MEASI INSTITUTE OF MANAGEMENT
CHENNAI-14

Approved by All India Council of Technical Education and
Affiliated to the University of Madras, ISO 9001:2015 Certified Institute

OPERATIONS MANAGEMENT

COURSE MATERIAL

VISION & MISSION STATEMENTS OF THE INSTITUTE

VISION;

- To emerge as the most preferred Business School with Global recognition by producing most competent ethical managers, entrepreneurs and researchers through quality education.

MISSION;

- **Knowledge through quality teaching learning process**; To enable the students to meet the challenges of the fast challenging global business environment through quality teaching learning process.
- **Managerial Competencies with Industry institute interface**; To impart conceptual and practical skills for meeting managerial competencies required in competitive environment with the help of effective industry institute interface.
- **Continuous Improvement with the state of art infrastructure facilities**; To aid the students in achieving their full potential by enhancing their learning experience with the state of art infrastructure and facilities.
- **Values and Ethics;** To inculcate value based education through professional ethics, human values and societal responsibilities.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO 1; Placement; To equip the students with requisite knowledge skills and right attitude necessary to get placed as efficient managers in corporate companies.

PEO 2; Entrepreneur; To create effective entrepreneurs by enhancing their critical thinking, problem solving and decision-making skill.

PEO 3; Research and Development; To make sustained efforts for holistic development of the students by encouraging them towards research and development.

PEO4; Contribution to Society; To produce proficient professionals with strong integrity to contribute to society.

Program Outcome;

PO1; Problem Solving Skill; Apply knowledge of management theories and practices to solve business problems.

PO2; Decision Making Skill; Foster analytical and critical thinking abilities for data-based decision making.

PO3; Ethical Value; Ability to develop value based leadership ability.

PO4; Communication Skill; Ability to understand, analyze and communicate global, economic, legal and ethical aspects of business.

PO5; Individual and Leadership Skill; Ability to lead themselves and others in the achievement of organizational goals, contributing effectively to a team environment.

PO6; Employability Skill; Foster and enhance employability skills through subject knowledge.

PO7; Entrepreneurial Skill; Equipped with skills and competencies to become an entrepreneur.

PO8; Contribution to community; Succeed in career endeavors and contribute significantly to the community.

Subject Code	Subject Name	L	T	P	S	C
PMF2L	**OPERATIONS MANAGEMENT**	**3**	**1**	**0**	**1**	**4**

Course Objectives	
C1	To understand the challenges involved in production design &capacity planning and provide insights on make or buy decisions
C2	To determine multiple plant location decisions and effective utilization of plant layout.
C3	To explain the models, concepts and techniques adopted in the areas of inventory control and maintenance
C4	To elucidate the importance of work study and quality control tools
C5	To provide insights on service operations management and waiting line analysis.

SYLLABUS

Unit. No.	Details	Hours
Unit I	**INTRODUCTION:** Operations Management- Nature, Scope, Historical Development, Functions- Long term Vs Short term issues- A Systems Perspective- Challenges- Manufacturing Trends in India-Production Design and Process Planning-Types of Production Processes- Plant Capacity-Capacity Planning-Make or Buy Decisions- Use of Crossover Chart for Selection Processes-Types of Charts used in Operations Management.	12
Unit II	**FACILITY DESIGN:** Plant Location; Factors to be considered in Plant Location- Location Analysis Techniques- Choice of General Region, Particular community and Site- Multiple Plant Location Decision- Plant Location Trends. Layout of Manufacturing Facilities; Principles of a Good Layout- Layout Factors- Basic Types of Layout- Principles of Materials Handling- Materials Handling Equipment's- Role of Ergonomics in Job Design.	12
Unit III	**INVENTORY CONTROL AND MAINTENANCE:** Basic Inventory Models- Economic Order Quantity- Economic Batch Quantity-Reorder Point-Safety Stock- Inventory Costs-Classification and Codification of Stock- ABC Classification-Materials Requirement Planning (MRP) - JIT- Implications of Supply Chain Management. Maintenance; Preventive Vs Breakdown Maintenance- Group	12

	Replacement Vs Individual Replacement- Breakdown Time Distribution- Maintenance of Cost Balance- Procedure for Maintenance.	
Unit IV	**DESIGN OF WORK SYSTEMS AND QUALITY CONTROL:** Work Study- Objectives- Procedure- Method Study and Motion Study- Work Measurement-Time Study-Performance Rating- Allowance Factors- Standard Time- Work Sampling Techniques- Job Sequencing and Scheduling. Quality Control; Purpose of Inspection and Quality Control- Different Types of Inspection- Acceptance Sampling- The Operating Characteristic Curve- Control Charts for Variables and Attributes.	12
Unit V	**SERVICE OPERATIONS MANAGEMENT:** Introduction to Services Management- Nature of Services- Types of Services- Service Encounter-Designing Service Organizations- Service Facility Location and Layout- Service Blueprinting-Waiting Line Analysis for Service Improvement- Service Processes and Service Delivery.	12
	Total Hours	**60**
Reference Books		
1.	Chary, S.N., Production and Operations Management, 5th Edition, Tata McGraw-Hill, 2012.	
2.	Gore, A. and Panizzolo, R., Operations Management, Cengage Learning India, 2012.	
3.	Heizer, J., Render, B. and Rajashekhar, J., Operations Management, 9th Edition, Pearson, 2009.	
4.	Krajewski, L., Operations Management; Processes and Supply Chains, 9th Edition, Pearson, 2011.	
5.	Metters, R., .King-Metters, K.H., Pullman, M. and Walton, S., Successful Service Operations Management, Cengage Learning, 2nd Edition 2012.	
6.	Panneerselvam. R, Production and Operations Management, 3rd Edition, PHI Learning, 2012.	
E-Sources		
1.	lib.mdp.ac.id/ebook/.../Karya%20Umum-Operations%20Management.pdf	
2.	www.shsu.edu/~mgt_ves/mgt560/ServiceManagement.ppt	
3.	dl4a.org/uploads/pdf/Ebook%20for%20production%20and%20operations%20 management.pdf	
4.	https://www.mheducation.co.uk/he/chapters/9780077133016.pdf	

5.	zums.ac.ir/files/research/site/ebooks/strategy/operations-strategy.pdf		
Assessment Tools Used			
1.	Assignments	6.	Group Discussion
2.	Internal Assessment Tests	7.	Simulation
3.	Model Exam	8.	Videos
4.	Seminars	9.	Synetics
5.	Case studies	10.	Quiz
Content Beyond Syllabus			
1.	Operations strategy		
2.	Total Quality Management		
3.	Statistical Quality Control		
4.	Lean Management		
5.	Supply Chain Management		
Additional Reference Books			
1.	William J Stevenson, Operations Management, Tata McGraw Hill, 12th Edition, 2015.		
2.	Russel and Taylor, Operations Management, Wiley, 9th Edition, 2016.		
3.	Aswathappa K and Shridhara Bhat K, Production and Operations Management, Himalaya Publishing House, Revised Second Edition, 2008.		
4.	Mahadevan B, Operations Management Theory and practice, Pearson Education, 2007.		

Course Outcomes		
CO No.	On completion of this course successfully, the students will;	**Program Outcomes (PO)**
C205.1	Be aware on the concepts of production design, capacity planning and make or buy decisions	PO2, PO4
C205.2	Possess knowledge on plant location decisions and utilization of plant layout	PO2, PO7
C205.3	Have better understanding on Inventory models and maintenance techniques.	PO6, PO7
C205.4	Be aware about work study procedures and the importance on quality control tools	PO1, PO2, PO6, PO7
C205.5	Have insight on service operations, service delivery and waiting line analysis	PO6, PO7

UNIT I- INTRODUCTION

Operations

Operations are often defined as a transformation or conversion process wherein inputs such as materials, machines, labour and capital are transformed into outputs (goods and services). Operations are useful actions or activities which are done methodically as part of plan of work by a process that is designed to achieve the pre-decided objectives.

Operations Management

Operations Management refers to a set of activities that creates value in the form of goods and/or services by transforming inputs into outputs. Operations management designs and operates productive systems or operating systems such as banks, hospitals, hotels, government agencies and manufacturing plants. Operations management includes activities such as organising work, selecting processes, arranging layouts, locating facilities, designing jobs, measuring performance, controlling quality, scheduling work, managing inventory and planning production.

INPUT
Land, Material, Labour & Capital

PROCESS
Conversion Process

OUTPUT
Goods & Services

Feedback | CONTROL | Feedback

Difference between Goods and Services

(i) Services are usually ***intangible*** whereas goods are ***tangible*** (*i.e.*, can be touched and seen)

(ii) Services are often ***produced and consumed simultaneously***, services cannot be stored whereas goods can be produced and inventoried before consumption or use.

(iii) Services are often ***unique***, for example insurance policies, medical treatment procedures, haircut styles, *etc.*

(iv) Services have ***high customer interaction,*** services are often difficult to standardize and automate because customer interaction demands uniqueness. The service product may have to be customized in most of the service offerings.

(v) Services are often ***knowledge based*****,** for example educational, health-care, legal and consultancy services and, therefore, difficult to standardize and automate.

(vi) Services are frequently ***dispersed*** because services may have to delivered to the client/customer at his/her place or office, a retail outlet or even at the residence of the customer/client.

(vii) Goods can be inventoried and can be resold whereas reselling of services is unusual and services cannot be inventoried.

(viii) Some aspects of quality of goods are measurable whereas many aspects of quantity of services are difficult to measure.

(ix) Selling and production are distinct in case of goods whereas in case of services selling is often a part of the service.

(x) Goods can be transported whereas service cannot be transported but the service provider can be transported.

(xi) Location of facility to manufacture goods, affects costs whereas location of service facility affects customer contact.

(xii) Manufacturing of goods can be easily automated whereas service is

often difficult to automate.

Distinction between Production Management and Operations Management Production Management refers to the application of management principles to the production function in a productive system such as a factory or a manufacturing plant. (e.g., steel plant, cement plant, etc.). It involves application of planning, organizing, directing and controlling the production processes employed for the conversion of inputs into outputs in a productive system.

Operations Management refers to a set of activities that creates value in the form of goods and/ or services by transforming inputs into outputs. Operations management designs and operates productive systems or operating systems such as banks, hospitals, hotels, government agencies and manufacturing plants. Operations management includes activities such as organizing work, selecting processes, arranging layouts, locating facilities, designing jobs, measuring performance, controlling quality, scheduling work, managing inventory and planning production.

The two apparent differences between production management and operations management are:

(i) The term "production management" is mainly used for a productive system where tangible good are produced; whereas the term "operations management" is more frequently used where various inputs are transformed into intangible services.

(ii) Operations management is the more recent term used to activities involved in the process of transforming inputs into outputs (goods and/or services) in a productive system, whereas the term "production management" (or manufacturing management) was used earlier to refer to activities related to the process of transforming inputs into outputs (mainly tangible goods).

Nature and Scope of Operations Management

The scope of operations management is very vast and covers the following activities:

- Selection of location
- Forecasting
- Capacity planning
- Scheduling
- Managing inventories
- Assuring quality
- Motivating employees

- Deciding where to locate facilities
- Design of work system
- Operations planning and control
- Resource requirement planning
- Capacity requirement planning
- Project management
- Quality management

Historical Development of Operations Management

The production of goods for sale and the modern factory system had their roots in the Industrial Revolution (which began in the 1770's in England and spread to other countries in

Europe and later to the US in 19th century). However, the substitution of machine power to human power started with the most significant invention of steam engine by James Watt in 1764. followed by invention of spinning jenny (1770) and powerloom (1785). Adam Smith advocated the concept of "division of labour" in his book "The Wealth of Nations" in 1776 and in 1832, Charles Babbage recommended the use of scientific methods for analysing production problems.

However, the era of scientific management started with the work of F.W. Taylor in 1878 who studied work methods in great detail to identify the best methods for doing each job. Taylor's book "The Principles of Scientific Management" published in 1911, laid the foundation for the field of production management.

A number of other pioneers also contributed to this movement including the following :

- Frank Gilbreth and his wife Lillian Gilbreth were recognized for their contribution to the development of the "Principles of motion economy" and the concept of "Therbligs" in 1911.
- Henry Gantt recognized the value of non-monetary rewards to motivate workers and developed widely used system of scheduling (machine loading) called "Gantt chart" in 1912
- Harrington Emerson applied Taylor's ideas to develop organisational structure and encouraged the use of experts to improve organisational efficiency.
- Henry Ford developed the concept of mass production and assembly

lines with conveyors in 1913, in his automobile plant. Ford also used the concepts of "interchangeable parts" and division of labour (of Adam Smith) which enabled him to tremendously increase the production rate in his factories.

- F.W. Harris developed the concept of "Economic Order Quantity" in 1915 which is still recognized as a classical work in inventory control systems. In 1931, Dodge and Romig and W. Shewhart developed the concept of sampling inspection and use of statistical tables for acceptance sampling plans. Earlier in 1924,
- Shewhart developed the concept of statistical quality control and use of control charts to control the quality of on-going processes.
- The "human relations movement" was started by Elton Mayo in 1930's, through his famous experiments at Western Electric's Hawthorne plant and his findings came to be known as "Hawthorne effect". His studies revealed that in addition to physical and technical aspects of work, worker motivation is critical for improving productivity.

- During the 1940's, Abraham Maslow developed motivational theory known as "Hierarchy of Needs Theory" which was later refined by Frederick Herzberg as "Motivation-Hygiene" theory in 1950s. Douglas McGregor added "Theory X" and "Theory Y" in 1960. In 1970, William Ouchi added "Theory Z" which combined the Japanese approach and the traditional Western approach to management.
- After World War II, operations research and quantitative techniques were applied to production management resulting in decision models for forecasting, inventory management, project management and other areas of production management. Widespread use of personal computers and user-friendly software's have popularized application of these quantitative techniques in production management since the 1980's.
- Development in Management Information Systems (MIS) and Decision Support Systems (DSS) provided a further boost to the developments in production management. Advanced manufacturing technology enabled production managers to use Computer-Aided-Design (CAD), Computer-Aided-Manufacturing (CAM), Computer Numerically Controlled (CNC) machines, Robots, Computer Integrated Manufacturing (CIM), Flexible Manufacturing System (FMS), etc., in the field of production management.
- Moreover, a number of Japanese manufacturers have developed modern management practices that have increased the productivity of their operations and the quality of their products. The new approaches in

production management emphasize quality (Total Quality Management) and continuous improvement (Kaizen), worker teams and empowerment to achieve customer satisfaction. The Japanese have spawned the "quality revolution" and adopted Just-In-Time (JIT) production system to put themselves in the forefront of time-based competition

Objectives of Operations Management

Some of the important objectives of operations management are :

(i) Maximum customer satisfaction through quality, reliability, cost and delivery time.

(ii) Minimum scrap/rework resulting in better product quality.

(iii) Minimum possible inventory levels (*i.e.,* optimum inventory levels).

(iv) Maximum utilization of all kinds of resources needed.

(v) Minimum cash outflow.

(vi) Maximum employee satisfaction.

(vii) Maximum possible production (*i.e.,* outputs).

(viii) Higher operating efficiency.

(ix) Minimum production cycle time.

(x) Maximum possible profit or return on investment.

(xi) Concern for protection of environment.

(xii) Maximum possible productivity

Functions of Operations Management / Key functions of an Operations Manager

Operations Management is a branch that deals with managing operations and processes within the organisation. Efficacious management of operations ensures successful delivery of the project. The operation managers optimize the operations by making judicious use of resources and capital. They manage all the aspects related to the operations that take place in businesses. Operation managers are not only found in a company but also in manufacturing units. They are required to perform various functions as a part of their job responsibilities. Some of the key functions of an Operations Manager include:

- Managing finance

Finance plays a chief role in operations management. It is essential to ensure that the organization's finance has been utilized properly to carry out major functions such as the creation of goods or services so that the customer's needs could be satisfied.

- Operation

This function in operation management is mainly concerned with planning, organizing, directing and controlling all the activities of an organisation which helps in converting the raw materials and human efforts into valuable goods and services for satisfying customer needs.

- Strategy

Strategy in operation management refers to planning tactics that could help them to optimize the resources and have a competitive edge over others. Business strategies imply to supply chain configuration, sales, capacity to hold money, optimum utilization of human resources and many more.

- Design of the product

Incorporating innovative technologies play a crucial role in the selling of a product. Thus it is the duty of operations manager to ensure that the product is designed catering to the market trends and needs of the customers. The modern-day customers are more concerned about the quality of the product than its quantity. So, the operation managers focus on producing top- notch quality products.

- Forecasting

Forecasting refers to the process of making an estimation regarding certain events that might occur in the future. In operation management, forecasting refers to the estimation of customer's demand so that production can be done accordingly. Through this, the manager gets to know what to produce, when to produce and how to produce in accordance with the customer's needs.

- Supply Chain Configuration

The main motive of Supply Chain Configuration is to ensure effective management, monitoring and controlling of all the main activities that are held in a firm. The supply chain configuration starts from the supply of the raw materials and continues till the production of the final product and then their selling to the customers which will satisfy their needs and wants.

- Managing the Quality

Quality management plays an imperative role in selling a product. The operation manager allocate the task of quality management to a team and then supervise their task. The managers identify project defects and rectify them to ensure quality. For this, certain systems are used that measure and maintain the quality of the product.

Issues related to decisions

The problems involved in production management require two major types of decisions relating to :

(i) Design of the production system and

(ii) Operation and control of the production system.

Decisions related to the design of production system are long-run decisions whereas, decisions related to operations and control of the production system are short-run decisions. The problems involve the relative balance of the emphasis on such factors as cost, service and reliability of both functional and time performance, which depends on the basic purposes of the total enterprise and on the general nature of goods and services produced. In general, manufacturing organizations emphasize more on cost, consistent with quality and delivery commitments whereas, service organizations may emphasize reliability and service, consistent with cost objectives (*for example,* hospitals).

Long-Run Decisions

Long-run decisions related to the design of the production system are:

(i) **Selection and Design of Products**: Product selections and designs with productive capability are interdependent.

(ii) **Selection of Equipment and Processes:** Selection of the most economic equipment and processes among the various alternatives considered, the firm's capability to invest in capital assets and its basic approach to production (*i.e.,* job, batch, mass or continuous production) must be considered.

(iii) **Production Design of Parts Processed**: Production design aims at selection of equipment, processes, and tools for economic production which set limits on the cost of outputs.

(iv) **Job Design:** It involves basic organisation of work as well as matching workers to their jobs in order to reduce fatigue and improve productivity.

(v) **Location of the System:** It is a trade-off decision since there is no one best location for a productive system to be located. The balance of cost factors determined by various considerations is critical.

(vi) **Facility Layout**: This involves decisions related to design capacity, basic modes of production, shifts of working, use of overtime and subcontracting. In addition, operations and equipment must be located in relation to each other such that the overall material handling cost is minimized. Other factors involved are heating, lighting and other utility requirements, the allocation of storage

space, washing space and the design of the building to house the layout.

Short-Run Decisions

Short-run decisions related to the operations and control of the system are :

(i) **Inventory and Production Control:** Decisions made are concerned with allocation of productive capacity consistent with demand and inventory policy. Feasible schedules must be worked out and the load on machines and labour and the flow of production must be controlled.

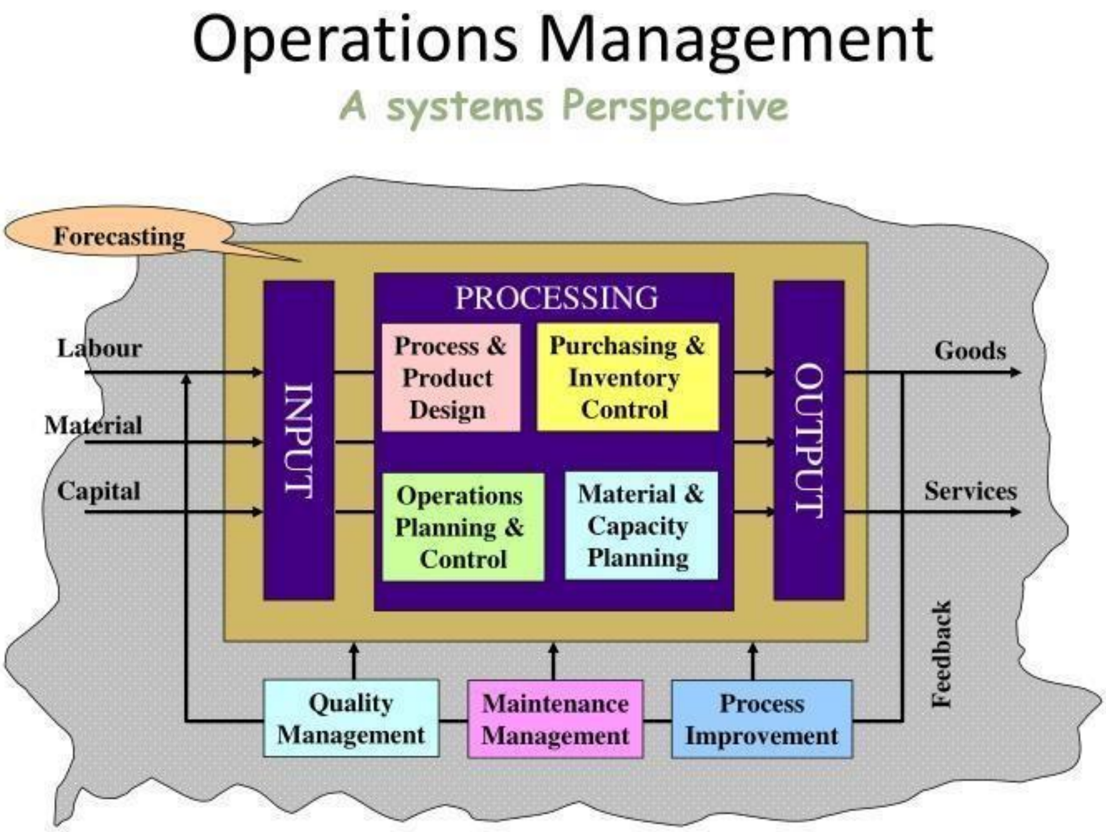
(ii) **Maintenance and Reliability of the System:** Decisions must be made regarding the maintenance effort, maintenance policy and practice recognizing the fact that machine down time may lead to idling of labour and production stoppage resulting in lost sales.

(iii) **Quality Control:** Decisions must be made to set permissible levels of risk that bad parts are produced and shipped or the risk that good parts are scrapped due to sampling inspection. Inspection costs must be balanced with the probable losses due to passing defective materials or products. Decisions regarding controlling the quality of on-going processes must be taken.

(iv) **Labour Control:** Labour is the major cost element in most products and services. Hence, work measurement and wage incentive systems must be developed to control labour costs and to increase labour productivity.

(v) **Cost Control and Improvement:** Day-to-day decisions which involve the balance of labour, material and overhead costs must be made by production supervisors.

A SYSTEM PERSPECTIVE - OPERATIONS MANAGEMENT



Systems Approach To Operations Management

An organized enterprise does not, of course, exist in a vacuum. Rather, it is dependent on its external environment; it is a part of larger systems such as the industry to which it belongs, the economic system, and society. Thus, the enterprise receives inputs, transforms them, and exports the outputs to the environment

- **Inputs and Claimants**

The inputs from the external environment may include people, capital, and managerial skills, as well as technical knowledge and skills. In addition, various groups of people will make demands on the enterprise. For example, employees want higher pay, more benefits, and job security. On the other hand, consumers demand safe and reliable products at reasonable prices. Suppliers want assurance that their products will be bought. Stockholders want not only a high return on their investment but also security for their money. Federal, state, and local governments depend on taxes paid by the enterprise, but they also expect the enterprise to comply with their laws. Similarly, the community demands that enterprises be good citizens providing the maximum number of jobs with a minimum of pollution. Other claimants to the enterprise may include financial institutions and labor unions; even competitors have legitimate claim for fair play. It is clear that many of these claims are incongruent, and it is manager's job to integrate the legitimate objectives of the claimants.

- **The Managerial transformation Process**

It is the task of managers to transform the inputs, in an effective and efficient manner, into outputs. Of course, the transformation process can be viewed from different perspective. Thus, one can focus on such diverse enterprise functions as finance, production, personnel, and marketing. the most comprehensive and useful approach for discussing the job of managers is to use the managerial functions of planning, organizing, staffing, leading, and controlling as a framework for organizing managerial knowledge.

- **The Communication System**

Communication is essential to all phases of the managerial process for two reasons. First, it integrates the managerial functions. For example, the objectives set in planning are communicated so that the appropriate organization structure can be devised. Communication is essential in the selection, appraisal, and training of managers to fill the roles in this structure. The second purpose of the communication system is to link the enterprise with its external environment, where many of the claimants are.

- **External Variables**

Effective managers will regularly scan the external environment. While it is true that managers may have little or no power to change the external environment, they have no alternative but to respond to it.

- **Outputs**

It is the task of managers to secure and utilize inputs to the enterprise, to transform them through the managerial functions — with due consideration for external variables to outputs.

Although the kinds of outputs will vary with the enterprise, they usually include many of the following: products, services, profits, satisfaction, and integration of the goals of various claimants to the enterprise.

Challenges in Operations Management / Challenges faced by Operations Manager

The key challenges facing service operations managers are:

- **Managing multiple customers**

Many service organizations often serve heterogeneous group of customers, in different ways and different types of customers. Understanding who the curious customers are, understanding their needs and expectations, developing relationships with them and managing the various customers are key tasks for service operations managers.

- **Understanding the service concepts**

There may be differing views about what service an organisation is selling and/or the customer is buying. Articulating and communicating the service concept is critical for classifying the organisation service product to all its customers and for ensuring that it can be delivered to customer specification.

- **Managing the outcome and experience**

For many services, there is no clear boundary between experience and the outcome. E.g. customers in a restaurant are buying both the meal and the way they are served. The intangible nature of the experience provides particular problems for both specification and control.

- **Managing the real time**

Many services happen in real time. They cannot be delayed or put-off. e.g. aircrafts coming into land cannot be put on hold while controllers take a break.

Also, during a service encounter, it is not possible to undo what is done. In manufacturing operations it is possible to scrap defective products and remake them, but in service operations it is not possible to undo defective service rendered to a customer.

- **Knowing, implementing and influencing strategy**

Operations which are the doing part of the business are also responsible for implementing strategy of the service organisation. Service operations managers must understand their role, not only in implementing strategy but also in contributing to it or influencing the strategy.

Service operations managers need to provide platform for their organizations for competitive advantage through competence in service operations.

- **Continually improving operations**

Service operations managers are faced with a challenge of how continually to improve and develop their real improvements. They should manage the increased complexity resulting from change and also improve efficiency as well as quality of service operations.

- **Encouraging innovations**

Innovation looks for what is new rather than improving the existing service operations usually require elements of financial risk because innovations require time and money and personal risk for service managers champion change putting their reputation on the line.

- Managing short term and long term issues simultaneously

Organizations are under pressure to perform in the short term which leaves little time for medium term operational improvement or long term strategic planning.

Many service operations managers focus their time and effort on managing day to day operations to ensure the delivery of an appropriate quality of service operations management are frequently neglected .

Recent trends in Operations Management

Many recent trends in operations management relate to global competition and the impact it has on manufacturing firms. Some of the recent trends are:

1. **Global Market Place:** Globalisation of business has compelled many manufacturing firms to have operations in many countries where they have certain economic advantage. This has resulted in a steep increase in the level of competition among manufacturing firms throughout the world.
2. **Production/Operations Strategy:** More and more firms are recognizing the importance of production/ operations strategy for the overall success of their business and the necessity for relating it to their overall business strategy.
3. **Total Quality Management (TQM):** TQM approach has been adopted by many firms to achieve customer satisfaction by a never-ending quest for improving the quality of goods and services.
4. **Flexibility:** The ability to adapt quickly to changes in volume of demand, in the product mix demanded, and in product design or in delivery schedules, has become a major competitive strategy and a competitive advantage to the firms. This is sometimes called as agile manufacturing.

5. **Time Reduction:** Reduction of manufacturing cycle time and speed to market for a new product provide competitive edge to a firm over other firms. When companies can provide products at the same price and quality, quicker delivery (short lead times) provides one firm with competitive edge over the other.

6. **Technology:** Advances in technology have led to a vast array of new products, new processes and new materials and components. Automation, computerization, information and communication technologies have revolutionized the way companies operate. Technological changes in products and processes can have great impact on competitiveness and quality, if the advanced technology is carefully integrated into the existing system.

7. **Worker Involvement:** The recent trend is to assign responsibility for decision making and problem solving to the lower levels in the organisation. This is known as employee involvement and empowerment. Examples of worker involvement are quality circles and use of work teams or quality improvement teams.

8. **Re-engineering:** This involves drastic measures or break-through improvements to improve the performance of a firm. It involves the concept of clean-slate approach or starting from scratch in redesigning the business processes.

9. **Environmental Issues:** Today's production managers are concerned more and more with pollution control and waste disposal which are key issues in protection of environment and social responsibility. There is increasing emphasis on reducing waste, recycling waste, using less-toxic chemicals and

using biodegradable materials for packaging.

10. **Corporate Downsizing (or Right Sizing):** Downsizing or right sizing has been forced on firms to shed their obesity. This has become necessary due to competition, lowering productivity, need for improved profit and for higher dividend payment to shareholders.

11. **Supply-Chain Management:** Management of supply-chain, from suppliers to final customers reduces the cost of transportation, warehousing and distribution throughout the supply chain.

12. **Lean Production:** Production systems have become lean production systems which use minimal amounts of resources to produce a high volume of high quality goods with some variety. These systems use flexible manufacturing systems and multi-skilled workforce to have advantages of both mass production and job production (or craft production).

MANUFACTURING TRENDS IN INDIA

- Today many sections of the Indian manufacturing sector are extremely innovative. Among such innovative manufacturing sectors are the automotive sector, auto- components sector, assembly lines, IT manufacturing sector, and small components manufacturing sector.
- The Indian government has aimed to increase the domestic manufacturing sectors share to 25% of GDP by 2022. This will be made possible in some part by greater innovation in Indian industry.
- One of the growth drivers behind the success of the Indian manufacturing sector is the use of **innovative technology**. Behind the success of such innovative technology is a greater willingness on the part of Indian firms to spend on R&D.

- Over the past decade, India's expenditure in science has increased three-fold and the countries share of global patents has been increasing as well.

Benefits of Increased R&D Spending

- India's expenditure on R&D as a percentage of GDP has remained stagnant at 0.6 to
  0.7 of GDP, however GDP has increased and so has the sum spent on R&D. Greater spending on R&D leads to innovation.
- Such innovation is visible among a handful of private Indian companies who are innovating in the personal protective equipment (PPE) space. Such innovation includes manufacturing PPE that meets the newest European Norms (EN).
- Also, one of the largest truck manufactures in India by using R&D is manufacturing trucks that are better suited to Indian roads. Such trucks produce the right amount of power, have an ideal suspension, offer excellent mileage, and rarely break down. Small components manufacturers in India are spending on R&D to manufacture better tools and in hydro-forming, robotics and other areas. A number of such manufacturers supply to overseas and domestic automotive giants.

Automation in Domestic Manufacturing

- One of the innovations of Indian industry is the use of automation in a variety of tasks. Along numerous assembly lines in India industrial robots are working alongside human workers.
- The use of industrial robots in India is not nearly as widespread as their use in more developed economies. However the fact that they are being used in a country that is

still overwhelmingly dependent on human capital for labour points to a uniquely Indian business innovation.

- Gradually the use of automation in India will increase and unlike many experts' predictions, widespread automation in Indian factories should be expected sooner rather than later. Because increases in productivity raise standards of living, automation holds the potential to raise living standards drastically.
- The need to invest in large scale automation is imperative because an economy that doesn't will be at risk of being forever left behind those which do.

AI and Technology Driven Innovation

- Almost certainly the potential for AI in the manufacturing sector is immense. Although today the use of AI in Indian manufacturing is not widespread it is growing, and its use is common among newly formed startups in the manufacturing space. Society needs to be prepared for a series of AI led disruptions over the next few decades.
- When technology is disruptive it creates new opportunities for consumers. Disruptive technologies today are one of the key drivers of economic growth globally. Such technologies have nearly transformed what many urban and rural consumers in India do in their daily lives. These same technologies are also transforming the countries manufacturing sector.
- **In the future, the impact of technologies such as Digital Supply Chains, Big Data, Internet of Things (IoT), AI, and robotics will be even more acutely felt by the Indian manufacturing sector.**

While India is still a developing country, it climbed 3 spots to the 57th position on the Global Innovation Index (GII) in 2018. The rise in the GII is certainly a reason for cheer yet India holds the potential to do much more.

PRODUCT DESIGN

Product design is the process of deciding on the unique characteristics and features of the company's product. Process selection is the development of the process necessary to produce the designed product. Product design and process selection are typically made together.

Product design must support product manufacturability (the ease with which a product can be made).

Product design defines a product's characteristics of;

- appearance,
- materials,
- dimensions,
- tolerances, and
- performance standards

A good product design has following common features:

- **Utility:** The product design should make product utility as per expectation of customers and provide steady performance through the product life.
- **Aesthetics:** Product aesthetics is important in success of the product. The product aesthetics is dependent on market and end customer.
- **Producible:** Product design should enable effective production of

product through available production methods.

- **Profitability:** Product design should make economic sense as to deliver value to customer and sustainability to the organization.
- **Differentiable:** A good product design should enable product to be differentiate among its competition. This can be achieved by attractive packaging and also by providing additional service on the product.

Product Design Process

The product design process, as expressed by Koberg and Bagnell, typically involves three main aspects

- **Analysis**
- **Concept**
- **Synthes**

is Analysis

- **Accept Situation:** Here, the designers decide on committing to the project and finding a solution to the problem. They pool their resources into figuring out how to solve the task most efficiently.[6]
- **Analyze:** In this stage, everyone in the team begins research. They gather general and specific materials which will help to figure out how their problem might be solved. This can range from statistics, questionnaires, and articles, among many other sources.

