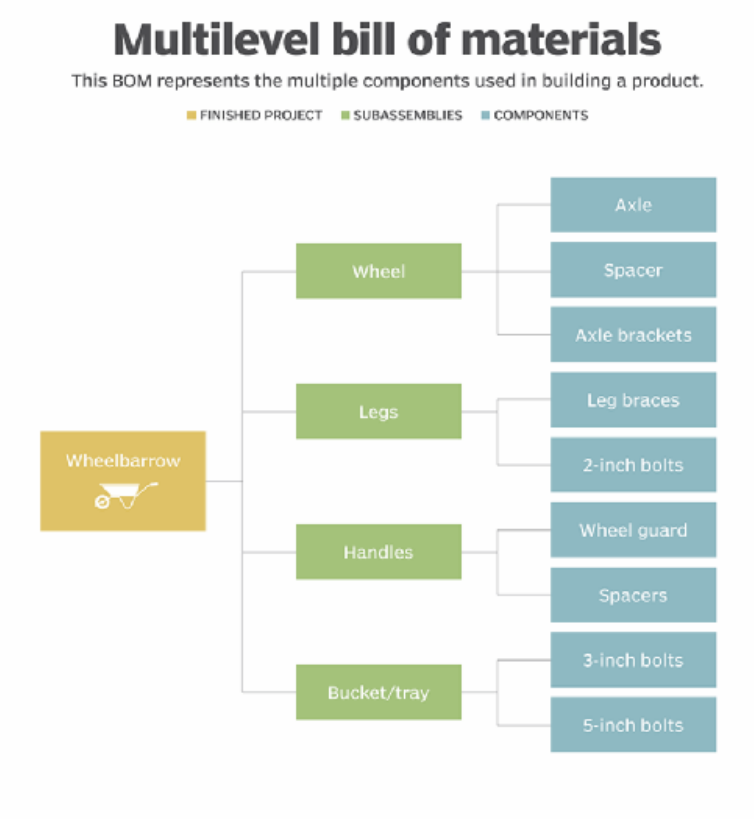


Fig 4.5 – Multilevel bill of materials

MRP Inputs and Outputs

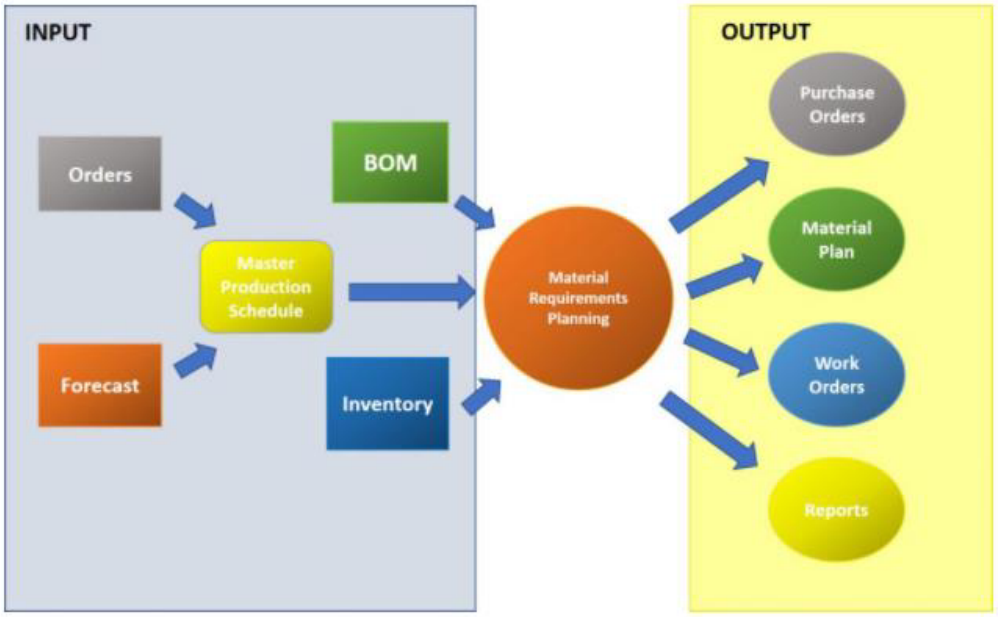


Fig 4.4 – Inputs and Outputs of MRP

MRP Inputs

There are a few key elements that you'll need to consider when creating an MRP plan. These elements include:

- Master Production Schedule (MPS): This schedule considers all outstanding work orders and plans labor, machinery usage, and workstations appropriately.
- Inventory Status File (ISF): This file includes information on all raw materials, finished goods, and work-in-progress inventory.
- The Bill of Materials (BOMs): This lists the materials, components, and sub-assemblies required to produce each product and is needed to accurately forecast supply planning.

MRP Outputs

The MRP process generates a number of outputs that can be used to improve your operations management. These outputs include:

- Purchase Orders: These orders are generated for the raw materials required to produce a product.
- Production Plans: These plans outline the steps required to produce a product.

- Inventory Reports: These reports show the quantities of each material that are available.

Definitions of Terms used in MRP System

1. **Master Production Schedule (MPS)**

Schedule of the quantity and timing of all end products to be produced over a specific planning horizon. MPS is developed from customer's firm orders or from forecasts of demand or both. It is an input to the MRP system.

2. **Product structure**

Indicates the level of components required to produce an end product.

3. **Bills of Material (BOM)**

A list indicating the quantities of all raw materials, parts, components, sub assemblies and major assemblies that go into an end product. It gives details of the build-up of a product. It may also be called as indented parts list.

4. **Bills of Material file**

A bills of material file, also known as product-structure file is a computerized file listing all finished products, the quantity of raw materials, parts, sub assemblies and assemblies in each product. The bills of material file must be kept up-to- date as and when the products are redesigned or modified with addition/deletion of some parts, components and subassemblies.

5. **Inventory status file**

It is a computerized file with a comprehensive record of each and every material held in inventory. The information included in this file are materials on hand or on order, planned orders, planned order releases, allocated materials, lot sizes, lead times, safety stock levels, costs and suppliers for each material. The inventory file must be kept up-to-date taking into consideration the daily inventory transactions such as receipts, issues, scrapped materials, planned orders and order releases.

6. MRP computer program

It is a computer program which processes the MRP information. Its inputs are the MPS, inventory status file and bills of material file. The primary outputs are : planned order schedule, planned order releases and changes to planned orders.

7. Available inventory

Materials that are held in inventory or which are on order but are not either safety stock or allocated to other uses.

$$\left.\begin{array}{r}\text{Available inventory}\\ \text{of an item at the end}\\ \text{of a time period}\end{array}\right\} = \left\{\begin{array}{l}\text{[Scheduled receipts + planned}\\ \text{order receipts – gross requirements}\\ \text{for that period] + Quantity available}\\ \text{from the previous period}\end{array}\right.$$

8. Allocated inventory

Materials that are held in inventory or on order but which have been allocated to specific production orders (committed for use) in the future. These materials are not available to meet future requirements for use on other orders.

9. On-hand inventory

The quantity of a material physically held in inventory [illegible] of time. It may include safety stock and allocated inventory except materials on order.

10. Planning horizon

The number of time periods (days, weeks or months) included in the MPS, CRP, MRP and departmental schedules.

11. Action Bucket

The unit of time measurement in MRP systems. It is a particular period of time in the planning horizon. *For example,*, Bucket # 10 means the tenth period (usually a week in duration) of the planning horizon.

12. Gross requirements

The total quantity of an item needed at the end of a period to meet the planned output levels, not considering any availability of the item in inventory or scheduled receipts.

13. Scheduled receipts

The quantity of an item that will be received at the beginning of a time period from a supplier as result of orders already placed (open orders).

14. Planned order receipts

The quantity of an item that is planned to be ordered so that it will be received at the beginning of the time period to meet the net requirements for that time period. The order is yet to be placed.

15. Planned order releases

The quantity of an item that is planned to be ordered and the planned time period for releasing this order so that the item will be received when needed. This time schedule is determined by offsetting the planned order receipts schedule to allow for lead times, *i.e.*,

$$\begin{pmatrix}\text{Planned order release}\\ \text{(time schedule)}\end{pmatrix} = \begin{pmatrix}\text{Planned order receipt}\\ \text{(time schedule)}\end{pmatrix} - \text{(lead time)}$$

When this order is released, it becomes a scheduled receipt.

16. Net requirements

The quantity of an item that must be procured to meet the scheduled output for the period.

$$\begin{pmatrix}\text{Net requirements}\\ \text{for the period}\end{pmatrix} = \begin{pmatrix}\text{Net requirements}\\ \text{for the period}\end{pmatrix} = \begin{pmatrix}\text{Gross requirements}\\ \text{for the period}\end{pmatrix} - \begin{pmatrix}\text{Material available}\\ \text{for the period}\end{pmatrix}$$

17. Low-level coding

The coding of each material at the lowest level in any product structure that it appears. A component can appear at more than one level in the product structure. Because MRP computer programs process net requirements calculations for all products level by level from end items down to the raw materials, low level coding avoids redundant net requirements calculations.

18. Lot-sizing decisions

Whenever there is a need for the net requirement of a material, a decision must be taken regarding the quantity of material to be ordered (either purchase order or production order). Lot sizing decisions include both the batch or lot size (quantity) as well as the timing of these lots.

19. Dependent Demand

Demand for a raw material, part or a component, that is dependent on the demand for the end product in which these materials are used.

20. Independent demand

Demand for a material that is independent of the demands for other materials. For example, demand for end products are independent of demand for parts, raw materials or components as their demands are determined by customers outside the organization.

21. Lumpy demand

If the demand for the materials varies greatly from time period to time period (say week to week), the demand is said to be "lumpy demand".

22. Capacity requirement planning

The process of reconciling the Master Production Schedule to the available capacities of production departments (viz., machine and labour capacities) over the planning horizon.

23. Load Schedules

A load schedule is a device for comparing the actual labour-hours and machine-hours required to produce the MPS against the available labour-hours and machine-hours in each week.

24. Net change MRP

MRP systems that generate outputs emphasizing only the changes to last MRP outputs. Planned order schedules in these systems would indicate only the changes to the previous report and not a completely new schedule.

25. Regenerative MRP

MRP systems that periodically generate one complete set of MRP outputs. In these systems, a planned order schedule would be a complete report not be comprised solely of changes to an earlier report.

26. Product Explosion

The process of determining from the product structure and planned order releases and the gross requirements for components.

27. Pegging

The process of tracing through the MRP records and all levels in the product structure to identify how changes in the records of one component will affect the records of other components. Pegging shows the level-by-level linkages among components and their time-phased status in the MRP records.

28. Cycle counting

Counting on-hand inventories at regular intervals to verify inventory quantities shown in the MRP.

29. Time fence

A designated length of time that must pass without changing the MPS, to stabilize the MRP system.

30. Lot-for-lot ordering

A lot sizing policy in which order quantity equals net requirement for the period.

31. **Period-order quantity (POQ) method**

Also known as part-period method, it is a lot-sizing policy in which order quantity varies according to a comparison of holding versus ordering costs.

$$\text{P.O.Q.} = \frac{\text{No. of weeks per year}}{\text{No. of orders per year (N)}} = \frac{52}{\text{N}} \text{ weeks}$$

$$\text{No. of orders per year (N)} = \frac{\text{Annual Demand (units)}}{\text{Economic Order Quantity}}$$

$$\text{Order quantity} = \text{Net requirements of periods equal to POQ}$$

32. **Frozen MPS**

The early time periods of the MPS that can be assumed to not to be subject to change. Frozen periods of MPS enables managers to commit funds, order materials as such plans will not need to be subsequently changed.

MRP in manufacturing

- MRP is essential to the efficiency, effectiveness and ultimately the profitability of a manufacturing operation.

- Without the right raw materials and components on hand, manufacturers can't hope to keep up with the demand for products at the optimal cost and quality.

- They will also be less able to respond to fluctuations in demand by adjusting production.

- MRP can also make the later stages of production, such as assembly and packaging, proceed more smoothly and predictably by removing most of the uncertainty over inventory and minimizing the time needed to manage it.

- MRP is useful in both discrete manufacturing, in which the final products are distinct items that can be counted -- such as bolts, subassemblies or automobiles -- and process manufacturing, which results in bulk products, including chemicals, soft drinks and detergent, that can't be separately counted or broken down into their constituent parts.

MRP COMPUTATIONAL PROCEDURE

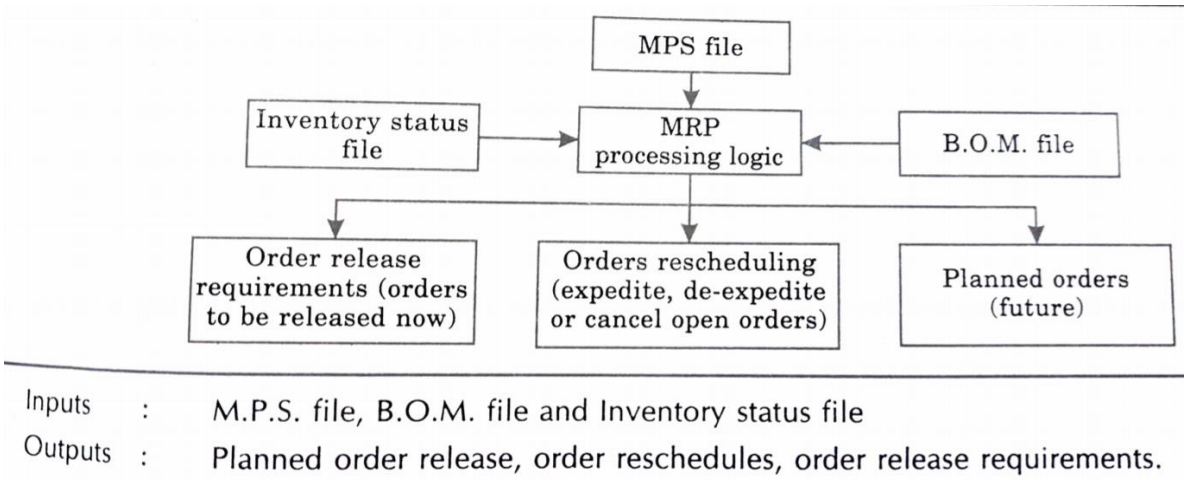


Fig 4.5 –MRP System

MRP Inputs

1. The master production schedule is the key input which drives the MRP program. The MPS tells the program what the company intends to produce. As an illustration, let us consider a portion of the MPS for XYZ company which is given below in *Table 13.1*.

Table 13.1

End item	Week Number											
	1	2	3	4	5	6	7	8	9	10	11	12
001-3 drawer filing cabinet							200			200		200
002-4 drawer filing cabinet				120			120	240		120		
003-Desk						300			300		180	

The three major MRP inputs are:
(i) Master production schedule file
(ii) Bill of materials file
(iii) Inventory status file.

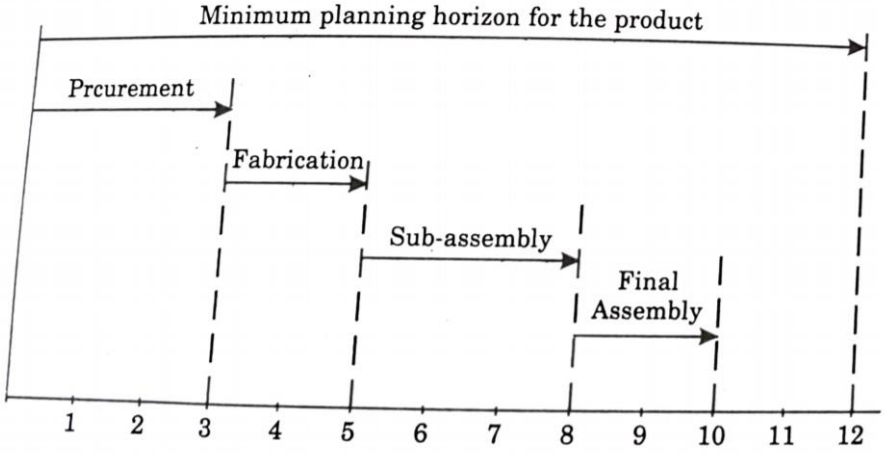
The above figure shows the Master Production Schedule of XYZ company manufacturing office equipments and furnitures. The MPS is prepared for one quarter (12 weeks period). The time bucket in the planning horizon is one week. The quantities indicated in the MPS may include both plans to produce end items that have been ordered by customers (customer's firm orders) and plans to produce end items for forecast sales.