Concept

- **Define:** This is where the key issue of the matter is defined. The conditions of the problem become objectives, and restraints on the situation become the parameters within which the new design must be constructed

Synthesis

- **Ideate:** The designers here brainstorm different ideas, solutions for their design problem. The ideal brainstorming session does not involve any bias or judgment, but instead builds on original ideas.
- **Select:** By now, the designers have narrowed down their ideas to a select few, which can be guaranteed successes and from there they can outline their plan to make the product.
- **Implement:** This is where the prototypes are built, the plan outlined in the previous step is realized and the product starts to become an actual object.
- **Evaluate:** In the last stage, the product is tested, and from there, improvements are made. Although this is the last stage, it does not mean that the process is over. The finished prototype may not work as well as hoped so new ideas need to be brainstormed

Factors Affecting Product Design

Correct Team Selection: This is very essential to get the correct team in place which has expert designers who are not only aware and comfortable with technology but also understanding of customer expectation.

Customer Involvement: Involvement of customer in product design and testing can provide insight into the direction of the project

Prototyping and testing: Product design is high risk concept as it involves commitment of capital and man-power; therefore, it is imperative that extensive prototyping and testing are done with customer and market.

Raw Material: It is essential that raw material to be used in the production meets the quality standards of the end product. Furthermore, procurement system needs to be in place to ensure continuous, cost effective supply.

Production method and process layout: Feasibility of production method and process layout determines future success of the product.

External Factors: Environmental and government regulations plays an important part in product design. And these norms are updated from time to time, so product design should have the flexibility to adapt.

PRODUCT DEVELOPMENT

A successful product development requires a total-company effort. The most successful innovating companies make a consistent commitment of resources to product development, design a new product strategy that is linked to their strategic planning process, and set up formal and sophisticated organizational arrangements for managing product development process.

The product development process for finding and growing new products consist of eight major steps as below;

- Idea generation
- Idea screening
- Concept development and testing
- Marketing Strategy Development
- Business analysis
- Product Development
- Test marketing
- Commercialization

PROCESS PLANNING

Process planning is concerned with planning the conversion or transformation processes needed to convert the materials into finished products .A production process is a series of manufacturing operations performed at workstations to achieve the design specifications of the planned output

.A vast number of different operations and various kinds of equipments and machines may be required to produce a complex product (for e.g. an aircraft or a ship). Simpler parts may require fewer operations (for e.g. a bolt and a nut).

Process planning consists of two parts namely

1. **Process design**
2. **Operations design**

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

- The nature of the product
- The materials used
- The quantities being produced
- The existing physical layout of the plant

Process design is not directly concerned with the content of operations constituting the process, or with the detailed method of carrying out the operations. It comes out with recommendations for primary (work station) and secondary equipment (accessories) required for the most effective and efficient production of the products and work flow. The process analysis decisions are reflected in a route sheet. A route sheet normally specifies the sequence of operations in a process by name and numbers. A rout sheet is prepared for each component.

Operation design:

Operations design is concerned with the design of the individual manufacturing operations .It consists of examining the man-machine relationship in the manufacturing process for converting the raw materials into the finished or semi-finished product .Operations design must specify how much of man and machine time is required for each unit of production.

Operation design is concerned with the work content constituting the operation and method of performing the work, given the resources allocated to the process. Similar to process design, operation design generates an operation sheet. It specifies the steps and elements of work for each operation. These are specified in a proper sequence. Together with the route sheet and operation sheet provide all the information required to perform a process effectively and efficiently.

Principles of Process Planning

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.

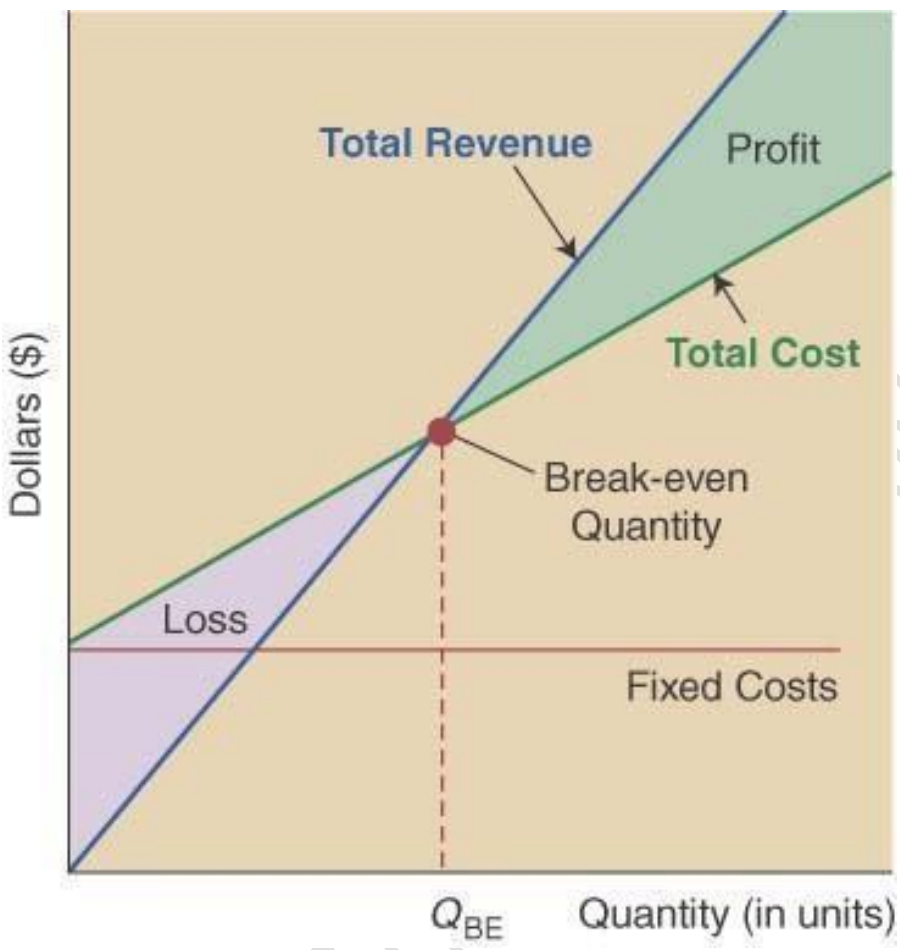
Process planning in manufacturing may include the following activities:

1. Selection of raw-stock,
2. Determination of machining methods,
3. Selection of machine tools,
4. Selection of cutting tools,
5. Selection or design of fixtures and jigs,
6. Determination of set-up,
7. Determination of machining sequences,
8. Calculations or determination of cutting conditions,
9. Calculation and planning of tool paths,
10. Processing the process plan

BREAK-EVEN ANALYSIS

Break-even analysis is a technique widely used in production management. It is based on categorizing production costs between those which are "variable" (costs that change when the production output changes) and those that are "fixed" (costs not directly related to the volume of production). The variable and fixed costs are compared with sales revenue in order to determine the level of sales volume, sales value or production at which the business makes neither a profit nor a loss (the "break-even point").

The Break-Even Chart: The break-even chart is a graphical representation which represents the relationship between the various costs of production with the volume of production.



- The point at which neither profit nor loss is made is known as the "break-even point (BEP)" and is represented on the break-even chart by the intersection of the lines representing total cost and total revenue.
- As output increases, variable costs incurred increases, meaning that total costs (fixed + variable) also increase. At low levels of output, costs are greater than revenue or income. At the point of intersection, BEP, total costs are

exactly equal to total revenue or income, and hence neither profit nor loss is made.

PRODUCTION SYSTEM

The production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management.

Characteristics of a production system:

1. Production is an organized activity, so every production system has an objective.
2. The system transforms the various inputs to useful outputs.
3. It does not operate in isolation from the other organization system.
4. There exists a feedback about the activities, which is essential to control and improve system performance.

Classification of Production System

1. **Intermittent production**
   a. **Job shop (eg., dam building, aircraft fabrication)**
   b. **Batch (eg., textiles, furniture)**
2. **Continuous production**
   a. **Mass (eg., soaps, chocolates, automobile assembly line)**
   b. **Flow process (eg., oil refining, chemicals)**

1. INTERMITTENT PRODUCTION

- Intermittent means something that starts (initiates) and stops (halts)at irregular (unfixed) intervals (time gaps).
- In the intermittent production system, goods are produced based on customer's orders.
- These goods are produced on a small scale.
- The flow of production is not continuous.
- In this system, large varieties of products are produced. These products are of different sizes.

- The design of these products goes on changing according to the design and size of the product. Therefore, this system is very flexible

a. **JOB SHOP PRODUCTION**

- Job shop production are characterised by manufacturing of one or few quantity of products designed and produced as per the specification of customers within prefixed time and cost. The distinguishing feature of this is low volume and high variety of products.
- A job shop comprises of general purpose machines arranged into different departments.
- Each job demands unique technological requirements, demands processing on machines in a certain sequence.

Characteristics of Job shop production

The Job-shop production system is followed when there is:

- High variety of products and low volume.
- Use of general purpose machines and facilities.
- Highly skilled operators who can take up each job as a challenge because of uniqueness.
- Large inventory of materials, tools, parts.
- Detailed planning is essential for sequencing the requirements of each product, capacities

Advantages of job shop production:

- Because of general purpose machines and facilities variety of products can be produced.
- Operators will become more skilled and competent, as each job gives them learning opportunities.
- Full potential of operators can be utilized.
- Opportunity exists for creative methods and innovative ideas.

Limitations of Job shop production

- Higher cost due to frequent set up changes.
- Higher level of inventory at all levels and hence higher inventory cost.
- Production planning is complicated.
- Larger space requirements.

b. BATCH PRODUCTION

Batch production is defined by American Production and Inventory Control Society (APICS) "as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing." It is characterised by the manufacture of limited number of products produced at regular intervals and stocked awaiting sales.

Characteristics of Batch production

Batch production system is used under the following circumstances when:

- There is shorter production runs.
- Plant and machinery are flexible.

- Plant and machinery set up is used for the production of item in a batch and change of set up is required for processing the next batch.
- Manufacturing lead time and cost are lower as compared to job order production.

Advantages of batch production:

- Better utilization of plant and machinery.
- Promotes functional specialisation.
- Cost per unit is lower as compared to job order production.
- Lower investment in plant and machinery.
- Flexibility to accommodate and process number of products.
- Job satisfaction exists for operators.

Limitations of Batch production

- Material handling is complex because of irregular and longer flows.
- Production planning and control is complex.

2. CONTINUOUS PRODUCTION

Production facilities are arranged as per the sequence of production operations from the first operations to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc.

Characteristics of Continuous production

- Dedicated plant and equipment with zero flexibility.
- Material handling is fully automated.

- Process follows a predetermined sequence of operations.
- Component materials cannot be readily identified with final product.
- Planning and scheduling is a routine action.

Advantages of Continuous production

- Standardization of product and process sequence.
- Higher rate of production with reduced cycle time.
- Higher capacity utilization due to line balancing.
- Manpower is not required for material handling as it is completely automatic.
- Person with limited skills can be used on the production line.
- Unit cost is lower due to high volume of production.

Limitations of Continuous production

- Flexibility to accommodate and process number of products does not exist.

- Very high investment for setting flow lines.
- Product differentiation is limited.

a) **MASS PRODUCTION**

- Manufacture of discrete parts or assemblies using a continuous process are called mass production.
- This production system is justified by very large volume of production. The machines are arranged in a line or product layout.
- Product and process standardization exists and all outputs follow the same path.

Characteristics of Mass production

- Standardization of product and process sequence.
- Dedicated special purpose machines having higher production capacities and output rates.
- Large volume of products.
- Shorter cycle time of production.
- Lower in process inventory.
- Perfectly balanced production lines.
- Flow of materials, components and parts is continuous and without any back tracking.
- Production planning and control is easy.
- Material handling can be completely automatic.

Advantages of Mass production

- Higher rate of production with reduced cycle time.

- Higher capacity utilization due to line balancing.
- Less skilled operators are required.
- Low process inventory.
- Manufacturing cost per unit is low.

Limitations of Mass production

- Breakdown of one machine will stop an entire production line.
- Line layout needs major change with the changes in the product design.
- High investment in production facilities.
- The cycle time is determined by the slowest operation.

b) FLOW PROCESS PRODUCTION

Flow production is a process in which homogeneous products are produced continuously. This production approach reduces cost and increases efficiency. These systems are highly automated, and workers act as monitors rather than as active participants.

Characteristics of Flow process production

- Material handling is fully automated.
- Very less work in process inventory, as material flow is continuous
- Component materials cannot be readily identified with final product.
- Production Planning and scheduling can be predefined.

PLANT CAPACITY

The upper limit or ceiling on the load that an operating unit can handle is called its capacity. Plant Capacity is the rate of productive capability of a facility. The operating unit might be a plant, department, machine, store, or worker.

The load can be specified in terms of either inputs or outputs. To understand these consider the following examples.

• **Capacity in respect of capability**: Airlines capacity measures their capacity in Available Seat Miles (ASMs) over a year. Or hospitals may measure its capacity in number of beds available. However this measure is incorrect, as it doesn't consider outpatient treated by the hospital.

• **Capacity in respect of inputs**: A machine is able to process 120 pounds of raw materials in every hour it works, so its input capacity is 120- pounds/hour.

• **Capacity in respect of outputs**: A machine can produce 20 units of finished goods in every hour it works, so its output capacity is 20 units/hour.

CAPACITY PLANNING

Capacity Planning is the process of determining the production capacity needed by an organisation to meet changing demands for its products. It is the process used to determine how much capacity is needed (and when) in order to manufacture greater product or begin production of a new product. Capacity planning is central to the long term success of an organisation.

Capacity planning is generally viewed in terms of three time horizons or durations.

- **Long Range Capacity Planning** which is usually having a time horizon of more than one or two years. It is carried out for productive resources which take a long time to acquire or dispose of such as buildings, equipment or facilities such as machinery, materials handling equipments and transportation vehicles etc.
- **Intermediate Range Capacity Planning** which has a time horizon or duration for the next 6-18 months. The intermediate range capacity may be varied by such alternatives such as hiring or laying off labour, purchasing or making new tools and minor equipments and outsourcing/subcontracting etc.
- **Short Range Planning** which has a time horizon or duration of less than one month. This is concerned with day to day planning such as daily scheduling of activities and machine loading or weekly scheduling process which involves making adjustments to eliminate the variance between planned output and actual output. It is concerned with overtime, transfer of personnel and changing the production routings.

ESTIMATING THE CAPACITIES OF EXISTING FACILITIES

To estimate the capacities of existing facilities in a firm, it is necessary to know about the various types of capacity and the measures of capacity

Types of capacity

Production capacity: It is the maximum rate of production (or output) of an organisation. Several factors underlying the concept of capacity make its understanding and use somewhat complex. Variation in employee absenteeism, equipment breakdowns, vacations, holidays, delays in material procurement/delivery, work schedules, working hours, use of overtime, temporary workers, outsourcing etc., must be taken into account when estimating the production capacity.

Design capacity: It refers to the maximum output that can possibly be attained. It is the maximum rate of output achieved under ideal conditions.

Effective capacity: It is the maximum possible output given a product mix, scheduling difficulties, machine maintenance, quality factors, absenteeism etc. Effective capacity is usually less than design capacity because of capacity losses due to realities such as product mix changes, need for periodic preventive maintenance of equipment, problems in scheduling and balancing operations, coffee breaks, lunch breaks and so on.

Maximum capacity: It is also known as **Peak capacity**, it is the maximum output that a facility can achieve under ideal conditions. Where capacity is measured relative to equipment alone, it is known as related capacity.

Measures of capacity

Different measures of capacity are applicable in different situations. For example, capacity of an automobile plant can be measured in terms of the number of automobiles produced per unit of time whereas capacity of a hospital is measured in terms of the number of patients that can be treated per day.

Therefore, capacity of a facility can be either measured in terms of inputs. An important measure of system effectiveness is the capacity utilisation rate which reveals how close a firm is to its best operating point i.e. design capacity.

Capacity utilisation rate = (Capacity used(i.e.Actual output)) / (Best operating level (or design capacity))

Best operating level is the level of capacity for which the facility was designed and thus is the volume of output at which average unit cost is minimum. Another measure of system effectiveness is efficiency which is the ratio of actual output to the effective capacity.

Efficiency = (Actual Output) / (Effective Capacity)

DETERMINANTS OF EFFECTIVE CAPACITY

a) **Facilities factors: (Design, Location, Layout)**

The design of facilities, including size and provision for expansion, is very important. Location factors, such as transportation costs, distance to market, labor supply, energy sources, and room for expansion, are also important.

b) **Product/service factors: (Design, Product or service mix)**

Product and service design can have a tremendous influence on capacity. For example, when items are similar, the ability of the system to produce those items is generally much greater than when successive items differ. A restaurant that offers a limited menu can usually prepare and serve meals at a faster rate than a restaurant with an extensive menu.

c) **Process factors: (Quantity capabilities, Quality capabilities)**

The quantity capability of a process is an obvious determinant of capacity. A subtler determinant is the influence of output quality. For instance, if quality of output does not meet standards, the rate of output will be slowed by the need for inspection and rework activities.

d) **Human factors: (Job content, Job Design, Training and experience, Motivation, Compensation, Learning rates, Absenteeism and labor turnover)**

The tasks that make up a job, the variety of activities involved, and the training, skill, and experience required to perform a job all have an impact on the potential and actual output.

e) **Operations factors: (Scheduling, Materials management, Quality assurance, Maintenance politics, Quality assurance)**

Scheduling problems may occur when an organization has differences in equipment capabilities among alternative pieces of equipment or differences in job requirements. Inventory stocking decisions, late deliveries, acceptability of purchased materials and parts, and quality inspection and control procedures also can have an impact on effective capacity. Many decisions made concerning system design have an impact on capacity; the same is true for operating decisions.

f) **External Factors: (Product Standards, Safety regulations, Unions, Pollution control standards)**

External factors like product standards, safety regulations, unions, pollution control standards etc are also the determinant factors in the production operation efficiency of a business organization.

STEPS IN CAPACITY PLANNING / PROCEDURE FOR CAPACITY PLANNING

1. Assessment of Existing Capacity

Capacity of a unit can be measured in terms of output or inputs. Output measure is appropriate in case of manufacturing concerns, e.g., automobile plant (number of cars), iron and steel plant (tons of steel), brewery (barrels of bear), cannery (tons of food), power company, (megawatts of electricity), etc. Service concerns like hospitals (number of beds), airlines (number of seats), theatres (number of seats), restaurants (number of tables), university (number of students), warehouse (cubic feet of space), etc., can measure capacity in terms of inputs.

2. Forecasting Future Capacity Needs

Short term capacity requirements can be estimated by forecasting product demand at different stages of the product life cycle.

It is more difficult to anticipate long-term capacity requirements due to uncertainties of market and technology. Capacity forecast helps to determine the gap between the existing capacity and estimated capacity so that necessary adjustments may be made. For example, a company engaged in manufacturing two products may find that one product has a low demand in summer (e.g. coffee or tea) while another product has low demand in winter (e.g. cold drink).

3. Identifying Alternative ways of Modifying Capacity

In case where the existing capacity is inadequate to meet the forecast demand capacity, the expansion is required to meet the shortage. Additional shifts may be employed to expand the capacity. Expansion will provide economies of scale and help in meeting the forecast demand.

But it involves additional investment and danger of fall in forecast demand in future. When the existing capacity exceeds forecast capacity, there is a need for reduction of excess capacity. Developing new products, selling of existing facilities, layout of workers or getting work from other firms are the methods of overcoming it.

4. Evaluation of Alternatives

Various alternatives for capacity expansion or reduction are evaluated from economic, technical and other viewpoints. Reactions of employees and local community should also be considered. Cost Benefit analysis, Decision theory and Queuing theory are the main techniques of evaluating alternatives.

5. Choice of Suitable Course of Action

After performing the cost-benefit analysis of various alternatives to expand or reduce the capacity, the most appropriate alternative is selected.

Major factors considered in capacity planning

- Level of demand

- Cost of production
- Availability of funds
- Management policy.

Importance of Capacity Planning

Capacity planning is important due to the following reasons:

- Capacity limits the rate of output. Therefore, capacity planning determines the ability of an enterprise to meet future demand for its products and services.
- Capacity influences the operating costs. Capacity is determined on the basis of estimated demand. Actual demand is often different from estimated demand. As a result, there arises excess capacity or under capacity. Excess or idle capacity increases the cost per unit of output. Whereas under capacity results in the loss of sales.

- Capacity decisions leave a direct impact on the amount of fixed investment made initially.
- Capacity decisions result in long-term commitment of funds. Such long-term decisions cannot be reversed except at major costs

MAKE OR BUY DECISIONS

The make-or-buy decision is the action of deciding between manufacturing an item internally (or in-house) or buying it from an external supplier (also known as outsourcing). Such decisions are typically taken when a firm that has manufactured a part or product, or else considerably modified it, is having issues with current suppliers, or has reducing capacity or varying demand

Factors favoring make decisions (in-house manufacture)

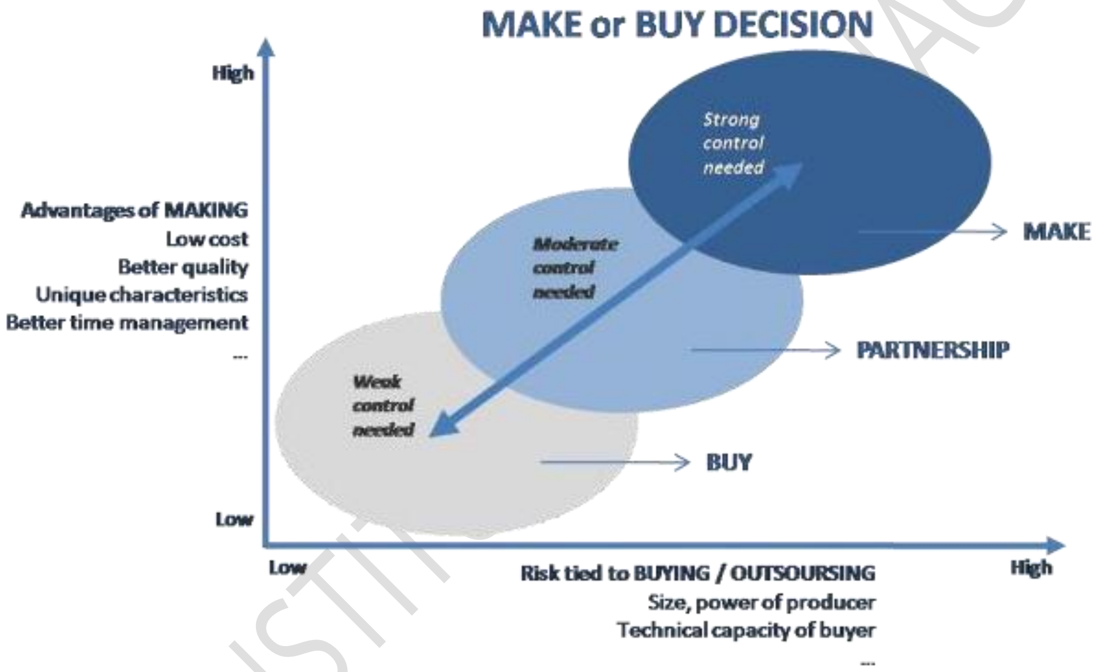
- Wish to integrate plant operations
- Need for direct control over manufacturing and/or quality
- Cost considerations (costs less to make the part)
- Improved quality control
- No competent suppliers and/or unreliable suppliers
- Quantity too little to interest a supplier
- Design secrecy is necessary to protect proprietary technology
- Control of transportation, lead time, and warehousing expenses

- Political, environmental, or social reasons
- Productive utilization of excess plant capacity to assist with absorbing fixed overhead (utilizing existing idle capacity)
- Wish to keep up a stable workforce (in times when there are declining sales)
- Greater guarantee of continual supply

Costs for the make analysis

- Direct labor expenses
- Incremental inventory-carrying expenses
- Incremental capital expenses
- Incremental purchasing expenses
- Incremental factory operating expenses

- Incremental managerial expenses
- Delivered purchased material expenses
- Any follow-on expenses resulting from quality and associated problems



Factors favoring Buy decisions (purchase from outside)

- Suppliers' specialized know-how and research are more than that of the buyer
- Lack of expertise
- Small-volume needs
- Cost aspects (costs less to purchase the item)

- Wish to sustain a multiple source policy
- Item not necessary to the firm's strategy
- Limited facilities for a manufacture or inadequate capacity
- Brand preference
- Inventory and procurement considerations

Cost factors for the buy analysis

- Transportation expenses
- Purchase price of the part
- Incremental purchasing expenses

- Receiving and inspection expenses
- Any follow-on expenses associated with service or quality

Steps In Make or Buy Decision (with an illustration Step 1

Carry out the **quantitative analysis** by comparing the expenses incurred in each option. The expense of purchasing products is the price paid to suppliers to purchase them. On the contrary, the cost of manufacture includes both variable and fixed expenses. For example, a business requires 10 units of its item in 10 consecutive periods. The company can either buy the units at $100 per unit or expend $1,000 to set up manufacture facilities and $8 to manufacture each unit. As the business expends $10,000 to buy the products and $9,000 to manufacture the same quantity of products, with respect to make-or-buy, the business would do better to manufacture the goods, on the basis of only quantitative factors.

Step 2

Think about all the **qualitative factors** that may have a bearing on the decision **to manufacture the products**. This incorporates all pertinent factors that cannot be decreased to numbers such as the quality of the business' production department and its experience. An example for this is that it may be possible that the business has zero experience in manufacturing a specific good and its previous experience in manufacturing other goods cannot be applied.

Step 3

Think about **qualitative factors** that may have a bearing on the decision **to buy the products from external suppliers**. Such factors include: the quality of the suppliers' management, its dependability and the quality of its goods. An example for this is that it is probable that the supplier has considerable experience in manufacturing the item being considered and the business may want to develop a long-term relationship with a supplier.

Step 4

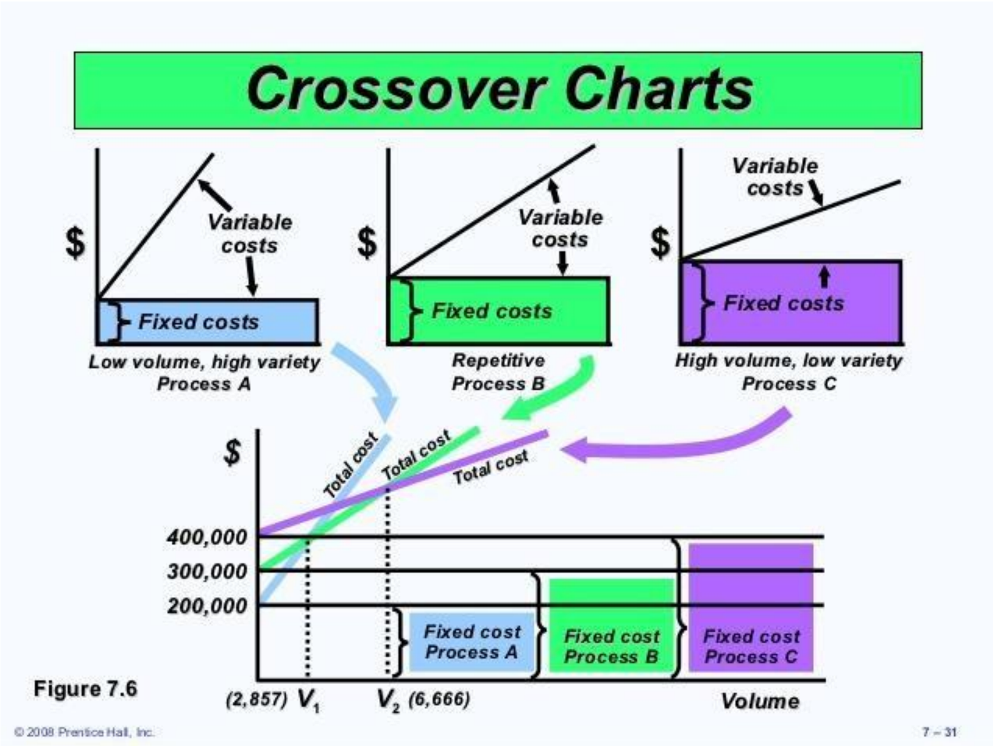
Factor the **qualitative aspects into the quantitative assessment** so as to complete it. An example for this in this case is that: even though it is cheaper for the business to manufacture its products, there are grounds to believe that its goods would be of a lower grade than those it can buy. In addition, as the business desires to forge a long-term relationship with its supplier, it may desire to purchase its goods from that supplier so as to commence the relationship.

Step 5

Arrive at **a final make-or-buy decision** after considering both quantitative and qualitative factors. This would depend on the particular business and what it is doing so as to create profits. Continuing with the above example, even if it is likely that the business may buy better grade products than those it can manufacture in-house, the quality of its goods/products may not have a bearing on its sales on the basis of its business model and what it is putting on the market. If such is the case, the wish to develop a long-term relationship may or may not be adequate to prevail over the $1,000 savings in expenses; instead it depends on how strong is the business' yearning for the relationship and what it hopes to accomplish by starting it.

USE OF CROSS OVER CHARTS FOR SELECTION PROCESSES

- The cross-over (or "indifference") point is found when we are indifferent between two or more plans.
- Cross over charts identifies the best process considering
  - Cost (Fixed and Variable cost)
  - Nature of product
  - Volume of production


Crossover Charts
$
Variable costs
Fixed costs
Low volume, high variety
Process A
$
Variable costs
Fixed costs
Repetitive
Process B
$
Variable costs
Fixed costs
High volume, low variety
Process C
$
Total cost
Total cost
Total cost
400,000
300,000
200,000
Fixed cost Process A
Fixed cost Process B
Fixed cost Process C
(2,857) V1
V2 (6,666)
Volume
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7 – 31
Figure 7.6

A crossover chart for process selection focuses on:

- labor costs.
- material cost.
- both labor and material costs.
- fixed and variable costs.
- fixed costs.

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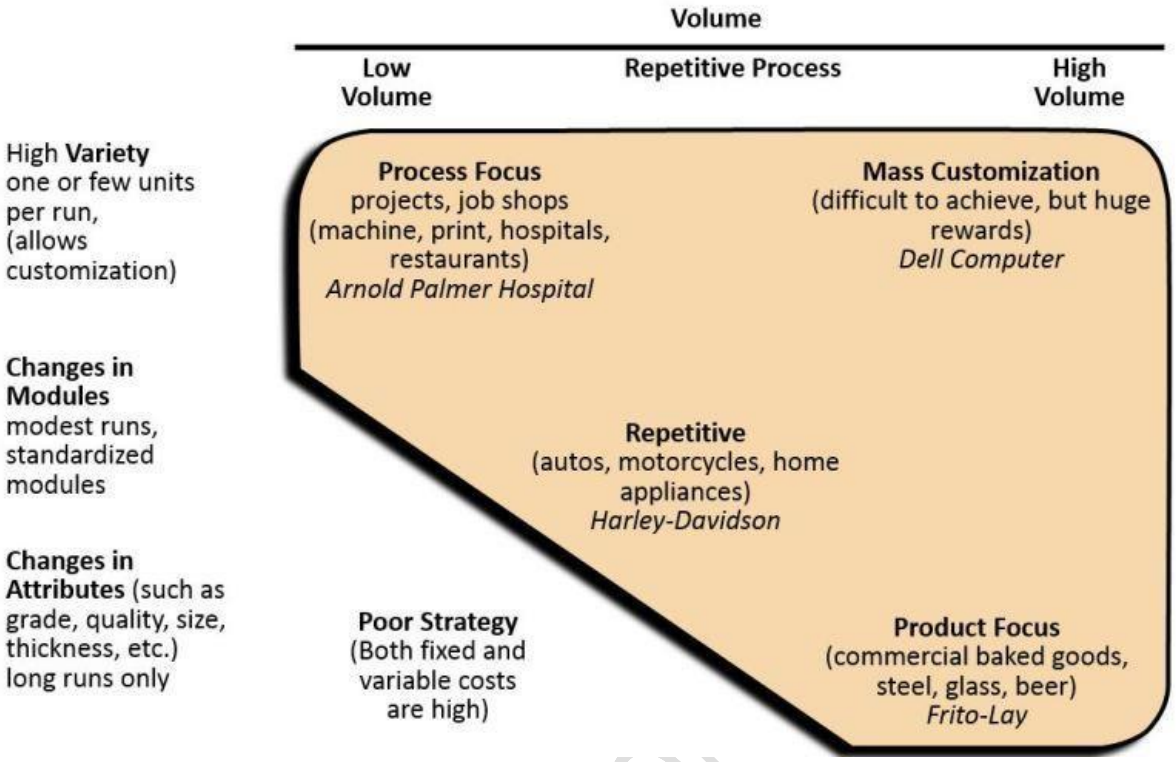
Types of Process strategies

- **Process Focus**
- **Repetitive Focus**
- **Product Focus**
- **Mass Customization**


Volume
Low Volume
Repetitive Process
High Volume
High Variety one or few units per run, (allows customization)
Changes in Modules modest runs, standardized modules
Changes in Attributes (such as grade, quality, size, thickness, etc.) long runs only
Process Focus projects, job shops (machine, print, hospitals, restaurants) Arnold Palmer Hospital
Mass Customization (difficult to achieve, but huge rewards) Dell Computer
Repetitive (autos, motorcycles, home appliances) Harley-Davidson
Poor Strategy (Both fixed and variable costs are high)
Product Focus (commercial baked goods, steel, glass, beer) Frito-Lay

TYPES OF CHARTS USED IN OPERATIONS MANAGEMENT

Process selection charts

- Break even chart
- Cross over chart

Macro motion study

- Operations process chart
- Flow process chart
- Two handed process chart
- Multiple activity chart

Micro motion study

- SIMO chart

Scheduling

- Gantt chart

Quality control charts

- Control charts
  - X bar and R chart
  - P Chart
  - C Chart

UNIT II - FACILITY DESIGN

PLANT LOCATION

Plant location refers to the choice of the region where men, materials, money, machinery and equipment are brought together for setting up a business or factory. A plant is a place where the cost of the product is kept to low in order to maximize gains. Identifying an ideal location is very crucial, it should always maximize the net advantage, must minimize the unit cost of production and distribution. Plant location decisions are very important because once the plant is located at a particular site then the organization has to face the pros and cons of that initial decision.

FACTORS AFFECTING THE PLANT LOCATION

Decisions regarding selecting a location need a balance of several factors. These are divided into primary factors and secondary factors; here both the factors can influence the business in the long run.

PRIMARY FACTORS

- **Availability of raw materials**

Availability of raw materials is the most important factor in plant location decisions. Usually, manufacturing units where there is the conversion of raw materials into finished goods is the main task then such organizations should be located in a place where the raw materials availability is maximum and cheap.