The minimum planning horizon for each product must usually be greater than the cumulative time required for procurement of raw materials and components and for performance of all other production operations such as fabrication, subassembly and final assembly as illustrated in *Exhibit 13.6*.

This minimum planning horizon (*i.e.*, time period) may be considered as a 'time fence' within which changes to the MPS are not permitted except in extreme situations (e.g., a customer's order is cancelled)

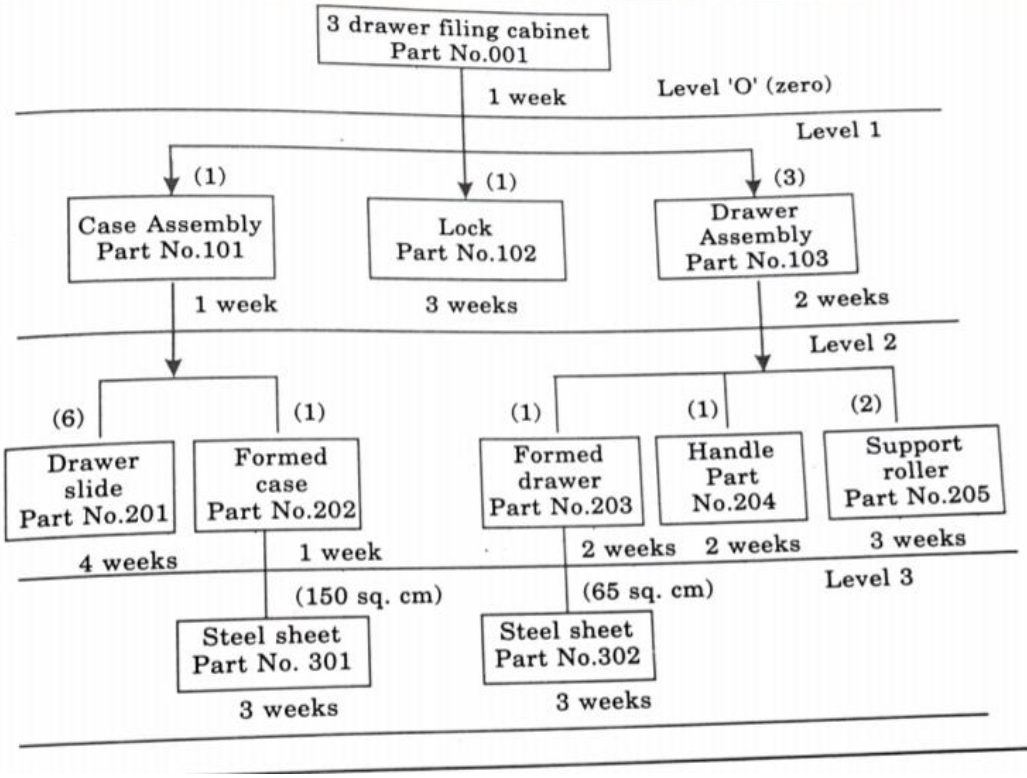
The maximum length of time that is planned in a MPS will depend on the company's ability to forecast demand and its requirements, but a one-year span is usually common.

Exhibit 13.6



2. Bill of Materials file : The MRP program obtains information about the components needed to make an end product from the bill-of-materials file, which is also known as product-structure file. A bill of material not only lists all the required parts but also is structured to reflect the sequence of steps required to produce the end product. The B.O.M. has a series of levels, each of which represents a stage in the manufacture of the end product.

Exhibit 13.7 : Product Structure Tree for 3 Drawer Filing Cabinet



The highest level or zero-level of the B.O.M. represents the final assembly or end product. The next lower level might represent the sub assemblies that are combined to make the final assembly. The next lower level might represent the parts needed to make the sub assemblies and the bottom most level might represent the raw materials from which the parts are made.

Each component at any level of the B.O.M. is identified by a unique part number. Determining all the lower-level components needed to make a parent item is called 'exploding' the requirements of the bill-of-materials. A 'where-used list' indicates the next assembly in which a component or part is used and can be used to determine what products cannot be made if some components are not available on time.

Exhibit 13.7 (see p.285) shows the product-structure tree for 3 drawer filing cabinet manufactured by XYZ company :

The bill-of-material for the three-drawer cabinet would contain the following items are listed in *Table 13.2*.

A drawer assembly consists of a formed drawer, one handle, and two support rollers. The formed case and formed drawer are made of steel sheet. The cabinet case assembly contains one case assembly and three drawer assemblies. The cabinet case assembly consists of a formed case and six slides and one lock.

3. Inventory Status file : This file contains important information such as what items should be ordered, and when orders should be released. The inventory status file keeps data about the

projected use and receipts of each item and determines the amount of inventory that will be available in each time bucket. If the projected available inventory is not sufficient to meet the requirement in a period, the MRP program will recommend that the item be ordered.

Table 13.2 :

Part No.	Quantity	Description
001	1 no.	3 drawer filing cabinet
101	1 no.	Case assembly
102	1 no.	Lock
103	3 nos.	Drawer assembly
101	1	Case assembly
201	6	Drawer slides
202	1	Formed case
103	1	Drawer assembly
203	1	Formed drawer
204	1	Handle
205	2	Support rollers
202	1	Formed case
301	150 sq.cm.	Steel sheet
203	1	Formed drawer
302	65 sq.cm.	Steel sheet

Exhibit 13.8 shows the 3 drawer filing cabinet.

Exhibit 13.8 shows the 3 drawer filing cabinet.

Exhibit 13.8 : Three Drawer Filing Cabinet

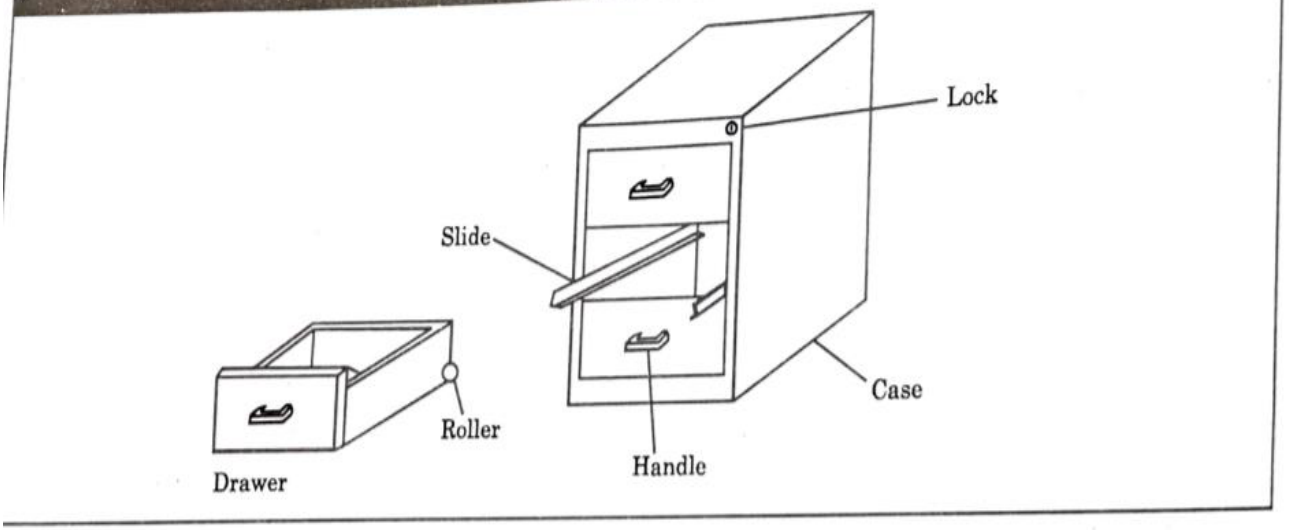


Table 13.3 shows the inventory record for the drawer assembly for filing cabinets.

4. Gross Requirements : The gross requirements shown in Table 13.3 project the use of the item viz., drawer assembly (part no.103) in the end product viz., 3-drawer filing cabinet (part no.001). In this example, the company needs 600 drawers in week No. 6 to make the 200 nos of 3 drawer filing cabinets that are to be started in week no.6 so that they will be completed by week no.7 as specified in MPS (Ref. Table 13.1). An additional 600 drawers are

to be started into assembly in week no.9 to meet the requirement of 200 nos of 3 drawer filing cabinet in the week no.10 *(Ref. Table 13.1)*.

Table 13.3 : Inventory Record for the Drawer Assembly for Filing Cabinets

Item 103 Lead time = 2 weeks. Drawer Assembly	Week												
	1	2	3	4	5	6	7	8	9	10	11	12	
Gross requirements						600			600		600		
Scheduled receipts		800											
On hand	40	40	840	840	840	840	240	240	240	–360	–360	–960	
Net requirements									360		600		
Planned order release							360		600				

5. Scheduled Receipts : The numbers in the scheduled receipts row indicate when the previously released orders (*i.e.*, open orders) if any are scheduled to be received and available for use. In the example, an order for 800 nos of drawers is scheduled to be completed in week no.2.

6. On Hand inventory : The numbers in the 'on hand' row indicate the number of units projected to be available at the end of each time period (*i.e.*, week). The quantity of 40 nos indicates the beginning inventory in the beginning of week no.1. The numbers in other blocks of the 'on hand' row represent the quantity scheduled to be on hand at the end of each period (*i.e.*, week).

$$\begin{pmatrix}\text{'On hand' inventory}\\ \text{for period 'n'}\end{pmatrix} = \begin{pmatrix}\text{'On hand' for}\\ \text{the period 'n – 1'}\end{pmatrix} + \begin{pmatrix}\text{Scheduled receipts}\\ \text{for the period 'n'}\end{pmatrix} - \begin{pmatrix}\text{Gross requirements}\\ \text{for the period n}\end{pmatrix}$$

7. Net requirements : The amount of net requirements in any period can be calculated by subtracting from the gross requirements for that period, any scheduled receipts for that period and any positive quantity 'on-hand' for the previous period.

$$\begin{pmatrix}\text{Net requirement}\\ \text{for the period 'n'}\end{pmatrix} = \begin{pmatrix}\text{Gross}\\ \text{requirements}\\ \text{for period 'n'}\end{pmatrix} - \begin{pmatrix}\text{Scheduled}\\ \text{receipts}\\ \text{for period 'n'}\end{pmatrix} - \begin{pmatrix}\text{On hand inventory}\\ \text{at the end of}\\ \text{period 'n – 1'}\end{pmatrix}$$

For e.g., $\begin{pmatrix}\text{Net requirement}\\ \text{for } 9^{th} \text{ week}\end{pmatrix}$ = (600 – NIL – 240) = 360 numbers

8. Planned order releases : Numbers in 'planned order releases' row indicate when orders should be placed to meet the requirement for the item. The time period at which the order should be released is found by subtracting the lead time from the 'net requirement' period (this procedure is called 'offsetting' by lead time)

9. Lot-for-lot ordering : In this method, one order is planned for each period in which there is a net requirement. The planned order release will be for the quantity which is indicated in the 'net requirement' row for that period. In this example, the lead time to produce a drawer assembly is 2 weeks. Hence the net requirement of 360 drawers for the week no. 9 should be planned for order release in week no.7 and the net requirement of 600 drawer assemblies in week no. 11 should be planned for order release in week no. 9.

MANUFACTURING RESOURCE PLANNING (MRP II)

Manufacturing Resource Planning (MRP II) is an integrated information system used by businesses. Manufacturing Resource Planning (MRP II) evolved from early Materials Requirement Planning (MRP) systems by including the integration of additional data, such as employee and financial needs.

The system is designed to centralize, integrate, and process information for effective decision making in scheduling, design engineering, inventory management, and cost control in manufacturing.

Manufacturing resource planning is a system that is used to effectively plan the use of a manufacturer's resources. It enables manufacturers to develop a precise production schedule for the future that minimizes costs and maximizes the use of the resources available at their disposal.

Sales forecasting helps a manufacturer estimate the expected demand for a product so that they can source the proper amount of raw materials and schedule deliveries and quantities on time. It also provides a target production level to determine the number of machine units and labor required during a given production cycle.

Manufacturing resource planning arrives at the optimal order quantity and frequency for raw materials by adding the average use for a planned replenishment lead time with the safety stock that is required to protect against stock-outs.

Thus, **"When to Order" = Average Use Time + Safety Stock**

The term manufacturing resource planning refers to an information system that is used by businesses involved in manufacturing goods. The integrated information system facilitates the decision-making process for management by centralizing, integrating, and processing information related to the manufacturing process.

It enables management to make an accurate visualization of the scheduling and inventory process and design engineering and to effectively employ cost-control measures.

The MRP II was developed in 1980 after a need for a software that integrates accounting systems while making forecasts about inventory requirements. The earlier version, MRP I, was developed in 1964, and the first company to use it was Black and Decker.

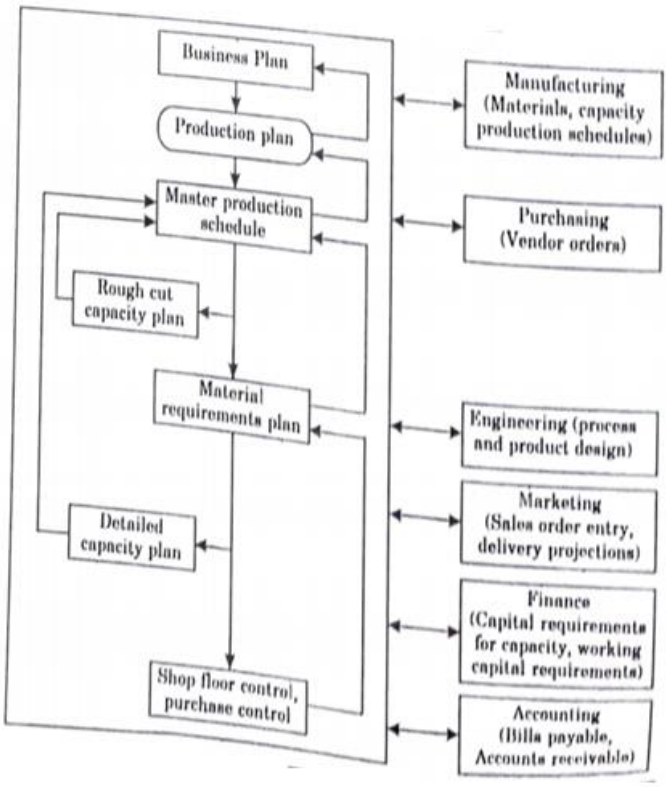
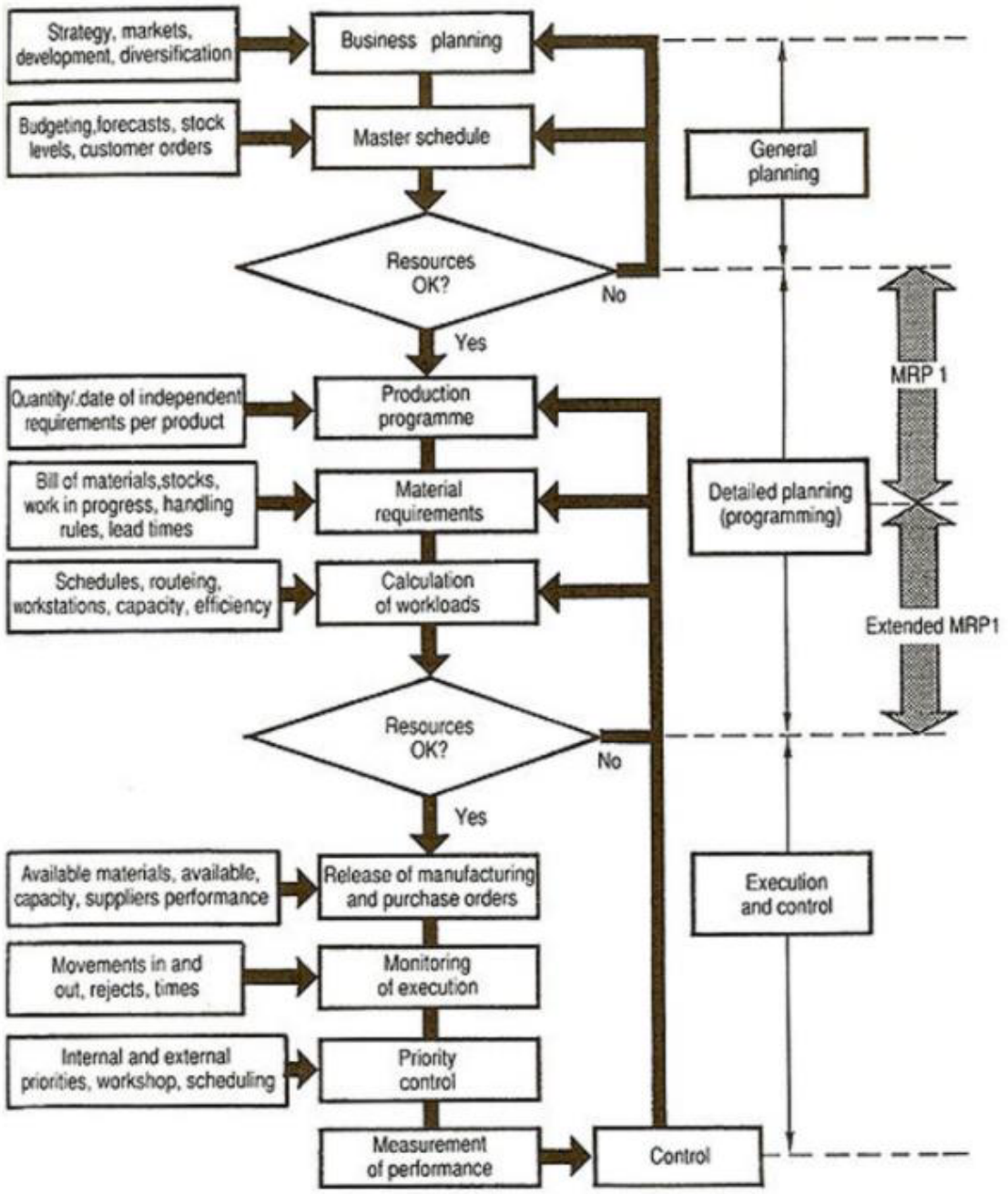


Fig 4.6 – MRP II – An Integrated System pf Planning and Control

Manufacturing Resource Planning (or MRP2) - Around 1980, over-frequent changes in sales forecasts, entailing continual readjustments in production, as well as the unsuitability of the parameters fixed by the system, led MRP (Material Requirement Planning) to evolve into a new concept .



Benefits

MRP II systems can provide:

- Better control of inventories
- Improved scheduling
- Productive relationships with suppliers

For design / engineering:

- Improved design control

- Better quality and quality control

For financial and costing:

- Reduced working capital for inventory
- Improved cash flow through quicker deliveries
- Accurate inventory records

MRP I included the following three major functionalities:

- master production scheduling
- bill of materials
- inventory tracking

MRP II includes those three, plus the following:

- machine capacity scheduling
- demand forecasting
- quality assurance
- general accounting

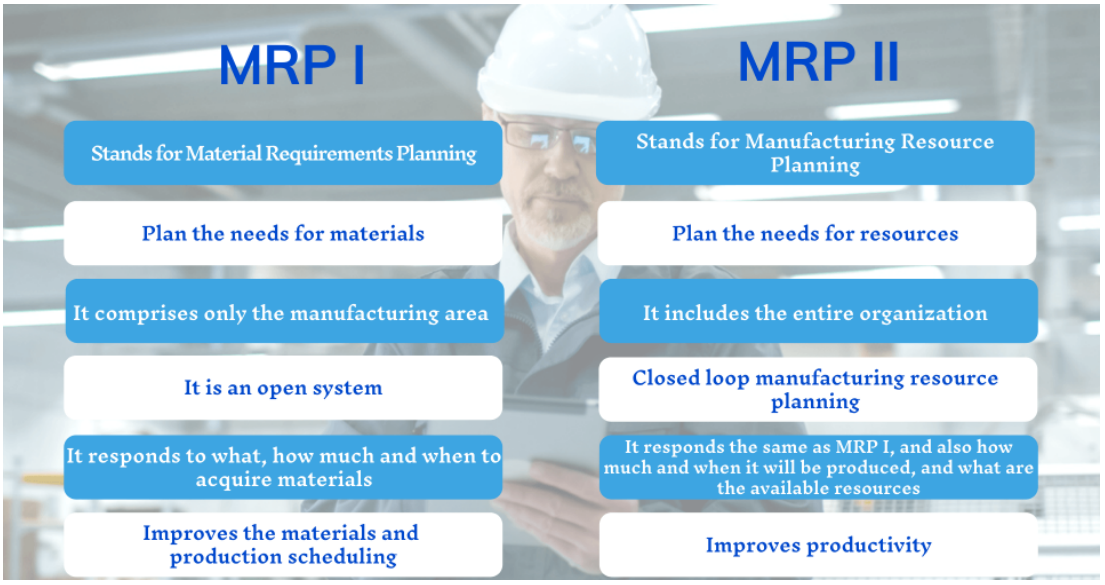


Fig 4.7 – MRP I vs MRP II

ENTERPRISE RESOURCE PLANNING (ERP)

In today's rapidly evolving business landscape, efficient operations management is crucial for organizations to maintain a competitive edge. Enter Enterprise Resource Planning (ERP) is a powerful technology that has revolutionized how companies handle their operational processes. ERP in operations management refers to integrating various business functions, such as manufacturing, supply chain, finance, and human resources, into a unified digital ecosystem.

This integration enables seamless communication, data sharing, and streamlined workflows, enhancing productivity, better decision-making, and improved overall efficiency. In this blog, we will delve into the pivotal role of ERP in optimizing operations management strategies and propelling businesses toward sustained success.

ERP in Operations Management is an all-encompassing software solution to refine and maximize diverse organizational and operational procedures. By amalgamating various departments and functionalities into a cohesive framework – including manufacturing, supply chain, human resources, and finance – it facilitates seamless data exchange, heightened communication, and more informed decision-making.

The outcome of this integration is heightened effectiveness, diminished expenditures, and elevated overall output. Now, let's delve into a comprehensive examination of the primary attributes.

1. **Centralized Database**

A centralized database in ERP acts as a single repository for all organizational data. This means that information from various departments, such as sales, inventory, finance, and HR, is stored in one location. This centralization eliminates data duplication and ensures data consistency. For instance, when a customer's contact information is updated in the CRM module, the same updated data is instantly reflected across all relevant modules, preventing discrepancies and confusion.

2. **Integration**

Integration within ERP goes beyond mere data sharing; it orchestrates processes across departments. When an order is placed, the ERP system initiates a sequence of events: it checks inventory levels, triggers procurement if needed, schedules production, and updates financial records. This end-to-end integration not only accelerates processes but also reduces errors that might occur when disparate systems communicate separately.

3. **Real-time Reporting and Analytics**

ERP's reporting and analytics capabilities empower users with data-driven insights. Managers can generate real-time reports, charts, and graphs that provide a holistic view of business operations. For example, production managers can track production line efficiency in real time, identifying bottlenecks and optimizing workflows promptly. These insights enable quicker and more informed decision-making at all levels of the organization.

4. **Supply Chain Management**

In the supply chain management module of ERP, various processes are streamlined for optimal efficiency. Demand forecasting relies on historical data, market trends, and current orders, ensuring that inventory levels are maintained at just the right quantities to fulfill orders without excess stockpiles. If stock levels drop below a set threshold, the system automatically generates purchase orders, maintaining a seamless supply chain.

5. **Financial Management**

ERP's financial management module handles intricate financial tasks. It automates processes such as invoicing, accounts payable, and receivable, minimizing human error and ensuring accurate financial records. Additionally, the module keeps track of tax regulations and accounting standards, ensuring compliance and reducing the risk of financial discrepancies or legal issues.

6. **Human Resource Management**

ERP's HR module encompasses the entire employee lifecycle. It manages recruitment, employee onboarding, training, performance evaluations, and payroll. This detailed tracking ensures that each employee's journey is well-documented and aligns with organizational goals. For instance, performance evaluations can be linked to skill development programs, promoting a skilled and motivated workforce.

7. **Customer Relationship Management (CRM)**

The CRM functionality in ERP focuses on nurturing and enhancing customer relationships. It tracks customer interactions, including inquiries, purchases, and service requests. This information aids sales teams in understanding customer preferences and behavior, enabling targeted marketing campaigns and personalized customer interactions. The system also helps customer service teams resolve issues efficiently by providing a comprehensive view of customer history.

8. **Mobile and Remote Access**

ERP's mobile and remote access feature extends its functionality beyond the office walls. Authorized users can access the ERP system from their mobile devices or remote locations. For instance, a sales representative visiting a client can use their tablet to check inventory levels, place orders, and update customer information in real time. This ensures that critical decisions and actions can be taken even when not in the office.

In summary, ERP features work cohesively to create an integrated, efficient, and data-driven environment for organizations. By utilizing a centralized database, fostering integration, providing real-time insights, optimizing supply chains, managing finances, enhancing HR processes, nurturing customer relationships, and enabling mobile access, ERP systems empower businesses to operate smoothly and competitively in today's fast-paced business landscape.

Role of Erp in Inventory Management

Enterprise Resource Planning (ERP) systems are crucial in efficient business inventory management. By providing an integrated and centralized platform, ERP systems enable organizations to optimize inventory processes, enhance visibility, and streamline operations. Through real-time data synchronization and automation, ERP systems contribute to minimizing stock levels, reducing carrying costs, and improving overall supply chain management. Let us explore the role of ERP in inventory management in detail :

1. **Real-time Visibility**

ERP systems provide a comprehensive view of inventory levels, spanning various locations and departments. This real-time visibility helps businesses track inventory movement, assess stock availability, and anticipate potential shortages or excesses. With accurate and up-to-date information, organizations can make informed decisions to optimize inventory levels and meet customer demands efficiently.

2. **Demand Forecasting**

ERP systems leverage historical sales data, market trends, and other relevant factors to predict future demand. By analyzing patterns and seasonality, businesses can create more accurate demand forecasts. These forecasts assist in planning production schedules, optimizing inventory levels, and avoiding costly stock outs or overstock situations.

3. **Inventory Optimization**

ERP systems utilize sophisticated algorithms to balance supply and demand, considering factors such as lead times, order quantities, and reorder points.

This optimization minimizes carrying costs while ensuring that the right amount of stock is available to meet customer demands. This approach prevents excess inventory and reduces the risk of stockouts.

4. **Automated Reordering**

ERP systems automate the reordering process by setting predefined stock thresholds. When inventory levels drop below a certain point, the system automatically generates purchase orders or production orders, streamlining the replenishment process. This automation reduces manual errors and eliminates the need for constant monitoring.

5. **Supplier Collaboration**

ERP systems facilitate efficient communication between businesses and suppliers. Electronic data interchange (EDI) capabilities and online portals enable seamless order placement, order confirmation, and delivery tracking. This collaboration ensures timely replenishment, reduces lead times, and enhances overall supply chain efficiency.

6. **Batch and Serial Tracking**

ERP systems enable tracking of items by batch or serial numbers throughout the supply chain. This capability is essential in industries with strict regulations, such as pharmaceuticals and electronics. It aids in managing recalls, tracing the origin of defective products, and ensuring compliance with quality standards.

7. **Multi-location Management**

ERP systems are equipped to manage inventory across multiple warehouses, stores, or distribution centers. They provide centralized control over stock levels, allowing businesses to allocate inventory efficiently based on demand patterns, location preferences, and supply constraints. This approach minimizes excess stock and optimizes resource utilization.

8. **Data Analytics**

ERP systems gather and analyze inventory-related data, offering valuable insights into inventory turnover rates, slow-moving items, and stock movement patterns. This data helps organizations identify opportunities to optimize their inventory management strategies, make informed decisions, and implement continuous improvement measures.

By addressing these roles comprehensively, ERP systems play a pivotal role in modernizing and enhancing inventory management practices, leading to cost savings, improved customer satisfaction, and streamlined operations.

Examples of Erp in Inventory Management

Enterprise Resource Planning (ERP) systems play a pivotal role in optimizing inventory management by streamlining processes, enhancing visibility, and ensuring efficient resource allocation. These systems integrate various departments, data, and functions into a centralized platform, enabling businesses to manage their inventory effectively.

Here are some of the prominent examples of ERP in inventory management:

1. **SAP ERP**

SAP's ERP software offers comprehensive inventory management tools that enable businesses to monitor stock levels, track movements, and optimize reorder points. It provides real-time insights into inventory positions across multiple locations, helping to reduce stockouts and overstocking.

2. **Oracle NetSuite**

Oracle NetSuite's ERP solution incorporates advanced inventory management capabilities. It allows businesses to manage multiple warehouses, track inventory levels in real time, and automate reorder processes. The system also offers demand forecasting and order fulfillment features.

3. **Microsoft Dynamics 365**

This ERP system provides a robust inventory management module that offers visibility into stock levels, automates replenishment processes, and optimizes stock movement. It integrates seamlessly with other Microsoft tools, enhancing overall business operations.

4. **Infor CloudSuite**

Infor's ERP solution includes powerful inventory management features that support multi-site inventory control, demand forecasting, and vendor management. Its advanced analytics capabilities enable data-driven decision-making for better inventory management strategies.

5. **Epicor ERP**

Epicor's ERP system offers inventory optimization tools that aid in managing stock levels, reducing carrying costs, and improving demand forecasting accuracy. It also facilitates efficient tracking of inventory movements throughout the supply chain.

6. **Acumatica Cloud ERP**

Acumatica's ERP solution empowers businesses with real-time insights into inventory positions, helping to minimize stockouts and streamline order fulfillment. It enables businesses to manage multiple warehouses, track lot and serial numbers, and automate inventory replenishment processes.

These ERP systems go beyond basic inventory tracking and management, offering advanced features like demand forecasting, integration with other business processes, and analytics-driven decision support. By employing these systems, enterprises can attain increased authority over their inventory, lower expenses, and improve the overall effectiveness of their supply chain.