- **Nearness to the market**

Nearness of market for the finished goods not only reduces the transportation costs, but it can render quick services to the customers. If the plant is located far away from the markets then the chances of spoiling and breakage become high during transport. If the industry is nearer to the market then it can grasp the market share by offering quick services.

- **Availability of labor**

Another most important factor which influences the plant location decisions is the availability of labor. The combination of the adequate number of labor with suitable skills and reasonable labor wages can highly benefit the firm. However, labor-intensive firms should select the plant location which is nearer to the source of manpower.

- **Transport facilities**

In order to bring the raw materials to the firm or to carrying the finished goods to the market, transport facilities are very important. Depending on the size of the finished goods or raw materials a suitable transportation is necessary such as roads, water, rail, and air. Here the transportation costs highly increase the cost of production, such organizations can not complete with the rival firms. Here the point considered is transportation costs must be kept low.

- **Availability of fuel and power**

Unavailability of fuel and power is the major drawback in selecting a location for firms. Fuel and power are necessary for all most all the manufacturing units, so locating firms nearer to the coal beds and power industries can highly reduce the wastage of efforts, money and time due to the unavailability of fuel and power.

- **Availability of water**

Depending on the nature of the plant firms should give importance to the locations where water is available.

For example, power plants where use water to produce power should be located near the water bodies.

<u>SECONDARY FACTORS</u>

- **Suitability of climate**

Climate is really an influencing factor for industries such as agriculture, leather, and textile, etc. For such industries extreme humid or dry conditions are not suitable for plant location. Climate can affect the labor efficiency and productivity.

- **Government policies**

While selecting a location for the plant, it is very important to know the local existed Government policies such as licensing policies, institutional finance, Government subsidies, Government benefits associated with establishing a unit in the urban areas or rural areas, etc.

- **Availability of finance**

Finance is the most important factor for the smooth running of any business; it should not be far away from the plant location. However, in the case of decisions regarding plant location, it is the secondary important factor because financial needs can be fulfilled easily if the firm is running smoothly. But it should be located nearer to the areas to get the working capital and other financial needs easily.

- **Competition between states**

In order to attract the investment and large scale industries various states offer subsidies, benefits, and sales tax exemptions to the new units. However, the incentives may not be big but it can help the firms during its startup stages.

- **Availability of facilities**

Availability of basic facilities such as **schools, hospitals, housing and recreation clubs**, etc can motivate the workers to stick to the jobs. On the other hand, these facilities must be provided by the organization, but here most of the employees give preference to work in the locations where all these benefits/facilities are available outside also. So while selecting plant location, organizations must give preference to the location where it is suitable for providing other facilities also.

- **Disposal of waste**

Disposal of waste is a major problem particularly for industries such as chemical, sugar, and leather, etc. So that the selected plant location should have provision for the disposal of waste.

LOCATION ANALYSIS TECHNIQUES

Various models are available which help to identify the ideal location.

Some of the popular models are:

1. Factor rating method
2. Weighted factor rating method
3. Load-distance method
4. Centre of gravity method
5. Break even analysis

1. FACTOR RATING METHOD

The process of selecting a new facility location involves a series of following steps:

- Identify the important location factors.
- Rate each factor according to its relative importance, *i.e.*, higher the ratings is indicative of prominent factor.
- Assign each location according to the merits of the location for each factor.
- Calculate the rating for each location by multiplying factor assigned to each location with basic factors considered.

- Find the sum of product calculated for each factor and select best location having highest total score.

ILLUSTRATION 1: *Let us assume that a new medical facility, Health-care, is to be located in Delhi. The location factors, factor rating and scores for two potential sites are shown in the following table. Which is the best location based on factor rating method?*

Sl. No.	*Location factor*	*Factor rating*	*Rating*	
			Location 1	*Location 2*
1.	Facility utilization	8	3	5
2.	Total patient per month	5	4	3
3.	Average time per emergency trip	6	4	5
4.	Land and construction costs	3	1	2
5.	Employee preferences	5	5	3

SOLUTION:

Sl. No.	*Location factor*	*Factor rating (1)*	*Location 1*		*Location 2*	
			(Rating) (2)	*Total= (1) . (2)*	*(Rating) (3)*	*Total = (1) . (3)*

1.	Facility utilization	8	3	24	5	40
2.	Total patient per Month	5	4	20	3	15
3.	Average time per emergency trip	6	4	24	5	30
4.	Land and construction costs	3	1	3	2	6
5.	Employee Preferences	5	5	25	3	15
			Total	96	Total	106

The total score for location 2 is higher than that of location 1. Hence location 2, is the best choice.

2. WEIGHTED FACTOR RATING METHOD

In this method to merge quantitative and qualitative factors, factors are assigned weights based on relative importance and weightage score for each site using a preference matrix is calculated. The site with the highest weighted score is selected as the best choice.

ILLUSTRATION 2: *Let us assume that a new medical facility, Health-care, is to be located in Delhi. The location factors, weights, and scores (1 = poor, 5 = excellent) for two potential sites are shown in the following table. What is the weighted score for these sites? Which is the best location?*

Sl. No.	*Location factor*	*Weight*	*Scores*	
			Location 1	*Locatio 2 n*
1.	Facility utilization	25	3	5
2.	Total patient km per month	25	4	3
3.	Average time per emergency trip	25	3	3
4.	Land and construction costs	15	1	2
5.	Employee preferences	10	5	3

SOLUTION: The weighted score for this particular site is calculated by multiplying each factor's weight by its score and adding the results:

Weighed score location 1 = 25 × 3 + 25 × 4 + 25 × 3 + 15 × 1 + 10 × 5

= 75 + 100 + 75 + 15 + 50 = 315

Weighed score location 2 = 25 × 5 + 25 × 3 + 25 × 3 + 15 × 2 + 10 × 3

= 125 + 75 + 75 + 30 + 30 = 335

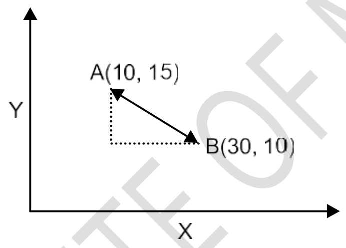
Location 2 is the best site based on total weighted scores.

3. LOAD-DISTANCE METHOD

The load-distance method is a mathematical model used to evaluate locations based on proximity factors. The objective is to select a location that minimizes the total weighted loads moving into and out of the facility. The distance between two points is expressed by assigning the points to grid coordinates on a map. An alternative approach is to use time rather than distance.

Distance Measures

Suppose that a new warehouse is to be located to serve Delhi. It will receive inbound shipments from several suppliers, including one in Ghaziabad. If the new warehouse were located at Gurgaon, what would be the distance between the two facilities? If shipments travel by truck, the distance depends on the highway system and the specific route taken. Computer software is available for calculating the actual mileage between any



two locations in the same county. However, for load-distance method, a rough calculation that is either Euclidean or rectilinear distance measure may be used. Euclidean distance is the straight-line distance, or shortest possible path, between two points.

Fig. 2.2 *Distance between point A and point B*

The point A on the grid represents the supplier's location in Ghaziabad, and the point B represents the possible warehouse location at Gurgaon. The distance between points A and B is the length of the hypotenuse of a right triangle, or

$$d_{AB} = \text{Sqrt}\left((X_A - X_B)^2 + (Y_A - Y_B)^2\right)$$

where d_{AB} = distance between points A

and B X_A = *x*-coordinate of point A

Y_A = *y*-coordinate of point A X_B = *x*-coordinate of

point B Y_B = *y*-coordinate of point B

Rectilinear distance measures distance between two points with a series of 90° turns as city blocks. Essentially, this distance is the sum of the two dashed lines representing the base and side of the triangle in figure. The distance travelled in the *x*-direction is the absolute value of the difference in *x*-coordinates. Adding this result to the absolute value of the difference in the *y*-coordinates gives

$D_{AB} = |X_A - X_B| + |Y_A - Y_B|$

Calculating A Load-Distance Score

Suppose that a firm planning a new location wants to select a site that minimizes the distances that loads, particularly the larger ones, must travel to and from the site. Depending on the industry, a load may be shipments from suppliers, between plants, or to customers, or it may be customers or employees travelling to or from the facility. The firm seeks to minimize its load- distance, generally by choosing a location so that large loads go short distances.

To calculate a load-distance for any potential location, we use either of the distance measures and simply multiply the loads flowing to and from the facility by the distances travelled. These loads may be expressed as tones or number of trips per week.

This calls for a practical example to appreciate the relevance of the concept. Let us visit a new Health-care facility, once again.

ILLUSTRATION 3: *The new Health-care facility is targeted to serve seven census tracts in Delhi. The table given below shows the coordinates for the centre of each census tract, along with the projected populations, measured in thousands. Customers will travel from the seven census tract centres to the new facility when they need health-care. Two locations being considered for the new facility are at (5.5, 4.5) and (7, 2), which are the centres of census tracts C and F. Details of seven census tract centres, co-ordinate distances along with the population for each centre are given below. If we use the population as the loads and use rectilinear distance, which location is better in terms of its total load- distance score?*

Sl. No.	*Census tract*	*(x, y)*	*Population (l)*
1	A	(2.5,4.)	2
2	B	(2.5,2.)	5
3	C	(5.5,4.)	10
4	D	(5, 2)	7
5	E	(8, 5)	10
6	F	(7, 2)	20
7	G	(9, 2.5)	14

SOLUTION: Calculate the load-distance score for each location. Using the coordinates from the above table. Calculate the load-distance score for each tract.

Using the formula $D_{AB} = |X_A - X_B| + |Y_A - Y_B|$

Census tract	*(x, y)*	*Population (l)*	*Locate at (5.5, 4.5)*		*Locate at (7, 2)*	
			Distance (d)	*Load-distance*	*Distance (d)*	*Load-distance*
A	(2.5, 4.5)	2	3 + 0 = 3	6	4.5 + 2.5 = 7	14
B	(2.5, 2.5)	5	3 + 2 = 5	25	4.5 + 0.5 = 5	25
C	(5.5, 4.5)	10	0 + 0 = 0	0	1.5 + 2.5 = 4	40
D	(5, 2)	7	0.5 + 2.5 = 3	21	2 + 0 = 2	14
E	(8, 5)	10	2.5 + 0.5 = 3	30	1 + 3 = 4	40
F	(7, 2)	20	1.5 + 2.5 = 4	80	0 + 0 = 0	0
G	(9, 2.5)	14	3.5 + 2 = 5.5	77	2 + 0.5 = 2.5	35
			Total	239	Total	168

Summing the scores for all tracts gives a total load-distance score of 239 when the facility is located at (5.5, 4.5) versus a load-distance score of 168 at location (7, 2). Therefore, the location in census tract F is a better location.

4. CENTRE OF GRAVITY

Centre of gravity is based primarily on cost considerations. This method can be used to assist managers in balancing cost and service objectives. The centre of gravity method takes into account the locations of plants and markets, the volume of goods moved, and transportation costs in arriving at the best location for a single intermediate warehouse.

The centre of gravity is defined to be the location that minimizes the weighted distance between the warehouse and its supply and distribution points, where the distance is weighted by the number of tones supplied or consumed. The first step in this procedure is to place the locations on a coordinate system. The origin of the coordinate system and scale used are arbitrary, just as long as the relative distances are correctly represented. This can be easily done by placing a grid over an ordinary map. The centre of gravity is determined by the formula.

$C_X = D_{iX}W_i / W_i$; $C_Y = D_{iY}W_i / W_i$

where Cx = x-coordinate of the centre of gravity Cy = y-coordinate of the centre of gravity Dix = x-coordinate of location i

D_{iy} = *y*-coordinate of location *i*

ILLUSTRATION 4: *The new Health-care facility is targeted to serve seven census tracts in Delhi. The table given below shows the coordinates for the centre of each census tract, along with the projected populations, measured in thousands. Customers will travel from the seven census tract centres to the new facility when they need health- care. Two locations being considered for the new facility are at (5.5, 4.5) and (7, 2), which are the centres of census tracts C and F. Details of seven census tract centres, coordinate distances along with the population for each centre are given below. Find the target area's centre of gravity for the Health- care medical facility.*

Sl. No.	*Census tract*	*(x, y)*	*Population (l)*
1	A	(2.5,4.5)	2
2	B	(2.5,2.5)	5
3	C	(5.5,4.5)	10
4	D	(5, 2)	7
5	E	(8, 5)	10
6	F	(7, 2)	20
7	G	(9, 2.5)	14

SOLUTION: To calculate the centre of gravity, start with the following information, where population is given in thousands.

Sl. No.	*Census tract*	*(x, y)*	*Population (l)*	*Lx*	*Ly*
1	A	(2.5, 4.5)	2	5	9
2	B	(2.5, 2.5)	5	12.5	12.5
3	C	(5.5, 4.5)	10	55	45
4	D	(5, 2)	7	35	14
5	E	(8, 5)	10	80	50
6	F	(7, 2)	20	140	40
7	G	(9, 2.5)	14	126	35
		Total	68	453.50	205.50

Next we find C_x and C_y.

Cx = 453.5/68 = 6.67 Cy = 205.5/68 = 3.02

The centre of gravity is (6.67, 3.02). Using the centre of gravity as starting point, managers can now search in its vicinity for the optimal location.

5. BREAK EVEN ANALYSIS

Break even analysis implies that at some point in the operations, total revenue equals total cost. Break even analysis is concerned with finding the point at which revenues and costs agree exactly. It is called 'Break-even Point'. The Fig. 2.3 portrays the Break Even Chart:

Break even point is the volume of output at which neither a profit is made nor a loss is incurred. The Break Even Point (BEP) in units can be calculated by using the relation:

BEP = Fixed cost / Contribution per unit

Contribution per unit = Selling price - Variable cost per

unot BEP = Fixed cost / PV Ratio

PV Ratio = Contribution / Sales

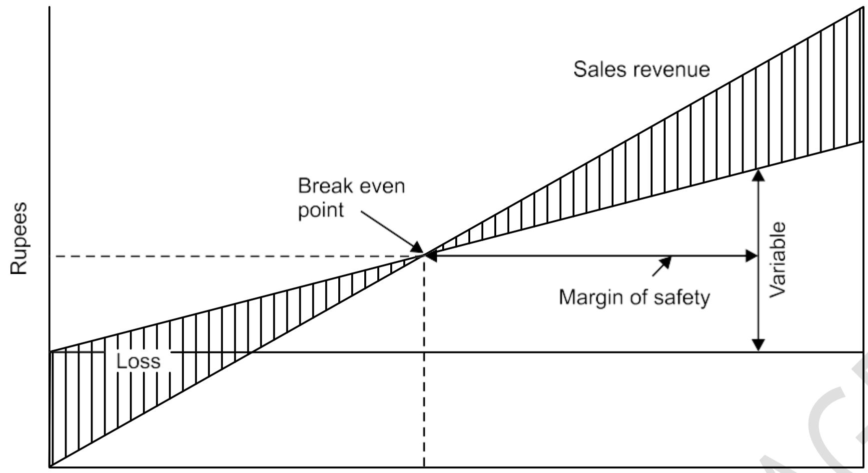


Fig. 2.3 *Units of output or percentage of capacity*

Plotting the break even chart for each location can make economic comparisons of locations. This will be helpful in identifying the range of production volume over which location can be selected.

ILLUSTRATION 5: *Potential locations X, Y and Z have the cost structures shown below. The ABC company has a demand of 1,30,000 units of a new product. Three potential locations X, Y and Z having following cost structures shown are available. Select which location is to be selected and also identify the volume ranges where each location is suited?*

	Location X	*Location Y*	*Location Z*
Fixed Costs	Rs. 150,000	Rs. 350,000	Rs. 950,000
Variable Costs	Rs. 10	Rs. 8	Rs. 6

SOLUTION: Solve for the crossover between X and Y:

$$10X + 150,000 = 8X + 350,000$$

$$2X = 200,000$$

$$X = 100,000$$

units Solve for the crossover between Y and Z:

$$8X + 350,000 = 6X + 950,000$$

$$2X = 600,000$$

$$X = 300,000 \text{ units}$$

Therefore, at a volume of 1,30,000 units, Y is the appropriate strategy.

From the graph (Fig. 2.4) we can interpret that location X is suitable up to 100,000 units, location Y is suitable up to between 100,000 to 300,000 units and location Z is suitable if the demand is more than 300,000 units.

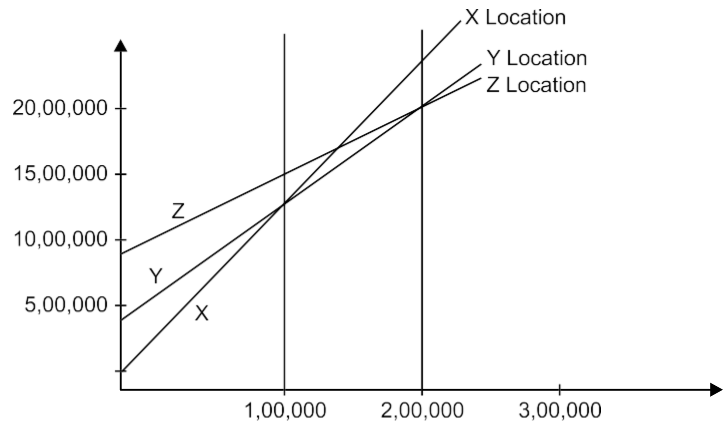


Fig. 2.4 *BEP chart*

STEPS IN LOCATION SELECTION

1. Domestic or International Location
2. **Selection of the region**
3. **Selection of the locality or community**
4. **Selection of the exact site**

1. DOMESTIC OR INTERNATIONAL LOCATION

- The 1st step in plant location is to decide whether the facility should be located domestically or internationally.
- With increasing internationalisation of business, the issue of home or foreign country is gaining greater relevance.
- If the management decides on foreign location the next logical step would be to decide upon a particular country for location.
- This is necessary because countries across the world varying with each other to attract foreign investments. The choice of particular country depends on such factors as political stability, export and import quotas, currency and exchange rates, cultural and economic peculiarities, and natural or physical conditions.

2. SELECTION OF THE REGION

The selection of a particular region out of the many natural regions of a country is the second step of plant location.

The factors plant location are discussed earlier in detail in this unit

3. SELECTION OF THE LOCALITY OR COMMUNITY

Selecting a particular locality or community in a region is the third step in selection of plant location

The selection of a locality in a particular region is influenced by the following factors:

- Availability of labour

Labour is an important factor in the production of goods. An adequacy of labour supply at reasonable wages is very essential for the smooth and successful working of an organisation.

- Civic amenities for workers

Besides good working conditions inside the factory, the employees require certain facilities outside it. Recreation facilities such as clubs, theatres, parks, must be provided for the employees. They require schools for their children. A place which abounds in all these facilities will naturally be preferred to another place which lacks them.

- Existence of complimentary and competing industries
- ➢ The existence of complementary industries is favorable to the location of industries, because an industrial unit, in association with other units, can get the following benefits:
- ➢ An industrial unit, in collaboration with other similar units, can secure materials on better terms than it can do it by itself.
- ➢ The concentration of similar industries at one place improves the labour market both for the employer and employee.
- ➢ The specialised centers, bank, become familiar with the requirements of the industry, this makes the granting of loans easy
- ➢ The group of plants will attract a variety of repair plants, such as foundries, machine, shops, tool makers and the like.
- ➢ The reputation build up by the existing units will be shared by the new units established in the same locality.
- Finance and research facilities

Adequate capital is essential for the successful working of any organisation. A place where facilities for raising capital are available attracts new industries. This is particularly true in developing countries, where capital is not available uniformity throughout the country. In advanced countries thee case is different because, in such countries, capital is distributed uniformly.

- Availability of water and fire fighting facilities

- Some industries require a plentiful supply of water for their working. Some of these are fertiliser units, rayon manufacturing units, absorbent cotton manufacturing units, leather tanneries, bleaching, dyeing and screen printing units.
- These factories must be located in places where water is available in abundance.
- Water may be obtained from the local authority, from the canal, from a river or a lake, or by sinking a borewell. In any case, the supply of water should be considered with respect to its regularity, cost and purity.

- <u>Local taxes and restrictions</u>

Local authorities collect charges for the supply of water, electricity and other facilities. They also collect various taxes from industrial units. They impose restrictions on the location of new units in the public interest. It is natural, therefore for industrialists to prefer an area where such taxes and restrictions are the least tedious

- Personal factors

There are entrepreneurs, especially small industrialists, who locate their plants purely on personal grounds disregarding economic considerations. Such locations sometimes may totally disapprove the current theories of plant location.

4. SELECTION OF SITE

The selection of an exact site in a chosen locality is the fourth step I plant location. The selection of the site is influenced by the following considerations:

- **Soil, size and topography**

➢ For factories producing engineering goods, the fertility or otherwise of the soil may not be a factor influencingplant location. But for agro-based industries, a fertile soil is necessary for ensuring a strategic plant location.

➢ The area of the land should be such as to accommodate not only the existing manufacturing facilities, but offer scope for future expansion programs as well.

➢ Besides the area, the cost of land deserves consideration. If the land is to be purchased, and if the place enjoys all the facilities for plant location, its price should not affect the decision to locate the plant in that particular place, because the cost of land forms a small percentage of the total fixed investment.

- But if the land is to be leased, the question of rent, rates and taxes has to be seriously considered because they constitute a part of the permanent working expenses.
- The topography of the place deserves consideration to some extent. A hilly, rocky and rough terrain is unsuitable for plant location because a great deal of expenditure has to be incurred to level it.

- **Disposal of waste**

The site selection for the location of the plant should have the provision for the disposal of the waste. There must be enough land for dumping of the solid waste.The site selected should, as far as possible, be in the midst of good scenery. The question of beauty should not be ignored.

LOCATION DECISION

While taking plant location decision organizations need to consider various factors such as availability of men, materials, money, machinery and equipment. At the same time plant, location decisions should also focus on expanding and developing facilities, the nearness of the market, transport facilities, availability of fuel and power, availability of water and disposal of water etc. There is no exact method of analysis or assurance for the selection of an optimal location. But an extent of analysis and study can help in maximizing the probability of finding the right locations.

If an organization is placed in a potentially satisfactory location then it can fulfill the objectives smoothly in the long run, on the other hand, opt for a poor location does not give the expected results due to the non-availability of raw materials, problems from local people, problems associated with availability and disposal of water, power supply problems, etc. However following a systematic method in order to evaluate the better location can give maximum results in generating profits.

PLANT LOCATION DECISION AT VARIOUS SITUATIONS

The need for selecting a suitable location arises because of following situations.

I. When starting a new organisation, *i.e.*, location choice for the first time.
II. In case of existing organisation.

I. In Case of Location Choice for the First Time or New Organisations

Cost economies are always important while selecting a location for the first time, but should keep in mind the cost of long-term business/organisational objectives. The following are the factors to be considered while selecting the location for the new organisations:

1. **Identification of region:** The organisational objectives along with the various long- term considerations about marketing, technology, internal organisational strengths and weaknesses, region- specific resources and business environment, legal-governmental environment, social environment and geographical environment suggest a suitable region for locating the operations facility.

2. **Choice of a site within a region:** Once the suitable region is identified, the next step is choosing the best site from an available set. Choice of a site is less dependent on the organisation's long-term strategies. Evaluation of

alternative sites for their tangible

and intangible costs will resolve facilities-location problem.

The problem of location of a site within the region can be approached with the following cost-oriented non-interactive model, *i.e.*, dimensional analysis.

3. **Dimensional analysis:** If all the costs were tangible and quantifiable, the comparison and selection of a site is easy. The location with the least cost is selected. In most of the cases intangible costs which are expressed in relative terms than in absolute terms. Their relative merits and demerits of sites can also be compared easily. Since both tangible and intangible costs need to be considered for a selection of a site, dimensional analysis is used.

The existing firms will seek new locations in order to expand the capacity or to place the existing facilities. When the demand for product increases, it will give rise to following decisions:

- Whether to expand the existing capacity and facilities.
- Whether to look for new locations for additional facilities.
- Whether to close down existing facilities to take advantage of some new locations.

II. In Case of Location Choice for Existing Organisation

In this case a manufacturing plant has to fit into a multi-plant operations strategy. That is, additional plant location in the same premesis and elsewere under following circumstances:

1. Plant manufacturing distinct products.
2. Manufacturing plant supplying to specific market area.
3. Plant divided on the basis of the process or stages in manufacturing.
4. Plants emphasizing flexibility.

The different operations strategies under the above circumstances could be:

1. **Plants manufacturing distinct products:** Each plant services the entire market area for the organization. This strategy is necessary where the needs of technological and resource inputs are specialized or distinctively different for the different product-lines.

For example, a high quality precision product-line should not be located along with other product-line requiring little emphasis on precision. It may not be proper to have too many contradictions such as sophisticated and old equipment, highly skilled and semi- skilled personnel, delicates processes and those that could permit rough handlings, all under one roof and one set of managers. Such a setting leads to much confusion regarding the required emphasis and the management policies.

2. **Manufacturing plants supplying to a specific market area:** Here, each plant manufactures almost all of the company's products. This type of strategy is useful where market proximity consideration dominates the resources and technology considerations. This strategy requires great deal of coordination from the corporate office. An extreme example of this strategy is that of soft drinks bottling plants.

3. **Plants divided on the basis of the process or stages in manufacturing:** Each production process or stage of manufacturing may require distinctively different equipment capabilities, labour skills, technologies, and managerial policies and emphasis. Since the products of one plant feed into the other plant, this strategy requires much centralized coordination of the manufacturing activities from the corporate office that are expected to understand the various technological aspects of all the plants.

4. **Plants emphasizing flexibility:** This requires much coordination between plants to meet the changing needs and at the same time ensure efficient use of the facilities and resources. Frequent changes in the long-term strategy in order to improve be efficiently temporarily, are not healthy for the organization. In any facility location problem the central question is: 'Is this a location at which the company can remain competitive for a long time?

For an established organization in order to add on to the capacity, following are the ways:

(a) *Expansion of the facilities at the existing site:* This is acceptable when it does not violate the basic business and managerial outlines, *i.e.*, philosophies, purposes, strategies and capabilities. For example, expansion should not compromise quality, delivery, or customer service.

(b) *Relocation of the facilities (closing down the existing ones):* This is a drastic step which can be called as 'Uprooting and Transplanting'. Unless there are very compelling reasons, relocation is not done. The reasons will be either bringing radical changes in technology, resource availability or other destabilization.

All these factors are applicable to service organizations, whose objectives, priorities and strategies may differ from those of hardcore manufacturing organizations.

PLANT LOCATION TRENDS

The traditional factors like nearness of sources of raw materials, motive power, nearness of markets, labor supply etc have no longer remained the effective pulling forces in the location of industries. The location trends have changed substantially due to the development of substitute raw materials, network of electrification and transportation by roads and railway, mobility of the labor and persuasive and compulsive policies of the government for balanced regional development.

The recent trends in the selection of industrial location can be described as under:

- **Priority for the suburban areas**

The industrialists show their preference for the suburban area as the site for establishment of a new unit or relocation of the existing one. The industrial policy of the government does not permit the establishment of a new unit or expansion of an existing one in city areas. At the same time infrastructure facilities are developed in the suburban areas.

- **Industrial development in the notified backward areas**

In order to have balanced regional development, the Central Government as well as the State Government has notified certain backward areas Different types of incentives like cash subsidy, tax relief, financial assistance with low interest rates, cheaper land and power supply etc are provided. So, many such areas have been developed substantially in the recent times.

- **Establishment of Industrial estate**

Industrial estate is a piece of vast land sub-divided into different industrial plots wherein factory sheds are constructed. The Government of India has planned a national policy for the development of industrial estates. It assigned the responsibility of the development of industrial estates to State Governments. In each state, the State Development Corporation (SDC) has developed many industrial estates practically in all the districts of the state. Industrial estates have also been developed by private entrepreneurs and Chambers of Commerce. The plots of land along with factory sheds and infrastructure facilities are developed in the industrial estates and are sold to the prospective promoters. The establishment of industrial estates has greatly affected the location of industries.

- **Decentralization of industries**

Under the conscious industrial policy of the Government, concentration of industrial units is prevented through licensing policy. New units are not permitted to be started in certain industrially congested areas. Similarly, existing units either establish their additional plants in a less developed area or sometimes relocate the whole unit in such areas.

- **Increased role of the Government in the decision of location of industries** Government through its persuasive and compulsive methods greatly influences the location decision in recent times. It provides certain attractive incentives to the promoters to establish their units in less developed areas, at the same time it does not permit excessive industrialization in certain developed areas.

- **Competition between Government and institutions**

As industry provides job opportunities to the local population, many local organizations attempt to tempt the prospective promoters to establish the units in their areas. They provide different types of incentives like cheap land, relief in local taxes etc. Sometimes the objective of local organizations and the government comes in conflict on the issues of location of industries. Thus, the whole pattern of decision about the location of industries has undergone substantial changes in recent times.

PLANT LAYOUT

Plant layout refers to the physical arrangement of production facilities. It is the configuration of departments, work centres and equipment in the conversion process. It is a floor plan of the physical facilities, which are used in production.

According to Moore "*Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling* *equipment and all other supporting services along with the design of best structure to contain all these facilities*".

OBJECTIVES OF PLANT LAYOUT

The primary goal of the plant layout is to maximise the profit by arrangement of all the plant facilities to the best advantage of total manufacturing of the product.

The objectives of plant layout are:

- Streamline the flow of materials through the plant.
- Facilitate the manufacturing process.
- Maintain high turnover of in-process inventory.
- Minimise materials handling and cost.
- Effective utilisation of men, equipment and space.
- Make effective utilisation of cubic space.
- Flexibility of manufacturing operations and arrangements.
- Provide for employee convenience, safety and comfort.
- Minimize investment in equipment.
- Minimize overall production time.
- Maintain flexibility of arrangement and operation.
- Facilitate the organizational structure.

PRINCIPLES OF PLANT LAYOUT

1. **Principle of integration:** A good layout is one that integrates men, materials, machines and supporting services and others in order to get the optimum utilisation of resources and maximum effectiveness.
2. **Principle of minimum distance:** This principle is concerned with the

minimum travel (or movement) of man and materials. The facilities should be arranged such that, the total distance travelled by the men and materials should be minimum and as far as possible straight line movement should be preferred.

3. **Principle of cubic space utilisation:** The good layout is one that utilise both horizontal and vertical space. It is not only enough if only the floor space is utilised optimally but the third dimension, *i.e.,* the height is also to be utilised effectively.

4. **Principle of flow:** A good layout is one that makes the materials to move in forward direction towards the completion stage, *i.e.,* there should not be any backtracking.

5. **Principle of maximum flexibility**: The good layout is one that can be altered without much cost and time, *i.e.,* future requirements should be taken into account while designing the present layout.

6. **Principle of safety, security and satisfaction:** A good layout is one that gives due consideration to workers safety and satisfaction and safeguards the plant and machinery against fire, theft, etc.

7. **Principle of minimum handling:** A good layout is one that reduces the material handling to the minimum.

FACTORS INFLUENCING PLANT LAYOUT

(i) **Nature of the product :** The size, shape, characteristics and many other properties of the product influence the choice of the layout e.g. products having sensitive chemical properties needs more provision for safety equipment. Some products need air-conditioned plants. Efficient material handling system can be used for light products.

(ii) **Size of Output :** If standardized items are to be produced in bulk then product or line layout is more suitable. If some specific products are to be manufactured once in life time, then functional layout will be more appropriate.

(iii) **Nature or Manufacturing System :** For intermittent type of industries functional layout is better and in the case of continuous manufacturing system one can very well use product or line layout.

(iv) **Location of the Plant :** Layout is greatly influenced by the size, shape, climatic conditions and by-laws of the area where plant site is selected. There will be different transport arrangement if site is located near the railway line, otherwise the approach will be different. If floor space is square and too many machines and operations are involved in the production process then layout can be planned in different shapes.

(v) **Machines or Equipment :** Heavy machines making too much movement during operations need stationary type of layout. Layout also depends on the size of the machines.

(vi) **Climatic conditions,** requirements of light, temperature etc. also play an important role in designing a layout.

(vii) **Balancing Production Lines.** It is also very important aspect. The sequence of machines and equipment arranged to produce the desired product is known as Production lines. It should also be maintained so that productivity of plants & equipment may be ensured.

(viii) **Plant environment.** In planning factory layout, heat, light, noise, ventilation and other aspects of plant climate should be given due consideration. For example, paint shops and plating sections should be located on an outside wall so that dangerous fumes may be removed through proper ventilation. Type of machines, materials and equipment used also exercise consider-able influence on plant location.

(ix) **Spatial requirements.** The spatial needs for machines, material handling equipment and available floor space are important influences on plant location. Spatial requirements also depend upon the position and needs of workers. Employee facilities and safety should be duly considered.

(x) **Repairs and maintenance.** Machines and equipment should not be fixed so close to each other that it may create problems in repairs, maintenance and replacement. Access to machine parts for repairs and maintenance should be provided.

(xi) **Balance.** Proper balance between processes helps to avoid bottlenecks. The arrangement of machine capacity should be such as to ensure a uniform flow of work. At the same time the layout should be designed in such a manner that there is minimum possible movement of materials and men.

(xii) **Management policy.** Management policies regarding size, quality, employee facilities and delivery schedules should be considered while deciding plant layout. For example, size (demand forecast) will determine the size of work stations. Need for flexibility should also be considered. The layout designer must have a complete understanding of management policies that have a bearing on plant layout.

CLASSIFICATION OF LAYOUT

Layouts can be classified into the following five categories:

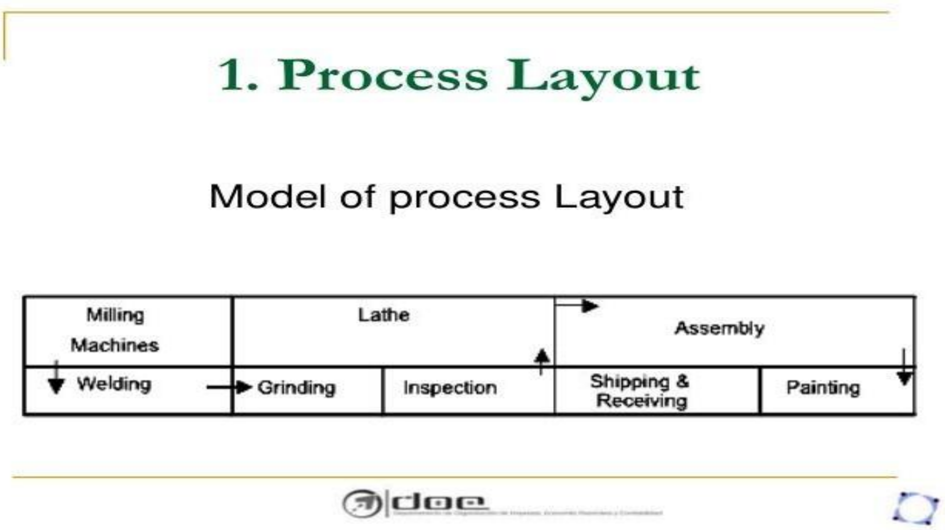
1. Process layout
2. Product layout
3. Combination layout
4. Fixed position layout
5. Group layout

1. PROCESS LAYOUT

Process layout is recommended for batch production. All machines performing similar type of operations are grouped at one location in the process layout *e.g.,* all lathes, milling machines, etc. are grouped in the shop will be clustered in like groups.