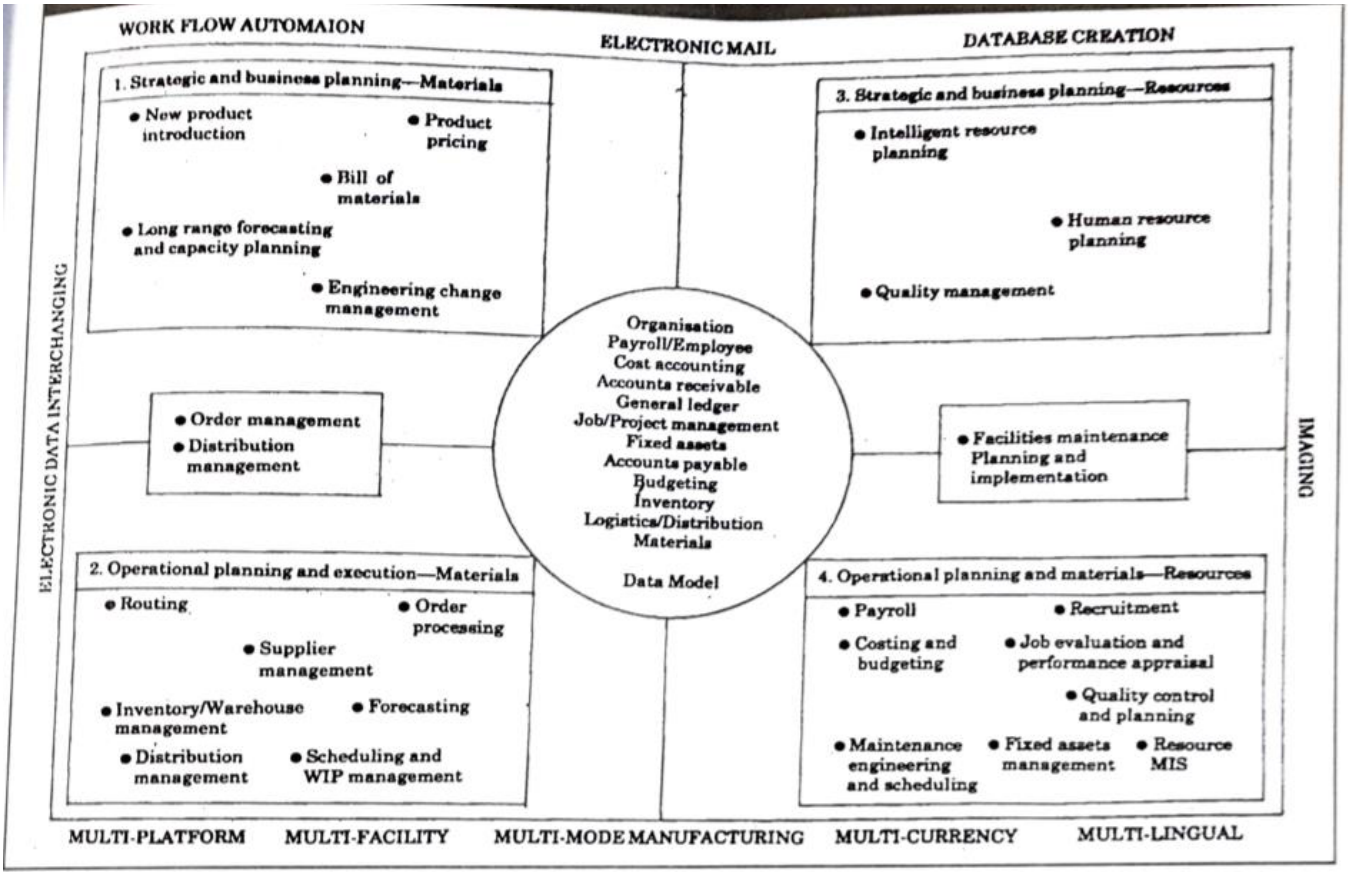


Fig 4.8 – General Model of ERP

Scope of ERP

- Enterprise Resource Planning (ERP) is a modular and robust system designed for small-sized, mid-sized & large-sized enterprises.
- It supports inventory, purchasing, supply chain, sales and material management, quality, research and finance, human resource, production and service functions.

- ERP software indeed covers the complete business operating functional range.
- Manufacturing: It means manufacturing and production process such as such as scheduling, planning and tracking supplies, parts and products before, throughout the production and after the manufacturing procedure.
- **Managing:** It means the entire management of the organization such as purchasing, HR, financials, IT, quality and other things the organization do. The information should be conveyed at the right time in a correct form to facilitate the suggested correct decision-making by directors, managers, and executives of the enterprise.
- **Selling & Delivery:** This segment manages the entire process from marketing, quoting, estimating, engaging and ordering products and services. It ensures to timely deliveries of good supplies and a profitable sale of products.
- **Servicing to customers:** Offering satisfied and proper customer services is significant to future relations and sales of the enterprises. To get a complete feedback for your customers, knowing your product and how it is fulfilling the needs of the customers in the market means expanding the life span of your relationships with your customer.
- It helps the company to control the day-to-day activities, makes easier the processes and provides better coordination amongst all the segments of the organization. Although all the modules are the essential to the existence of an ERP but manufacturing module is the main and important module. It provides various benefits to the businesses.

Applications of ERP

Below is a list of the significant areas where an ERP is vastly in use:

•Manufacturing and Production

Manufacturing Process, Cost Management, Scheduling, Engineering, Bills of Material, Capacity, Work flow Management, Quality Control, Manufacturing Projects etc.

•Supply Chain Management

Purchasing, Supply Chain Planning, Order Entry, Product Configuration, Inventory, Supplier Scheduling, Inspection of goods, Commission Calculation and many more.

•Financials

Cash Management, General Ledger, Accounts Receivable & Payable, Fixed Assets and many more.

•Projects

Costing, Billing, Time and Expense, Activity Management

•Human Resources (HR) management

Payroll, Training, Human Resources,Attendance & Time, other Benefits etc.

•CRM management (Customer Relationship Management)

Service, Sales and Marketing, Customer Contact, Commissions, and Call Center support etc.

•Data Warehouse management

Several Self-Service interfaces for Suppliers, Employees and Customers etc.

Thus, ERP software in the modern time fulfills all the business requirements of all sized Free Articles, typed business organizations.



Fig 4.9 – ERP FUNCTION

Benefits of ERP

ERP brings together, people who work on shared tasks within the same enterprise or in their dealings with suppliers and customers and ensures the smooth flow of information at all levels and accessibility to up-to-date information.

Some of the tangible benefits ERP are:

(a) Reduction of lead time by 60 per cent.
(b) 99 per cent on-time shipments.
(c) Doubled business.
(d) Increase of inventory turnover to over 30 per cent.
(e) Reduction of cycle time to 80 per cent.
(f) Reduction of work-in-process inventory to 70 per cent.

Some of the intangible benefits are:

(a) Better customer satisfaction. (b) Improved vendor performance.
(c) Reduced quality costs. (d) Improved resource utilisation.
(e) Improved information accuracy. (f) Improved decision-making capability.

Disadvantages of ERP

- Increase complexity
- Add short-term costs
- More time-consuming

UNIT V

STORES MANAGEMENT AND MATERIAL HANDLING

STORES MANAGEMENT

After inspection, the purchased materials are taken to preservation if they are meant for stock. Non-stock items are directly taken to the assembly lines for inspection. Preservation or storage is another aspect of materials management. With proper management and co-ordination (particularly with purchasing, receiving and inspection), storage can contribute to effective operations.

STORE

- Store is an important component of material management since it is a place that keeps the materials in a way by which the materials are well accounted for, are maintained safe, and are available at the time of requirement.
- Storage is an essential and most vital part of the economic cycle and store management is a specialized function, which can contribute significantly to the overall efficiency and effectiveness of the materials function.
- The term store keeping refers to the actual handling of the materials received into, held in and issued from the store.
- The main activities involved are receiving materials, including quantity verification and visual inspection, inspection of items, preservation of items.
- Store-keeping activity does not add any value to the materials.
- In fact it adds only to the cost.
- The organization is to spend money on space (expenditure on land, building passage and roads), machinery (store equipment), facilities (e.g. water, electricity, communication etc.), personnel, insurance, maintenance of store equipment, stationary etc.
- All of these get added to the organizational overheads and finally get reflected in the costing of the finished product. However, it is an essential function in any organization.

Main Process of a Store



Fig 5.1 – Main Process of a store

Typically a store has a few processes and a space for storage. The main processes of store are

(i) to receive the incoming materials (receiving),

(ii) to keep the materials as long as they are required for use (keeping in custody),

and

(iii) to move them out of store for use (issuing). The auxiliary process of store is the stock control also known as inventory control.

- In a manufacturing organization, this process of receiving, keeping in custody, and Issuing forms a cyclic process which runs on a continuous basis.
- The organizational set up of the store depends upon the requirements of the organization and is to be tailor made to meet the specific needs of the organization.

NATURE OF STORES

Dictionary defines store as building where goods are kept. Stores is defined as supplies of goods. And storage is defined as the act of storing the goods. Some people use the term store-keeping which has the same meaning as storage.

In popular usage the term stores is *used to cover all aspects of preservation of goods i.e., building, supplies and the act of storing.*

Stores or storage is the function of receiving, storing and issuing materials. It involves supervision or the clearance of incoming supplies, to ensure that they are maintained in good condition, safely and in readiness for use when required while they are in storage and issuing them against authorised requisitions. In short, it is connected with the physical handling and well-being of the stocks.

It should be mentioned that stores is not meant for stocking purchased materials alone. Partly-finished goods, finished goods, spares, and consumables stores are also kept in stores. The emphasis here is on the storing of incoming materials.

Importance

Efficient storage of stores yields the following benefits:

1. Ready accessibility of major materials permitting efficient service to users.
2. Efficient space utilisation and flexibility of arrangement.
3. A reduced need for materials handling equipment.
4. A minimisation of materials deterioration and pilferage.
5. Ease of physical counting.

Objectives of store management

An efficient stores management has normally the following main objectives.

- To ensure uninterrupted supply of materials without delay to various users of the organization.
- To prevent overstocking and under stocking of the materials
- To ensure safe handling of materials and prevent their damage.
- To protect materials from pilferage, theft, fire and other risks
- To minimize the cost of storage
- To ensure proper and continuous control over the materials.
- To ensure most effective utilization of available storage space
- To optimize the efficiency of the personnel engaged in the store

Functions of a store management

Store personnel are responsible for carrying out the following functions.

- Receipt of incoming materials
- Supervision of unloading of materials and tallying of materials
- Checking for damages or shortages and preparation of the report
- Filling of 'goods inward', 'day book', or 'daily collection' register
- Completion of vendors consignment note (challan)
- Making arrangement for inspection and getting the inspection completed
- Preparation of 'goods receipt note' (GRN)
- Preparation of 'goods rejection memo' (in case of rejection of materials)
- Sending of materials to the respective stores
- Sending of the relevant documents to the respective departments
- Ensuring all storage and material handling facilities are in proper working order
- Ensuring good housekeeping and cleanliness in the storage space
- Checking, counting and tallying of materials before issue
- Making prompt entries in 'Bin card' or stock card
- Ensuring correct documentation of material receipts and material issues
- Ensuring safe and proper handling of materials so as not to damage them

- Ensuring proper record keeping and correct accounting of materials
- Ensuring regular stock verification
- Ensuring that rules and regulations relating to physical custody and preservation of materials are followed
- Ensuring safety of materials and personnel

STORES LAYOUT

Stores layout is a fundamental factor in determining the efficient performance of the department. The following factors deserve serious consideration, while planning for the stores layout:

1. Provisions for easy receipt, storage and disbursement of materials, nearness to point of use.
2. Minimum handling and transportation of materials, good accessibility for handling equipment, and personnel.
3. Adequate capacity provision for flexibility for future expansion.
4. Efficient utilisation of floor space and height.
5. Clear identification of materials, quick location of items and ease of physical counting.
6. Protecting against waste, deterioration, damage and pilferage.
7. Design the buildings' physical appearance to create goodwill and to invite business.
8. Arrange storage for fast and easy customer order processing.
9. Use compatible storage or display equipment to create good interior appearances.
10. Install good lighting to prevent theft, parts damage and errors in stocking.
11. Plan storage for easy shelf-life rotation to permit first-in-first-out control.
12. Segregate rebuilt, re-manufactured, used, and new merchandise.
13. Include safety as a part of the facility plan.
14. Maintain a periodic house-keeping and re-arrangement plan.

Two aspects of stores layout are significant, viz., (1) storage system and (2) type of stores layout.

Store layout is the design of a store's floor space and the placement of items within that store.

It depends on the following factors:

1. Flow of Materials:

According to this factor, materials should move minimum possible distances.

2. Character of Materials:

The materials that are not damaged by weather can be stored outside in shed.

Materials like cement, plaster etc., must be placed in dry place. Tools and machines etc., should also be placed in dry places and coated to prevent rusting.

3. Quantity, Weight etc. of Materials:

It is necessary to find the space required for different purposes.

4. Frequency of Handling:

Handling consists of the following four stages:

(a) Receipts,

(b) Inspection,

(c) Storage and

(d) Issue of materials.

The following are general hints to carry out these stages of handling smoothly and correctly:

1. Layout is such that material may be quickly received in stores.

2. Unloading platforms are built of suitable height.

3. All around the stores there is thorough siding. If trucks are used for transporting the materials, sufficient parking space is provided.

4. For heavy material, suitable equipment for internal transport is provided.

5. It is to be seen that each section of the store has sufficient allotting space. The material is to be arranged in such a way that inward and outward movement of supplies can be carried out smoothly.

STORAGE SYATEM

Choosing the most suitable storage system means *dealing with a number of interacting, and often conflicting factors*. Inevitably, the degree of mechanisation affects layout while the scarcity of space affects the height to which, racking is erected. The need for rapid, intensive order packing means a need for rapid, and easy access to stock. But accessibility weighs against space economy. A satisfactory storage system is, therefore, a compromise between the use of space and the use of time. The way in which stock is located, helps make the compromise a satisfactory one.

There are three basic ways of locating stock: fixed location, random location, and zoned location.

Fixed location means that, goods of a particular type have a position in the store assigned to them exclusively. It means that while stock can be found immediately without a complex system for recording its position, there can be considerable waste of space, because when stocks of any one item are low the space left vacant cannot be filled.

The assignment of fixed position to a particular type of goods is made on any one of the following basis:

1. On the basis of supplier.
2. On the basis of similarity of the items.
3. On the basis of the joint issue of the items.
4. On the basis of the size and frequency of use.

Random location means that items can be stored in any storage position which is available. Space is thus better utilised but, particularly where there are a large number of product lines, a record has to be kept of where goods are and frequency of when they entered the storage area.

Zoned location means that goods of a particular product group are kept in a given area. They may be randomly stored in a zoned location or stored according to fixed locations.

Types of Store Layout

Whatever the location followed, stock may be kept on one side of the aisle in which case it is called comb type layout.

Goods may be placed on either side of the aisle in which case the method is called tree type layout.

Selecting a particular type depends on the availability of space and the layout of the building.

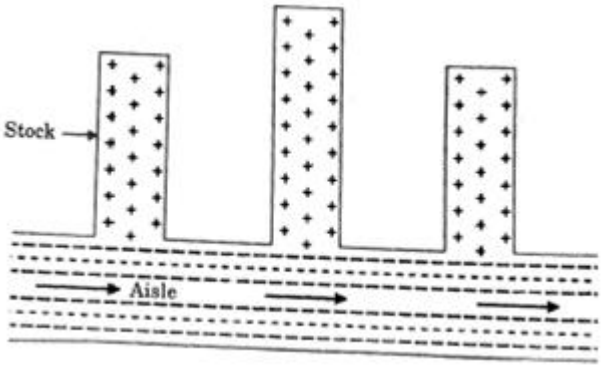


Fig 5.2 – Comb Type Layout

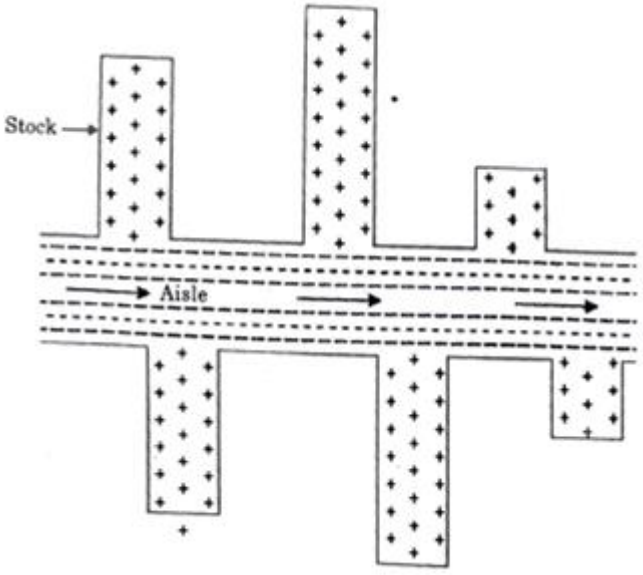


Fig 5.3 – Tree Type Layout

Location of a Store:

(a) Centralised Store:

- In small factories, it is desirable to centralise the materials so that they may be brought under the control of one store-keeper and the store-room should be as far as possible near the place, where material is to be used.
- If there are several manufacturing departments, the store-room will be most conveniently situated, where it is near to all depart-ments. This will reduce handling and a lot of manual work is eliminated. This type is called Centralised Store.

(b) Decentralised Store:

- In large factories, where there are several departments, each using different type of materials, it becomes beneficial to separate the stores.
- For example, near the welding department, store the materials required for welding; near the foundry department, store the items which are used there; near assembly department, store the parts that are required there and so on.