Thus, in process layout the arrangement of facilities are grouped together according to their functions. A typical process layout is shown in Fig. 2.5. The flow paths of material through the facilities from one functional area to another vary from product to product. Usually the paths are long and there will be possibility of backtracking.

Process layout is normally used when the production volume is not sufficient to justify a product layout. Typically, job shops employ process layouts due to the variety of products manufactured and their low production volumes.



Advantages.

1. In process layout machines are better utilized and fewer machines are required.
2. Flexibility of equipment and personnel is possible in process layout.
3. Lower investment on account of comparatively less number of machines and lower cost of general purpose machines.
4. Higher utilisation of production facilities.
5. A high degree of flexibility with regards to work distribution to machineries and workers.
6. The diversity of tasks and variety of job makes the job challenging and interesting.
7. Supervisors will become highly knowledgeable about the functions under their department.

Limitations

1. Backtracking and long movements may occur in the handling of materials thus, reducing material handling efficiency.

2. Material handling cannot be mechanised which adds to cost.
3. Process time is prolonged which reduce the inventory turnover and increases the in- process inventory.
4. Lowered productivity due to number of set-ups.
5. Throughput (time gap between in and out in the process) time is longer.
6. Space and capital are tied up by work-in-process.

2. PRODUCT LAYOUT

In this type of layout, machines and auxiliary services are located according to the processing sequence of the product. If the volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit. Special purpose machines are used which perform the required function quickly and reliably.

The product layout is selected when the volume of production of a product is high such that a separate production line to manufacture it can be justified. In a strict product layout, machines are not shared by different products. Therefore, the production volume must be sufficient to achieve satisfactory utilisation of the equipment. A typical product layout is shown

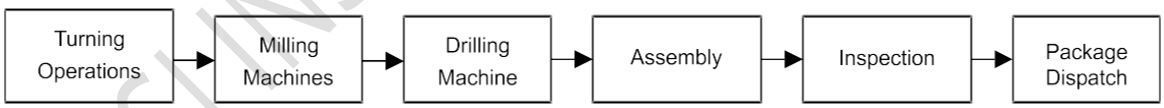


Fig: *Product layout*

Advantages

1. The flow of product will be smooth and logical in flow lines.
2. In-process inventory is less.
3. Throughput time is less.

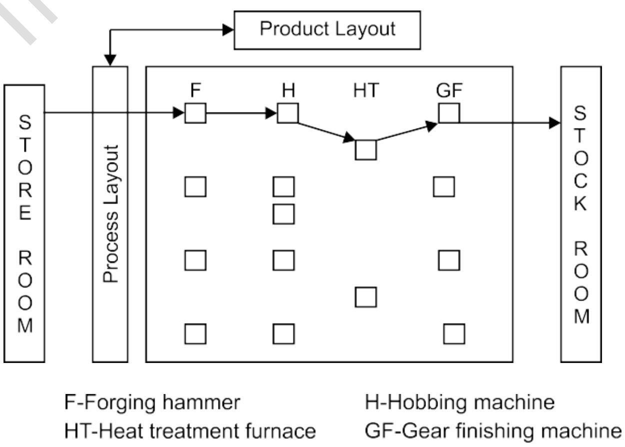
4. Minimum material handling cost.
5. Simplified production, planning and control systems are possible.
6. Less space is occupied by work transit and for temporary storage.
7. Reduced material handling cost due to mechanised handling systems and straight flow.
8. Perfect line balancing which eliminates bottlenecks and idle capacity.
9. Manufacturing cycle is short due to uninterrupted flow of materials.
10. Small amount of work-in-process inventory.
11. Unskilled workers can learn and manage the production.

Limitations

1. A breakdown of one machine in a product line may cause stoppages of machines in the downstream of the line.
2. A change in product design may require major alterations in the layout.
3. The line output is decided by the bottleneck machine.
4. Comparatively high investment in equipments is required.
5. *Lack of flexibility*. A change in product may require the facility modification.

3. COMBINATION LAYOUT

A combination of process and product layouts combines the advantages of



both types of layouts. A combination layout is possible where an item is being made in different types

Fig. *Combination layout for making different types and sizes of gear*

and sizes. Here machinery is arranged in a process layout but the process grouping is then arranged in a sequence to manufacture various types and sizes of products. It is to be noted that the sequence of operations remains same with the variety of products and sizes. Figure shows a combination type of layout for manufacturing different sized gears.

4. FIXED POSITION LAYOUT

This is also called the **project type** of layout. In this type of layout, the material, or major components remain in a fixed location and tools, machinery, men and other materials are brought to this location. This type of layout is suitable when one or a few pieces of identical heavy products are to be manufactured and when the assembly consists of large number of heavy parts, the cost of transportation of these parts is very high.

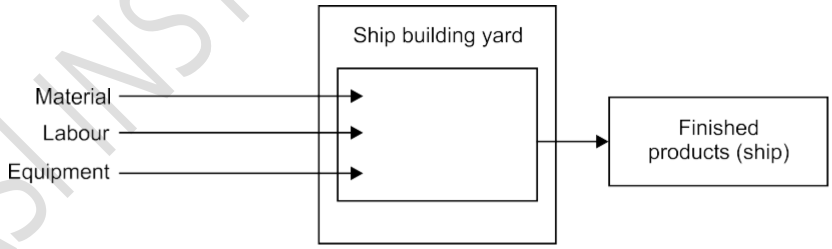


Fig. *Fixed position layout*

Advantages

The major advantages of this type of layout are:

1. Helps in job enlargement and upgrades the skills of the operators.
2. The workers identify themselves with a product in which they take interest and pride in doing the job.
3. Greater flexibility with this type of layout.
4. Layout capital investment is lower.

5. GROUP LAYOUT (OR CELLULAR LAYOUT)

- There is a trend now to bring an element of flexibility into manufacturing system as regards to variation in batch sizes and sequence of operations. A grouping of equipment for performing a sequence of operations on family of similar components or products has become all the important.
- Group technology (GT) is the analysis and comparisons of items to group them into families with similar characteristics. GT can be used to develop a hybrid between pure process layout and pure flow line (product) layout. This technique is very useful for companies that produce variety of parts in small batches to enable them to take advantage and economics of flow line layout.
- The application of group technology involves two basic steps; first step is to determine component families or groups. The second step in applying group technology is to arrange the plants equipment used to process a particular family of components.

This represents small plants within the plants. The group technology reduces production planning time for jobs. It reduces the set-up time.

- Thus **group layout** is a combination of the product layout and process layout. It combines the advantages of both layout systems. If there are *m*-machines and *n*- components, in a group layout (Group-Technology Layout), the *m*-machines and *n* components will be divided into distinct number of machine-component cells (group) such that all the components assigned to a cell are almost processed within that cell itself. Here, the objective is to minimize the inter cell movements.
- In-group technology layout, the objective is to minimize the sum of the cost of transportation and the cost of equipments. So, this is called as multi-objective layout. A typical process layout is shown in Fig. 2.9.

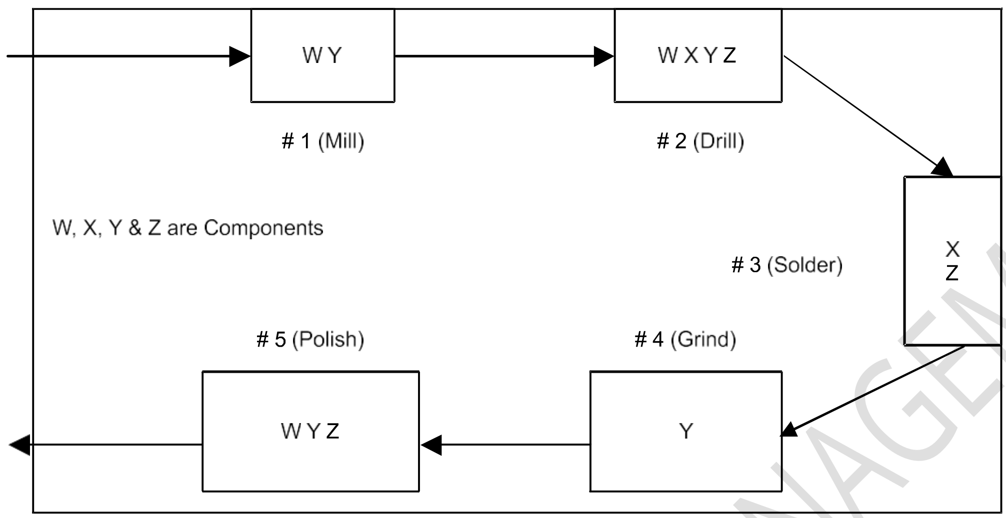


Fig. 2.9 *Group layout or Cellular layout*

Advantages of Group Technology Layout

Group Technology layout can increase—

1. Component standardization and rationalization.
2. Reliability of estimates.
3. Effective machine operation and productivity.
4. Customer service. It can decrease the—

1. Paper work and overall production time.
2. Work-in-progress and work movement.
3. Overall cost.

Limitations of Group Technology Layout

This type of layout may not be feasible for all situations. If the product mix is completely dissimilar, then we may not have meaningful cell formation.

MATERIAL HANDLING

Material handling is the movement, protection, storage and control of materials and products throughout manufacturing, warehousing, distribution, consumption and disposal. As a process, material handling incorporates a wide range of manual, semi-automated and automated equipment and systems that support logistics and make the supply chain work.

PRINCIPLES OF MATERIALS HANDLING

- **Planning**: Define the needs, strategic performance objectives and functional specification of the proposed system and supporting technologies at the outset of the design. The plan should be developed in a team approach, with input from consultants, suppliers and end users, as well as from management, engineering, information systems, finance and operations.
- **Standardization**: All material handling methods, equipment, controls and software should be standardized and able to perform a range of tasks in a variety of operating conditions.
- **Use of Gravity:** Material handling processes should be simplified by reducing, combining, shortening or eliminating unnecessary movement that will impede productivity. Examples include using gravity to assist in material movement, and employing straight-line movement as much as possible.
- **Ergonomics**: Work and working conditions should be adapted to support the abilities of a worker, reduce repetitive and strenuous manual labor, and

emphasize safety.

- **Unit load:** Because less effort and work is required to move several individual items together as a single load (as opposed to moving many items one at a time), unit loads— such as pallets, containers or totes of items— should be used.
- **Space utilization:** To maximize efficient use of space within a facility, it is important to keep work areas organized and free of clutter, to maximize density in storage areas (without compromising accessibility and flexibility), and to utilize overhead space.
- **System**: Material movement and storage should be coordinated throughout all processes, from receiving, inspection, storage, production, assembly, packaging, unitizing and order selection, to shipping, transportation and the handling of returns.
- **Environment:** Energy use and potential environmental impact should be considered when designing the system, with reusability and recycling processes implemented when possible, as well as safe practices established for handling hazardous materials.
- **Automation:** To improve operational efficiency, responsiveness, consistency and predictability, automated material handling technologies should be deployed when possible and where they make sense to do so.
- **Life cycle cost:** For all equipment specified for the system, an analysis of life cycle costs should be conducted. Areas of consideration should include capital investment, installation, setup, programming, training, system testing,

operation, maintenance and repair, reuse value and ultimate disposal.

MATERIAL HANDLING EQUIPMENTS

The term ‘material handling equipment’ is a pretty broad one. There’s plenty of situations where it’s critical to move large and often heavy materials in a production environment. Any piece of equipment that helps with this process could be labeled ‘material handling equipment’.

. Anything that deals with the transportation, storage and control at any stage of the processing of materials can be classified as material handling equipment.

CLASSIFICATION OF MATERIAL HANDING EQUIPMENTS

1. INDUSTRIAL TRUCKS

Industrial trucks refer to the different kinds of transportation items and vehicles used to move materials and products in materials handling.

- These transportation devices can include small hand-operated trucks, pallet-jacks, and various kinds of forklifts.
- These trucks have a variety of characteristics to make them suitable for different operations. Some trucks have forks, as in a forklift, or a flat surface with which to lift items, while some trucks require a separate piece of equipment for loading.
- Trucks can also be manual or powered lift and operation can be walk or ride,

requiring a user to manually push them or to ride along on the truck.

Industrial Trucks

- **Manual**
  - 2 wheeled burrow
  - 3 wheeled burrow
  - 4 wheeled burrow
- **Powered**
  - **Driver walk (Driver remains on ground)**
    - Platform type
    - Pallet lift
    - High lift fork
  - **Driver ride (driver on the truck)**
    - Platform
    - Pallet lift
    - Telescopic fork lift

Fig. 25.12. Platform truck (high-lift type).

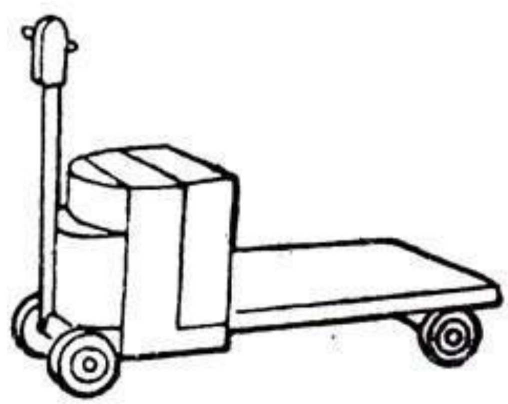


Fig. 25.11. Platform truck (low-lift type).

In fork lift truck the forks are attached to a column on the truck. Forks can be lifted to the desired height along with the material (boxes, etc.) on them and the material can be stacked at the proper place, even very close to the roof. Fork lift trucks are used for short distances (40 to 70 metres) travel and find indoor applications normally.

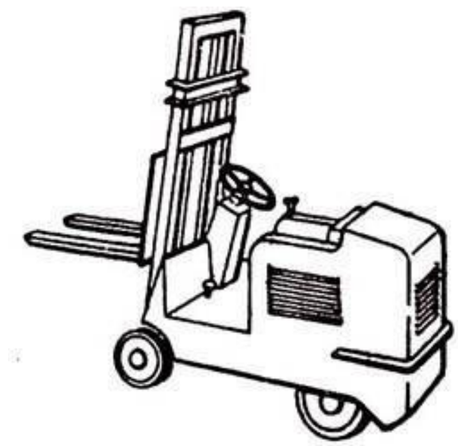


Fig. 25.13. Fork truck (counterbalance type).

2. CRANES

- **Overhead bridge crane**
- **Jib crane**
- **Gantry crane**

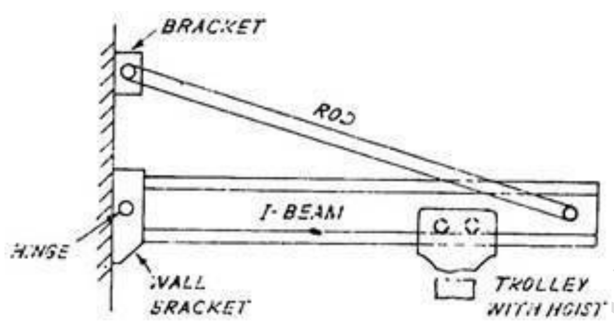


Fig. 25.5. Jib crane.

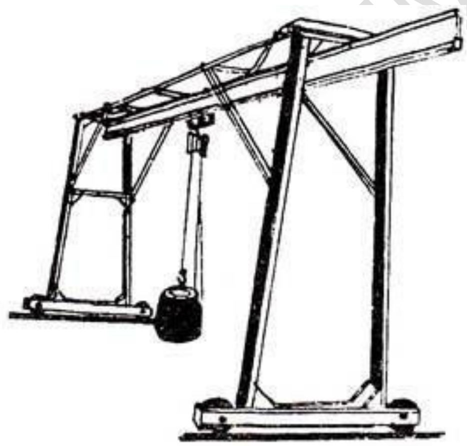


Fig. 25.6. Gantry crane.

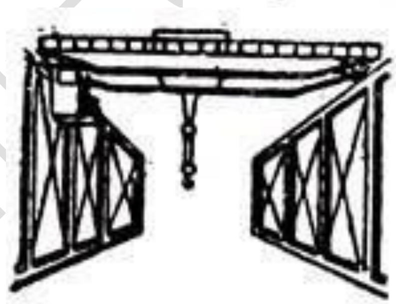


Fig. 25.19. Bridge crane.

Cranes are employed for lifting and lowering bulky items and packages or cases. they find applications in heavy engineering and generally in intermittent type of production. They provide overhead movements. The crane hook can move in a rectangular area (overhead bridge crane) or a circular area (jib crane).

- An **overhead bridge crane** finds applications in most of the industries, making engines, compressors, pressure vessels, foundries, steel mills, etc.

- A **jib crane** is preferred where lifting of the jobs is required in a few locations only or where bridge crane cannot be erected; for example, outside near the wall of the building. In a jib crane the hoist unit may be mounted on an I-section jib which is in turn supported on a column.
- A **gantry crane** acts as an auxiliary to bridge crane. It is on wheels and can be moved at the place of use.

3. HOISTS

- Chain type
- Pneumatic
- Electrical

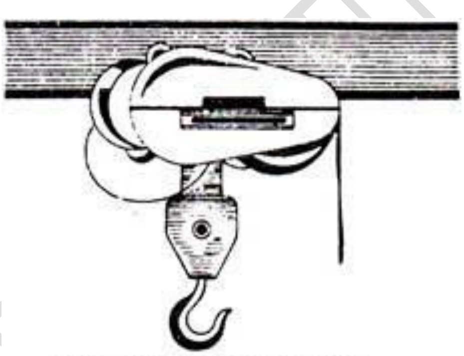


Fig. 25.7. Electrical hoist.


Fig. 25.14. Chain hoist.

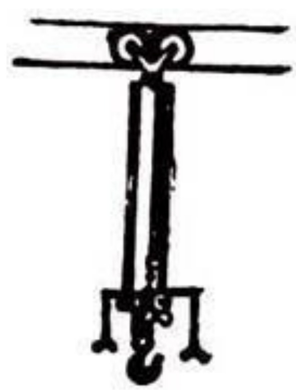


Fig. 25.16. Air hoist.

HOIST may be mounted on a single rail. It finds applications in wire drawing and many other factories employing chemical cleaning of material, etc.

4. MONORAIL

- Trolley
- Carrier

Monorail is an I-section beam attached to the ceiling and having either a trolley or carrier moving along it. The material can be transferred from one place to another along the beam. It is employed for intermittent type material handling in machine shop and other shops.

5. CONVEYORS

- Belt conveyors
- Roller conveyors
- Bucket conveyors
- Chain / Cable
- Pipeline (Pneumatic)

CONVEYORS are employed to transport materials, over a fixed path which may be horizontal or inclined (up or down), to different locations in a factory. They prove economical if the flow of material is continuous.

- In a **belt conveyor**, the belt may be flat or of trough shape to hold (granular) materials which may tend to fall from the flat belt. The belt material maybe rubber covered canvas, steel, plain fabric or woven wire (high temperature use). A fixed conveyor is used on the mass production shop floor whereas portable conveyors are preferred for intermittent jobs like unloading of a freight car, etc.

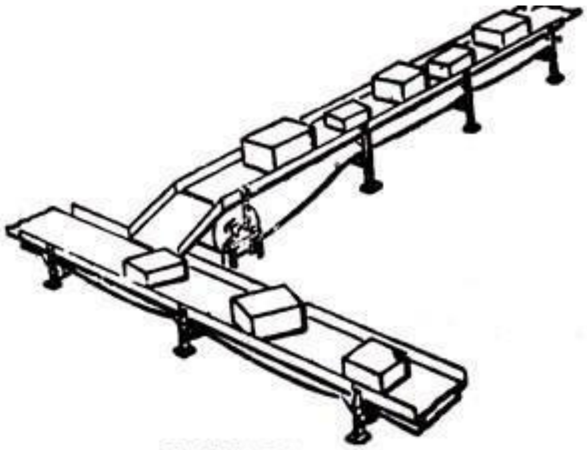


Fig. 25.21. Belt conveyor.

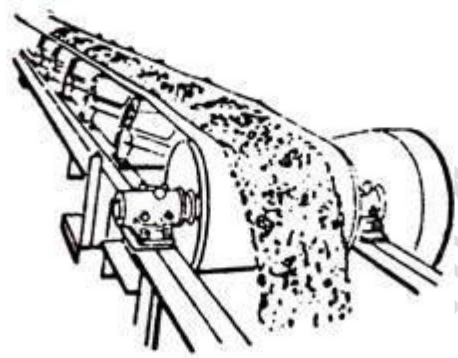


Fig. 25.20. Belt conveyor.

- Roller conveyors may be gravity aided or powered and are employed for transporting products having flat bottoms. Bigger jobs can be handled as they are, whereas small items are put in boxes, tins or pallets before being transferred. Roller conveyors can move the material along straight or curved paths.

Fig. 25.23. Roller conveyor.

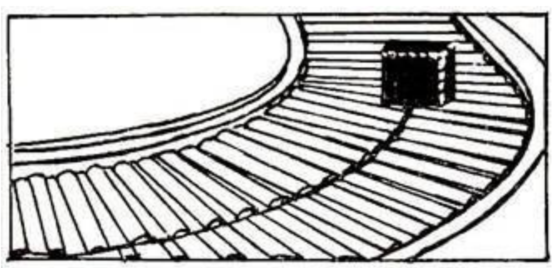


Fig. 25:9. Roller conveyor.

- Gravity type conveyors should be preferred as compared to line conveyors wherever practical. Gravity conveyor is easy to set up as it does not involve any power drive. Packages of hosiery goods, steel sheets, etc., can be transferred using gravity conveyors.

Fig. 25.22. Slat conveyor.

- Belt conveyors are substituted for roller conveyors when the parts are small and are required to be transferred separately, from one station to another.

The mechanism of transporting the materials in a drag conveyor can be a screw (as in automatic feed in poultry farms), a pusher bar, a scraper (for moving granular or powder materials) or an overhead endless chain along a fixed path. The chain has chain links which push the material forward.

A bucket conveyor moves the granular materials or powder or liquid. The buckets may be mounted on a chain or belt.

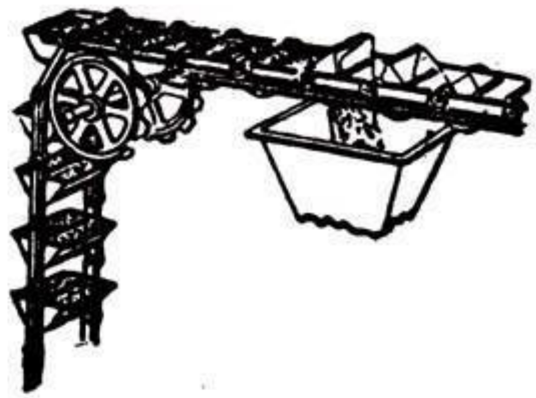


Fig. 25.29. Pivoted bucket conveyor.

A chain conveyor consists of overhead mounted endless chain. It is supported from the ceiling and has a fixed path to travel. It saves valuable floor space. The arrangement is such that the lifting mechanism (may be an electromagnet or a hook) lowers down for loading and unloading of the products.

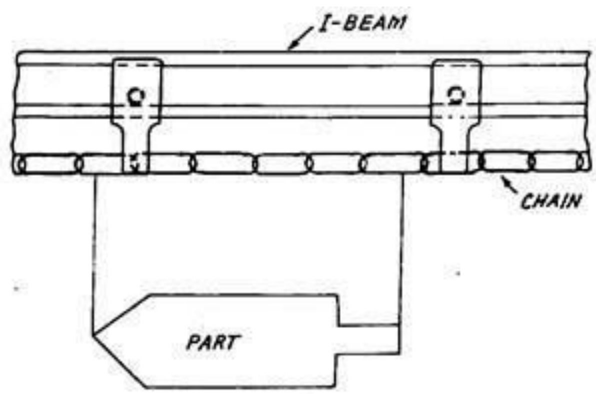


Fig. 25.10. Chain conveyor.

Chain conveyors are used in refrigeration industries for painting and plating of the refrigerator shells. In another application a telescopic mast (pole) may join its upper end with the overhead chain conveyor and the lower end with a trolley; so that as the endless chain moves, the trolley (with the material in it) also moves in the direction in which chain travels.

Pipe line conveyors are used for transporting granular (wheat) or pulverized materials (salt) through the pipes. Gravity or air flow moves the material ahead.

6. SLIDES AND CHUTES

- Straight
- Spiral
- Vibrating

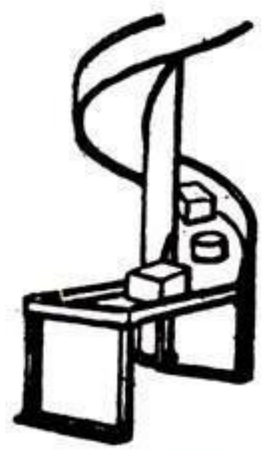


Fig. 25.31. Spiral chute.

They transfer small jobs which can slide down under gravity. Vibrating slides transport materials up an incline also (cigarette factories). Chutes have sheet metal or roller base for transferring components down the incline. Chutes generally feed parts (which they receive from, say sheet metal presses) to the conveyor which takes the parts to their destination.

7. LIFTS

In multistorey plants, material is lifted up and transported by lifts. It is a fast and flexible equipment for floor to floor travel. Buckets or trays can be mounted on the endless chain running from the ground floor to the top floor. The material can be loaded in the trays automatically.

8. TRACTORS AND TRAILERS

Tractors, three wheeled or four wheeled employ I.C. Engine drive and are generally used for outdoor applications. Material is loaded in the trailers which are attached to the towing tractor. Trailers can either be uncoupled from the tractor train, or the material loaded in them can be dumped out, at respective stations. Tractor train is very helpful in big industries.

Fig. 25.32. Industrial tractor.

PRINCIPLE OF UNIT LOAD AND CONCEPT OF CONTAINERIZATION AND PALLETIZATION:

- It is easier and faster to move hundred small parts say castings or cardboard sheets by grouping them in one unit than moving them individually one by One. This principle of unit load can also be explained like this.

- If the bearer of a hotel removes cups, plates and other crockery from a table by placing them in a tray, it is called material handling by unit loads. Definitely, he would have spent much more time and efforts in removing all the crockery by one cup or one plate at a time.

- By using available machines (like one for strapping steel strips around cotton bales), fork lift trucks, skids and pallets (see Fig. 25.33), it is easy to handle materials in unit loads and stack them neatly and properly (even as high as the ceiling) thereby reducing the storage space requirements.

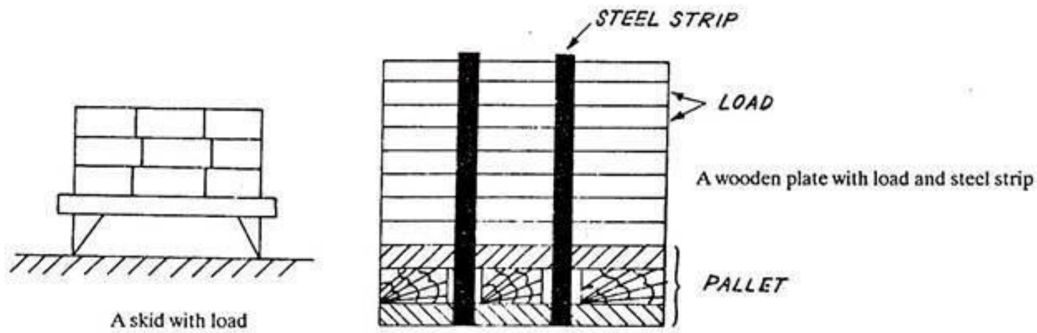


Fig. 25.33. Skid and pallet.

- Depending upon the types of items to be transferred, a suitable pallet can be designed. For example, items irregular in shape and liable to be damaged by crushing utilize a post pallet whereas small jobs can be placed in wire mesh box

- Containerization uses principle of unit load. In this system, big metal containers have number of small products filled in them. These containers are placed on the truck or in the trailers which are pulled by tractors or trucks.

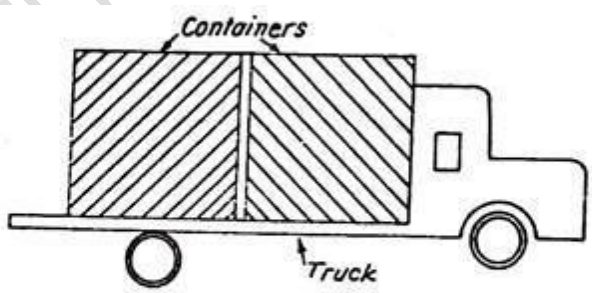


Fig. 25.36. Truck with containers.

- Afterwards, the containers can be loaded on railway trailers and can be taken to places from where, with the help of cranes, they can be shipped. Items like refrigerators, air- conditioners or televisions can be sent to distant places using the principle of containerization. The system is much safer and involves a lot of saving.

APPLICATIONS OF MATERIAL HANDLING

- Forecasting
- Resource allocation
- Production planning
- Flow and process management
- Inventory management and control
- Customer delivery
- After-sales support and service

ROLE OF ERGONOMICS IN JOB DESIGN

Job design is the process of deciding the contents of a job, the techniques, systems, and procedures required to carry out the job, and the relationship of the jobholder with other workers. It determines the nature and number of tasks done, the way of doing such tasks, and the order of doing such tasks in a job.

Elements of job design

1. **Tasks**
   - One of the most fundamental considerations behind job design is the tasks that need to be completed. The organization needs to consider the most efficient manner in which it is able to meet performance standards and obligations.
   - When separating tasks into different job positions, it considers how the tasks will be completed, what tasks will be performed, how many will be completed in each job position and the order in which the worker will complete them.
   - For example, a food manufacturer that employs a direct sales team might combine selling, delivery, ordering and merchandising tasks into one position in order to decrease labor costs and increase customer service satisfaction. It may or may not decide that a separate position needs to be created to load and unload the delivery trucks in order to increase the productivity of its sales representatives.
2. **Job Enlargement**
   - The act of job enlargement increases the variety of tasks involved in a job. It

accomplishes this by combining a few of the tasks that were previously performed by separate job positions.

- Job enlargement allows organizations to provide workers with greater responsibility and opportunities for skill enhancement. It also strives to relieve individual workers of boredom associated with routine and repetition.
- A secondary objective of job enlargement is to increase employee motivation by creating work-related challenges and giving them a more interesting set of tasks to perform.

3. Job Rotation

- Job rotation seeks to create the same type of enhancements seen with job enlargement. The difference is that instead of combining tasks from different positions, it allows workers to change job functions. Provided that the organization is able to draw upon internal and external resources to administer cross-training, individual workers are able to periodically move from one job to another.

- In job rotation, responsibility levels do not change, but the tasks that the workers perform do. Rotations might occur on an hourly, daily, weekly or monthly basis.
- In a retail environment, for example, an employee might rotate back and forth between being a floor stocker, cashier and customer service desk associate.

4. Job Enrichment

- A fourth element of job design is job enrichment. It seeks to enhance a position by adding opportunities for higher levels of responsibility, recognition through achievement and personal skill development.
- The difficulty of the tasks might be increased, or managerial planning and control functions might be assigned to the employee. Special project teams or being designated as a team expert also fall under job enrichment.
- The main objective of job enrichment is to increase employee motivation and job satisfaction.

Ergonomics (human factors)is a branch of science that aims to learn about human abilities and limitations, and then apply this learning to improve people's interaction with products, systems and environments.

- An important consideration of job design is workplace ergonomics.

- Improperly designed jobs can cause various injuries such as carpel tunnel syndrome, tennis elbow, and other conditions, arising out of repetitive movements, extreme temperatures, use of improper tools, and other work-related aspects.
- Job-design ergonomics concentrates on optimizing the workstation and tools and ensuring that the worker remains aligned with the work process in the best possible way, eliminating awkward body positions, and ensuring minimal strain or musculoskeletal injury. Consideration of human factors also emphasizes designs that reduce the potential for human error

Benefits of a Workplace Ergonomics Process

1. **Ergonomics reduces costs.** By systematically reducing ergonomic risk factors, you can prevent costly MSDs. With approximately $1 out of every $3 in workers compensation costs attributed to MSDs, this represents an opportunity for significant cost savings. Also, don't forget that indirect costs can be up to twenty times the direct cost of an injury.
2. **Ergonomics improves productivity.** The best ergonomic solutions will often improve productivity. By designing a job to allow for good posture, less exertion, fewer motions and better heights and reaches, the workstation becomes more efficient.
3. **Ergonomics improves quality.** Poor ergonomics leads to frustrated and fatigued workers that don't do their best work. When the job task is too physically taxing on the worker, they may not perform their job like they were trained. For example, an employee might not fasten a screw tight enough due to a high force requirement which could create a product quality issue.
4. **Ergonomics improves employee engagement.** Employees notice when the company is putting forth their best efforts to ensure their health and safety. If an employee does not experience fatigue and discomfort during their workday, it can reduce turnover, decrease absenteeism, improve morale and increase employee involvement.
5. **Ergonomics creates a better safety culture.** Ergonomics shows your company's commitment to safety and health as a core value. The cumulative effect of the previous four benefits of ergonomics is a stronger safety culture for

your company. Healthy employees are your most valuable asset; creating and fostering the safety & health culture at your company will lead to better human performance for your organization

UNIT III - INVENTORY CONTROL AND MAINTENANCE

Inventory

Inventories refer to those products or goods a firm is manufacturing for sale and components that make up the product.

INVENTORY MODEL

All models are classified into two major types:

1. **Deterministic Models**
    - The deterministic models are built on the assumption that there is no uncertainty associated with demand and replenishment of inventories. On the contrary, the probabilistic models take cognizance of the fact that there is always some degree of uncertainty associated with the demand pattern and lead time of inventories.
    - In brief, the deterministic models are built on the assumption that there is no uncertainty associated with demand and replenishment of inventories.
2. **Probabilistic Models**
    - On the contrary, the probabilistic models take cognizance of the fact that there is always some degree of uncertainty associated with the demand pattern and lead time of inventories.

Deterministic Inventory models - types

- Economic Ordering Quantity (EOQ) Model,

- ABC Analysis

Probabilistic Inventory models - types

- A fixed order quantity model (Q-system)
- A fixed time period model (P-system)

ECONOMIC ORDER QUANTITY

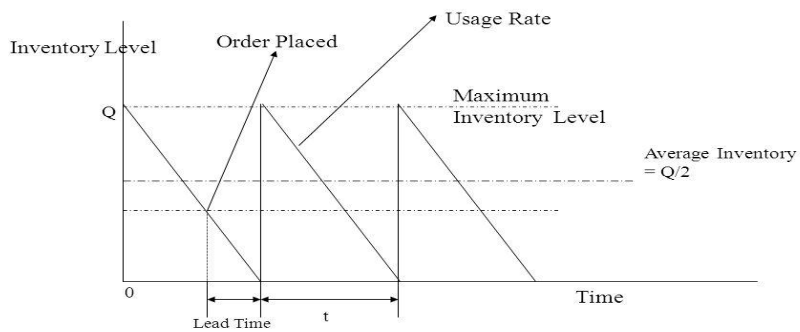
The Economic Order Quantity (EOQ) is the number of units that a company should add to inventory with each order to minimize the total costs of inventory—such as holding costs, order costs, and shortage costs.

Model I: Purchasing model (Economic Order Quantity) with shortage (Basic Inventory Model)

Assumptions

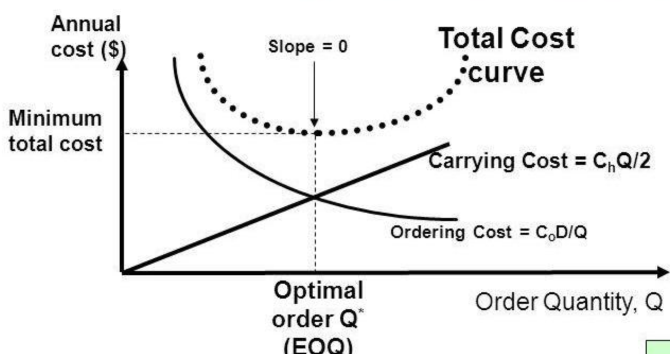
- Demand is deterministic, constant and it is known.
- Stock replenishment is instantaneous (lead time is zero)
- Price of the materials is fixed (quantity discounts are not allowed)
- Ordering cost does not vary with order quantity.

BASIC EOQ MODEL



INVENTORY MODELS 22

EOQ Model Cost Curves



D = Demand/year
C_o = cost per order
C_h = Holding (carrying) cost

Average inventory = Q/2

Expected Number of Orders $= N = \dfrac{D}{Q^*}$

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

Expected Time Between Orders $= \dfrac{Q^*}{D}$

Total Costs	= Carrying Cost	+	Ordering Cost	
C_t	= $C_hQ/2$	+	C_oD/Q	

1

Model II: Purchasing Model (EOQ) with shortages

One of the banes of any inventory manager is the occurrence of an inventory shortage (sometimes referred to as a stock out)—demand that cannot be met currently because the inventory is depleted. This causes a variety of headaches, including dealing with unhappy customers and having extra record keeping to arrange for filling the demand later (backorders) when the inventory can be replenished. By assuming that planned shortages are not allowed, the basic EOQ model presented above satisfies the common desire of managers to avoid shortages as much as possible.

Assumptions:

- Shortage cost is small
- No demand is lost because of shortage as the customers will back order
- Delayed delivery is accepted
- Replenishment is instantaneous

EOQ Model with Shortages
Model Formulation (1 of 2)

Total shortage costs $= C_s \frac{S^2}{2Q}$ Total carrying costs $= C_c \frac{(Q-S)^2}{2Q}$

Total ordering cost $= C_o \frac{D}{Q}$

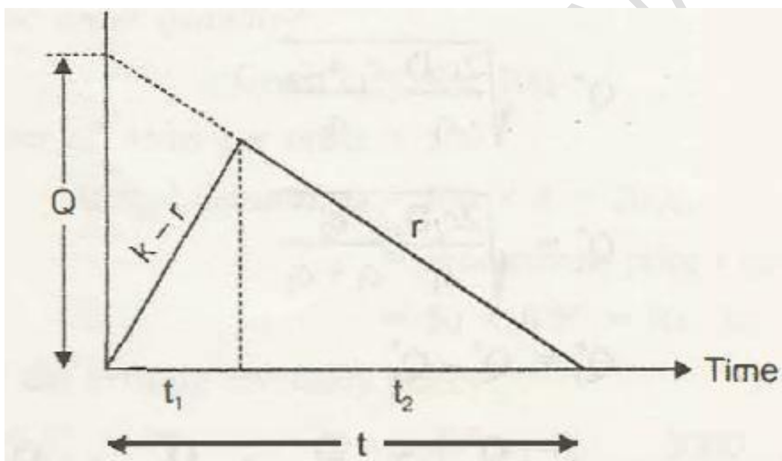
Total inventory cost $= C_s \frac{S^2}{2Q} + C_c \frac{(Q-S)^2}{2Q} + C_o \frac{D}{Q}$

Optimal order quantity $= Q_{opt} = \sqrt{\frac{2C_o D}{C_c}\left(\frac{C_s + C_c}{C_s}\right)}$

Shortage level $= S_{opt} = Q_{opt}\left(\frac{C_c}{C_c + C_s}\right)$

Model III: Manufacturing Model (EBQ) without shortages Assumptions

- Items are manufactured, shortages are not allowed,
- Demand is uniform,
- Lead time is zero,
- Items are produced and used to meet demand simultaneously for a portion of an inventory cycle.



In this model,

- Inventory is building up at a constant rate of (k- r) units per unit time during t_1.
- No production during t_2 and the demand is met at the rate of r per unit of time.

Q* = EOQ/Economic batch quantity

$$= \sqrt{\frac{2c_s . r}{c_1(1 - r/k)}}$$

t_1^*= period of production as well as consumption

$= Q^* / k$

t_2 = penod of consumption only = r

n^* = optimum number of production runs per year

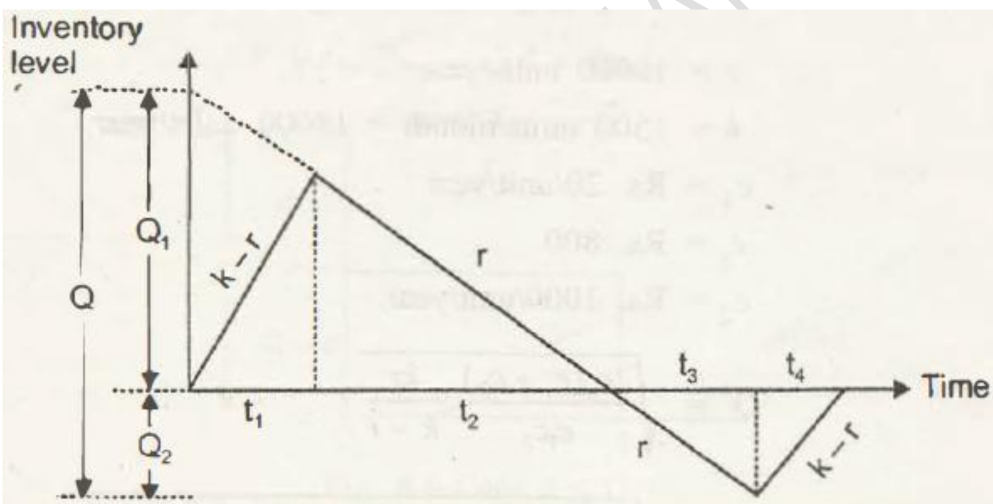
$= r / Q^*$

Cycle time $t^* = t_1^*$

$+t_2^*$ Total minimum cost= $\sqrt{2rc_sc_1(1 - r/k)}$.

Model IV: Manufacturing model (EBQ) with shortages

In this model, the items are produced and consumed simultaneously for a portion of cycle time. The rate of consumption of items is uniform throughout the year. The cost of production per unit is the same irrespective of production lot size. In this model, stock out/shortage is permitted. It is assumed that the stock out units will be satisfied from the units which will be produced at a later date with a penalty (like rate reduction).This is called back ordering,



Here during L_p inventory is built up at the rate of (k - r), during t2, inventory is consumed at the rate of r,

during t3, shortage is building at the rate of r,
during t4, shortage is being filled at the rate of (k - r).

Demand = r

Manufacturing

rate= k

Q^* = EOQ/Economic batch quantity

Q_1^* = maximum inventory level = $(1 - r/k)Q^* - Q_2^*$

$$Q^* = \sqrt{\frac{2c_s(c_1 + c_2)}{c_1 c_2} \cdot \frac{kr}{k - r}}$$

$$Q_1 + Q_2 = \left(1 - \frac{r}{k}\right)Q$$

$$Q_2^* = \text{no. of shortages} = \sqrt{\frac{2c_s\, c_1}{(c_1 + c_2).c_2}.r\left(1 - \frac{r}{k}\right)}$$

t^* = production cycle time

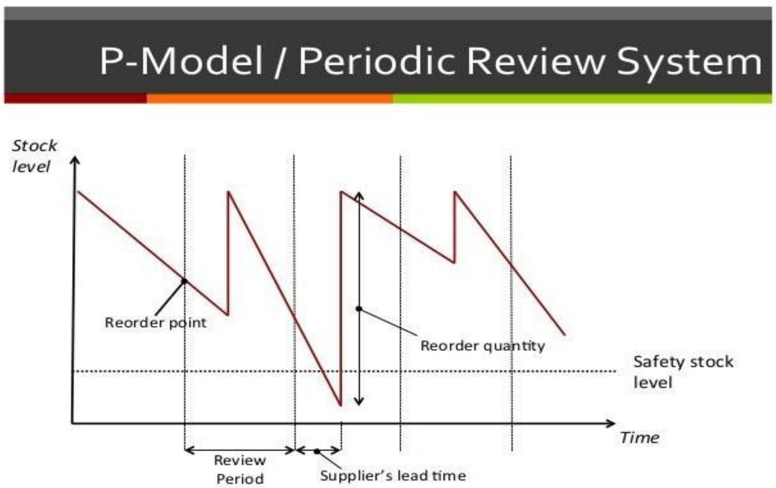
w.r.t (r) Manufacturing time

w.r.t (k)

$$t_1^* = \frac{Q_1^*}{k - r},\ t_2^* = \frac{Q_1^*}{r},\ t_3^* = \frac{Q_2^*}{r},\ t_4^* = \frac{Q_2^*}{k - r}$$

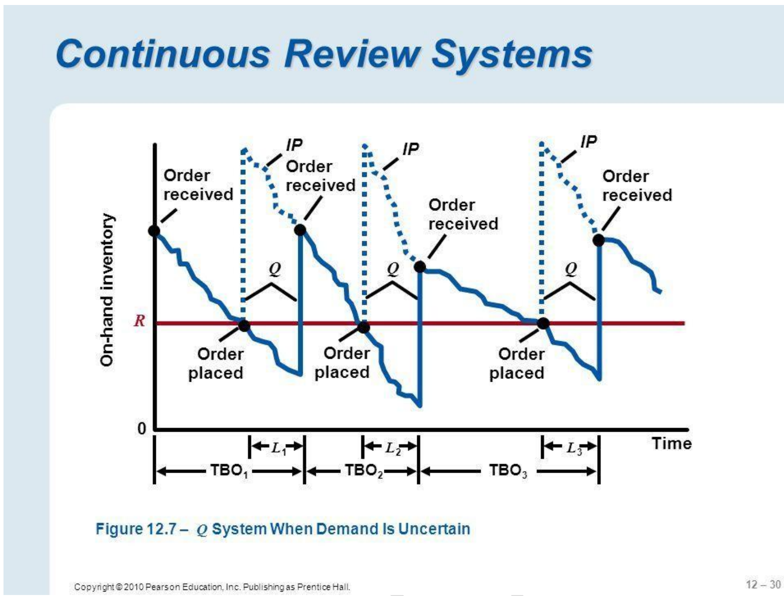
$$\text{Total minimum production inventory cost} = \sqrt{\frac{2c_1c_2c_s r}{c_1 + c_2}.\left(1 - \frac{r}{k}\right)}$$

- **<u>Periodic Review System (P) or Fixed Interval Reorder System</u>**



- In the periodic review system (P) an item's inventory position is reviewed periodically rather than continuously.
- Such a system can simplify delivery scheduling, because it establishes a routine.
- A new order is always placed at the end of each review and the time between orders (TBO) is fixed at *P*.
- Demand is a random variable. So, demand between reviews varies.
- In a P system, the lot size *Q* may change from one order to the next, but the time between orders is fixed.

 Continuous Review (Q) System Or Fixed Order-Quantity System



- A continuous review (Q) system or reorder point (ROP) system or fixed order- quantity system tracks the remaining inventory of an item each time a withdrawal is made to determine whether it is time to reorder.
- In practice, these reviews are done frequently (e.g. daily) and often continuously (after each withdrawal).
- At each review a decision is made about an item's inventory position.
- If it is considered to be too low, the system triggers a new order.

REORDER POINT

 The reorder point (ROP) is the level of inventory which triggers an action to replenish that particular inventory stock. It is a minimum amount of an item which a firm holds in stock, such that, when stock falls to this amount, the item must be reordered.

- It is normally calculated as the forecast usage during the replenishment lead time plus safety stock. In the EOQ (Economic Order Quantity) model, it was assumed that there is no time lag between ordering and procuring of materials.
- Therefore the reorder point for replenishing the stocks occurs at that level when the inventory level drops to zero and because instant delivery by suppliers, the stock level bounce back.

Reorder Point = Normal consumption during lead-time + Safety Stock Reorder Level = Average Weekly Demand × Average Lead Time + Safety Stock

Advantages of reorder point based system

- One of the key benefits of this system is that it allows a smooth inventory flow with no halts in between. This further builds on the inventory discipline of your business.

  - Makes space to identify procurement issues and helps in resolving the same leading to a smoother process.
  - Makes sure that the stock is available at all times and thus avoids any production glitches.
  - Unnecessary expenditure in stocking and maintaining the inventory is reduced.
  - Helps the business to take appropriate decisions by helping to track the entire procurement procedure.

SAFETY STOCK

Safety stock is an additional quantity of an item held in inventory in order to reduce the risk that the item will be out of stock. Safety stock acts as a buffer in case the sales of an item are greater than planned and/or the supplier is unable to deliver additional units at the expected time.

Benefits

- Safety stock protects against unforeseen variation in supply and/or demand

- To compensate forecast inaccuracies (only in case demand is bigger than the forecast)
- Its purpose is to prevent disruptions in manufacturing or deliveries
- Avoid stock outs to keep customer service and satisfaction levels high

INVENTORY COSTS

Various costs associated with Inventory are:

a. **Purchase (or production) cost:** The value of an item is its unit purchasing (production) cost. This cost becomes significant when availing the price discounts. This cost is expressed as Rs.

/unit

b. **Capital cost:** the amount invested in an item, (capital cost) is an amount of capital not available for other purchases. If the money were invested somewhere else, a return on the investment is expected. A charge to inventory expenses is made to account for this return. The amount of the charge reflects the percentage return expected from other investment.

c. **Ordering cost:** It is also known by the name procurement cost or replenishment cost or acquisition cost. Cost of ordering is the amount of money expended to get an item into inventory. This takes into account all the costs incurred from calling the quotation to the point at which the items are taken to stock.

There are two types of costs- Fixed costs and variable costs.

Fixed costs do not depend on the number of orders whereas variable costs change with respect to the number of orders placed. The salaries and wages of permanent employees involved in purchase function and control of inventory, purchasing, incoming inspection, accounting for purchase orders constitute the major part of the fixed costs. The cost of placing an order varies from one organization to another. They are generally classified under the following heads:

(i) Purchasing: The clerical and administrative cost associated with the purchasing, the cost of requisitioning material, placing the order, follow-up, receiving and evaluating quotations.

(ii) Inspection: The cost of checking material after they are received by the supplier for quantity and quality and maintaining records of the receipts.

(iii) Accounting: The cost of checking supply against each order, making payments and maintaining records of purchases.

d. **Transportation costs**: The expenses involved in moving products or assets to a different place, which are often passed on to consumers. For example, a business would generally incur a transportation cost if it needs to bring its products to retailers in order to have them offered for sale to consumers.

e. **Inventory carrying costs (Holding cost):** These are the costs associated with holding a given level of inventory on hand and this cost vary in direct proportion to the amount of holding and period of holding the stock in stores. The holding costs include.

- Storage costs (rent, heating, lighting, etc.)
- Handling costs: Costs associated with moving the items such as cost of labor, equipment for handling.
- Depreciation, taxes and insurance.
- Costs on record keeping.
- Product deterioration and obsolescence.

- Spoilage, breakage, pilferage and loss due to perishable nature.

f. **Shortage cost**: When there is a demand for the product and the item needed is not in stock, then we incur a shortage cost or cost associated with stock out. The shortage costs include:

- Backorder costs.
- Loss of future sales.
- Loss of customer goodwill.
- Extra cost associated with urgent, small quantity ordering costs.
- Loss of profit contribution by lost sales revenue.

CLASSIFICATION OF STOCK

Inventory is classified as follows

1. **Based on operation process**

- **Raw materials**
- **Works-in-process**
- **Finished goods**
- **Spares**

2. **Based on inventory movements**

- **Cycle stock** – inventories for satisfying usual (predicted) demand between replenishments (receiving new ordered quantities)
- **In-transit inventories / pipeline stock** – items that are en route from one location to another. They may be considered part of cycle stock even they are not available for sale or shipment until after they arrive at the destination.

- **Safety or buffer stock** – held in excess of cycle stock because of uncertainty in demand or lead time. Amount depends on extent of demand fluctuation, replenishment lead time and planned availability level for customers. Makes the majority of inventory in the typical logistic system
- **Speculative stock** – held some reasons other than satisfying current demand (getting quantity discounts, forecasted purchase price increase or materials shortage, protecting against strikes/natural disasters etc. Production economies may also lead to the manufacture of products at times other than when they are in demand.
- **Seasonal stock** – form of speculative stock that involves accumulation of inventory before a seasonal period begins (or ends – in agriculture)
- **Dead stock** - items for which no demand has been registered for some specified period of time (obsolete products, demand season ended, etc).

3. Based on functions

- **Lot-size Inventories:** Some business firms prefer to purchase materials in bulk because they receive a discount on bulk purchases. Big business firms can afford to buy in large quantities. To produce the goods in exact amount of their demand is not generally possible and practical. Some inventories accumulate. The inventories accumulated as a result are known as lot-size inventories.
- **Fluctuation Inventories:** Because of the demand and supply factors, the market for certain commodities or raw materials generally fluctuates. This fluctuation is marked in respect of agro-based products.

- **Anticipation Inventories:** When a business firm anticipates a price rise or introduces the business promotion tools, it will need to accumulate inventories. The raw materials may be stored in the form of semi-finished goods or stored in their original form. These inventories are known as anticipation inventories.

CODIFICATION OF STOCK

Codification is a process of representing each item by a number, the digits of which indicate the group, the subgroup, the type and the dimension of item.

Objectives of Codification

In order to identify the items correctly and logically for processing the transactions, and to facilitate easy location in stores, a codification system should be evolved with the following objectives.

i) **Accurate and logical identification**: A separate code allotted to each of the items available in the warehouse indicating the size, quality price, usability, special characteristics, specification etc.

ii) **Prevention of duplication**: All items are separately codified and are arranged in a logical order. Similar materials are grouped together (such as stationery items, hardware items) and given a code.

iii) **Standardization and reduction of varieties**: For codification, grouping of identical item is done and it enables the stores to examine the entire range of items. It facilitates the elimination of those varieties in place of which other varieties of the same quality can be used. This reduces the number of varieties to a minimum. If proper standardization is achieved and the number of items is kept at the minimum, it will considerably reduce investment in various items as well as the cost of inventory carrying.

iv) **Efficient purchasing**: The filling up of purchase requisition, and preparation of purchase orders are simplified by the use of codes which easily indicates the materials required. Buying instructions to the suppliers become easy and quick if there is proper understanding of codification by the suppliers.

v) Efficient recording and accounting codes leads to effective stock control, efficient recording and it results in yielding accounting. Chances of mistakes are minimized. Pricing and valuation also become more accurate and reliable.

vi) Easy locating, indexing and inspection of all materials is possible.

vii) **Easy computerization**: The computer work well with codes then with long description of materials.

Codification systems

Some of the systems of codification are:

1) Arbitrary system
2) Numerical System
3) Mnemonic system or alpha numeric system
4) Decimal system
5) Brisch system
6) Kodak system

1. Arbitrary Systems

Arbitrary system as the word 'arbitrary' indicates, is based on the serial number under which a material is received and the same is allotted as a code number. Using this approach, all inventory items are simply assigned arbitrary numbers in sequence as they are added to the stores account. Each item thus has a discrete number, but it bears no systematic relationship to the numbers assigned to related items

For example, if bearings are received and suppose a number 5090 has already been allotted to the previous item received, then the code number of these bearings will be 5091

2. Numerical System

A numerical system assigns a six to ten digit code number to each item. The first several numbers usually indicate the classification to which the item belongs, the next several numbers typically indicate the sub-class, and the last three numbers are usually uncoded.

The following example illustrates the concept:

3 - General Class

129 - Generic

Class 017 - Sub-

class

503 - Specific item number

3. Mnemonic System

A mnemonic system functions much like a numerical system. However, it combines numeric and alphabetic notations in its symbols. For example, the carriage bolt described under the numerical system in the following manner:

P Fa BCS 503

P denotes a purchased part, Fa is a fastener, BCS stands for bolt, carriage, with a square neck, and 503 represents the specific number of the bolt.

4. Decimal System

- Decimal system of codification may said to be the universal in its working. It is simple and easy to codify items under this system. Day by day, the number of items in almost every sphere of industry is increasing. Hence, codifications should be such as may meet the increasing requirements and it should also be simple, handy and easily adaptable.
- Under this system items up to 5,00,000 can be easily codified and at the same time each symbol will give the history, size, specification and complete picture of the item. Modern industrial concerns are generally adopting 7 to 11 digits for codifying the materials.

5. **Brisch System**

The Brisch system consist of seven digits applied in three stages. The items are grouped into suitable preliminary categories, such as assemblies, sub-assemblies, components and off the shelf items. After these preliminary categories, items are grouped within the respective class in order to bring similar items together. The Brisch system through it consists only of seven digits, is quite comprehensive as the basis is on logical major groupings.

6. **Kodak System**

The Kodak system consists of 10 digits of numerical code. The logic of major grouping is based on sources of supply. All materials are divided into 100 basic classifications, contributed only by procurement considerations. For instance, a bolt is listed as hardware item if this is listed in hardware catalogues and available with hardware suppliers. If this bolt is available as a part of the machine, it will be available under maintenance.

Advantages of Codification

- As a result of rationalized codification, many firms have reduced the number of items.
- It enables systematic grouping of similar items and avoids confusion caused by long description of the items.
- Since standardization of names is achieved through codification, it serves as the starting point of simplification and standardization.
- It helps in avoiding duplication of items and results in the minimization of the number of items, leading to accurate records.
- Codification enables easy recognition of an item in stores, thereby reducing clerical efforts to be minimum.
- If items are coded according to the sources, it is possible to bulk the items while ordering.

ABC CLASSIFICATION

- ABC analysis is a technique of categorizing inventory items according to their substantial impact on the overall expenditure of an organization. It grants a solution to faulty inventory administration within the purchased items or availed services.
- ABC analysis is an "inventory categorization method" which entails the dividing items into three categories, A, B and C: "A" contains the "most valuable items" and"C" consists the "least valuable items", whereas "B" contains items ranging between "A" and "C". It aims to focus on the critical few (Aitems) and not on the trivial many (C-items).

Steps in ABC analysis

Following are the steps for the classification of items by ABC analysis:

1. The unit cost and the demand of each item is obtained over a given period.
2. Multiply the unit cost by the calculated annual usage to obtain the net cost.
3. All the items are listed out and arranged in a descending annual cost.
4. Sum up the cost and add up the number of items then, compute percentage on the total inventory of total cost and for total number of items consumed.
5. Draw a graph of percentage items vs percentage cost.
6. Mark from the curve the rational limits of A (70% of annual consumption), B (20% of annual consumption) and C (10% of annual consumption) categories.

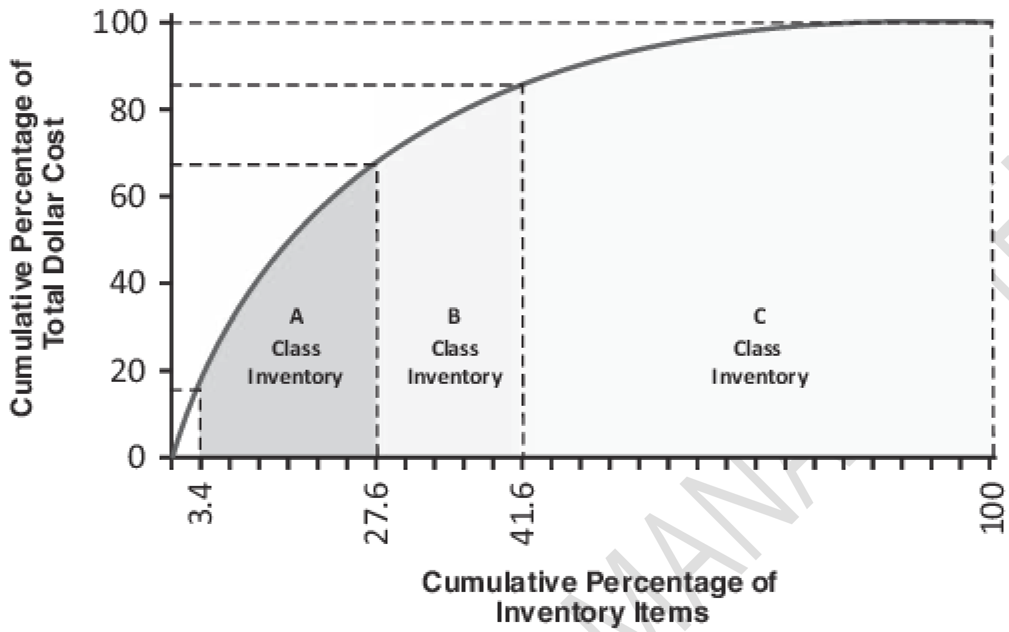


Fig: Example of ABC Inventory classification

Limitations of ABC analysis

1. Conflict with other cost systems. ABC cost allocation differs from the traditional cost system allocation.
2. This method needs more resources to maintain compared to the traditional costing systems.
3. This is a continuous process which needs added data measurement and collection.
4. It needs periodical assessment and updating.
5. This analysis is built on the monetary value of the materials in use. Other important factors one ignored.

MATERIALS REQUIREMENT PLANNING (MRP)

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.

OBJECTIVES OF MATERIAL REQUIREMENT PLANNING

- **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.

- **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.

- **Realistic delivery commitments**

By using MRP, production can give marketing timely information about likely delivery times to prospective customers.

- **Increased efficiency**

MRP provides a close coordination among various work centers and hence help toachieve uninterrupted flow of materials through the production line. This increases the efficiency of production system.

MRP SYSTEM

The inputs to the MRP system are:

(1) A master production schedule,

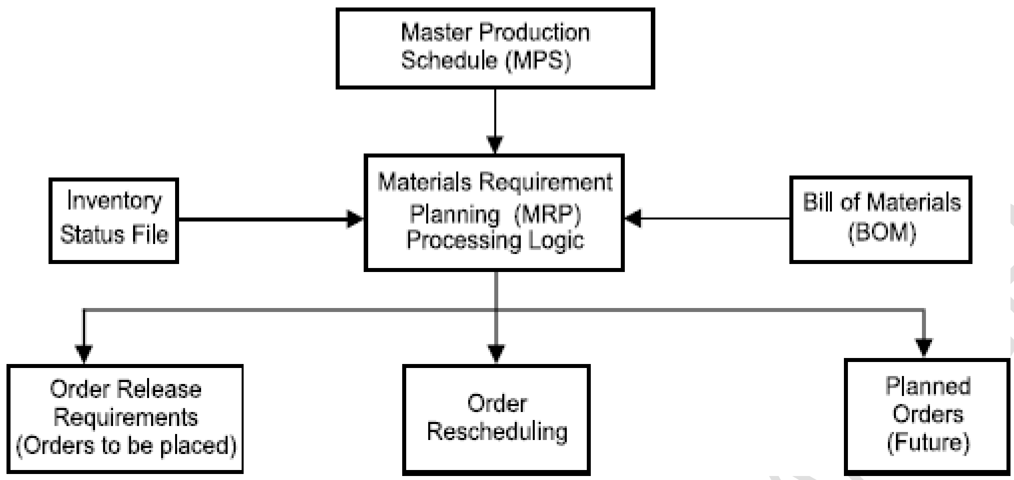
(2) An inventory status file and

(3) Bill of materials (BOM).

Using these three information sources, the MRP processing logic (computer programme) provides three kinds of information (output) for each product component:

- Order release requirements,
- Order rescheduling and
- Planned orders.

MRP SYSTEM



INPUTS OF MRP

Master Production Schedule (MPS)

MPS is a series of time phased quantities for each item that a company produces, indicating how many are to be produced and when. MPS is initially developed from firm customer orders or from forecasts of demand before MRP system begins to operate. The MRP system whatever the master schedule demands and translates MPS end items into specific component requirements. Many systems make a simulated trial run to determine whether the proposed master can be satisfied.

Inventory Status File

Every inventory item being planned must have an inventory status file which gives complete and up to date information on the on-hand quantities, gross requirements, scheduled receipts and planned order releases for an item. It also includes planning information such as lot sizes, lead times, safety stock levels and scrap allowances.

Bill Of Materials (BOM)

BOM identifies how each end product is manufactured, specifying all subcomponents items, their sequence of build up, their quantity in each finished unit and the work centers performing the build up sequence. This information is obtained from product design documents, workflow analysis and other standard manufacturing information

OUTPUTS OF MRP

Purchase Orders (PO): This is the recommended purchasing schedule that includes the order you give to suppliers to send the materials. The PO includes a schedule with quantities and start and finish dates to meet the MPS.

Work Orders: This details the work that goes into producing the end product, including which departments are responsible for what part, what materials are necessary, and what the start and end dates are.

Reports: MRP generates primary and secondary reports. The primary reports include all three of the above — those that deal with production and inventory planning and control. Secondary reports are those that detail things, such as performance control, exception data (e.g., errors or late orders), deviations, and predictors of future inventories and contracts.

MATERIAL REQUIREMENTS PLANNING STEPS AND PROCESSES

MRP works because it is a well-organized framework of processes and calculations. An MRP system can completely transform a company's operational procedures. Many people within an organization contribute to the MRP process, including sales, production, purchasing, receiving, stockroom, and shipping personnel.

MRP consists of three basic steps:

Identifying The Quantity Requirements: Determine what quantity is on hand, in an open purchase order, planned for manufacturing, already committed to existing orders, and forecasted. These requirements are specific to each company and each company location and change with the date.

Running the MRP Calculations: Create suggestions for materials that you consider critical, expedited, and delayed.

Complete the Orders: Delineate the materials for the manufacturing orders, purchase orders, and other reporting requirements.

FUNCTIONS OF MATERIAL REQUIREMENT PLANNING (MRP)

Utilizing a systemic approach, the system is able to efficiently keep production up to schedule through data analysis and simple integration. Although the system can not run a production facility all on it's own, it still is able to maintain a steady flow of materials throughout the supply chain through decision-making capabilities. Various functions of an MRP system include the following:

Inventory Management - Arguably the main objective of an MRP system, the feature is to ensure that materials are available at a moments notice. This eliminates the need for manual- entered data and is able to carry out material orders with ease. It also is able to alert the facility when products are ready to be delivered

Cost Reduction - In correlation with inventory management, cost is reduced significantly. Through ensuring a steady flow of inventory, holding and untimely-delivery cost are reduced, ultimately bringing more revenue into the operation.

Production Optimization - Although the main goal of MRP is to oversee and manage materials, it benefits the rest of the system as well. As materials are flowing throughout the supply chain, equipment and employees are able to work at a much faster and efficient rate as well

JUST-IN-TIME (JIT) INVENTORY SYSTEM

The just-in-time (JIT) inventory system is a management strategy that aligns raw material orders from suppliers directly with production schedules. Companies use this inventory strategy to increase efficiency and decrease waste by receiving goods only as they need them for the production process, which reduces inventory costs. This method requires producers to forecast demand accurately.

The Purpose of JIT

- Ordering inventory on an as-needed basis means that the company does not hold any safety stock, and it operates with continuously low inventory levels.
- This strategy helps companies lower their inventory carrying costs, increase efficiency and decrease waste.
- JIT requires manufacturers to be very accurate in forecasts for the demand of their products.
- Just-in-time inventory management is a positive cost-cutting inventory management strategy, although it can also lead to stockouts.

- The goal of JIT is to improve a company's return on investment by reducing non-essential costs.

BENEFITS OF JIT

The most significant benefit is to improve the responsiveness of the firm to the changes in the market place thus providing an advantage in competition. Following are the benefits of JIT:

- *Product cost*—is greatly reduced due to reduction of manufacturing cycle time, reduction of waste and inventories and elimination of non-value added operation.
- *Quality* —is improved because of continuous quality improvement programs.
- *Design*—Due to fast response to engineering change, alternative designs can be quickly brought on the shop floor.
- Productivity improvement.
- Higher production system flexibility.
- Administrative and ease and simplicity
- Reduction in inventory
- Improved quality
- Reduced space requirements
- Shorter lead times
- Lower production costs
- Increased productivity
- Increased machine utilization
- Greater flexibility

ADVANTAGES OF ADOPTING JUST-IN-TIME

- Just-in-time approach keeps stock holding costs to a minimum level. The released capacity results in better utilization of space and bears a favourable impact on the insurance premiums and rent that would otherwise be needed to be made.