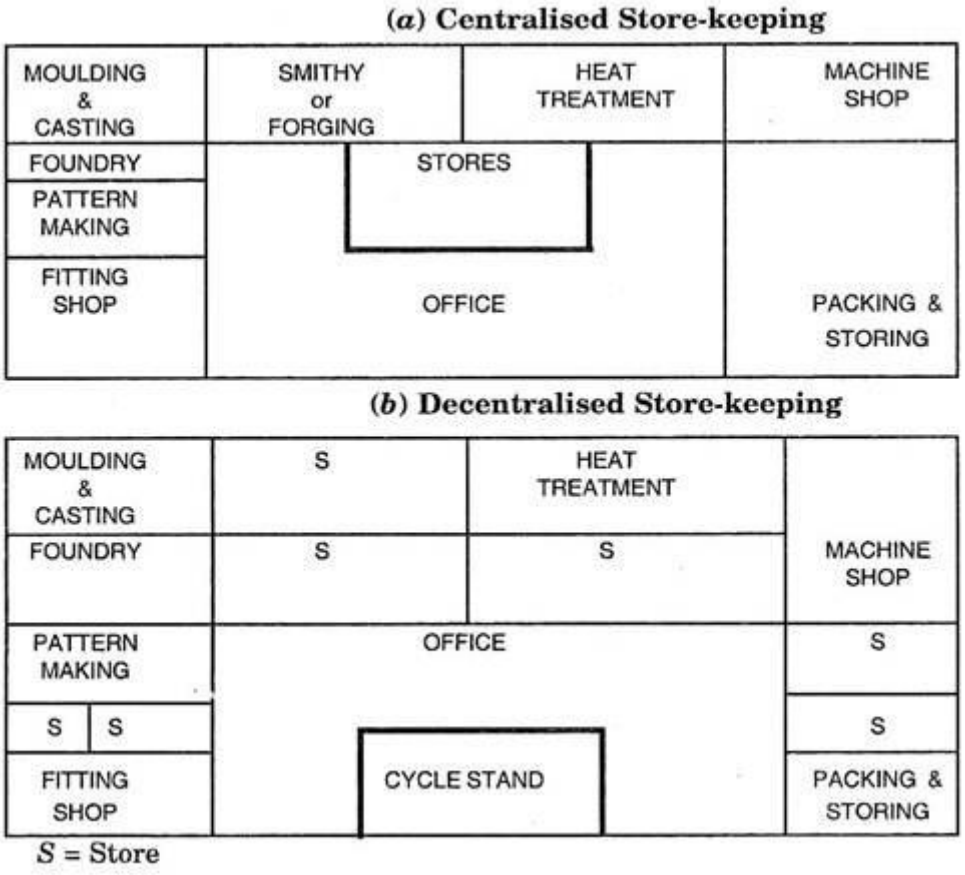


Fig 5.4 – Centralised and Decentralised Sore Keeping

STOCK VERFICATION

Stock Verification is the physical counting of stock. Where counting is not possible, measuring or weighing is done. The results of such physical checking are systematically recorded.

Stock verification is necessary because:

(a) It minimizes pilferage and fraudulent practices,

(b) It ensures accuracy and usefulness of documents,

(c) It brings about a reconciliation of the stock records and documents.

(d) It identifies areas for more disciplined document control and

(e) It backs up the balance sheet stock figures Stock verification is the task of the materials audit department. Verification may be continuous or periodical.

Types of Stock Verification:

1. Perpetual or Continuous Verification:

Under this system, verification of stock continues throughout the, year according to plan. Different items of stores are verified according, to their nature, importance and issue fend, etc. twice, thrice or even more in a year. A perpetual inventory is, therefore, maintained showing all transactions so that reconciliation can be done.

The system of continuous verification has the following advantages:

(1) The materials audit staff can carry on their work independently.

(2) More detailed investigation is possible with regard to discrepancies as the investigation is spread over the year.

(3) Preparation of final accounts is not delayed as the data for the final accounts remain ready after audit.

(4) The operations of the stores continue and remain unaffected,

(5) There is no need to 'freeze' the operation because there are the perpetual inventory records.

(6) It is possible for the records to remain more up to date.

According to S N Chary "the normal business of the stores can go on as usual and more importantly the discrepancies do not come out all at once as in the annual stock-taking, so there is time to investigate discrepancies thoroughly."

2. Periodic Verification:

- This system of stock verification is done generally once a year — at the close of the year.
- The period covers usually accounting year.
- Since the whole audit work is involved, the verification takes a few days of a week or so to complete.
- During the audit period, no transactions can take place and therefore, problems may crop up.
- Physical stock-taking is a matter of careful planning.
- Various steps are involved. A detailed programme has to be prepared giving complete breakdown of the process—store wise and otherwise.
- Several departments are involved in chalking out programmer, particularly materials management and finance departments.
- In a periodical stock verification system, the audit staffs are instructed to complete the work as expeditiously as possible, since the usual store transactions remain suspended during the audit period.
- Verification cards and check sheets must be prepared according to requirements.
- Cards must be serially numbered for easy reference and control. Separate provisions are made for damaged or deteriorated items. Each member of the verification staff should have selected areas for verification to ensure orderly compilation of the job without duplication or omission.

3. Blind Verification

- Under this system the stock verifiers are given the location, but not details about code numbers, description and stock record balances.
- The underlying logic here is that the verifier will not have his own idea about the stock position and he may just mention the same figures in record without actual verifi-cation of stock.
- This method is not very popular.
- It virtually serves no purpose when the entire operation of stores has to be well-planned.
- The modern trend is toward the applica-tion of the ABC technique for stock verification.

CLASSIFICATION AND CODIFICATION

Classification of Materials

- 'Classification'refers to the systematic division, grouping or categorization of materials or store items with reference to some common characteristic.
- Classification of materials can be made on different bases namely nature, manufacturing process, value, purpose etc.
- For identification of materials being purchased and stored it is necessary that they should be properly classified.
- The store incharge should make a close study of the materials during the process of storage for the purpose of their (i) safe custody, (ii) meticulous handling and storing, and (iii) protection from damages, fire, pilferage, spoilage, etc.
- He is responsible for the classification of the materials.

The broad classification according to the materials (i) nature, (ii) use, and (iii) service can be done in the following, classes:

(i) Raw Materials

(ii) Consumable Stores

(iii) Machinery and Plant

(iv) Equipment: Factory and office

(v) Inflammable Stores

(vi) Chemical

(vii) Furniture and Fixtures

(viii) Scrap Materials

(ix) Packaging Materials

(x) General Stores.

Basis of Classification of Materials

The important basis of classification of materials may be given as follows:

0n the Basis of Nature

On the basis of nature, materials may be divided into:

(i) Direct Materials: Direct materials are those items of material which can be identified with a product or a group of products in a manufacturing concern and can be easily measured and charged directly to the product. Such materials form the part of the finished product e.g., timber in furniture, cloth in garments, bricks, sand and cement in building, yarn in cloth etc.

(ii) Indirect Materials: These are the materials which cannot be traced to a specific product and cannot be charged directly to the various products. These materials do not form part of the product. Examples of indirect materials are—repair and maintenance stores, lubricating oils, cleaning materials, cotton rags etc.

On the Basis of Manufacturing Process

On the basis of the manufacturing process, stores are divided into:

(i) Pre-process Stock: These are the items of stores which are yet to be taken into the manufacturing process and are obtained prior to the commencement of the manufacturing process or production. These include raw materials, bought-out parts and assemblies, and stock in pipeline of materials in transit.

(ii) Intermediate Stock: Intermediate stock comprises the parts or assemblies which are manufactured within the factory for use in the final product.

(iii) Finished Goods or Finished Products: As the name indicates, finished goods are the items which have been duly manufactured in the factory and are ready for shipment or sale to the customers.

On the Basis of Value

On the basis of the value, the stores items may be divided into:

(i) Category ‘A’: Category ‘A’ consists of materials which constitute 5% to 10% of the total items in the stores and represent 70% to 85% of the total stores value.

(ii) Category ‘B’: This category consists of materials which constitute 10% to 20% of the total items in the stores and also represent 10% to 20% of the total stores value.

(iii) Category ‘C’: This category consists of cheap materials which constitute 70% to 85% of the total items in the stores and represent 5% to 10% of the total stores value.

Category ‘A’ items constitute costly items calling for greater degree of control for preserving them. A reasonable degree of care may be taken to control category ‘B’ items while a routine type of care may be applied to control ‘C’ category or residuary items.

On the Basis of Movement of Stores

On the basis of the movement or rate of consumption, stores items may be divided into:

(i) Fast Moving Stock: Fast moving stock indicates the items of materials which exhaust at a very fast speed on account of high demand from production departments of a manufacturing concern.

(ii) Slow Moving Stock: This category indicates the items of stores or materials which are consumed or exhausted at a very slow speed on account of low demand from the production departments of the manufacturing concern.

(iii) Dormant Stock: This category covers stores items which do not have any demand at present and may regain demand in future. This category includes seasonal materials which are required during specified seasons.

Advantages of Classification Of Materials

The main advantages of classifying stores items may be given as follows:

1. Helpful in Grouping of Stores Items: Classification process helps in the grouping of the different items of materials in the store. Items falling under a particular category can be stored at one place which ensures optimum utilization of storage space.

2. Easy Location: Proper classification of stores items helps in the easy identification of the various items. The store-keeping staff can easily find out the materials whenever these are required in the production departments.

3. Proper Accounting: Record-keeping process of properly classified items of stores is simplified. Simplified record-keeping ensures accuracy in posting the receipts and issues in the stores records.

4. Proper Care: By classifying the various store items on the basis of value, their relative importance can be ascertained and suitable degree of supervision and control may be exercised over them with reference to such value.

5. Avoidance of Duplication: Proper classification of the store items helps in avoiding the possibility of duplication in stocking the same item of material.

6. Standardization: Classification helps in the standardization of various items in the stores. Standardization of store items involves the variety reduction through the use of fixed sizes and types. Standardization aims at having uniform standards for similar items.

Codification of Materials

- After having classified or grouped the various items of stores, it is necessary and useful to codify them.
- Codification is the process of assigning a number or symbol to each store item in addition to its name for making its identification easy and convenient.
- Codification of store items leads to saving in time and labour on account of substitution of a symbol or number for a longer name.
- There are different kinds of store codes in use and most of them are specially designed to suit the requirements of a particular organization.
- These codes may be based upon the nature of stock items, the purpose for which these items are used or on any other basis which is considered as suitable according to the local circumstances.
- Also, accurate identification of the materials may require a lengthy description which may be complicated and hence may add to the confusion.
- Codification is necessary as it refers to as allotment of logical and systematic numbers or alphabets or both (as a mixture) so as to help in simple but accurate identification of the materials.

Advantages of Codification

The following are the main advantages of codification :

1. It avoids the long and unwieldy descriptions.

2. It tries to have accurate and logical identification.

3. It prevents duplication.

4. It standardizes the purchasing as well as storage.

5. It reduces the varieties.

6. It makes purchasing, recording, accounting, computerizing pricing, costing, location, indexing and inspection efficient and result-producing.

7. It assures planned and quality production.

Systems of Codification

The following four systems of codification are commonly used in a materials department:

1. Alphabetical system is one in which codes to materials are allotted in alphabets which have no relation to numbers. Each item of the storehouse is grouped according to nature, use etc. of the item and materials are then analyzed from the point of view of codification. Say, for example, Iron ore is given a code of IN-O and Iron Bars the IN-BA and so on.

2. Numerical system is one in which codes to materials are based on numbers. Numbers are allotted as codes to materials making provision for future expansion as well. Say, for example, Iron ore is given a code of 05—10 and Iron Bars the 11—67 and so on.

3. Decimal system is one in which codes to materials are again based on numbers but instead of dash in between two number decimals are put. This makes the codes more flexible and future expansion is very much possible. Say, for example, Iron ore is given a code of or Iron Bars the 11. 67.03 and so on.

4. Combined Alphabetical and numerical system. This combines all the three above. Say, for example, Iron ore is given the code of IN–05.10 and Iron Bars the IN-11.6 and so on.

Bins and Racks

- Bin is a compartment or a separated portion of a particular almirah, pigeon-hole, cabinet, etc. utilized to store only one type of materials.
- A bin card is used for depicting the quality and quantity of the materials stored therein.
- It functions as a materials movement record and as replenishment index.
- It is a brief version of the stock ledger pertaining to an item.
- It serves the purpose of a ready-reckoner for the item binned therein.
- It, thus, serves as a mirror of the bin. The following is the specimen proforma of a bin card:

Bin Card

Bin No. .....
Article. .....
Code No. Identification. .....
Unit of Issue .....

Max. Stock .....
Min. Stock .....
Order Stock .....
Danger Stock .....

Date	Delivery or Issue Note No.	Qty./ Weight		Balance	Date	Delivery or Issue Note No.	Qty. / Weight		Balance
		Receipt	Issue				Receipt	issue	

Fig 5.5 – Bin Card

- Racks are used for keeping materials inside the store.
- This is just like an almirah either open or close.
- They are mostly used for keeping general store items.
- They are in common use. Racks are fixed or movable frames of either wood or metal bars.
- Racks for storing tubes, bars, sheets, plates, types, cables, drums, etc.
- The racks may also be specially designed.

CODIFICATION OF MATERIALS

- After having classified or grouped the various items of stores, it is necessary and useful to codify them.
- Codification is the process of assigning a number or symbol to each store item in addition to its name for making its identification easy and convenient.
- Codification of store items leads to saving in time and labour on account of substitution of a symbol or number for a longer name.
- There are different kinds of store codes in use and most of them are specially designed to suit the requirements of a particular organization.
- These codes may be based upon the nature of stock items, the purpose for which these items are used or on any other basis which is considered as suitable according to the local circumstances.
- Also, accurate identification of the materials may require a lengthy description which may be complicated and hence may add to the confusion.
- Codification is necessary as it refers to as allotment of logical and systematic numbers or alphabets or both (as a mixture) so as to help in simple but accurate identification of the materials.

- Systematic concise representation of equipment, raw material, tools, spares, suppliers .
- Coding refers to the process of assigning symbols to the parts.
- Coding is define as process of allocating symbol to the parts. The symbol represent design characteristics of parts , manufacturing attributes or both.

IMPORTANCE OF CODING

- Due to industrial requirement organization has to store large no. materials. Therefore there should be some mean of identifying them hence Coding is used.
- Classification and codification of materials are steps in maintaining stores in a systematic way.
- Materials are coded in such way that storing, issuing and identifying of materials become easy.

CRITERIA FOR EFFECTIVE CODING

- Code should be Simple.
- Code should be unique.
- Coding should be compact, concise and consistent.
- Code should be sufficiently flexible to meet future demands.

OBJECTIVES OF CODING

- To bring all similar items together under one classification or group.
- To classify an item according to its nature of characteristics.
- To avoid duplication and confusion.
- To fix essential parameters to specify an item.

Advantages of Codification

The following are the main advantages of codification :

1. It avoids the long and unwieldy descriptions.

2. It tries to have accurate and logical identification.

3. It prevents duplication.

4. It standardizes the purchasing as well as storage.

5. It reduces the varieties.

6. It makes purchasing, recording, accounting, computerizing pricing, costing, location, indexing and inspection efficient and result-producing.