- The just-in-time approach helps to eliminate waste. Chances of expired or out of date products; do not arise at all.
- As under this management method, only essential stocks which are required for to manufacturing are obtained, thus less working capital is required. Under this approach, a minimum re-ordering level is set, and only when that level is reached, order for fresh stocks are made and thus this becomes a boon to inventory management too.
- Due to the abovementioned low level of stocks held, the ROI (Return On Investment? of the organizations be high in general.

- As this approach works on a demand-pull basis, all goods produced would be sold, and thus it includes changes in demand with unanticipated ease. This makes JIT appealing today, where the market demand is fickle and somewhat volatile.
- JIT emphasizes the 'right-first-time' concept, so that rework costs and the cost of inspection is minimized.
- By following JIT greater efficiency and High-quality products can be derived.
- Better relationships are fostered along the production chain under a JIT system.
- Higher customer satisfaction due to continuous communication with the customer.
- Just In Time adoption result in the elimination of overproduction.

DISADVANTAGES OF ADOPTING JIT SYSTEMS

- JIT approach states ZERO tolerance for mistakes, making re-work difficult in practice, as inventory is kept to a minimum level.
- A successful application of JIT requires a high reliance on suppliers, whose performance is outside the purview of the manufacturer.
- Due to no buffers in JIT, production line idling and downtime can occur which would have an unfavorable effect on the production process and also on the finances.
- Chances are quite high of not meeting an unexpected increase in orders as there will be no excess inventory of finished goods.
- Transaction costs would be comparatively high depending upon the

frequency of transactions.

- JIT may have certain negative effects on the environment due to the frequent deliveries as the same would result in higher use and cost of transportation, which in turn would consume more fossil fuels.

IMPLICATIONS OF SUPPLY CHAIN MANAGEMENT (SCM)

Supply Chain Management (SCM) is the management of a network of all business processes and activities involving procurement of raw materials, manufacturing and distribution management of Finished Goods. SCM is also called the art of management of providing the Right Product, At the Right Time, Right Place and at the Right Cost to the Customer.

- Supply Chain Strategies are the critical backbone to Business Organizations today. Effective Market coverage, Availability of Products at locations that hold the key to revenue recognition depends upon the effectiveness of Supply Chain Strategy rolled out.
- Inventory control and inventory visibility are two very critical elements in any operations for these are the cost drivers and directly impact the bottom lines on the balance sheet. Inventory means value and is an asset to the company. Every business has a standard for inventory turnaround that is optimum for the business. Inventory turnaround refers to the number of times the inventory is sold and replaced over a period of twelve months. The health of the inventory turn relates to the health of business.
- In a global scenario, the finished goods inventory is held at many locations and distribution centers, managed by third parties. A lot of inventory would also be in the pipeline in transportation, besides the inventory with distributors and retail stocking points. Since any loss of inventory anywhere in the supply chain would result in loss of value, effective control of inventory and visibility of inventory gains importance as a key factor of Supply Chain Management function.
- Inventory can be a vital part of managing supply chains. Because of this, the status of a firm's inventory is often used as a litmus test for the overall "health" of its supply chain management processes and decision-making. For example, consider the firm that has excessive amounts of inventory in the form of safety stock. Such high safety stock is indeed a problem in and of

itself because of the costs of holding this inventory and the opportunity costs of having working capital tied up in assets that aren't being converted to sales.

- The larger issue here, however, is that this safety stock situation is likely a symptom of some sort of ineffective supply chain management decision-making. Perhaps demand forecasting is constantly and significantly inaccurate, maybe supplier lead times are unnecessarily long, perhaps firm operations are laden with bottlenecks and inefficient inventory handling, or maybe transportation carriers are not providing quality service in the form of delivering inventory damage-free and on-time.
- These are but a few examples of supply chain management ineffectiveness that often manifest in the form of either extensive levels of stagnant inventory or consistent out-of- stocks. Hence, inventory is an important supply chain measurement tool because it is likely one of the first signs that some root cause(s) is causing supply chain inefficiencies.

IMPORTANCE OF INVENTORY MANAGEMENT IN SUPPLY CHAIN

- Efficient management of Inventory has played a vital role in deciding a firm's ability to operate with good profit margins. High Inventory Turnover ratio indicates that a company is efficient in managing its inventories and is having high sales
- . Having no prior knowledge of financial concepts or relevant industry experience, I was forced to think that if the Sales factor in the equation was not in our control, having less inventory would be the way to achieve high Inventory Turnover ratio.
- The reality however is different. Having low inventory might often result in company not being able to meet the committed service levels, which obviously means that more often than not, customers will be sent back home without the product they wanted or would be directed to other stores. This situation stresses the importance of efficient inventory management and its significance in efficiently managing your supply chain.
- While Inventory was regarded as an asset, the Japanese changed the way inventory was perceived by the introduction of concepts like "Just in Time" and considered inventory as a necessary "evil". The key to the just in time methodology are factors like inventory being closely managed, understanding the customers buying behaviors, having reliable suppliers and removing unnecessary inspection steps. Concepts such as these have changed the way companies perceive the idea of inventory management. Firms now believe that excessive cash tied up in unwanted inventory can be

utilized in other avenues that would generate profits.

- Many companies have been successful in achieving this through improvement of flow of materials in their supply chain. These companies in addition to focusing on the efficient ways to do things, also focused on the strict “don’ts” such as purchasing huge stock and treating them as an asset, excessive changes to schedules, treating all types of stock in the same way without any regard to the value of the good.
- “With the new reengineering in management and companies not just adopting just-in- time inventory practices but engaging in more integrated supply chain management, attention has recently been more focused on creating processes that reduce or eliminate inventories, mainly by reducing or eliminating uncertainties that make them necessary. These efforts have been motivated in part by the recognition that metrics describing the performance of a company's inventory management practices can be important signals to shareholders regarding the efficiency of the company's operations and hence its profitability”[2]

- The idea of an integrated inventory management has helped companies through Optimization and Coordination. The integrated system allows companies to optimize the linkage between supply chain and inventory and coordinate the inventory management to reduce costs and enhance differentiation. The maintenance of lower transaction costs and optimum inventory control management is not without some costs and tradeoff

MAINTENANCE

Maintenance is the process of keeping the machine and equipment in good working condition so that the efficiency of machine is retained and its life is increased.

"Plant maintenance is a combination of actions carried out by an organization to replace, repair, service the machineries, components or their groups in a manufacturing plant, so that it will continue to operate satisfactorily"

OBJECTIVE OF PLANT MAINTENANCE

The objective of maintenance is to maximize the performance of productive resources of an organization by ensuring that these resources perform regularly and efficiently. This is achieved by preventing the breakdown and failures and by minimizing the production loss.

The main objectives of plant maintenance are:

- To maximize the availability of plant, equipment and machinery for productivity through planned maintenance.

- To extend the life span of the plant, equipment, machinery etc., by minimizing their wear and tear and deterioration.
- To reduce the cost of production due to plant breakdown due to improper plant maintenance.
- To help the production department to go ahead with their production plans without any problem.
- To ensure operational readiness of all production facilities for emergency use at all times, such as firefighting equipment, first aid facilities, alternative method of production and packing etc.
- To provide management with proper information on the cost and effectiveness of maintenance.
- To ensure safety of staff through regular inspection and maintenance of facilities such as boilers, compressors, elevations, material handling system, conveyors , dangerous heavy machineries etc.

BREAKDOWN (REACTIVE) MAINTENANCE

Breakdown maintenance is basically the 'run it till it breaks' maintenance mode. No actions or efforts are taken to maintain the equipment as the designer originally intended to ensure design life is reached.

In this method the machines are allowed to run without carrying out any maintenance activities. Only when it becomes out of order (Stops working) it is repaired and set right. Next maintenance is done only when it breaks down again.

Advantages

- Involves low cost investment for maintenance.
- Less staff is required.

Disadvantages

- Increased cost due to unplanned downtime of equipment.
- Increased labor cost, especially if overtime is needed.
- Cost involved with repair or replacement of equipment.
- Possible secondary equipment or process damage from equipment failure.
- Inefficient use of staff resources.

PREVENTIVE MAINTENANCE

Preventive maintenance can be defined as, "Actions performed on a time or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.” Preventive maintenance is a means to increase the reliability of their equipment.

It is a method of maintenance aimed at avoiding or preventing breakdowns. The principle of preventive maintenance is ‘Prevention is better than cure’ Here some components are identified as weak spots in all machineries and equipment’s. These parts are inspected regularly. Minor repairs are carried out immediately as soon as there is necessity. This reduces the unanticipated breakdowns.

Advantages

- Cost effective in many capital intensive processes.
- Flexibility allows for the adjustment of maintenance periodicity.
- Increased component life cycle.
- Energy savings.
- Reduced equipment or process failure.

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Disadvantages

- Catastrophic failures still likely to occur.
- Labor intensive.
- Includes performance of unneeded maintenance.
- Potential for incidental damage to components in conducting unneeded maintenance

<u>Difference between Breakdown maintenance and Preventive maintenance</u>

Breakdown Maintenance	**Preventive Maintenance**
Maintenance is done only after machine fails to function	Maintenance is done before the machine fails
Maintenance is done after breakdown	It is done to prevent breakdown
The time of breakdown is unexpected. So the maintenance cannot be planned	Maintenance work is planned and scheduled in a well advanced manner
Not suitable for critical machineries like cranes , hoists , trucks boilers, furnaces, Valves etc.	Suitable for all types of equipment's and machineries
Cost due to down time is more	No down time
Production Loss takes place	No production Loss
The durability (Life) and efficiency of the equipment and machineries decreases due to poor maintenance	The durability (Life) and efficiency of the equipment and machineries increases decreases due to planned maintenance

It affects the quality of the goods produced by that equipment's and machineries	Preventive maintenance improves the quality of the goods
The Breakdown maintenance cannot be planned and scheduled as systematically and effectively as preventive maintenance	Preventive maintenance are planned and scheduled systematically and effectively

PREDICTIVE MAINTENANCE

Predictive maintenance can be defined as "Measurements that detect the onset of a degradation mechanism, thereby allowing causal stressors to be eliminated or controlled prior to any significant deterioration in the component physical state. Results indicate current and future functional capability".

Advantages

• Increased component operational life/availability.
• Allows for preemptive corrective actions.
• Decrease in equipment or process downtime.
• Decrease in costs for parts and labor.
• Better product quality.
• Improved worker and environmental safety.
• Improved worker morale.
• Energy savings.

Disadvantages

• Increased investment in diagnostic equipment.
• Increased investment in staff training.
• Savings potential not readily seen by management.

CORRECTIVE MAINTENANCE

- It is one type of planned maintenance and can be defined as "the practice carried out to restore the full performance of the equipment that has stopped working to acceptable standards. For instance, an engine may be in working condition, but does not make its full load because of worn–out piston rings. Thus, if the piston rings are replaced, it will bring back the performance of the engine to specified level".

- Corrective Maintenance, if properly implemented will result in reduction of maintenance costs and equipment's‟ downtime as well. Restoration of failed units is the primary intention of corrective maintenance, which is a one stretch job that must be fully completed once the activity is engaged.

- Corrective maintenance accentuate in getting complete information of every breakdown and the reason for each. Efforts are made to identify and eliminate the cause by activities such as improving maintenance practices, changing frequency of maintenance services and improving process control procedures.
- The use of planned preventive maintenance gives out a clear picture regarding the recurring failures of a particular component of an equipment such that the recurrence can be avoided and also informed to the manufacturer to incorporate changes in the design of equipment's.

TOTAL PRODUCTIVE MAINTENANCE (TPM)

- Total productive maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment.
- The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. It can be considered as the medical science of machines.
- TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Downtime for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process.
- The goal is to hold emergency and unscheduled maintenance to a

minimum. Avoid wastage in a quickly changing economic environment. Producing goods without reducing product quality. Reduce cost.

REPLACEMENT

Replacement models are concerned with the problem of replacement of machines, individuals, capital assets, etc. due to their deteriorating efficiency, failure, or breakdown.

- The primary objective of replacement is to direct the organization towards profit maximization or cost minimization.
- Deciding the replacement policy that determines the optimal replacement age of equipment, instead of using with higher maintenance costs for long time, is the main objective of replacement problem.
- For instance, in order to replace an:

1. item whether to wait till its failure or replacing at an early age with higher cost.
2. equipment whether to replace the inefficient equipment with a similar type of equipment or with a modern one.

Gradual Failure The mechanism under this category is progressive. That is, as the life of an item increases, its efficiency deteriorates, causing:

1. Increased expenditure for operating costs
2. Decreased equipment's‟ productivity
3. Decrease in the value of the equipment Example: bearings, pistons, piston rings, Automobile tyres, mechanical systems like machines, machine tools, flexible manufacturing equipment etc. fall under this category

Sudden Failure

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 equipment the period from installation to failure is not equal but will follow some „frequency distribution which may be progressive, retrogressive, or random in nature‟.

a) **Progressive failures:** In this mechanism, probability of failure increases as the life of equipment increases. Examples include: electric light bulbs, automobile tubes etc.

b) **Retrogressive failures**: Some equipment may prone to failure with high probability in the beginning of their life, and as the time progresses the probability of failure falls down. i.e., the capability of the equipment to survive in the beginning of life enhances its probable life. Industrial equipment's 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 equipment that fails from random causes such as physical shocks, not related to age. In such a case, virtually all equipment's fail prior to their expected life. Example: Electronic components like transistors, semiconductor 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.

GROUP VS INDIVIDUAL REPLACEMENT

The Replacement Theory is used in the cases like; existing items have out-lived, or it may not be economical anymore to continue with them, or the items might have been destroyed either by accident or otherwise.

The above discussed situations can be solved mathematically and categorized on some basis like:

- Items that deteriorate with time e.g. machine tools, vehicles, equipment buildings etc.
- Items becoming out-of-date due to new developments like ordinary weaving looms by automatic, manual accounting by tally etc.
- Items which do not deteriorate but fail completely after certain amount of use like electronic parts, street lights etc (Group Replacement) and

Replacement problems involve items that degenerate with use or with the passage of time and those that fail after a certain amount of use or time.

Items that deteriorate are likely to be large and costly (*e.g.,*machine tools, trucks, ships, and home appliances). Nondeteriorating items tend to be small and relatively inexpensive (*e.g.,* light bulbs, vacuum tubes, ink cartridges). The longer a deteriorating item is operated the more maintenance it requires to maintain efficiency. Furthermore, the longer such an item is kept the less is its resale value and the more likely it is to be made obsolete by new equipment. If the item is replaced frequently, however, investment costs increase. Thus the problem is to determine when to replace such items and how much maintenance (particularly preventive) to perform so that the sum of the operating, maintenance, and investment costs is minimized.

In the case of no deteriorating items the problem involves determining whether to replace them as a group or to replace individuals as they fail. Though group replacement is wasteful, labour cost of replacements is greater when done singly; for example, the light bulbs in a large subway system may be replaced in groups to save labour.

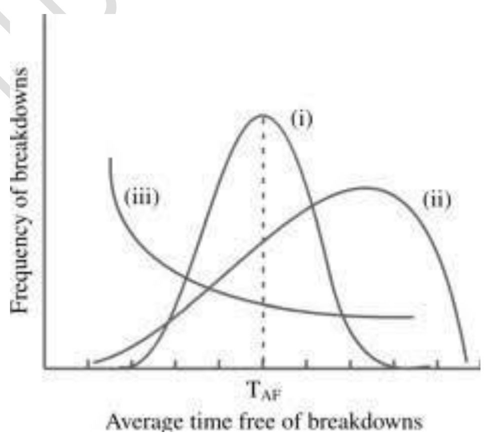
Replacement of items that fail suddenly

There are certain items which do not deteriorate but fail completely after certain amount of use. These kinds of failures are analyzed by the method called as group replacement theory. Here, large numbers of items are failing at their average life expectancy. This kind of items may not have maintenance costs as such but they fail suddenly without any prior warning. Also, in case of sudden breakdowns immediate replacement may not be available. Few examples are fluorescent tubes, light bulbs, electronic chips, fuse etc.

Let's consider the example of street lights. We often see street-lights being repaired by the corporation staff using extendable ladders. If a particular light is beyond repairs, then it is replaced. This kind of policy of replacement is called as „replacement of items as-and-when they fail" or 'Individual Replacement'. On the other hand, if all the street lights in a particular cluster are replaced as and when they fail and also simultaneously in groups, then the policy is called as 'Group Replacement'

BREAKDOWN TIME DISTRIBUTION

Breakdown time is the duration of the machine in the breakdown mode. Breakdown time distribution when plotted on the graph will show the frequency with which machines have maintenance-free performance for a given number of operating hours. Breakdown time distribution are developed from distribution of run time free of breakdowns as sown in the fig.



The above fig shows breakdown time distributions. These distributions take different shapes, depending on the nature of the equipment with which we are dealing. Variability of breakdown will be smaller with a simple machine compared to a complex machine, each part would have a failure distribution. When we combine these distributions in one distribution, of breakdown time of the machine , we would expect to find greater variability Breakdown time distribution data are basic to the formulation of any general policies concerning maintenance.

MAINTENANCE OF COST BALANCE

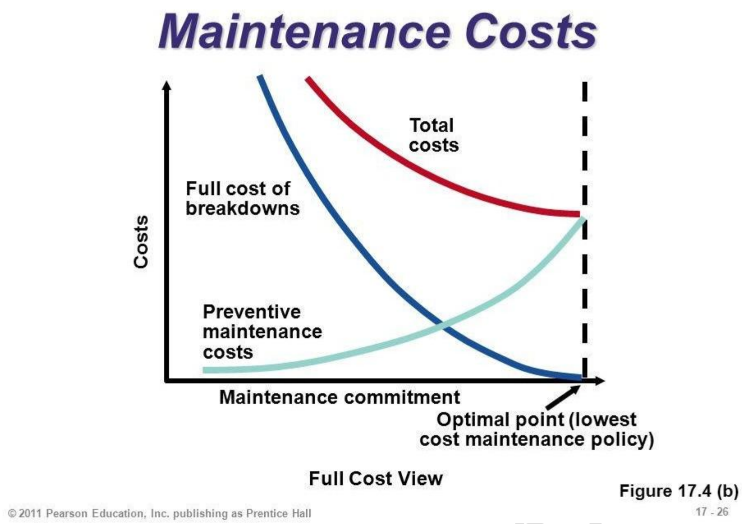
Breakdown of equipment makes the workers and machine idle resulting in loss of production, delay in schedules and expensive repairs. These downtime costs usually exceed the preventive maintenance costs of inspection, service and scheduled repairs up to the point 'M' shown in fig.

Beyond this optimal point an increasingly higher level of preventive maintenance is not economically justified and it is economical to adopt breakdown maintenance policy. The optimum level of maintenance activity 'M' is easily identified on theoretical basis, to dothis the details of the costs associated with breakdown and preventive maintenance must be known.

The cost associated with maintenance are

1. Down time cost- This is the loss of profit due to stoppage in production
2. Cost of material wasted
3. Wages paid to workers when they are idle due to breakdown
4. Cost due to idleness of machine
5. Cost of spares and other materials used for repair
6. Wages paid to maintenance people
7. Losses due to inefficient operation of machines
8. Capital requirements required for replacement of machines

The maintenance function acts in a role to keep equipment operating effectively to maintain quality standards as well as to maintain the cost of standard of output. The policies regarding the maintenance depends on the situation and the relative costs. Is routine preventive maintenance economical or will it be less costly to wait for breakdown to occur and then repair the equipment?



The decision regarding the appropriate level of preventive maintenance rests on the balance of costs,. Managers may select a policy that minimizes the sum of preventive maintenance costs plus repair, down time and quality related costs. Curve (blue)' represents the increase in costs that results from higher levels of preventive maintenance. These costs increase because of higher levels of preventive maintenance mean that we replace the parts before they fails and we replace more components when preventive maintenance is performed and we perform preventive maintenance frequently.

Curve (indigo) represents the decline in breakdown and repair, downtime and quality related costs as the level of preventive maintenance increases. With higher level of preventive maintenance, we should experience fewer actual breakdowns.

PROCEDURE OF PLANT MAINTENANCE

As the planned maintenance is the true maintenance function compared to the unplanned maintenance, which has not been foreseen or happened accidently, the techniques of plant maintenance are most applicable only to planned maintenance , which is the real maintenance function that should be taken by the industrial unit.

Planned maintenance is not a specific type of maintenance, but the application of maintenance should be tackled in a specific manner. It is the comprehensive planning of the maintenance function, and is designed as the work is organized and is carried out with forethought , control and reorder.

Techniques of planned maintenance

In order to set up planned maintenance system for an organization it is necessary to make a general appraisal of all the maintenance work to be carried out and the resources available for this work. The basic techniques in designing a planned maintenance system are as follows.

a) **Inventory of facilities**: Prepare a list of all facilities –plant, buildings, machines and equipment's in the organization which need to be maintained

b) **Identification of plant and equipment**: After completing inventory of all facilities to be maintained, it is essential that each facility is positively identified. A typical identification system makes use of six-digit.

c) **Marking the equipment**: When an item of equipment has been allocated an identification symbol, it should be marked clearly and where possible by a method that is standard throughout the organization.

d) **The facility Register**: The facility register is a record of all machinery, plant, equipment and building which has to be maintained, including technical details about each. The information contained in this facility register can act as a standard reference in terms of each facility's spares, current location, conditions, serviceability model. Size specification, etc

e) **Marking schedule**: A maintenance schedule is a comprehensive list of maintenance work to be done, specifying the frequency, the maintenance worker and the estimated time required to complete the maintenance work. The maintenance schedule is normally prepared on the basis Location Machine Type No of Machine within the group

f. **Job Specification**: Job specification is a document describing the work to be done. After scheduling maintenance work to be carried out on each facility, the details of the work to be carried out on each facility, the details of the work to be performed need to be communicated clearly and precisely to the maintenance workers to ensure effective maintenance.

g. **The Maintenance program**: It is a list allocating specific maintenance to a specific period.

i.e. When it is to be maintained. The generally used techniques are maintenance planning charts or visible record cards. In the planning charts the facilities to be maintained are listed down the left hand side of the chart or board. The time scale usually in days or weeks in days or weeks is marked along the top edge.

h. **Job Report:** Job report is a statement recording the work done and the conditions of the facility. For any planned maintenance scheme there must be a continuous flow of information to and from the persons doing the work. The feedback is essential for the control and adjustment of the plan.

UNIT IV –DESIGN OF WORK SYSTEMS AND QUALITY CONTROL WORK STUDY

Work-study forms the basis for work system design. The purpose of work design is to identify the most effective means of achieving necessary functions. This work-study aims at improving the existing and proposed ways of doing work and establishing standard times for work performance. Work-study is encompassed by two techniques,

- Method study
- Work measurement

Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

Work measurement is the application or techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level or performance.

Objectives of Work Study

- To achieve the smooth production flow with minimum interruptions.
- To reduce the cost of the product by eliminating waste and unnecessary operations.
- Better worker-management relations.
- To meet the delivery commitment.
- To reduce rejections and scrap and higher utilization of resources of the organization.
- To achieve better working conditions.
- To develop Better workplace layout.
- To improve upon the existing process or methods and helps in

standardization and simplification.

- To establish the standard time for an operation or job which has got application in manpower planning, production planning

METHOD STUDY

According to British Standards Institution "Method study is the systematic recording and critical examination or existing and proposed ways or doing work as a means or developing and applying easier and more effective methods and reducing cost."

The main purpose of method study is to eliminate the unnecessary operations and to achieve the best method of performing the operation. Method study is also called methods engineering or work design..

OBJECTIVES OF METHOD STUDY

Method study is essentially concerned with finding better ways of doing things. It adds value and increases the efficiency by eliminating unnecessary operations, avoidable delays and other forms of waste. The improvement in efficiency is achieved through:

1. Improved layout and design of workplace.
2. Improved and efficient work procedures.
3. Effective utilization of men, machines and materials.
4. Improved design or specification of the final product. The objectives of method study techniques are:

1. Present and analyze true facts concerning the situation.
2. To examine those facts critically.
3. To develop the best answer possible under given circumstances based on critical examination of facts.

SCOPE OF METHOD STUDY

The scope of method study is not restricted to only manufacturing industries. Method study techniques can be applied effectively in service sector as well. It can be applied in offices, hospitals, banks and other service organizations. The areas to which method study can be applied successfully in manufacturing are:

1. To improve work methods and procedures.
2. To determine the best sequence of doing work.

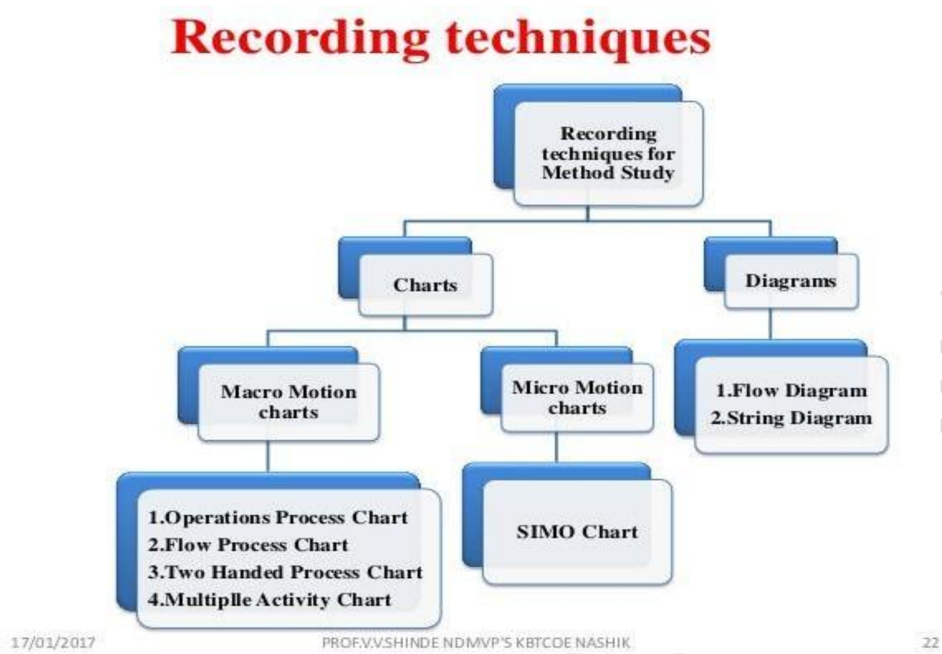
3. To smoothen material flow with minimum of back tracking and to improve layout.
4. To improve the working conditions and hence to improve labor efficiency.
5. To reduce monotony in the work.
6. To improve plant utilization and material utilization.
7. Elimination of waste and unproductive operations.
8. To reduce the manufacturing costs through reducing cycle time of operations.

STEPS OR PROCEDURE INVOLVED IN METHOD STUDY

The basic approach to method study consists of the following eight steps. The detailed procedure for conducting the method study is

1. **Select** the work to be studied and define its boundaries.
2. **Record** the relevant facts about the job by direct observation and collect such additional data as may be needed from appropriate sources.
3. **Examine** the way the job is being performed and challenge its purpose, place sequence and method of performance
4. **Develop** the most practical, economic and effective method, drawing on the contributions of those concerned.
5. **Evaluate** different alternatives to developing a new improved method comparing the cost- effectiveness of the selected new method with the current method with the current method of performance.
6. **Define** the new method, as a result, in a clear manner and present it to those concerned, i.e., management, supervisors and workers.
7. **Install** the new method as a standard practice and train the persons involved in applying it.
8. **Maintain** the new method and introduce control procedures to prevent a drifting back to the previous method of work. Note: Only the first two steps have been dealt in detail.

RECORDING TECHNIQUES IN METHOD STUDY


Recording techniques
Recording techniques for Method Study
Charts
Diagrams
Macro Motion charts
Micro Motion charts
1.Flow Diagram
2.String Diagram
1.Operations Process Chart
2.Flow Process Chart
3.Two Handed Process Chart
4.Multiplle Activity Chart
SIMO Chart
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TYPES OF CHARTS

It can be broadly divided into

(a) Macro motion charts and

(b) Micro motion charts.

Macro motion charts are used for macro motion study and micro motion charts are used for micro motion study. Macro motion study is one which can be measured through 'stop watch' and micro motion study is one which cannot be measured through stop watch.

(a) MACRO MOTION CHARTS

Following four charts are used under this type:

1. **Operation Process Chart** : It is also called outline process chart. An operation process chart gives the bird's eye view of the whole process by recording only the major activities and inspections involved in the process. Operation process chart uses only two symbols, i.e., operation and inspection. Operation, process chart is helpful to:

(a) Visualise the complete sequence of the operations and inspections in the process.

(b) Know where the operation selected for detailed study fits into the entire process.

(c) In operation process chart, the graphic representation of the points at which materials are introduced into the process and what operations and inspections are carried on them are shown.

2. **Flow Process Chart** :Flow process chart gives the sequence of flow of work of a product or any part of it through the work centre or the department recording the events using appropriate symbols. It is the amplification of the operation process chart in which operations; inspection, storage, delay and transportation are represented. However, process charts are of three types:

(a) Material type - Which shows the events that occur to the materials.

(b) Man type - Activities performed by the man.

(c) Equipment type - How equipment is

used. The flow process chart is useful:

(a) to reduce the distance travelled by men (or materials).

(b) to avoid waiting time and unnecessary delays.

(c) to reduce the cycle time by combining or eliminating operations.

(d) to fix up the sequence of operations.

3. **Two Handed Process Chart:** A two handed (operator process chart) is the most detailed type of flow chart in which the activities of the workers hands are recorded in relation to one another. The two handed process chart is normally confined to work carried out at a single workplace. This also gives synchronized and graphical representation of the sequence of manual activities of the worker. The application of this charts are:

- To visualize the complete sequence of activities in a repetitive task.
- To study the work station layout.

4. **Multiple Activity Chart:** It is a chart where activities of more than subject (worker or equipment) are each recorded on a common time scale to show their inter-relationship

Multiple activity chart is made:

- to study idle time of the man and machines,
- to determine number of machines handled by one operator, and
- to determine number of operators required in teamwork to perform the given job

Symbols Used in Method Study Graphical method of recording was originated by Gilberth, in order to make the presentation of the facts clearly without any ambiguity and to enable to grasp them quickly and clearly. It is useful to use symbols instead of written description.

Method Study Symbols

O - Operation
☐- INSPECTION
→ - TRANSPORTATION
D - DELAY

∇ - STORAGE

Operation O

An operation occurs when an object is intentionally changed in one or more of its characteristics (physical or chemical). This indicates the main steps in a process, method or procedure. An operation always takes the object one stage ahead towards completion. Examples of operation are: Turning, drilling, milling, etc. A chemical reaction. Welding, brazing and riveting. Lifting, loading, unloading. Getting instructions from supervisor. Taking dictation.

Inspection □

An inspection occurs when an object is examined and compared with standard for quality and quantity. The inspection examples are: Visual observations for finish. Count of quantity of incoming material. Checking the dimensions.

Transportation →

A transport indicates the movement of workers, materials or equipment from one place to another. Example: Movement of materials from one work station to another. Workers travelling to bring tools.

Delay D: Delay (Temporary Storage)

A delay occurs when the immediate performance of the next planned thing does not take place. Example: Work waiting between consecutive operations. Workers waiting at tool cribs. Operators waiting for instructions from supervisor.

Storage ∇

Storage occurs when the object is kept in an authorized custody and is protected against unauthorized removal. For example, materials kept in stores to be distributed to various work.

b) MICRO-MOTION STUDY CHART

- Micro-motion study provides a technique for recording and timing an activity.
- It is a set of techniques intended to divide the human activities in a groups of movements or micro-motions(called Therbligs) and the study of such movements helps to find for an operator one best pattern of movements that consumes less time and requires less effort to accomplish the task. Therbligs were suggested by Frank O. Gilberth, the founder of motion study.
- Micro-motion study was mainly employed for the job analysis. Its other applications includes:
  - As an aid in studying the activities of two or more persons on a group work?
  - As an aid in studying the relationship of the activities of the operator and the machine as a means of timing operations.
  - As an aid in obtaining motion time data for time standards.
  - Acts as permanent record of the method and time of activities of the

operator and the machine. (called Therbligs) and the study of such movements helps to find for an operator one best pattern of movements that consumes less time and requires less effort to accomplish the task.

- Therbligs were suggested by Frank O. Gilbreth, the founder of motion study. Micro-motion study was mainly employed for the job analysis.

SIMO CHART

SIMO chart is done as micro motion chart. SIMO Chart Simultaneous motion cycle chart (SIMO chart) is a recording technique for micro-motion study.

- A SIMO chart is a chart based on the film analysis, used to record simultaneously on a common time scale the Therbligs or a group of Therbligs performed by different parts of the body of one or more operators. It is the micro-motion form of the man type flow process chart.

- To prepare SIMO chart, an elaborate procedure and use of expensive equipment are required and this study is justified when the saving resulting from study will be very high.

DIAGRAMS USED IN METHOD STUDY

The flow process chart shows the sequence and nature of movement but it does not clearly show the path of movements. In the paths of movements, there are often undesirable features such as congestion, back tracking and unnecessary long movements.

To record these unnecessary features, representation of the working area in the form of flow diagrams, string diagrams can be made:

- To study the different layout plans and thereby; select the most optimal layout.
- To study traffic and frequency over different routes of the plant.
- Identification of back tracking and obstacles during

movements. Diagrams are of two types:

1. **Flow diagram and**
2. **String diagram.**

1. Flow Diagram

Flow diagram is a drawing, of the working area, showing the location of the various activities identified by their numbered symbols and are associated with particular flow process chart either man type or machine type. The routes followed in transport are shown by joining the symbols in sequence by a line which represents as nearly as possible the path or movement of the subject concerned. Following are the procedures to make the flow diagram:

1. The layout of the workplace is drawn to scale.
2. Relative positions of the machine tools, work benches, storage, and inspection benches are marked on the scale.
3. Path followed by the subject under study is tracked by drawing lines.
4. Each movement is serially numbered and indicated by arrow for direction.
5. Different colours are used to denote different types of movements.

2. String Diagram

- The string diagram is a scale layout drawing on which, length of a string is used to record the extent as well as the pattern of movement of a worker working within a limited area during a certain period of time.
- The primary function of a string diagram is to produce a record of a existing set of conditions so that the job of seeing what is actually taking place is made as simple as possible. One of the most valuable features of the string diagram is the actual distance travelled during the period of study to be calculated by relating the length of the thread used to the scale of drawing.
- Thus, it helps to make a very effective comparison between different layouts or methods of doing job in terms of the travelling involved.
- The main advantages of string diagram compared to flow diagram is that respective movements between work stations which are difficult to be traced on the flow diagram can be conveniently shown on string diagram.