7. It assures planned and quality production.

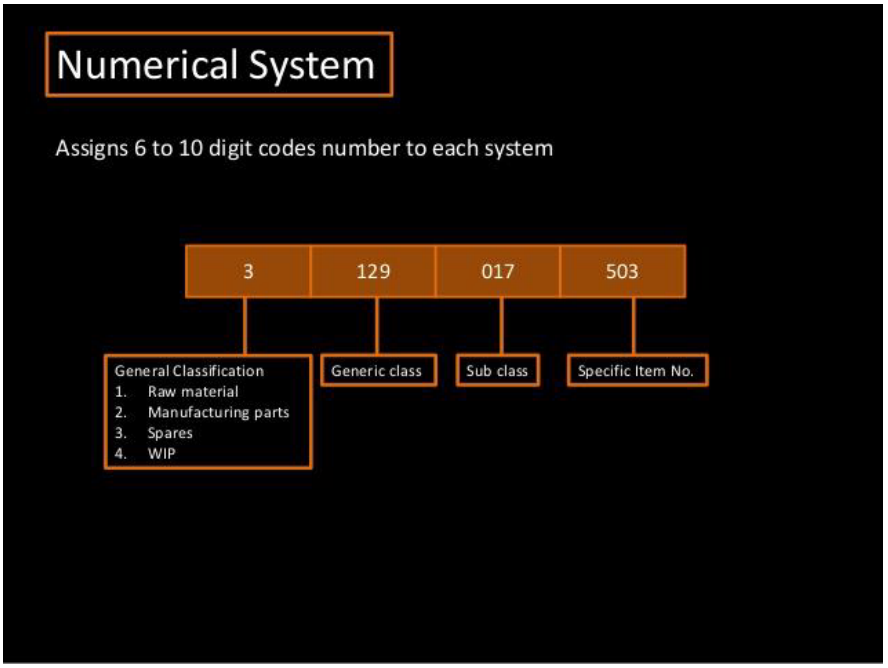
Systems of Codification

The following four systems of codification are commonly used in a materials department:

1. Alphabetical system is one in which codes to materials are allotted in alphabets which have no relation to numbers. Each item of the storehouse is grouped according to nature, use etc. of the item and materials are then analyzed from the point of view of codification. Say, for example, Iron ore is given a code of IN-O and Iron Bars the IN-BA and so on.

Item	*Code*
Raw material	A
Wood	B
Plastics	C
Paints	D
Greases	E
Varnishes	F

2. Numerical system is one in which codes to materials are based on numbers. Numbers are allotted as codes to materials making provision for future expansion as well. Say, for example, Iron ore is given a code of 05—10 and Iron Bars the 11—67 and so on.



Items	*Simple number*	*Block number*	*Dash or Stroke number*
Raw materials	0	1 – 100	
Cutting tools	1	101 – 150	
Metals	2	151 – 200	
Packing materials	3	201 – 300	
Stationary	4	301 – 500	
Fittings	5	501 – 600	
Electric parts	6	601 – 700	
Tools	7	701 – 800	
Fixtures	8	801 - 900	
Finished products	9	901 - 999	
Raw materials			
Wood	0	1 – 10	0 – 001
Teak wood	0	1	0 – 001/1
Plywood	0	2	0 – 001/2
Cutting tools	1	101 – 150	
Lathe tools	1	101	1 – 001/1
Milling cutters	1	102	1 – 102/2
Drill bits	1	103	1 – 103/6
Reamers	1	104	1 – 104/8
Metals	2	151- 200	
Cast iron	2	151 – 160	0 – 151
Grey cast iron	2	152	0 – 152/1
Malleable cast iron	2	153	0 – 153/2
Electric parts	6	601 – 700	
PVC wires	6	601	
Cable wires	6	605	
Bulbs 40 watt	6	610	

3. Decimal system is one in which codes to materials are again based on numbers but instead of dash in between two number decimals are put. This makes the codes more flexible and future expansion is very much possible. Say, for example, Iron ore is given a code of or Iron Bars the 11. 67.03 and so on.

Parameters	Main group	Sub-group 1	Sub-group 2
Copper	Cu		
Sheet		Sh	
5mm thickness			05

Thus, code for Copper Sheet of 5mm thickness is : **CuSh05**

4. Combined Alphabetical and numerical system. This combines all the three above. Say, for example, Iron ore is given the code of IN–05.10 and Iron Bars the IN-11.6 and so on.

	Main Group	Sub- Group 1	Sub- Group 2
Copper	**01**		
Copper Sheet		**02**	
Copper Sheet 5mm Thick			**03**

Thus, the code of Copper Sheet 5mm Thick = 01.02.03

MNEMONIC SYSTEM

- When we use letters to help memory, we call such a system a mnemonic system.
- A special application of the alphabetical system.
- Alphabets are allotted to an item according to its initials or abbreviation
- Eg: Stainless steel: SS

  Copper: Cu

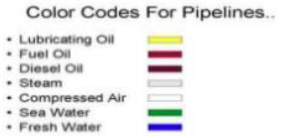


COLOUR CODING

- Color-coding easily identifies small parts.
- The various cables and wires of different colours are used in electrical fittings to identify their polarities.



- Colour codes are also used in foundries to identify different patterns and metals.
- Generally is used for Pipelines, Raw materials, lubricants etc.



Example

Private Cars



Taxis



British/Brisch Codification

- Consists of 7 digits and is applied in 3 phases
- The items are grouped into suitable preliminary categories, such as:
  - Assemblies
  - Sub assemblies
  - Components
  - off the shelf items.

  in order to bring **similar item** together
- The second block gives next level of classification based on the **type of materials**
- The third block gives the lowest level of classification normally the **specifications**

EXAMPLE



Kodak Codification

- Consists of 10 digits of numerical code.
- Originated by Eastman Kodak Company.
- Based on numerical system of codification and combines all good other points.
- Divided into few broad classification called Basic Classification.
- The basic classification is restricted to 100.
- Each class is then further divided into sub classes.
- Grouping is based on Source of supply

EXAMPLE

1. **If bolt is listed as hardware item**: Then will be available under hardware suppliers
If this **bolt is available as a part of the machine**: It will be available under maintenance

2. Eg – 40(Cutting Tools)0(drills)
- Each sub class is again further sub divided
- Eg – 400-00

SAFETY STOCK INVENTORY CONTROL

SAFETY STOCK

Safety stock is an extra quantity of a product which is stored in the warehouse to prevent an out-of-stock situation. It serves as insurance against fluctuations in demand.

Reasons for Keeping Inventories

1. **To stabilise production:** The demand for an item fluctuates because of the number of factors, *e.g.,* seasonality, production schedule etc. The inventories (raw materials and components) should be made available to the production as per the demand failing which results in stock out and the production stoppage takes place for want of materials. Hence, the inventory is kept to take care of this fluctuation so that the production is smooth.
2. **To take advantage of price discounts:** Usually the manufacturers offer discount for bulk buying and to gain this price advantage the materials are bought in bulk even though it is
not required immediately. Thus, inventory is maintained to gain economy in purchasing.
3. **To meet the demand during the replenishment period:** The lead time for procurement of materials depends upon many factors like location of the source, demand supply condition, etc. So inventory is maintained to meet the demand during the procurement (replenishment) period.

4. **To prevent loss of orders (sales):** In this competitive scenario, one has to meet the delivery schedules at 100 per cent service level, means they cannot afford to miss the delivery
schedule which may result in loss of sales. To avoid the organizations have to maintain inventory.

5. To keep pace with changing market conditions: The organizations have to anticipate the changing market sentiments and they have to stock materials in anticipation of non-availability
of materials or sudden increase in prices.

6. Sometimes the organizations have to stock materials due to other reasons like suppliers minimum quantity condition, seasonal availability of materials or sudden increase in prices.

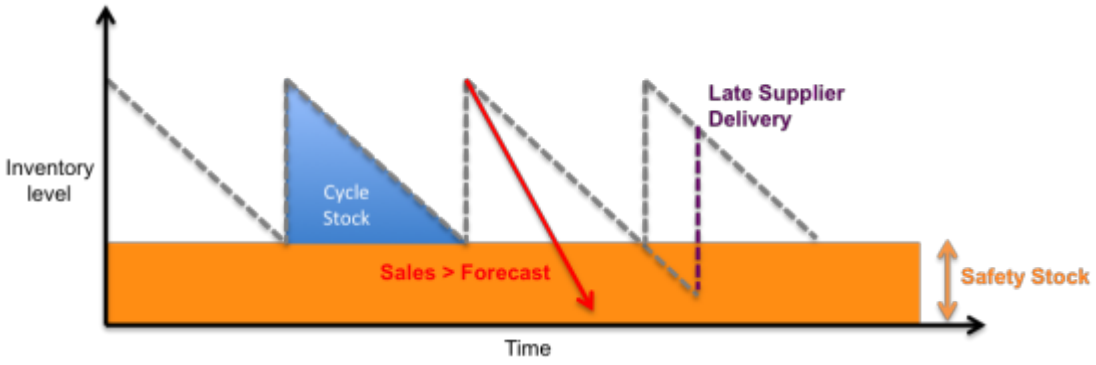


Fig 5.6 - Safety Stock Levels & the associated effects of variability in the supply chain

INVENTORY CONTROL

- The simplest definition of inventory control, also known as stock control, refers to the process of managing a company's warehouse inventory levels.
- It is the process of ensuring the right amount of supply is available in an organization. With the appropriate internal and production controls, the practice ensures the company can meet customer demand and delivers financial elasticity.
- The inventory control process involves managing items from the moment they are ordered; throughout their storage, movement and usage; to their final destination or disposal.
- Many systems, processes, and technologies have been developed over the years to help companies streamline the supply chain processes involved in inventory control systems.

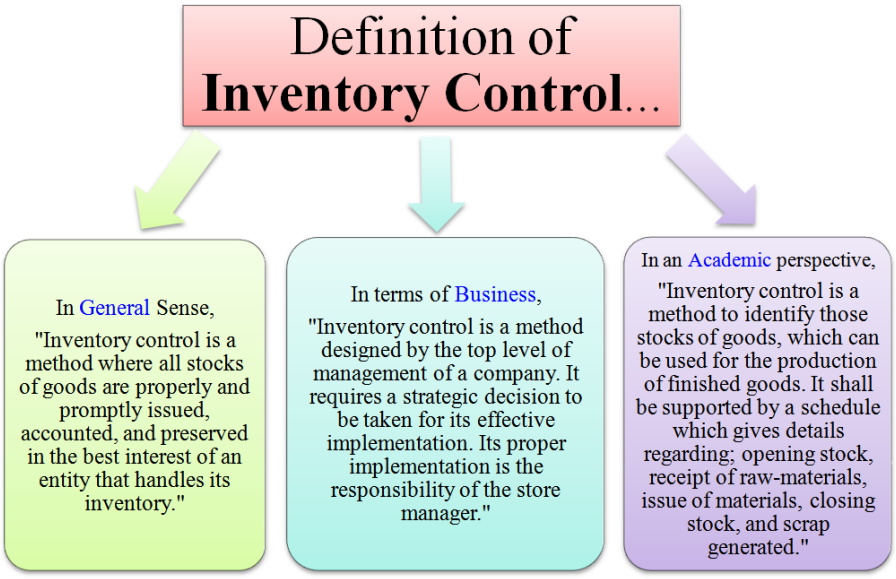


Fig 5.7 – Definition of Inventory Control

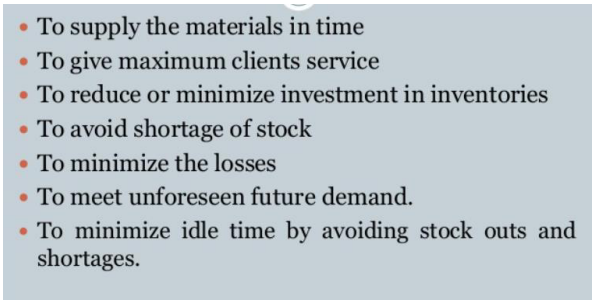
The below table explains different inventory types and the reason why such inventories are held by the business.

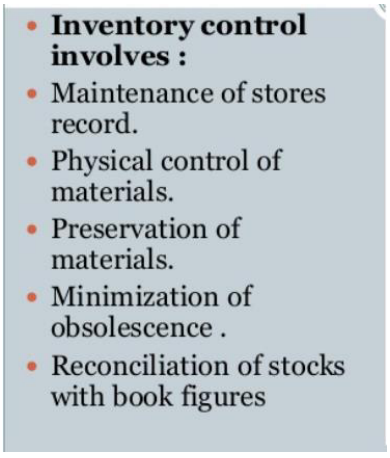
Raw materials	The reason for holding raw materials is to reap the price advantage available on purchase of bulk or on any seasonal raw materials which can be procured only during the harvest seasons.
Inventory in work-in-progress	The reason is to balance the production flow. Let's say if any batch order which requires the same kind of raw material, it can be diverted from the batch order that has been postponed by the management for certain time thereby not affecting the production flow.
Readymade components	A company usually does not produce every component that goes into the product. Sometimes they buy readymade components available in the market. In such a situation, it becomes necessary for the company to hold stock of those readymade inventories which are required in the production of the final product.

Finished goods	A company stocks the finished goods during the waiting period until it finds its customer. In some cases, more stocks are held to create demand for the product and get a high price for the product.

From the above, it's quite clear that for various reason, you need to hold inventories in the business. In this process, how much to stock is an important question that needs to be answered. Here is why inventory control plays an important role.

Objectives of Inventory Control





Benefits of Inventory Control

It is an established fact that through the practice of scientific inventory control, following are thebenefits of inventory control:

1. Improvement in customer's relationship because of the timely delivery of goods and service.
2. Smooth and uninterrupted production and, hence, no stock out.
3. Efficient utilisation of working capital. Helps in minimising loss due to deterioration, obsolescence damage and pilferage.
4. Economy in purchasing.
5. Eliminates the possibility of duplicate ordering.

INVENTORY CONTROL TECHNIQUES

1. ABC Analysis.

ABC analysis is an inventory control technique that categorizes inventory items based on their importance and profits. ABC inventory categorization follows the 80-20 rule where 80% (almost) of revenues come from 20% (almost) of items. This 20% of items are categorized as 'A' category. The next 30% of items are classified as 'B'. And the bottom 50% of items are classified as 'C'. This categorization helps business leaders understand which products or items are most important to the financial success of their business.

This ABC categorization technique splits items into three categories and controls inventories based on their importance:

- **Category A** is the most valuable product contributing to overall revenues.
- **Category B** is the products between the most and least valuable items.
- **Category C** is the least valuable item, vital for general business but doesn't matter much individually.

1. Economic order quantity.

Economic order quantity (EOQ) is a formula for ordering an ideal quantity based on factors such as purchase costs, carrying cost, holding cost, production cost, demands, and other variables.

The primary objective of EOQ is to minimize related costs. The formula determines the optimized number of product quantities to minimize the cost of goods sold (COGS). This helps free up tied cash in inventory for most businesses.

This formula is effective when businesses benefit from rates for bulk purchases, carrying and holding costs are significant factors, and costs decrease dramatically for large-scale production.

EOQ = square root of: [2(demand)(order cost)] / holding costs.

2. VED Analysis.

VED Analysis is a popular inventory management strategy for small and medium-sized manufacturers where some raw materials are vital but not easy to restock quickly. This analysis helps to organize items for a production schedule.

According to their criticality, VED (Vital, Essential, and Desirable) classifies materials into three **Vital, Essential, and Desirable**.

Vital items: Vital items are required to continue the business. Without these items, business becomes a stand-still. It is suicidal to stock-out vital items. Some items will be crucial in your business, and you cannot compromise on stocks for them. Always maintain a safe amount of inventory of these.

Essential items: Essential items are those whose stock-out cost would be very high. These items won't shut your shop, but your customers will expect you to have them. After vital items, make sure enough stock of Essential items.

Desirable items: These are good to have and may not directly affect your business. But they are adding more potential & opportunities. Maybe drops some sales due to stock-outs, but it is very nominal and easily recoverable.

3. FSN Analysis:

FSN analysis stands for **Fast-Moving, Slow-Moving, and Non-Moving**. It is a simple yet powerful inventory control technique used to categorize items based on their **demand rate**. This helps businesses prioritize their inventory efforts, allocate resources efficiently, and improve overall inventory performance.

Objectives of FSN Analysis:

- **Identify and prioritize fast-moving items.** These items require close monitoring, accurate forecasting, and frequent replenishment to avoid stockouts.
- **Optimize inventory levels** for each category, reducing holding costs for slow-moving and non-moving items.
- **Establish appropriate ordering and replenishment policies** based on the item's classification. This may involve different ordering frequencies, order quantities, and safety stock levels.