Following are the **procedures to draw string diagram**:

1. A layout of the work place of factory is drawn to scale on the soft board.
2. Pins are fixed into boards to mark the locations of work stations, pins are also driven at the turning points of the routes.
3. A measured length of the thread is taken to trace the movements (path).
4. The distance covered by the object is obtained by measuring the remaining part of the thread and subtracting it from original length.

MOTION STUDY

Motion study is part of method study where analysis of the motion of an operator or work will be studied by following the prescribed methods.

Principles of Motion study

There are a number of principles concerning the economy of movements which have been developed as a result of experience and which forms the basis for the development of improved methods at the workplace. These are first used by Frank Gilbreth, the founder of motion study and further rearranged and amplified by Barnes, Maynard and others.

The principles are grouped into three headings:

(a) Use of the human body.

(b) Arrangement of workplace.

(c) Design of tools and equipment.

(A) **Uses Of Human Body** When possible:

- The two hands should begin and complete their movements at the same time.
- The two hands should not be idle at the same time except during periods of rest.
- Motions of the arms should be made simultaneously.
- Hand and body motions should be made at the lowest classification at which it is possible to do the work satisfactorily.
- Momentum should be employed to help the worker, but should be reduced to a minimum whenever it has to be overcome by muscular effort.
- Continuous curved movements are to be preferred to straight line motions involving sudden and changes in directions.
- 'Ballistic' (i.e., free swinging) movements are faster, easier and more accurate than restricted or controlled movements.
- Rhythm is essential to the smooth and automatic performance of a repetitive operation. The work should be arranged to permit easy and natural rhythm wherever possible.
- Work should be arranged so that eye movements are confined to a comfortable area, without the need for frequent changes of focus.

(b) Arrangement of the Workplace

- Definite and fixed stations should be provided for all tools and materials to permit habit formation.
- Tools and materials should be pre-positioned to reduce searching.
- Gravity fed, bins and containers should be used to deliver the materials as close to the point of use as possible.
- Tools, materials and controls should be located within a maximum working area and as near to the worker as possible.
- Materials and tools should be arranged to permit the best sequence of motions.
- ‘Drop deliveries’ or ejectors should be used wherever possible, so that the operative does not have to use his hands to dispose of finished parts.

- Provision should be made for adequate lightning, and a chair of type and height to permit good posture should be provided.
- The height of the workplace and seat should be arranged to allow alternate standing and seating.

(C) Design of Tools and Equipments

- The colour of the workplace should contrast with that of work and thus reduce eye fatigue. 2. The hands should be relieved of all work of 'holding' the work piece where this can be done by a jig or fixture or foot operated device.
- Two or more tools should be combined where possible.
- Where each finger performs some specific movement, as in typewriting, the load should be distributed in accordance with the inherent capacities of the fingers.
- Handles such as those used on screw drivers and cranks should be designed to permit maximum surface of the hand to come in contact with the handle.
- Levers, cross bars and wheel bars should be in such position that operator can manipulate them with least body change and with greatest mechanical advantage.

RECORDING TECHNIQUES OF MOTION STUDY

Most of the techniques mentioned in method study is used in the motion study. They are as follows:

1. Macro Motion Study
   (a) Flow process chart
   (b) Two handed process chart.
2. Micro Motion Study
   - SIMO chart.

   (Explained earlier in this unit)

WORK MEASUREMENT (TIME STUDY)

Time study is also called work measurement. It is essential for both planning and control of operations.

According to British Standard Institute time study has been defined as "The application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.

OBJECTIVES OF WORK MEASUREMENT

- Comparing alternative methods.
- Assessing the correct initial manning (manpower requirement planning).
- Planning and control.
- Realistic costing.
- Financial incentive schemes.
- Delivery date of goods.
- Cost reduction and cost control.
- Identifying substandard workers.
- Training new employees.

TECHNIQUES OF WORK MEASUREMENT

For the purpose of work measurement, work can be regarded as:

1. **Repetitive work:** The type of work in which the main operation or group of operations repeat continuously during the time spent at the job. These apply to work cycles of extremely short duration.
2. **Non-repetitive work**: It includes some type of maintenance and construction work, where the work cycle itself is hardly ever repeated identically.

Various techniques of work measurement are:

1. Time study (stop watch technique),
2. Synthesis,
3. Work sampling,
4. Predetermined motion and time study,
5. Analytical estimating

STEPS IN TIME STUDY (STOP WATCH TECHNIQUE)

Stop watch time is the basic technique for determining accurate time standards.

They are economical for repetitive type of work.

Steps in taking the time study are:

- **Select** the work to be studied.
- **Define the work** by breaking down the operation into elements.

- **Obtain and record** all the information available about the job, the operator and the working conditions likely to affect the time study work.
- **Extend** An element is a instinct part of a specified activity composed of one or more fundamental motions selected for convenience of observation and timing.
- **Measure** the time by means of a stop watch taken by the operator to perform each element of the operation. Either continuous method or snap back method of timing could be used.
- At the same time, assess the operator's effective speed of work relative to the observer's concept of 'normal' speed. This is called performance rating.
- Adjust the observed time by rating factor to obtain normal time for each element **Normal time = (Observed time x Performance Rating) / 100**
- Add the suitable allowances to compensate for fatigue, personal needs, and contingencies. Etc. to give standard time for each element.
- Determine the allowances to be added to the normal time to determine the standard time by using the formula; **Standard time =Normal time x Allowances Factor**
    - **Allowance factor = 100/ (100- Allowance %)**
- **Compute** allowed time for the entire job by adding elemental standard times considering frequency of occurrence of each element.
- Make a detailed job description describing the method for which the standard time is established.
- **Test and review standards** wherever necessary

PERFORMANCE RATING

The Society of Advancement of Management (SAM) national committee defines the performance rating as "the process during which the time study engineer compares the performance of the operator under observation with the observer’s own concept of proper (normal) performance. It can also be considered as the efficiency of the worker.

Performance Rating = (Observed performance / Normal performance) x 100 %

The time taken for a job varies from person to person attributed to various reasons such as environmental factors and Human factors. Sometimes, we come across some complaints such as the worker is intentionally doing delay or the observer's judgment is prejudiced. To overcome such disputes, the normal rating is compared with performance rating to standardize the time and thence fix up target of an element or job.

PERFORMANCE RATING SYSTEM

Various systems of performance rating are as follows .

- **Westinghouse system of rating**

This system is based on four factors: (a) Skill (b) Effort (c) Condition (d) Consistency

- **Synthetic rating**

This system of rating was introduced by Morrow. The time study observer records the actual time of performance for the element as done in the previous method. Performance times for such elements have been standardised, which are known as "Predetermined Motion Time Standard Values" or 'PMTS Values. The PMT value for the elements from such tables are noted. The ratio of Predetermined Motion Time Standard value of the element (taken from tables) to Average Actual Time (Observed Time) for the same element gives the Rating Factor.

- **Objective rating**

It was proposed by M.E. Mundel . The speed or pace of the operator is rated against an objective pace standard. This objective pace standard is same for all the jobs irrespective of the job difficulty and its limiting effect on pace

- **Skill and effort rating**

This system was introduced by Charles E. Bedaux in 1961 and is also known as Bedaux system. In this system, the observer is supposed to evaluate the work rate or speed of worker's movement and how fast he is performing the motions, but not the movements and skill he is applying. Unlike the other methods Bedaux introduced a unit "B" that represents a standard minute, which is composed of (a) work component (b) relawjion component

- **Physiological evaluation of performance level.**

It is known fact that there is a relation between the physical work and the amount of oxygen consumed. It has also been tried out to find the changes in heartbeat for various physical works. This is assumed to be most reliable measure of muscular activity and studies are still going on by many experts in industrial engineering, bio-medical engineering and physiology. However this method is not in much use presently

COMPUTATION OF STANDARD TIME

Standard time is the time allowed to an operator to carry out the specified task under specified conditions and defined level of performance.

The various allowances are added to the normal time as applicable to get the standard time Standard time may be defined as the, amount of time required to complete a unit of work:

(a) under existing working conditions,

(b) using the specified method and machinery,

(c) by an operator, able to the work in a proper manner, and

(d) at a standard pace.

Normal time = (Observed time x Performance Rating) / 100

Standard time =Normal time x Allowances Factor

Thus basic constituents of standard time are:

1. Elemental (observed time).
2. Performance rating to compensate for difference in pace of working.
3. Relaxation allowance.
4. Interference and contingency allowance.
5. Policy allowance.

ALLOWANCE FACTORS

The **Allowance Factor (AF)** is the amount of time allowed for personal, fatigue, and unavoidable delays

The normal time for an operation does not contain any allowances for the worker. It is impossible to work throughout the day even though the most practicable, effective method has been developed. Even under the best working method situation, the job will still demand the expenditure of human effort and some allowance must therefore be made for recovery from fatigue and for relaxation. Allowances must also be made to enable the worker to attend to his personal needs.

TYPES OF ALLOWANCES

The allowances are categorised as:

(1) Relaxation allowance

(2) Interference allowance

(3) Contingency allowance

(4) Policy allowance

1. **Relaxation Allowance** Relaxation allowances are calculated so as to allow the worker to recover from fatigue. Relaxation allowance is a addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of allowance will depend on nature of the job. Relaxation allowances are of two types:

- fixed allowances and
- variable

allowances. Fixed allowances constitute:

(a) Personal needs allowance: It is intended to compensate the operator for the time necessary to leave, the workplace to attend to personal needs like drinking water, smoking, washing hands. Women require longer personal allowance than men. A fair personal allowance is 5% for men, and 7% for women.

(b) Allowances for basic fatigue: This allowance is given to compensate for energy expended during working. A common figure considered as allowance is 4% of the basic time. Variable Allowance Variable allowance is allowed to an operator who is working under poor environmental conditions that cannot be improved, added stress and strain in performing the job. The variable fatigue allowance is added to the fixed allowance to an operator who is engaged on medium and heavy work and working under abnormal conditions. The amount of variable fatigue allowance varies from organization to organization.

2 **Interference Allowance** It is an allowance of time included into the work content of the job to compensate the operator for the unavoidable loss of production due to simultaneous stoppage of two or more machines being operated by him. This allowance is applicable for machine or process controlled jobs.

Interference allowance varies in proportion to number of machines assigned to the operator. The interference of the machine increases the work content.

3. **Contingency Allowance** A contingency allowance is a small allowance of time which may be included in a standard time to meet legitimate and expected items of work or delays. The precise measurement of which is uneconomical because of their infrequent or irregular occurrence. This allowance provides for small unavoidable delays as well as for occasional minor extra work: Some of the examples calling for contingency allowance are:

- Tool breakage involving removal of tool from the holder and all other activities to insert new tool into the tool holder.

- Power failures of small duration.
- Obtaining the necessary tools and gauges from central tool store. Contingency allowance should not exceed 5%.

4. **Policy Allowance** Policy allowances are not the genuine part of the time study and should be used with utmost care and only in clearly defined circumstances. The usual reason for making the policy allowance is to line up standard times with requirements of wage agreement between employers and trade unions. The policy allowance is an increment, other than bonus increment, applied to a standard time (or to some constituent part of it, e.g., work content) to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstances. Policy allowances are sometimes made as imperfect functioning of a division or part of a plant.

WORK SAMPLING TECHNIQUES

Work sampling, also called 'Activity Sampling' or 'Ratio Delay Study', is based on the statistical method first devised by L.H.S. Tippet in 1934. He used this technique firstly, in the British textile industry. Later Morrow carried out several investigations.

Work sampling is the statistical technique for determining the proportion of time spent by workers in various defined categories of activity (e.g. setting up a machine, assembling two parts, idle…etc.).[1] It is as important as all other statistical techniques because it permits quick analysis, recognition, and enhancement of job responsibilities, tasks, performance competencies, and organizational work flows.

Other names used for it are 'activity sampling', 'occurrence sampling', and 'ratio delay study

PROCEDURE OF WORK SAMPLING FOR STANDARD TIME DETERMINATION

Work sampling can be very useful for establishing time standards on both direct and indirect labor jobs. The procedure for conducting work sampling study for determining standard time of a job can be described step-wise.

Step 1 . Define the problem.

- Describe the job for which the standard time is to be determined.
- Unambiguously state and discriminate between the two classes of activities of operator on the job: what are the activities of job that would entitle him to be in 'working" state.

This would imply that when operator will be found engaged in any activity other than those would entitle him to be in "Not Working" state.

Step 2. Design the sampling plan.

- Estimate satisfactory number of observations to be made.
- Decide on the period of study, e.g. two days, one week, etc.
- Prepare detailed plan for taking the observations.

This will include observation schedule, exact method of observing, design of observation sheet, route to be followed, particular person to be observed at the observation time, etc.

Step 3. Contact the persons concerned and take them in confidence regarding conduct of the study.

Step 4. Make the observations at the pre-decided random times about the working / not working state of the operator. When operator is in working state, determine his performance rating. Record both on the observation sheet.

Step 5. Obtain and record other information. This includes operator's starting time and quitting time of the day and total number of parts of acceptable quality produced during the day. **Step 6. Calculate the standard time per piece**

Determination Of Time Standards By Work Sampling (illustration):

With work sampling, it is possible to determine the percentage of the day a worker is idle and the percentage of the day he is working. The average performance index or the speed at which he worked during the working portion of the day, can also be determined.

For example, suppose Mohan Singh worked as a Drillman, and a work sampling study showed that he was idle 15% of the day or 72 minutes and that he worked the remainder of the day of 480 minutes at an average performance index of 110%. He drilled 400 items of acceptable quality during the day.

The standard time for the operation he performed can be calculated as shown below: It is assumed that 15% of the total time is taken as fatigue and other personnel allowances. As Standard Time

$$= \text{Allowances} \times \frac{\begin{pmatrix}\text{Total time}\\ \text{in minutes}\end{pmatrix} \times \begin{pmatrix}\text{Working time}\\ \text{in percent}\end{pmatrix} \times \begin{pmatrix}\text{Performance index}\\ \text{in percent}\end{pmatrix}}{\text{Total No. of items produced}}$$

$$= \left(\frac{100}{100-15}\right) \times \frac{480 \times 0.85 \times 1.10}{400} = \mathbf{1.32\ minutes}$$

Advantages of “work sampling” over “time study”:

- Operator is not subjected to long-period of observations.
- Group operations can be easily studied by a single analyst.
- It does not require continuous observation for a long period of time.
- Many operations or activities which are impractical or costly to be measured by time study can be measured by this.
- Observations may be taken over a period of days or weeks, thus decreasing the chance of day to day or week to week variations affecting the results.
- The man hours spent by the analyst are much less.
- A work sampling study can be stopped at any time without affecting the results.
- In this, random observations are taken by avoiding prolonged observations.
- This produces less fatigue and are less tedious to observer.
- It generally requires less time in calculating the results.
- No stop-watch or any other timing device is needed.
- Clerical time is minimized.

Disadvantages Of “Work Sampling” Over “Time Study”:

- It is not economical to study a single operator or machine or for studying operators or machines located over wide areas.
- It does not permit finer breakdown of activities and delays.
- Study made of a group presents average while there is no information about the magnitude of individual differences.
- Management and workers may not be able to understand work sampling as easily as they do time study.

- Some-time no record is kept about the study on the operator, therefore, a new study must be made when a change occurs in any element.

JOB SEQUENCING AND SCHEDULING

SCHEDULING

- Scheduling is defined as the allocation of resources over time to perform a collection of tasks
- The vital elements in scheduling models are resources and tasks. The set of tasks available for scheduling does not change over time, the system is called static', in contrast to cases in which new tasks arise over time, where the system is called dynamic
- **Operations schedules** are short-term plans designed to implement the sales and operations plan. Often, several jobs must be processed at one or more workstations. Typically, a variety of tasks can be performed at each workstation. If schedules are not carefully planned to avoid bottlenecks, waiting lines may develop

Objectives of Scheduling

- Maximization of the Utilization of Resources
- Minimization of the Work-in-process Inventory
- Minimization of Tardiness

Principles of Scheduling

1. ***The principle of optimum task size:*** Scheduling tends to achieve maximum efficiency when the task sizes are small, and all tasks of same order of magnitude.

2. ***Principle of optimum production plan:*** The planning should be such that it imposes an equal load on all plants.
3. ***Principle of optimum sequence:*** Scheduling tends to achieve the maximum efficiency when the work is planned so that work hours are normally used in the same sequence.

Inputs to Scheduling

1. Performance standards: The information regarding the performance standards (standard times for operations) helps to know the capacity in order to assign required machine hours to the facility.
2. Units in which loading and scheduling is to be expressed.
3. Effective capacity of the work centre.
4. Demand pattern and extent of flexibility to be provided for rush orders.

5. Overlapping of operations.
6. Individual job schedules.

Techniques of Scheduling

- **Master Scheduling (MS)**

It shows the dates on which important production items are to be completed. It's a weekly or monthly break-up of the production requirements for each product.

- **Shop Manufacturing Schedule**

After preparing the MS, shops schedules (SS) are prepared. It assigns a definite period of time to a particular shop for manufacturing products in required quantity. It shows how many products are to be made, and on what day or week

- **Backward or Reverse Scheduling**

Backward scheduling is often used in assembly type industries and commit in advance to specific delivery dates. Backward scheduling determines the start and finish times for waiting jobs by assigning them to the latest available time slot that will enable each job to be completed just when it is due, but done before. By assigning jobs as late as possible, backward scheduling minimizes inventories since a job is not completed until it must go directly to the next work centre on its routing.

- **Forward Scheduling:**

Forward Scheduling is commonly used in job shops where customers place their orders on "needed as soon as possible" basis. Forward scheduling determines start and finish times of next priority job by assigning it the earliest available time slot and from that time, determines when the job will be finished in that work centre. Since the job and its components start as early as possible, they will typically be completed before they are due at the subsequent work centers in the routing. The forward method generates in the process inventory that are needed at subsequent work centers and higher inventory cost. Forward scheduling is simple to use and it gets jobs done in shorter lead times, compared to backward scheduling.

- **Optimized Production Technique (OPT)**

It is a program help to recognize the existence of bottlenecks through which the flow gets restricted. It consists of modules that contain data on products, customer orders, work center capacities, etc., as well as algorithms to do the actual scheduling. A key feature of the program is to simulate the load on the system, identify bottleneck (as well as other) operations, and develop alternative production schedule.

GANTT CHARTS

- Gantt charts are named for Henry Gantt, a management pioneer of the early 1900s. He proposed the use of a visual aid for loading and scheduling. Appropriately, this visual aid is known as a Gantt chart.
- This Gantt chart is used to organize and clarify actual or intended use of resources within a time framework. Generally, time is represented horizontally with scheduled resources listed vertically. Managers are able to use the Gantt chart to make trial-and-error schedules to get some sense of the impact of different arrangements.
- There are a number of different types of Gantt charts, but the most common ones, and the ones most appropriate to our discussion, are the load chart and schedule chart.
- A load chart displays the loading and idle times for machines or departments; this shows when certain jobs are scheduled to start and finish and where idle time can be expected. This can help the scheduler redo loading assignments for better utilization of the work centers.
- A schedule chart is used to monitor job progress. On this type of Gantt chart, the vertical axis shows the orders or jobs in progress while the horizontal axis represents time. A quick glance at the chart reveals which jobs are on schedule and which jobs are on time.
- Gantt charts are the most widely used scheduling tools. However, they do have some limitations. The chart must be repeatedly updated to keep it current. Also, the chart does not directly reveal costs of alternate loadings

nor does it consider that processing times may vary among work centers.

Scheduling approaches used in two environments:

(1) Divergent flow processes or Job shop

A manufacturer's operation with divergent flows is often called a job shop, which specializes in low- to medium-volume production and utilizes job or batch processes.

(2) Line flow processes or line shop.

A manufacturer's operation with line flows is often called a flow shop, which specializes in medium- to high-volume production and utilizes line or continuous flow processes.

SEQUENCING

Sequencing is the order of processing a set of tasks over available resources. Scheduling involves sequencing'' task of allocating as well as the determination of process commencement and completion times i.e., time-tabling. Sequencing problems occur whenever there is a choice to the order in which a group of tasks can be performed.

Sequencing Models

All type of sequencing problems may be categorized in one of the following models:

- Sequencing n jobs on 1 machine.
- Sequencing n jobs on 2 machines.
- Sequencing n jobs on 3 machines.
- Sequencing n jobs on m machines.

. Assumptions in sequence problems

- Assumptions are usually made while dealing with sequencing problem
- Only one operation is carried out on a machine at a particular time
- Each operation once started must be completed
- An operation must be completed before is succeeding operation can start
- Only one machine of each type is available
- A job is processed as soon as possible but only in the order specified
- Processing times or independent of order of performing the operation
- The transportation time i.e., the time required to transport jobs from one machine to another is negligible.

- Jobs are completely known and are ready for processing when the period under consideration starts
- The costs of in process inventory for each job is same and negligibly small

Priority decision rules in sequencing

There are a number of priority rules or heuristics that can be used to select the order of jobs waiting for processing.

- **Random (R).** Pick any job in the queue with equal probability. This rule is often used as a benchmark for other rules.

- **First come/first served (FC/FS).** This rule is sometimes deemed to be fair since jobs are processed in the order in which they arrive.
- **Shortest processing time (SPT).** The job with the shortest processing time requirement goes first. This rule tends to reduce work-in-process inventory, average throughput time, and average job lateness.
- **Earliest due date (EDD)**. The job with the earliest due date goes first. This seems to work well if the firm performance is judged by job lateness.
- **Critical ratio (CR).** To use this rule one must calculate a priority index using the formula (due date–now)/(lead time remaining). This rule is widely used in practice.
- **Least work remaining (LWR).** An extension of SPT, this rule dictates that work be scheduled according to the processing time remaining before the job is considered to be complete. The less work remaining in a job, the earlier it is in the production schedule.
- **Fewest operations remaining (FOR).** This rule is another variant of SPT; it sequences jobs based on the number of successive operations remaining until the job is considered complete. The fewer operations that remain, the earlier the job is scheduled.
- **Slack time (ST).** This rule is a variant of EDD; it utilizes a variable known as slack. Slack is computed by subtracting the sum of setup and processing times from the time remaining until the job's due date. Jobs are run in order of the smallest amount of slack.
- **Slack time per operation (ST/O).** This is a variant of ST. The slack time is

divided by the number of operations remaining until the job is complete with the smallest values being scheduled first.

- **Next queue (NQ).** NQ is based on machine utilization. The idea is to consider queues (waiting lines) at each of the succeeding work centers at which the jobs will go. One then selects the job for processing that is going to the smallest queue, measured either in hours or jobs.
- **Least setup (LSU).** This rule maximizes utilization. The process calls for scheduling first the job that minimizes changeover time on a given machine.

These rules assume that setup time and setup cost are independent of the processing sequence. However, this is not always the case. Jobs that require similar setups can reduce setup times if sequenced back to back. In addition to this assumption, the priority rules also assume that setup time and processing times are deterministic and not variable, there will be no interruptions in processing, the set of jobs is known, no new jobs arrive after processing begins, and no jobs are canceled. While little of this is true in practice, it does make the scheduling problem manageable.

QUALITY CONTROL

- **Quality** of a product is defined as its fitness for the purpose for which it is made. Many characteristics of the product like its shape, colour, surface, finish etc. determine the quality of the product.

- **Quality control** is the planned and systematic actions which provides a mean to control and measure the characteristics of a product, process or a service to established requirements
- It is a process through which a business seeks to ensure that product quality is maintained or improved with either reduced or zero errors. Quality control requires the business to create an environment in which both management and employees strive for perfection. This is done by training personnel, creating benchmarks for product quality and testing products to check for statistically significant variations.
- Quality control (QC) is a process by which entities review the quality of all factors involved in production
- The quality control system verifies and maintains desired level of quality in an existing product or service by careful planning, use of proper equipments and continued inspection and corrective action as required to satisfy quality requirements

Objectives of Quality Control

- To decide about the standard of quality of a product that is easily acceptable to the customer.
- If the quality of product is falling down manufacturing, then to determine the different steps to check this deviation.
- To verify whether the product conforms to the predetermined standards.
- To take necessary steps so that the products which are below the standard do not reach to the customers.
- To take different measures to improve the standard of quality of product.
- To develop quality consciousness in the various sections of the manufacturing unit.
- To reduce the wastage of raw materials, men and machines during the process of production

Quality control tools & techniques

- Cause and Effect Diagrams
- **Control Charts**
- Flow-Charting
- Histogram
- Pareto Chart and Pareto Analysis
- Run Charts
- Scatter Diagrams
- Statistical Sampling
- **Inspection**

INSPECTION

Inspection is the activity of measuring, examining, testing one or more characteristics of a product or service and comparing the results with specified requirements in order to establish whether conformity is achieved for each characteristic.

Objectives of Inspection

- To detect and remove the faulty raw materials before it undergoes production.
- To detect the faulty products in production whenever it is detected.
- To bring facts to the notice of managers before they become serous to enable them discover weaknesses and over the problem.
- To prevent the substandard reaching the customer and reducing complaints.

- To promote reputation for quality and reliability of product.

PURPOSE OF INSPECTION

- Inspection separates defective components from non-defective ones and thus ensures the adequate quality of products.
- To determine if the process is changing.
- To determine if the process is approaching the specification limits.
- To rate quality of product.
- To rate accuracy of inspectors.

- To measure the precision of the measuring instrument.
- To secure products-design information.
- To measure process capability.

DIFFERENT TYPES OF INSPECTION

- **Tool Inspection**: Under this method, tools, fixtures, jigs and gauges are inspected in advance to the work of production.
- **First piece Inspection**: In the case of automatic machines, first 2 or 3 products are inspected. And, if they are found to be satisfactory, it is assumed that the work has begun correctly and the output will be satisfactory. Further production is continued after this inspection.
- **Periodic Inspection**: Under this Inspection, Inspection is undertaken at definite intervals to make sure that they are being produced after following the required standards.
- **Sample Inspection**: In this, certain percentage of finished products are drawi from a lot and inspected and the entire lot is judged by the result of these samples.
- **Operation Inspection**: Inspection is done as the completion of operation before the work in process passes to another operation or machine or department.
- **Working Inspection**: In this type, articles are inspected when they are completely manufactured before sending them to store.
- **Pilot piece Inspection**: This method is used in product layout. The product is passes through is entire sequence of operations on a

series of machines, installed for producing that product. After one piece is manufactured, each tool, each machine is tested so that all detective tools are replaced and all incorrect adjustments are made alright, when a good product starts coming. The production line is allowed for actual production.

- **Key operation Inspection**: Certain operations in a manufacturing cycle may be difficult. Such operations are known as key operations. Inspection is done prior to and immediately after the completion of each of these operations.
- **Functional Inspection**: This Inspection is carried out after the completion of the assembly to assure it will function as required.

- **Endurance Inspection**: This Inspection is carried out to estimate, how much time an assembly will withstand its use and to determine weakness for correction.

Drawbacks of Inspection

- Inspection adds to the cost of the product but not for its value.
- It is partially subjective, often the inspector has to judge whether a products passes or not.
- Fatigue and Monotony may affect any inspection judgment.
- Inspection merely separates good and bad items. It is no way to prevent the production of bad items.

ACCEPTANCE SAMPLING

Acceptance sampling uses statistical sampling to determine whether to accept or reject a production lot of material. It is usually done as products leaves the factory, or in some cases even within the factory. Most often a producer supplies a consumer a number of items and a decision to accept or reject the items is made by determining the number of defective items in a sample from the lot. The lot is accepted if the number of defects falls below where the acceptance number or otherwise the lot is rejected

Acceptance sampling is done on sample's post production to check for quality parameters as decided by the organization covering both attributes as well as variables. If the sample does not meet the required parameters of quality than that given lot is rejected, and further analysis is done to identify the source and rectify the defects. Acceptance sampling is done on the basis of inspection, which includes physical verification of color, size, shape, etc.

- **Acceptance sampling by attributes** assesses either the number of defects or the number of defective items in a sample. You might tally the total number of defects, in which case each defect in a single item with multiple defects is counted. Alternatively, you can count defective items, in which case the first problem makes an item defective, and you move on to evaluate the next item in your sample

- **Acceptance sampling by variables** is based on quality characteristics you can measure. For example, you might measure the length of the leads on capacitors, resistors, or other electronic components for circuit boards.

Lot Acceptance sampling plans

Lot Acceptance Sampling plan (LASP) fall into the following categories:

- **Single sampling plans:** One sample of items is selected at random from a lot and the disposition of the lot is determined from the resulting information. These plans are usually denoted as (n,c) plans for a sample size n,where the lot is rejected if there are more than cdefectives. These are the most common (and easiest) plans to use although not the most efficient in terms of average number of samples needed.
- **Double sampling plans:** After the first sample is tested, there are three possibilities:
  1. Accept the lot
  2. Reject the lot
  3. No decision

  If the outcome is (3), and a second sample is taken, the procedure is to combine the results of both samples and make a final decision based on that information.
- **Multiple sampling plans:** This is an extension of the double sampling plans where more than two samples are needed to reach a conclusion. The advantage of multiple sampling is smaller sample sizes.
- **Sequential sampling plans:** This is the ultimate extension of multiple

sampling where items are selected from a lot one at a time and after inspection of each item a decision is made to accept or reject the lot or select another unit.

- **Skip lot sampling plans:** Skip lot sampling means that only a fraction of the submitted lots are inspected

Terms In Acceptance Sampling

(i) Acceptable Quality Level (AQL):

It is the desired quality level at which probability of a acceptance is high. It represents maximum proportion of defectives which the consumer finds acceptable or it is the maximum percent defectives that for the purpose of sampling inspection can be considered satisfactory.

(ii) Lot Tolerance Percent Defective (LTPD) or Reject able Quality Level (RQL):

It is the quality level at which the probability of acceptance is low and below this level the lots are rejected. This prescribes the dividing line between good and bad lots. Lots at this quality level are considered to be poor.

(iii) Average outgoing Quality (A.O.Q):

Acceptance sampling plans provides the assurance that the average quality level or percent defectives actually going to consumers will not exceed certain limit. Fig 9.2 demonstrates the concept of average outgoing quality related with actual percent defectives being produced.

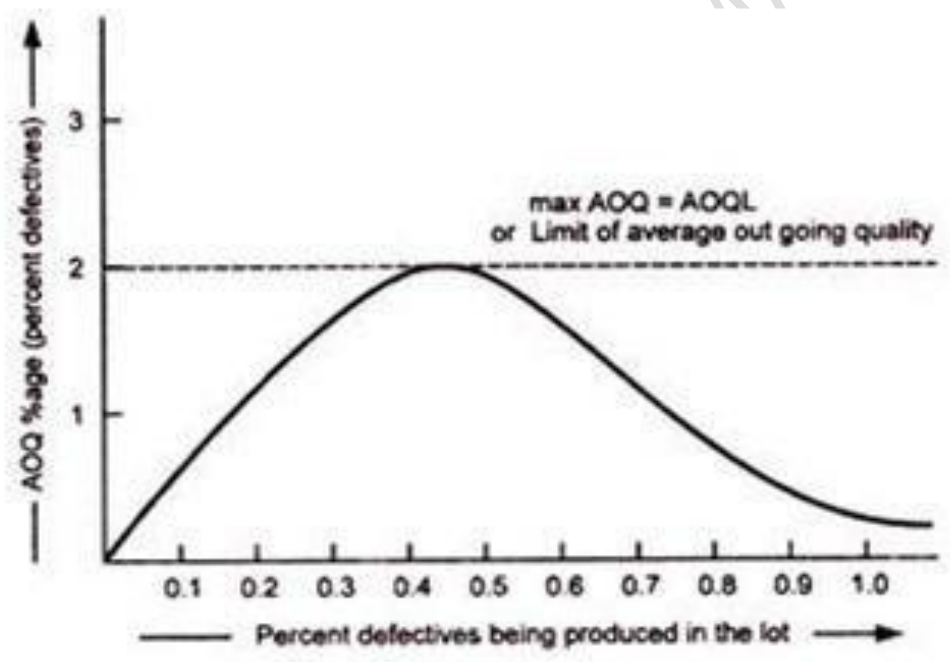


Fig. 9.3: An Average out going Quality (AOQ) Curve

If this upward trend continues, the acceptance plan beings to reject lots and when lots are rejected, 100% inspection is followed and defective units are replaced by good ones. The net effect is to improve the average quality of the outgoing products since the rejected lots which to are ultimately accepted contain all non-defective items (because of 100% inspection).

(iv) OPERATING CHARACTERISTIC CURVE OR O.C. CURVE:

Operating characteristic curve for a sampling plan is a graph between fraction defective in a lot and the probability of acceptance. In practice the performance of acceptance sampling for distinguishing defectives and acceptable or good and bad lots mainly depends upon the sample size (n) and the number of defectives permissible in the sample.

The O.C. curve of a 100 percent inspection plan is said to be an ideal curve, because it is generated by and acceptance plan which creates no risk either for producer or the consumer. Usually the producer's and consumer's risks are agreed upon and explicitly recorded in quantitative terms.

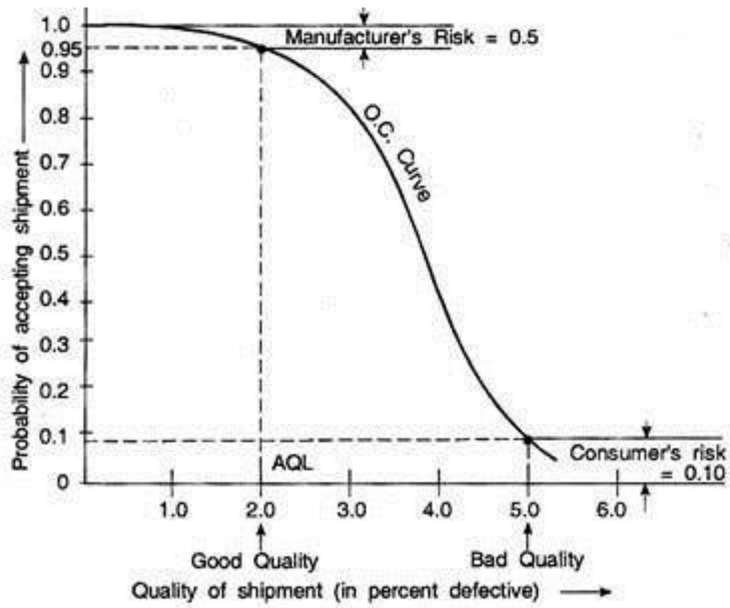


Fig. 60.1. O.C. Curve indicating sampling risks.