4. HML Analysis:

HML analysis is a tool used in inventory management to categorize items based on their **unit price**. It helps businesses prioritize their inventory control efforts and allocate resources effectively. HML stands for:

- **H:** High-value items (highest unit price)
- **M:** Medium-value items
- **L:** Low-value items

The **objectives** of HML analysis are to:

1. **Identify and prioritize high-value items.** This ensures that these items are closely monitored and controlled, minimizing the risk of stockouts and losses.
2. **Optimize inventory levels** for each category, reducing holding costs and improving cash flow.
3. **Establish appropriate ordering and replenishment policies** based on the item's classification.

5. SDE Analysis:

SDE analysis, standing for Scarce, Difficult, and Easy, is a simple yet effective inventory control technique that categorizes items based on the **availability of their supply**. It helps businesses prioritize inventory control efforts, allocate resources efficiently, and improve overall inventory performance.

Objectives of SDE Analysis:

- **Identify and prioritize scarce items:** These items are challenging to obtain and require close monitoring and proactive management.
- **Optimize inventory levels:** Maintain sufficient stock of scarce items while minimizing holding costs for easy-to-source items.
- **Establish appropriate ordering and replenishment policies:** Adapt policies based on the difficulty of acquiring each item.
- **Reduce inventory costs:** Minimize procurement risks and costs associated with scarce items.

6. GOLF Analysis:

GOLF analysis stands for **Government Supply, Ordinarily Available, Local Availability, and Foreign Source of Supply**. It is a comprehensive inventory control technique that analyzes items based on their **source of supply**. This analysis helps businesses optimize procurement strategies, streamline inventory processes, and minimize costs associated with inventory management.

Objectives of GOLF Analysis:

- **Identify and manage risks associated with different supply sources.** This allows businesses to take proactive measures to mitigate risks and ensure the timely availability of inventory.

- **Optimize procurement processes** for each source of supply, considering factors like cost, lead time, and order quantity.
- **Improve inventory visibility and control** by tracking inventory levels and movement based on their source.
- **Reduce procurement and inventory carrying costs** by identifying and eliminating inefficiencies in the supply chain.

How GOLF Analysis Works:

1. **Identify Inventory Items:** List all items in your inventory.
2. **Classify Inventory Sources:** Categorize each item based on its source:
    - **G:** Government Supply
    - **O:** Ordinarily Available
    - **L:** Locally Available
    - **F:** Foreign Source of Supply
3. **Analyze Each Source:** For each source, consider factors such as:
    - **Cost**: Price per unit, potential discounts, transportation costs.
    - **Lead Time**: Time between placing an order and receiving the goods.
    - **Order Quantity**: Minimum order quantity, economic order quantity.
    - **Payment Terms**: Payment methods, credit periods, discounts.
    - **Quality**: Consistency and reliability of supplier quality.
    - **Administrative Work**: Documentation, communication, and other administrative tasks.
4. **Develop Procurement Strategies:** Based on the analysis, develop specific procurement strategies for each source. This may involve different ordering frequencies, order quantities, safety stock levels, and supplier selection criteria.
5. **Monitor and Review:** Regularly monitor and review the performance of each source to identify opportunities for improvement and adapt to changing circumstances.

7. XYZ Analysis:

XYZ analysis is a simple yet powerful inventory control technique that helps businesses classify inventory items based on their **demand variability** and **forecast accuracy**. By understanding the demand patterns of different items, businesses can allocate resources effectively, optimize inventory levels, and improve overall inventory performance.

Divide items into three categories based on their CV:

- **X (High Variability):** High CV, indicating unpredictable demand and requiring close monitoring and frequent ordering.
- **Y (Moderate Variability):** Moderate CV, requiring some attention and possibly forecasting improvements.
- **Z (Low Variability):** Low CV, indicating predictable demand and allowing for less frequent ordering and lower safety stock levels.

Objectives:

1. **Identify and prioritize inventory items:** Focus attention on items with high demand variability and prioritize their control efforts.
2. **Optimize inventory levels:** Maintain sufficient stock to avoid stockouts while minimizing holding costs for items with low demand variability.
3. **Establish appropriate ordering and replenishment policies:** Implement different ordering frequencies, order quantities, and safety stock levels based on each item's demand characteristics.
4. **Improve forecasting accuracy:** Identify items with unpredictable demand and invest in better forecasting methods for those items.

8. SOS Analysis:

SOS Analysis, standing for Seasonal and Off-Seasonal, is a specific inventory control technique used for items with significant demand fluctuations based on seasonality. It helps businesses optimize their inventory levels, prevent stockouts during peak seasons, and avoid overstocking during off-seasons.

How SOS Analysis Works:

1. **Identify Seasonal Items:** Analyze historical sales data to identify items with significant demand fluctuations across seasons.
2. **Classify Demand Patterns:** Categorize seasonal patterns into distinct periods like peak season, off-season, and shoulder seasons.
3. **Quantify Demand:** Forecast demand for each season based on historical data, market trends, and promotional activities.
4. **Set Inventory Levels:** Determine the minimum and maximum stock levels for each season based on demand forecasts, lead times, and safety stock requirements.
5. **Develop Ordering Strategies:** Establish different ordering schedules and frequencies for each season based on demand fluctuations.
6. **Implement Promotional Strategies:** Utilize targeted promotions and discounts during off-seasons to stimulate sales and reduce inventory levels.

7. **Monitor and Review:** Regularly monitor inventory levels, sales data, and market trends to refine forecasts and adjust strategies as needed.

Minimum-Maximum Technique

The minimum-maximum system is often used in connection with manual inventory control systems. The minimum quantity is established in the same way as any re-order point. The maximum is the minimum quantity plus the optimum lot size. In practice, a requisition is initiated when a withdrawal reduces the inventory below the minimum level, the order quantity is the maximum minus the inventory status after the withdrawal. If the final withdrawal reduces the stock level substantially below the minimum level, the order quantity will be longer than the calculated EOQ.

The effectiveness of a minimum-maximum system is determined by the method and precision with which the minimum and maximum parameters are established. If these parameters are based upon arbitrary judgements with a limited factual basis, the system will

Two-Bin Technique

One of the oldest systems of inventory control is the two-bin system which is mainly adopted to control 'C' group inventories. In the two-bin system, stock of each item is separated into two bins. One bin contains stock, just enough to last from the date a new order is placed until it is received in inventory. The other bin contains a quantity of stock enough to satisfy probable demand during the period of replenishment. To start with the stock is issued from the first bin. When the first bin is empty an order for replenishment is placed, and the stock in the second bin is utilised until the ordered material is received.

Such a method is appropriate to ideal conditions in which rate of consumption is fairly constant and for items lead time of which is fairly established and regular.

Although the system itself possesses a high degree of automacy, in practice, we need to allow for variations in the rate of consumption as well as lead time. However, for such a system the most desirable quantity to re-order is the EOQ. Since the quantity to re-order is fixed in advance, initiation of replenishment action can be delegated to lower level staff and there is need to take physical count of inventory also.

A possible disadvantage of the system in some case is the requirement of additional storage facilities and perhaps some practical difficulty in keeping the two stocks properly separated.

MATERIAL HANDLING

Introduction

Raw materials form a critical part of manufacturing as well as service organization. In any organization, a considerable amount of material handling is done in one form or the other. This movement is either done manually or through an automated process.

Throughout material handling processes significant safety and health challenges are presented to workers as well as management. Therefore, manual material handing is of prime concern for health and safety professional, and they must determine practical ways of reducing health risk to the workers.

Manual material handling ranges from movement of raw material, work in progress, finished goods, rejected, scraps, packing material, etc. These materials are of different shape and sizes as well as weight.

Material handling is a systematic and scientific method of moving, packing and storing of material in appropriate and suitable location. The main objectives of material handling are as follows:

- It should be able determine appropriate distance to be covered.
- Facilitate the reduction in material damage as to improve quality.
- Reducing overall manufacturing time by designing efficient material movement
- Improve material flow control
- Creation and encouragement of safe and hazard-free work condition
- Improve productivity and efficiency
- Better utilization of time and equipment

It is critical for manufacturing organization to identify importance of material handling principle as the critical step in promoting the job improvement process. Manual material handling significantly increases health hazard for the workers in from lower back injuries.

In the current competitive and globalized environment, it is important to control cost and reduce time in material handling. An efficient material handling process promotes:

- Design of proper facility layout
- Promotes development of method which improves and simplifies the work process
- It improves overall production activity.
- Efficient material handling reduces total cost of production.

Principles of Material Handling

Material handling principles are as follows:

- **Orientation Principle:** It encourages study of all available system relationships before moving towards preliminary planning. The study includes looking at existing methods, problems, etc.

- **Planning Principle:** It establishes a plan which includes basic requirements, desirable alternates and planning for contingency.
- **Systems Principle:** It integrates handling and storage activities, which is cost effective into integrated system design.
- **Unit Load Principle:** Handle product in a unit load as large as possible
- **Space Utilization Principle:** Encourage effective utilization of all the space available
- **Standardization Principle:** It encourages standardization of handling methods and equipment.
- **Ergonomic Principle:** It recognizes human capabilities and limitation by design effective handling equipment.
- **Energy Principle:** It considers consumption of energy during material handling.
- **Ecology Principle:** It encourages minimum impact upon the environment during material handling.
- **Mechanization Principle:** It encourages mechanization of handling process wherever possible as to encourage efficiency.
- **Flexibility Principle:** Encourages of methods and equipment which are possible to utilize in all types of condition.
- **Simplification Principle:** Encourage simplification of methods and process by removing unnecessary movements
- **Gravity Principle:** Encourages usage of gravity principle in movement of goods.
- **Safety Principle:** Encourages provision for safe handling equipment according to safety rules and regulation
- **Computerization Principle:** Encourages of computerization of material handling and storage systems
- **System Flow Principle:** Encourages integration of data flow with physical material flow
- **Layout Principle:** Encourages preparation of operational sequence of all systems available
- **Cost Principle:** Encourages cost benefit analysis of all solutions available
- **Maintenance Principle:** Encourages preparation of plan for preventive maintenance and scheduled repairs
- **Obsolescence Principle:** Encourage preparation of equipment policy as to enjoy appropriate economic advantage.

Material handling operations are designed based upon principles as discussed above. Material handling equipment consists of cranes, conveyors and industrial trucks.

Importance of Materials Handling

1. Efficient materials handling is important to manufacturing operations. Materials sent by vendors must be unloaded, moved through inspections and production operations to stores and finally to the shipping department. These movements do not add value to the product but they do add to the cost.
2. Materials handling analysis is a subset of plant layout. Method study, plant layout and materials handling are all part of the design of a production facility and can hardly be treated as separate. Materials handling system and plant layout enhance effectiveness of each other. A good plant layout enables an operation to use the most efficient handling method. Efficient operation of appropriate materials handling methods reduces costs and enables maximum capabilities to be derived from a given production facility.

Objectives of Materials Handling

Even though the best solution to the materials handling problem, is *no handling*, it is hardly practicable in a manufacturing process. Hence, the *main objective* of materials handling is to reduce the number of handlings as well as the overall cost of material handling equipments and reducing the distances through which the materials are handled.

The following may be considered as other objectives of materials handling:

1. Lower unit materials handling costs.
2. Reduction in manufacturing cycle time through faster movement of materials and by reducing the distance through which the materials are moved. Reduction in manufacturing cycle time results in reduced work-in-progress inventory costs.
3. Contribution towards a better control of the flow of materials through the manufacturing facility.
4. Improved working conditions and greater safety in the movement of materials.
5. Contribute to better quality by avoiding damage to products by inefficient handling.
6. Increased storage capacity through better utilization of storage areas.
7. Higher productivity at lower manufacturing cost.

FACTORS AFFECTING THE SELECTION OF MATERIAL HANDLING EQUIPMENT

The following factors are to be taken into account while selecting material handling equipment.

1. ***PROPERTIES OF THE MATERIAL***

   Whether it is solid, liquid or gas, and in what size, shape and weight it is to be moved, are important considerations and can already lead to a preliminary elimination from the range of available equipment under review. Similarly, if the material is fragile, corrosive or toxic this will imply that certain handling methods and containers will be preferable to others.

2. ***LAYOUT AND CHARACTERISTICS OF THE BUILDING***

   Another restricting factor is the availability of space for handling. A low-level ceiling may preclude the use of hoists or cranes, and the presence of supporting columns in awkward places can limit the size of the material-handling equipment. If the building is multi-storied, chutes or ramps for industrial trucks may be used. The layout itself will indicate the type of production operation (continuous, intermittent, fixed position or group) and can indicate some items of equipment that will be more

suitable than others. Floor capacity also helps in selecting the best material handling equipment.

3. ***PRODUCTION FLOW***

   If the flow is fairly constant between two fixed positions that are not likely to change, fixed equipment such as conveyors or chutes can be successfully used. If, on the other hand, the flow is not constant and the direction changes occasionally from one point to another because several products are being produced simultaneously, moving equipment such as trucks would be preferable.

4. ***COST CONSIDERATIONS***

   This is one of the most important considerations. The above factors can help to narrow the range of suitable equipment, while costing can help in making a final decision. Several cost elements need to be taken into consideration when comparisons are made between various items of equipment that are all capable of handling the same load. Initial investment and operating and maintenance costs are the major cost to be considered. By calculating and comparing the total cost for each of the items of equipment under consideration, a more rational decision can be reached on the most appropriate choice.

5. ***NATURE OF OPERATIONS***

   The selection of equipment also depends on the nature of operations like whether handling is temporary or permanent, whether the flow is continuous or intermittent and material flow pattern-vertical or horizontal.

6. ***ENGINEERING FACTORS***

   The selection of equipment also depends on engineering factors like door and ceiling dimensions, floor space, floor conditions, and structural strength.

7. ***EQUIPMENT RELIABILITY***

   The reliability of the equipment and supplier reputation and the after-sale service also plays an important role in selecting

SELECTION AND DESIGN OF HANDLING SYSTEM

Materials handling systems are expensive to purchase and operate. The expenses are those of initial costs, labour cost for operating the material handling equipments and maintenance and repair costs. The indirect expenses are those resulting from damaged or lost materials, delays in material deliveries and accidents. Since these expenses are quite substantial, greater attention of management is needed to the design and selection of materials handling systems.

Since the pattern of flow of materials in a plant definitely affects the material handling costs, it is vital that the design and layout of buildings must be integrated with the design of the materials-handling system. Hence, the selection and design of the materials handling system should be done along with the development of the layout as each one affects the other.

For example, if overhead cranes are to be used, the structure of the building must be strong enough to support the operation of these services. If heavy loads are to be transported on trucks, floors must have adequate support to withstand these loads. Aisles or gangways must be wide enough to accommodate fork lift trucks that will travel through the areas carrying the loads. Adequate floor space has to be provided in the layout for fixed positions handling devices such as *conveyors.*

Steps to be followed in the selection and design of material handling systems are:

1. Identification of the appropriate systems.
2. Review of design criteria and objectives of the handling system.
3. Collection of data regarding flow pattern and flow requirements.
4. Identification of activity relationships between departments.
5. Determination of space requirement and establishment of material flow pattern.
6. Analysis of material and building characteristics.
7. Preliminary selection of basic handling system and generation of alternative systems considering feasibility of mechanisation and equipment capabilities.
8. Evaluation of alternatives with respect to optimal material flow, utilising gravity, minimum cost, flexibility, ease of maintenance, and capacity utilization.
9. Selection of the best suitable alternative system and checking it for compatibility with the layout.
10. Specification of the system.
11. Procurement of the equipment and installation of the system.

TYPES OF MATERIAL HANDLING EQUIPMENTS

Material handling equipment can be classified into two categories, namely:

1. **Fixed path equipment, and**
2. **Variable path equipment.**

a. Fixed path equipment which moves in a fixed path. Conveyors, monorail devices, chutes, and pulley drive equipment belong to this category. A slight variation in this category is provided by the overhead crane, which though restricted, can move materials in any manner within a restricted area by virtue of its design. Overhead cranes have a very good range in terms of hauling tonnage and are used for handling bulk raw materials, stacking and at times palletizing

b. Variable path equipment has no restrictions in the direction of movement although their size is a factor to be given due consideration trucks, forklifts mobile cranes and industrial tractors belong to this category. Forklifts are available in many ranges, they are maneuverable and various attachments are provided to increase their versatility.

Material Handing Types of equipment may be classified into five major categories.

1. ***CONVEYORS***

   Conveyors are useful for moving material between two fixed workstations, either continuously or intermittently. They are mainly used for continuous or mass production operations indeed, they are suitable for most operations where the flow is more or less steady. Conveyors may be of various types, with rollers, wheels or belts to help move the material along: these may be power-driven or may roll freely. The decision to provide conveyors must be taken with care since they are usually costly to install; moreover, they are less flexible and, where two or more converge, it is necessary to coordinate the speeds at which the two conveyors move.

2. ***INDUSTRIAL TRUCKS***

   Industrial trucks are more flexible in use than conveyors since they can move between various points and are not permanently fixed in one place. They are, therefore, most suitable for intermittent production and for handling various sizes and shapes of material. There are many types of a truck- petrol-driven, electric, hand-powered, and so on. Their greatest advantage lies in the wide range of attachments available; these increase the truck's ability to handle various types and shapes of material.

3. ***CRANES AND HOISTS***

   The major advantage of cranes and hoists is that they can move heavy materials through overhead space. However, they can usually serve only a limited area. Here again, there are several types of crane and hoist, and within each type, there are

various loading capacities. Cranes and hoists may be used both for intermittent and for continuous production.

4. ***CONTAINERS***

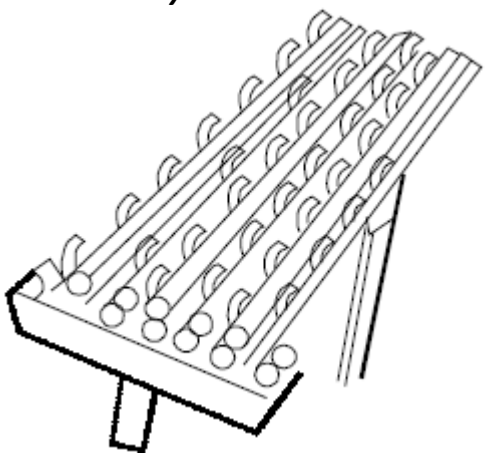
   These are either 'dead' containers (*e.g*. Cartons, barrels, skids, pallets) that hold the material to be transported but do not move or 'live' containers (*e.g*. wagons, wheelbarrows or computer self-driven containers). Handling equipments of this kind can both contain and move the material and is usually operated manually.

5. ***ROBOTS***

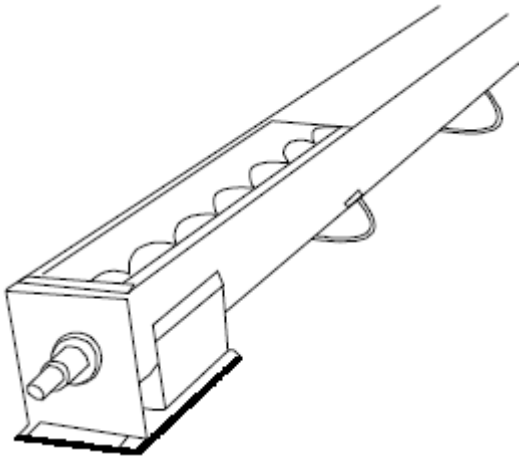
   Many types of robots exist. They vary in size, and in function and maneuverability. While many robots are used for handling and transporting material, others are used to perform operations such as welding or spray painting. An advantage of robots is that they can perform in a hostile environment such as unhealthy conditions or carry on arduous tasks such as the repetitive movement of heavy materials.

The choice of material-handling equipment among the various possibilities that exist is not easy. In several cases, the same material may be handled by various types of equipments, and the great diversity of equipment and attachments available does not make the problem any easier. In several cases, however, the nature of the material to be handled narrows the choice. Some of the material handling equipment are shown in the following figures.

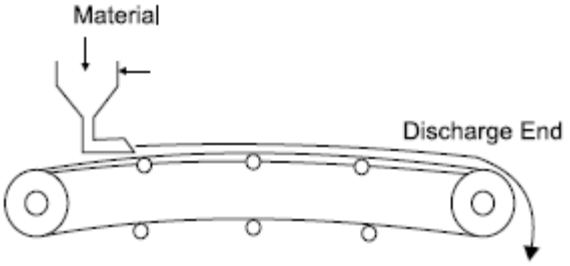
Wheel conveyor



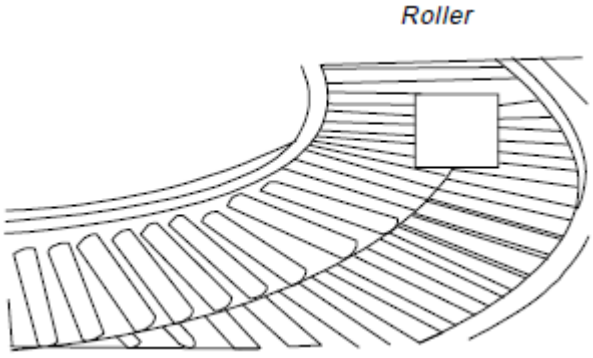
Screw conveyor roller



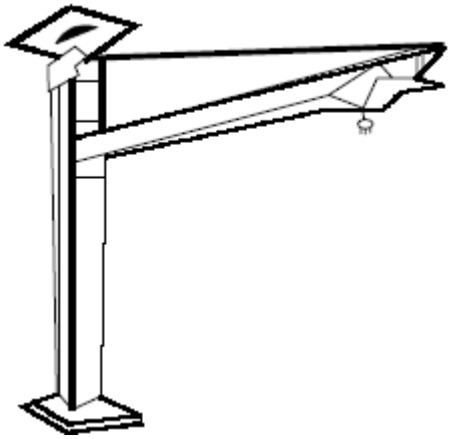
Belt conveyor



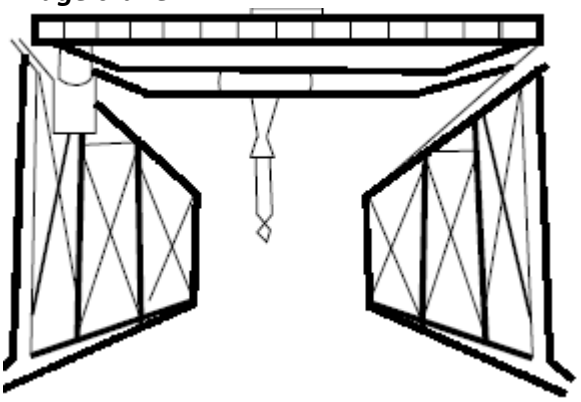
Roller conveyor



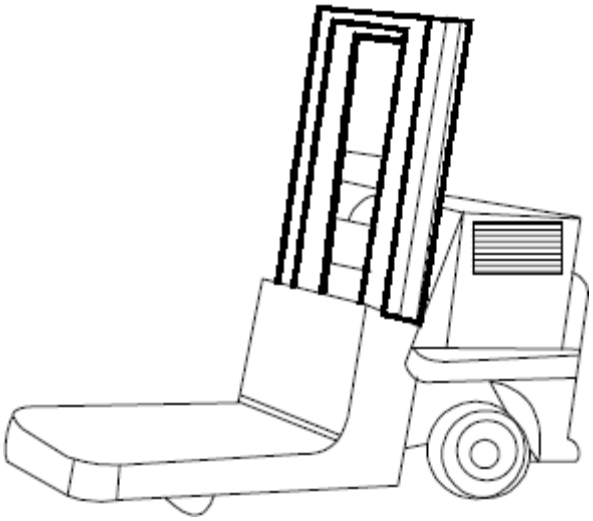
Jib crane



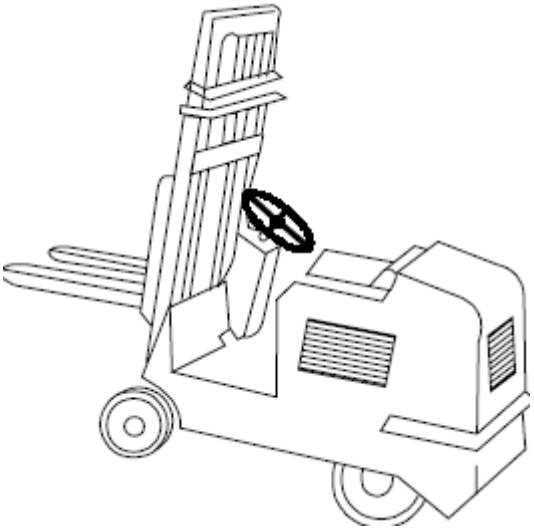
Bridge crane



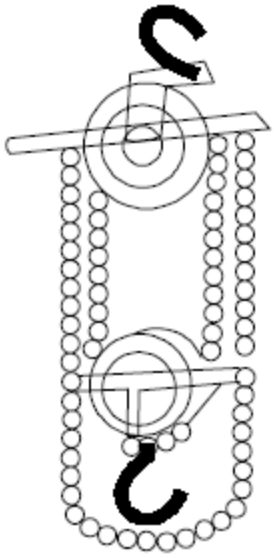
Platform truck



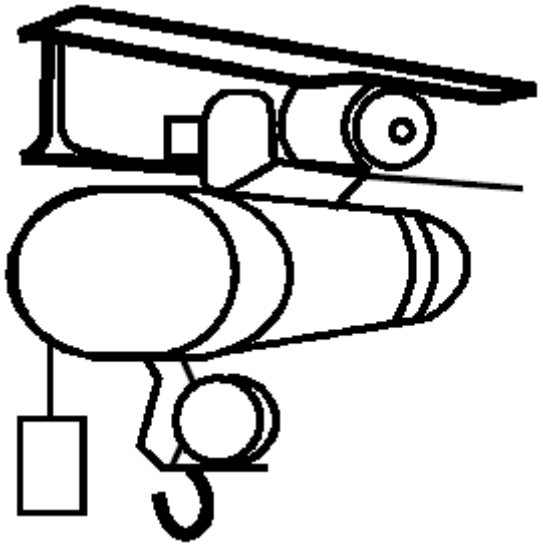
Fork truck



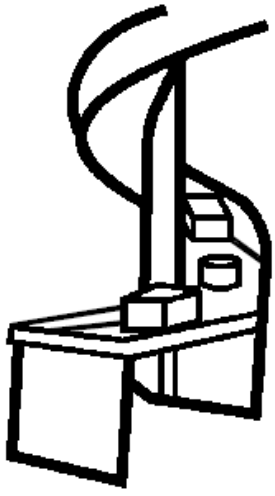
Chain hoist



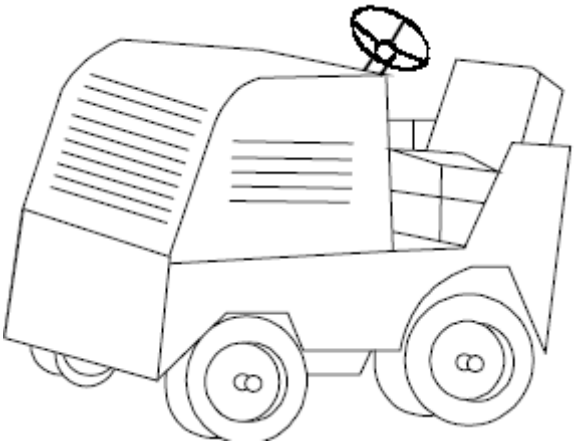
Electric hoist



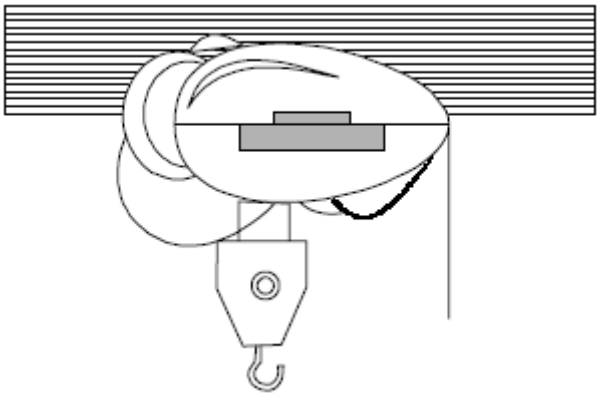
Spiral chute



Industrial tractor



Electrical hoist



Materials Handling and Plant Layout

Materials handling yields considerable influence on the plant layout. There is need for providing for storage and movement of materials from the time they are bought till they are converted into finished products. The storage and movement of materials require properly placed storage rooms and handling equipment. The type and size of storage, as also the type of materials movement equipment-cranes, trollies, pipelines, etc., depend upon:

- the type of raw material used, *i.e.*, whether liquid, solid, light, heavy, small or large; and
- the availability or scarcity of materials even when this is affected by seasonal variations and market conditions.

In factories where heavy raw materials are used, overhead cranes are required. Pipelines are used to transport iron ore, wheat, gas and salt. Gravity or airflow moves the material ahead in the pipelines. Similarly, roller conveyors, belt conveyors, and chain conveyors are used to move materials during various stages of production. It is obviously essential that a plant layout should be planned after bearing in mind the particular handling or moving equipment which may be required in the manufacturing process.

The usual way of taking the raw materials factor into account is to draw flow charts to visualise the paths of materials flow or movement, and then to eliminate cross-overs, long distances and back-trackings. The best plan is thus determined, around which the layout is planned.

Evaluation of Materials Handling Performance

Like any other materials activity, materials handling function should also be evaluated to judge its effectiveness. The performance of materials handling function can be evaluated with the help of several ratios such as the following:

1. Materials handling labour ratio.
2. Direct labour handling ratio.
3. Management/Operation ratio.
4. Manufacturing cycle efficiency ratio.
5. Space utilisation efficiency ratio.
6. Equipment utilisation ratio.
7. Aisle space potential ratio.
8. Materials handling personnel per 1000 factory employees.
9. Percentage of time lost by direct labour in materials.
10. Ratio of total number of moves to total number of operations.
11. Percentage of usable cubic footage usually occupied.
12. Materials handling costs as percentage of manufacturing expenses.

Safety in Materials Handling

Since about two-thirds of the general causes of accidents are directly related to materials handling, safety in materials handling is a major concern of production managers and safety engineers. The considerations for safe handling of materials are as follows :

(i) Instal adequate guards and safety devices on handling equipments.
(ii) Keep handling equipments in good operating conditions.
(iii) Replace manual handling by mechanised handling for difficult, hazarduous handling activities.
(iv) Do not permit the handling equipments to be overloaded or operated beyond rated capacity.
(v) Keep aisles clear and uncluttered.
(vi) Avoid conjestion of materials.
(vii) Maintain adequate lighting.
(viii) Maintain floors in good condition.
(ix) Provide good house keeping.
(x) Stack materials carefully.
(xi) Train operators in properly operating the handling equipments.
(xii) Highlight handling hazard or danger zones.

QUESTION BANK

UNIT I

1. Define Production Management and Operations Management.
2. Explain role of operations management in total management system.
3. Explain Functions of Production Planning and Control.
4. Explain in detail types of production process
5. Explain about product life cycle and process life cycle?

UNIT II

1. What is aggregate planning?
2. Explain Master Production Scheduling.
3. Explain about product sequencing and factors affecting determination of plant capacity.
4. What is plant layout? Explain the types of layouts
5. Explain about factors affecting Factory location.

UNIT III

1. Define Forecasting and explain importance of forecasting
2. Explain types of forecasting
3. What are the general principles of forecasting?
4. Explain different methods of qualitative forecasting.
5. Explain different methods of quantitative forecasting.

UNIT IV

1. Briefly explain the steps involved in materials requirement planning.
2. How do you prepare the production plan? Explain with a suitable example.
3. Explain the various stages of manufacturing resource planning with suitable diagram.
4. Discuss the different inputs and outputs of materials planning in an organisation.
5. Explain about Enterprise resource planning scope, benefits and applications.

UNIT V

1. Explain responsibilities of a store, objectives of store management and types of store layout.
2. Explain different methods of stock verification.
3. What are different techniques of inventory control and explain about ABC analysis.
4. What are the factors affecting selection of Material Handling Equipment?
5. Explain concept of material handling and Discuss Various material handling Equipments