The merit of any sampling plan depends on the relationship of sampling cost to risk. As the cost of inspection go down the cost of accepting defectives increases.

Characteristics of O.C. Curve:

(i) The larger the sample size and acceptance number steeper will be the slope of O.C. curve.

(ii) The O.C. curve of the sampling plans with acceptance number greater than zero are superior to those with acceptance number as zero.

(iii) Fixed sample size tends towards constant quality production.

Producer's and Consumer's Risk:

The acceptance or rejection of the whole batch of products in acceptance sampling depends upon the results of the sample inspected. There is always a chance that a sample may not be true representative of the batches or lots from which it is drawn.

This leads to following two types of risks:

(i) Producer risk.

(ii) Consumer risk.

(i) Producer Risk (α):

It is the small probability of a lot/batch being good or even better acceptable quality level (AQL) but yielding a bad sample and thus getting rejected. So this probability of rejection of a good lot which otherwise would have been accepted is known as producer's risk (α).

(ii) Consumer Risk (β):

It is the probability of a batch/lot being bad or worse than the limiting quality (LQ) but yielding a good sample and getting accepted. So this probability of a defective lot being accepted which otherwise would have been rejected is known as consumer risk (β).

Advantages of Acceptance Sampling:

- The method is applicable in those industries where there is mass production and the industries follow a set production procedure.
- The method is economical and easy to understand.
- Causes less fatigue boredom.
- Computation work involved is comparatively very small.
- The people involved in inspection can be easily imparted training.
- Products of destructive nature during inspection can be easily inspected by sampling.
- Due to quick inspection process, scheduling and delivery times are improved.

Limitations of Acceptance Sampling:

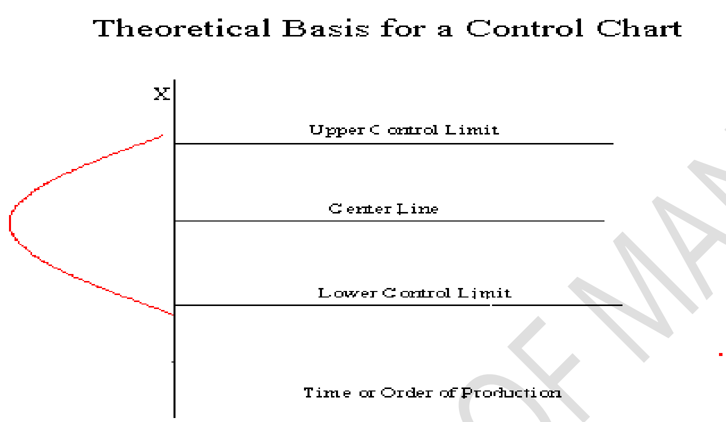
- It does not give 100% assurance for the confirmation of specifications so there is always some likelihood/risk of drawing wrong inference about the quality of the batch/lot.

- Success of the system is dependent on, sampling randomness, quality characteristics to be tested, batch size and criteria of acceptance of lot.

CONTROL CHARTS FOR VARIABLES AND ATTRIBUTES

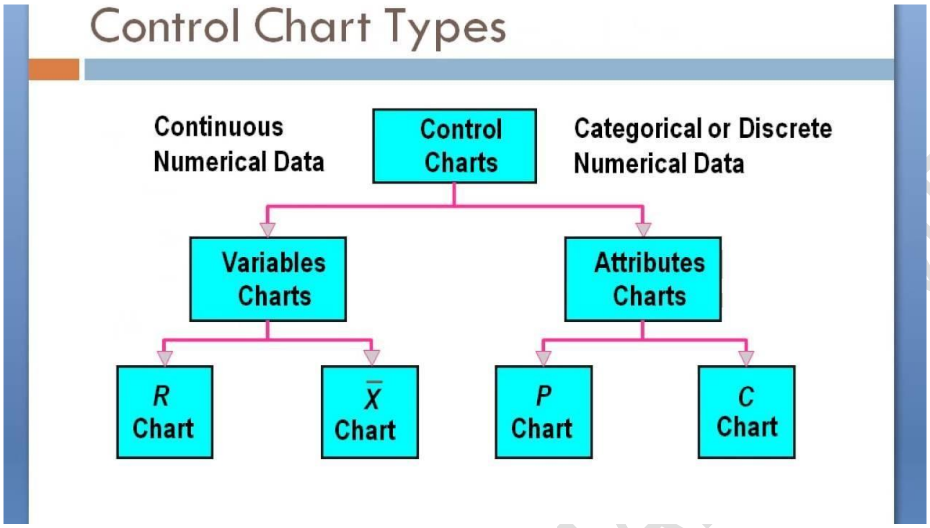
CONTROL CHART

A control chart is a graphical presentation that detects variations in



the processing and warns, if there is any departure from the specified tolerance limits.

The central line (CL) shows the average size. The other two lines one below the Central line (LCL) and the other above the Central line (LCL) indicate limits of tolerances. Deviations are permitted within the tolerance limits. Those measurements values which fall outside the tolerance limits are considered to be out of control points. According to the deviation, the manufacturer will initiate corrective actions to maintain the quality.


Control Chart Types
Continuous Numerical Data
Control Charts
Categorical or Discrete Numerical Data
Variables Charts
Attributes Charts
R Chart
$\bar{X}$ Chart
P Chart
C Chart

TYPES OF CONTROL CHARTS

- X-bar and R chart for process control
- P chart, for analysis of fraction detectives
- C chart, for control of number of defects per unit.

X- BAR CHART AND R-CHART

This chart is used for the quality characteristics which specified as variables i.e., on the basis of actual readings. The purpose of these charts is:

- To establish whether the process is in Statistical Continuum or not.
- To determine whether the process capability compatible with the specifications.
- To detect trends in the process so as o assist in planning adjustment and resetting of the process
- To show when the process is likely to be out of Control.

STEPS IN CONSTRUCTING AN Xbar-R CHART

1. Gather the data.

i. Select the subgroup size (n). Typical subgroup sizes are 4 to 5. The concept of rational subgrouping should be considered. The objective is to minimize the amount of variation within a subgroup. This helps us "see" the variation in the averages chart more easily.

ii. Select the frequency with which the data will be collected. Data should be collected in the order in which it is generated (in most cases).

iii. Select the number of subgroups (k) to be collected before control limits are calculated. You can start with initial control limits after ten subgroups, but recalculate the limits each time until you get to twenty subgroups.

iv. For each subgroup, record the individual, independent sample results.

v. For each subgroup, calculate the subgroup average:

$$\bar{X} = \frac{\sum X_i}{n} = \frac{X_1 + X_2 + \ldots X_n}{n}$$

For each subgroup, calculate the subgroup range:

R = Xmax - Xmin

where Xmax is the maximum individual sample result in the subgroup and Xmin is the minimum individual sample result in the subgroup.

2. Plot the data.

i. Select the scales for the x and y axes for both the X and R charts.

ii. Plot the subgroup ranges on the R chart and connect consecutive points with a straight line.

iii. Plot the subgroup averages on the X chart and connect consecutive points with a straight line.

3. Calculate the overall process averages and control limits.

- Calculate the average range (Rbar):

$$\overline{R} = \frac{\sum R_i}{k} = \frac{R_1 + R_2 + \ldots R_k}{k}$$

where k is the number of subgroups.

- Plot Rbar on the range chart as a solid line and label.
- Calculate the overall process average (Xdbar):

$$\overline{\overline{X}} = \frac{\sum \overline{X}_i}{k} = \frac{\overline{X}_1 + \overline{X}_2 + \ldots \overline{X}_k}{k}$$

- Plot X on the X chart as a solid line and label.
- Calculate the control limits for the R chart. The upper control limit is given by UCLr. The lower control limit is given by LCLr.

$$UCLr = D_4\overline{R}$$

$$LCLr = D_3\overline{R}$$

where D4, D3, are control chart constants that depend on subgroup size (table value).

- Plot the control limits on the R chart as dashed lines and label.
- Calculate the control limits for the X chart. The upper control limit is given by

$$UCLx = \overline{\overline{X}} + A_2\overline{R}$$

$$LCLx = \overline{\overline{X}} - A_2\overline{R}$$

UCLx. The lower control limit is given by LCLx.

where A2 is a control chart constant that depends on subgroup size (see the table below). h. Plot the control limits on the Xchart as dashed lines and label.

4. Interpret both charts for statistical control.

- Always consider variation first. If the R chart is out of control, the control limits on the X chart are not valid since you do not have a good estimate of . All tests for statistical control apply to the X chart. Points beyond the limits, number of runs and length of runs tests apply to the R chart.

$$\bar{X} = \frac{\sum X_i}{n} = \frac{X_1 + X_2 + \ldots X_n}{n}$$

R = Xmax – Xmin

$$\bar{R} = \frac{\sum R_i}{k} = \frac{R_1 + R_2 + \ldots R_k}{k}$$

$$\bar{\bar{X}} = \frac{\sum \bar{X}_i}{k} = \frac{\bar{X}_1 + \bar{X}_2 + \ldots \bar{X}_k}{k}$$

4. Interpret both charts for statistical control.

- Always consider variation first. If the R chart is out of control, the control limits on the X bar chart are not valid since you do not have a good estimate of . All tests for statistical control apply to the X bar chart. Points beyond the limits, number of

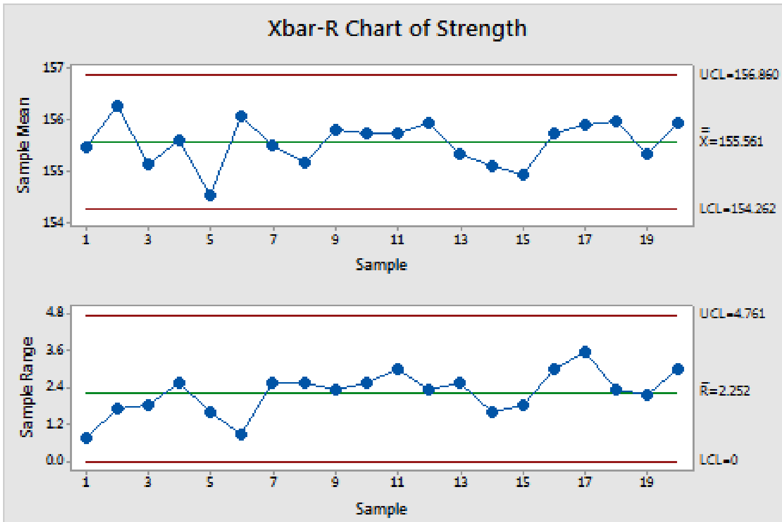
$$UCLx = \bar{\bar{X}} + A_2\bar{R}$$

$$LCLx = \bar{\bar{X}} - A_2\bar{R}$$

runs and length of runs tests apply to the R chart.

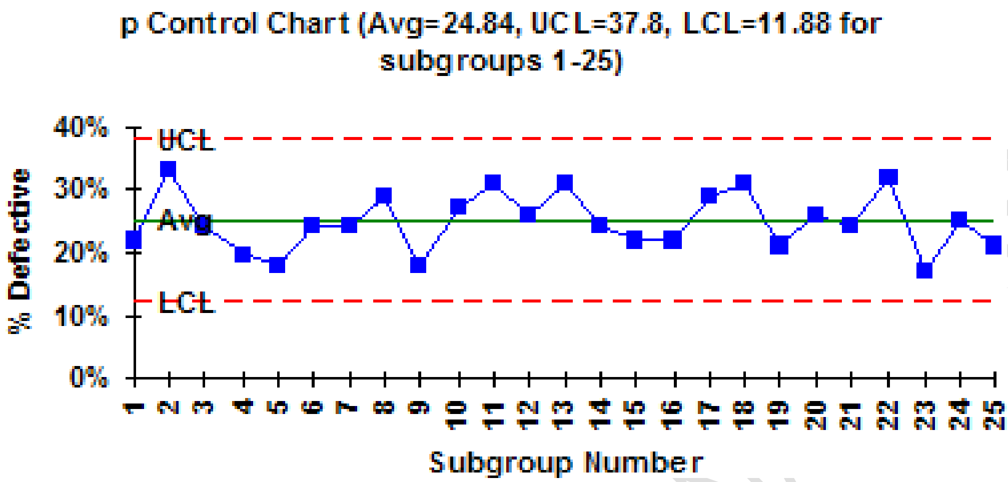
$$UCLr = D_4\bar{R}$$

$$LCLr = D_3\bar{R}$$



P CHART

***P*-charts** are used to measure the proportion / percent that are defective in a sample. A p- chart is an attributes control chart used with data collected in subgroups of varying sizes. Because the subgroup size can vary, it shows a proportion on nonconforming items rather than the actual count. P-charts show how the process changes over time. The process attribute (or characteristic) is always described in a yes/no, pass/fail, go/no go form. For example, use a p- chart to plot the prop of incomplete insurance claim forms received weekly. The subgroup would vary, depending on the total number of claims each week. P-charts are used to determine if the process is stable and predictable, as well as to monitor the effects of process improvement


p Control Chart (Avg=24.84, UCL=37.8, LCL=11.88 for subgroups 1-25)
UCL
Avg
LCL
40%
30%
20%
10%
0%
% Defective
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
Subgroup Number

CL =

$$\mathrm{UCL} = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_j}}$$

$$\mathrm{LCL} = \max\left[0,\ \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_j}}\right]$$

P-charts are used to:

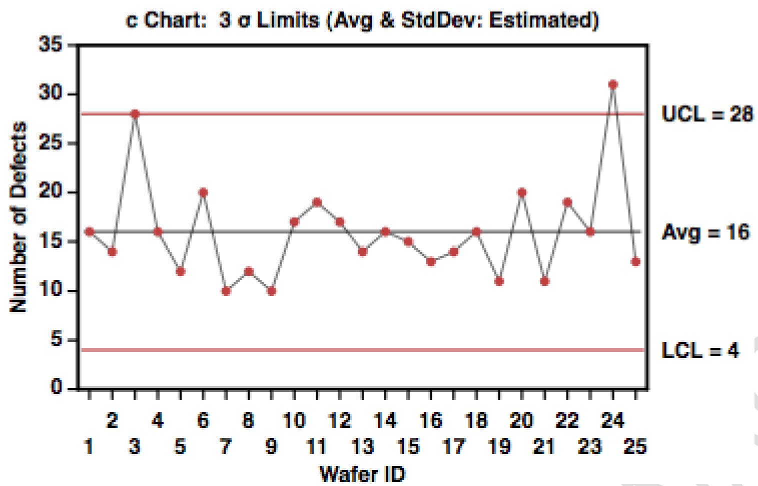
- Detect sudden changes in systems, which can be attributed to a cause.
- Assess the need for stratification into subgroups, like location, or time of day.
- Show whether the system is stable (i.e. in control).

C CHART

C charts are prepared where defective items are taken out by the number of defects in one item. Items which are according to specifications are termed as standard items. Items which have one or more defects, it means they do not fulfill one or more of the given specifications. All defects are not of the same value. so, we may like to control the defects per unit.

The number of defects in a piece is expressed as:

- Total no. of defects found in the sample
- Total no. of pieces in the samples inspected.



CL =

$$UCL = \overline{c} + 3\sqrt{\overline{c}}$$

$$LCL = \max(0, \overline{c} - 3\sqrt{\overline{c}})$$

Characteristics of C chart

The quality characteristics in such cases are the number of defects per unit.

C Chart is an improvement over P chart.

- It is the control chart in which number of defects in a piece or a sample is plotted.
- It controls number of defects observed per unit or per sample
- Sample size is constant.
- The chart is used where average number of defects are much less than the number of defects which would occur otherwise if everything possible goes wrong.
- Where P chart considers the number of defective pieces in a given sample C chart takes into account the number of defects in each defective piece or in a given sample. A defective piece may contain more than one defect, for example, a case pert may have blow holes and surface cracks at the same time.
- The C chart is preferred for large and complex parts But, the sue of C chart is limited. Ten castings were inspected in order to locate defects in them. Every casting was found to contain certain number of defects as given below, it is required to plot a C – Chart and draw the conclusions.
- Since all the values of C lie within the control limits, the process is under control. (Lower control limit is negative and thus has been taken as being zero)

APPLICATIONS OF CONTROL CHART

Control charts finds applications in controlling the quality characteristics of the followings:

- Final Assemblies (Attribute charts)
- Bullets and shells (Attribute charts)
- Soldered Joints (Attribute charts)
- Punch press works, forming (Attribute charts) and spot welding etc.
- Castings and cloth lengths (Attribute, C charts)
- Defects in components (C charts) made of glass
- Large and complex products (C charts) like bomber engines, turbines etc.
- Manufactured components like Shafts, spindles, ball pens, holes, slots etc. (Variable charts)
- For studying tool wear (Variable charts)
- Incoming material (Attribute or variable charts)

UNIT V -SERVICE OPERATIONS MANAGEMENT

Service operations Management is concerned with delivering service to the customers or users of the service. It involves the need of the customers, managing the needs of our customers, managing the processes that deliver the services, ensuring the objectives are met, while also paying attention to the continual improvement of our services.

Service operations Management is the term that is used to cover the activities, decisions and responsibilites of operations managers in service organisation

Service is the combination of customers experience and their perception of the outcome.

TYPES OF SERVICES

- **Business – to – consumer services (B2C)**

  B2C services are those that individulas purchase or on behalf of other individual. (e.g. **financial services** - Banks, Insurances, **retail** – super markets, hyper markets)

- **Business – to – business services (B2B)**

  B2B services are provided by businesses for other businesses or organisations. (e.g. consultants, communications, office equiment provision and support)

- **Internal services**

  Thera are many services in large organisations that do not deal with the external customer.(e.g. IT services, purchasing, finance, personnel)

- **Public services**

  These services are privided by central or local government for the community at large. Funding comes through the various forms of business and taxation, which is then largely allocated by policies set by government.

  (e.g. **Education** (schools, colleges**), health services** (hospitals) , police, prisons)

- **Not – for – profit services**

  Charities of various types which are mostly engaged in a mixture of fund raising, providing information about the cause or issue that conserns them, and in some form of social action. (e.g. charitites, Aid organisations, faith organisations)

Examples for service organisations – Hospitals, Hotels, schools, Colleges, Banks, Prisons, Consultancy, Training institutes, Retail Shops, IT, Airlines, Railways, etc.,

Characterisitcs of Services

1. Goods are tangible while services are intangible.
2. Customers participate in many service processes, activities, and transactions
3. The demand for services is more diffi cult to predict than the demand for goods
4. Services cannot be stored as physical inventory.
5. Service management skills are paramount to a successful service encounter.
6. Service facilities typically need to be in close proximity to the customer.
7. Patents do not protect services

Servicescapes

- Ambient Conditions: noise, music (tempo), lighting, temperature, scent (cookies), color (performance).
- Spatial Layout and Functionality: reception area, circulation paths of employees and customers, and focal points. (efficiency/uncertainty)
- Signs, Symbols, and Artifacts: selection, orientation, location, and size of objects

Types of service scapes are

- **Self-service (customer only)**: it must guide customers (signs, hot buttons on website)
- **Remote service (employee only)**: motivate employee and achieve operational efficiency
- **Professional services (both)** : project competence and authority

Strategic Role of Servicescapes

- Visually conveys usage and quality of service
- Facilitates the delivery of the service (employees & customers) (floorplan, layout of website); can encourage social interaction (waiting room)
- Acts as a market differentiator by signalling the intended market segment (signs of restaurants); conveys distinctiveness from competitors

SERVICE ENCOUNTER

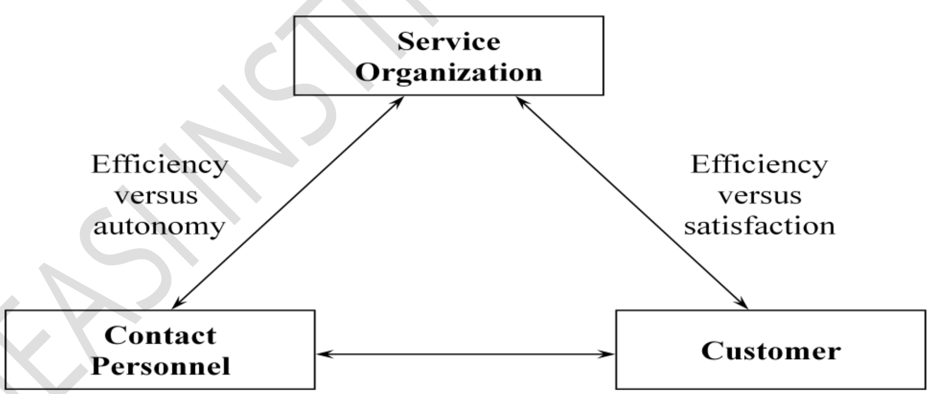
A service encounter is an interaction between the customer and the service provider.

Service encounters consist of one or more moments of truth—any episodes, transactions, or experiences in which a customer comes into contact with any aspect of the delivery system, however remote, and thereby has an opportunity to form an impression.

Employees who interact directly with customers, such as airline flight attendants, nurses, lawyers, fast-food counter employees

That period of time during which a customer directly interacts with a service

The Service Encounter Triad



Scope of service Encounters

A customer interacts with the service in any, or all, of the following ways:

- customer interacts with service employee(s)
- customer interacts with other customer(s)
- customer interacts with the physical surroundings
- customer interacts with the technology/equipment

Importance of Service Encounters

- Influence service quality perceptions
- Recovery
- Adaptation
- Spontaneity (Coping)

SERVICE FACILITY AND LAYOUT

Service Facility Design Considerations

- Nature and Objectives of Service Organization
- Land Availability and Space Requirements
- Flexibility
- Security
- Aesthetic Factors
- The Community and Environment

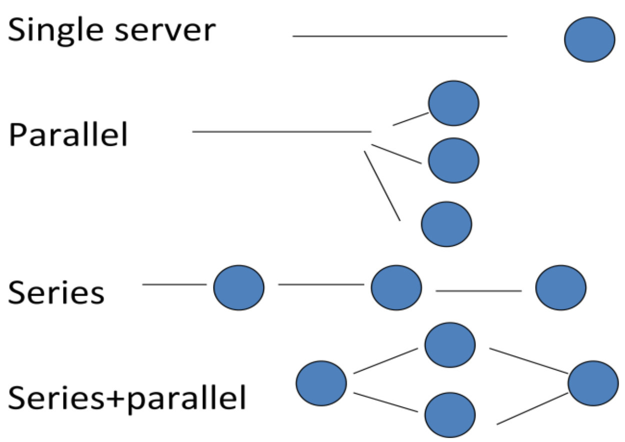
Characterisitcs of Facility Layout

- Volume of demand
- Variability in the service provided
- Degree of personalization
- Skills, attributes of employees
- Nature of consumer interaction (self-service)
- Cost of providing the service
- Implicit and explicit cost to the customer
- Flexibility
- Consistency (reproducibility)

TYPES OF LAYOUT - SERVICES

A) PRODUCT LAYOUT,

Product Layout, which organizes the steps in a service process in the order they are provided, such as the layout of the self-service stations at a cafeteria style restaurant



Product Layout - Types

B) PROCESS LAYOUT

Process Layouts, which organize materials and equipment according to the process performed, such as the different departments in a hospital;

- Similar operations grouped together
  - Employee skills or equipment
  - Type of service
  - Attitude/expectations of customers
- Intermittent flow
  - Variability in type of service
  - Variability in sequence of service delivery
- Point of control: scheduling
- Flexibility through:
  - Employees with broad skills
  - General purpose equipment
- Labour intensive
- Capacity to privide wide variety of services
- Cater for individual needs

C) FIXED POSITION LAYOUT

Fixed Position Layout, such as the special services desk at a bank, where all new account transactions take place, or an operating room in a hospital. The importance of ambience, the functionality of the space, and the signs, symbols and artifacts that provide cues to the customers about thestyle and nature of the service.

SERVICE OPERATIONS PLANNING AND CONTROL

Planning and control is concerned with the reconciliation between what the market requires and what the operation's resources can deliver. Planning and control activities provide the systems, procedures and decisions which bring different aspects of supply and demand together. The purpose is always the same – to make a connection between supply and demand that will ensure that the operation's processes run effectively and efficiently and produce products and services as required by customers.

For example, the way in which routine surgery is organized in a hospital. When a patient arrives and is admitted to the hospital, much of the planning for the surgery will already have happened. The operating theatre will have been reserved, and the doctors and nurses who staff the operating theatre will have been provided with all the information regarding the patient's condition. Appropriate preoperative and post operative care will have been organized. All this will involve staff and facilities in different parts of the hospital. All must be given the same information and their activities coordinated. Soon after the patient arrives, he or she will be checked to make sure that their condition is as expected. Blood, if required, will be cross- matched and reserved, and any medication will be made ready. Any last-minute changes may require some degree of replanning.

WAITING LINE (QUEUE) MANAGEMENT

The waiting line or queue management is a critical part of service industry. It deals with issue of treatment of customers in sense reduce wait time and improvement of service. Queue management deals with cases where the customer arrival is random; therefore, service rendered to them is also random.

A service organization can reduce cost and thus improve profitability by efficient queue management. A cost is associated with customer waiting in line and there is cost associated with adding new counters to reduce service time. Queue management looks to address this trade-off and offer solutions to management.

Queue Characteristics:

This looks at selection of customers from the queue for service.

Generally, customer selection is through first come first served method, random or last in first out. As a result, customers leave if the queue is long, customer leave if they have waited too long or switch to faster serving queue.

1. **Arrival rate** – The rate at which customers arrive at the system
2. **Service rate** – The rate at which the service is being done by the server
3. **Service Discipline** – FIFO, LIFO, Random order
4. **Queue Length** – No of customers in the system
5. **No of service channels** – Single channel / Multi channel
6. **Population** - Finite / Infinite

Managing waiting Lines

- **Waiting Line Problems**

Waiting in line is common phenomena in daily life, for example, banks have customers in line to get service of teller, cars queue up for re-filling, workers line up to access machine to complete their job. Therefore, management needs to work on formulae, which will reduce wait time

and create delighted customers without incurring an additional cost. Generally, queue management problems are trade off's situation between cost of time spent in waiting v/s cost of additional capacity or machinery.

- **Finite and Infinite Population**

In a waiting line scenario, there are cases of finite population of customers and infinite population of customers.A finite population scenario considers a fixed or limited size of customers visiting the service counter. It also assumes that customer once served will leave the line thus reducing overall population of customers. However finite population model also considers a scenario where the customer after getting served will revisit the service counter for reservice, leading to increase in finite population.

An infinite population theory looks at a scenario where subtractions and addition of customer do not impact overall workability of the model.

- **Queuing System.**

To solve problems related to queue management it is important to understand characteristics of the queue. Some common queue situations are waiting in line for service in super-market or banks, waiting for results from computer and waiting in line for bus or commuter rail. General premise of queue theory is that there are limited resources for a given population of customers and addition of a new service line will increase the cost aspect to the business. A typical queue system has the following:

- **Arrival Process:**

As the name suggests an arrival process look a t different components of customer arrival. Customer arrival could in single, batch or bulk, arrival as distribution of time, arrival in finite population or infinite population.

- **Service Mechanism**:

This looks at available resources for customer service, queue structure to avail the service and preemption of service. Underlining assumption here is that service time of

customers is independent of arrival to the queue.

Service Configuration

Another aspect of waiting line management is the service configuration. There are four types of service configuration, and they are as follows:

Single Channel, Single Phase (e.g. ship yards and car wash) Single Channel, Multi Phase (e.g. bank tellers)

Multi-Channel, Single Phase (e.g. separate queue of man and women for single ticket window) Multi-Channel, Multi Phase (e.g. Laundromat, where option of several washers and several Dryers)

TYPES OF SERVICE PROCESSES

Process Type	**Service Example**	**Characteristic**	**Management Challenge**
Project	Consulting	One-of-a-kind engagement	Staffing and scheduling
Job Shop	Hospital	Many specialized departments	Balancing utilization and scheduling patients
Batch	Airline	Group of customers treated simultaneously	Pricing of perishable asset (seat inventory)
Flow	Cafeteria	Fixed sequence of operations	Adjust staffing to demand fluctuations
Continuous	Electric Utility	Uninterrupted delivery	

SERVICE SYSTEM

The service system comprises the service delivery process and all of the supporting processes that are required in the co-creation of value for the customer.The service system is often the service organization. However, them service system can be expanded to include suppliers to whom part of the service delivery process has been outsourced and who therefore can affect the customer's experience (this is known as business process outsourcing or BPO) For example, when you make an online airline reservation at Expedia, how quickly and accurately Delta Airlines confirms your reservation and seat assignments significantly affects your experience and satisfaction with Expedia's reservation process.

SERVICE DELIVERY PROCESS.

This is the end-to-end process that directly interacts with the customer. It consists of all the steps that a customer goes through in the co-creation of value. The service delivery process begins when the customer first interacts with the service organization or system and ends when the delivery of the desired service is completed and the customer exits the process.

Supporting Process

These consist of all the other processes that together with the service delivery process define the service system. Each supporting process affects the customer's experience during the delivery of the service. Examples of supporting processes include the human resource management process and the information technology process.

Challenges in Designing the Service Process

Because services are intangible they can be difficult to describe, and that difficulty creates a challenge for service designers. Lynn Shostack identified four risks inherent in describing services

1. Oversimplification.

Shostack writes, "To say that 'portfolio management' means 'buying and selling stocks' is like describing the space shuttle as 'something that flies.'"All too often some of the most important steps in the service delivery process are overlooked in the initial design, only to be identified later when customers complain about the process.

2. Incompleteness

Customers are only able to describe the parts of the service with which they are familiar and with which they have direct contact.The designers must recognize that situations will often occur that were not anticipated, so the design of the process needs to be sufficiently flexible to accommodate them

3. Subjectivity.

People are biased by their own experiences with services or by personal situations that have nothing to do with the service.

For example, if you had a bad day at the office, your dinner that night, even if it is at your favorite restaurant, will most likely not leave you with a positive feeling.

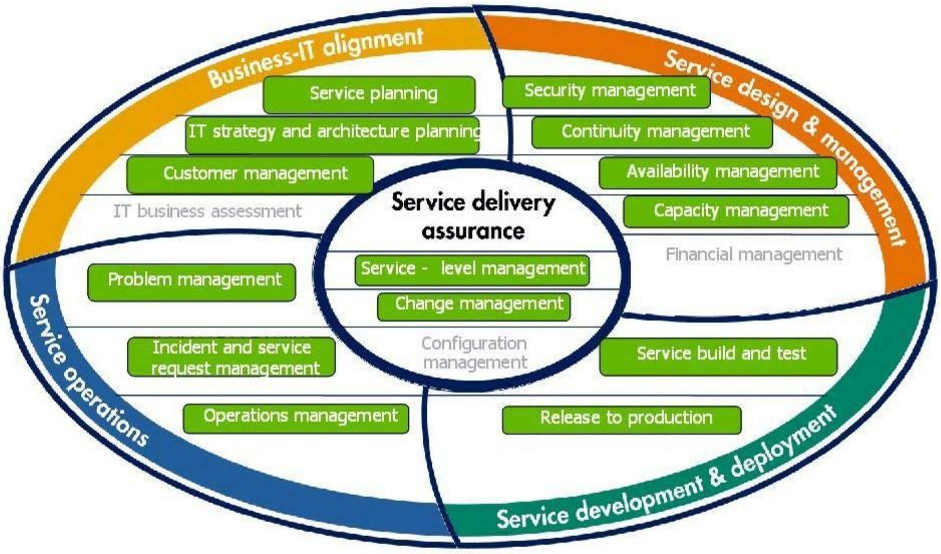
4. Biased interpretation

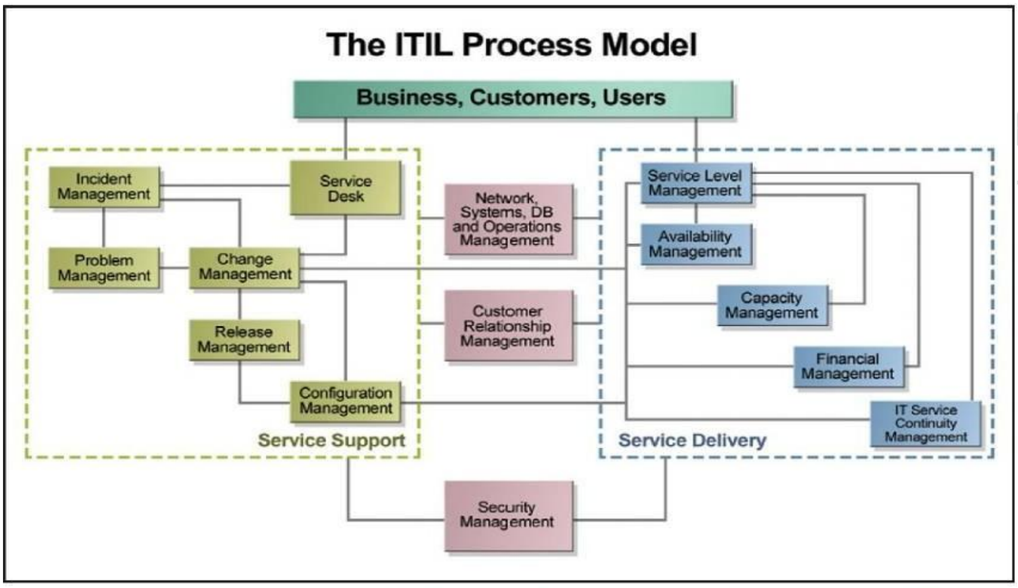
When people describe services to others additional bias is added in the way they use words, which are open to the interpreta tion of the listener.

For example, what one person means by “polite and responsive” may be very different from what other people think when they hear those same words. Like any process, the service design process can be improved by using a structured approach that systematically collects information from both customers and service providers to design a service process that meets customer needs, rather than a process that seems good to the manager.

Service Delivery – Exam

ples


Business-IT alignment
Service planning
IT strategy and architecture planning
Customer management
IT business assessment
Service design & management
Security management
Continuity management
Availability management
Capacity management
Financial management
Service delivery assurance
Service - level management
Change management
Configuration management
Service operations
Problem management
Incident and service request management
Operations management
Service build and test
Release to production
Service development & deployment



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