SEMESTER-II

ଓଡ଼ିଶା ରାଜ୍ୟ ମୁକ୍ତ ବିଶ୍ୱବିଦ୍ୟାଳୟ, ସମ୍ବଲପୁର

ODISHA STATE OPEN UNIVERSITY, SAMBALPUR

ଓଡ଼ିଶା ରାଜ୍ୟ ମୁକ୍ତ ବିଶ୍ୱବିଦ୍ୟାଳୟ, ସମ୍ବଲପୁର

Odisha State Open University

Sambalpur

BACHELOR OF BUSINESS ADMINISTRATION (BBA)

GENERIC ELECTIVE - 2

GEBBA-02: PRODUCTION AND OPERATION MANAGEMENT

Credit: 6

Block-1,2,3 & 4

GEBBA-02: PRODUCTION AND OPERATION MANAGEMENT

Brief Content

ODISHA STATE OPEN UNIVERSITY, SAMBALPUR

Programme Name: **Bachelor of Arts Business Administration**

Programme Code: **BBA** Course Name: **Production and Operation Management**

Course Code: **GEBBA-02** Semester: **II**

Credit: **6** Block No.: **1to 4** Unit No.: **1 to16** Pages: **289**

This study material has been developed by Odisha State Open University as per the UGC Prescribed Syllabus for Under Graduate Course in Business Administration under Choice Based Credit System (CBCS).

COURSE WRITERS

Mr. Manoj Kumar Behera
Associate Professor
PG Dept. of Commerce
Vikram Deb Autonomous College, Jeypore

Dr. Durga Madhab Mahapatra
Lecturer in Commerce
F M Autonomous College
Balasore

Dr. Debdutta Das
Assistant Professor
PG Dept. of Business Administration
Fakir Mohan University, Balasore

Ms. Priyanka Chakraborty
Assistant Professor
JIS College of Engineering, Kolkata

COURSE EDITORS

Ms. Rita Singh
Academic Consultant,
Odisha State Open University
Sambalpur, Odisha

Printed and Published by

Registrar
Odisha State Open University, Sambalpur

Printer:

GEBBA-02: PRODUCTION AND OPERATION MANGEMENT

CONTENTS

Unit 8- Product-process design Matrix and Services design matrix: Need for Product Planning and Development; Objectives of Product Planning and Development; Characteristics of successful Product Development; Role of Production Management in Product Development; Factors to be considered in Product Development; Product Design, Process Design and Production Design; Factors influencing Product Design; Characteristics of Good Product Design; The Product Design process as part of Product Development Process; Stages in Product Design; Design Documents for Production

Unit 9- Layout Decision: Introduction to plant Layout; Definitions of Plant Layout; Objectives of Plant Layout; Principles of Plant Layout; Need of Plant Layout; Major Factors affecting Plant Layout; The Importance of Layout; Applicability of Plant Layout

Unit 10- Location Decisions & Models: Importance of location decisions; advantages and Disadvantages of plant location and its decisions; Different Models of Plant Location Decision; Location Beak-even Analysis.

Unit 11-Capacity Planning: Defining capacity planning; Factors Influencing capacity plan; Capacity planning-how to make a successful plan? The know-how.

Unit 12- Decision trees analysis: Defining Decision Tree Analysis; Elements of Decision tree; How to prepare a decision tree analysis-The process; Pros & Cons of decision tree analysis

Unit 13- Aggregate Planning: Aggregate Planning Strategies; Factors for Aggregate Planning; Factors affecting Aggregate Planning; Techniques for Aggregate Planning; Mathematical Approaches to Aggregate Planning; Difference between Aggregate Planning in Manufacturing & Aggregate Planning in Services; Advantages of Aggregate Planning

Unit 14- Statistical Quality control: Definitions; Methodology & Tools of Statistical Quality Control; Quality Tools for problem solving; Statistical Quality Control implementation; Objectives of Statistical Quality Control; Benefits of Statistical Quality Control

Unit 15- Control charts: Intent and Benefits; Various Forms of Control Charts; Variable control charts vs. Attribute-based charts; Benefits of Control Attribute Chart; Benefits of Control Variable Charts; Traditional Chart Formats; State of Process Beyond Control; Managing The Process; Control charts for attributes

Unit 16- Elementary Queuing Theory: Objectives; Basic concept of Queuing theory; Characteristics; Queuing classification models using Kendal's and lee representations; Importance; Application of queuing theory; little's Law of queuing theory; Benefits of Queuing theory; Queuing networks

Block-1

Introduction to Production & Operations Management

Unit No.	Unit Name
Unit 1	Introduction to Production & Operations Management
Unit 2	Operation Strategies
Unit 3	Maintenance Management
Unit 4	Lean production

UNIT 1: INTRODUCTION TO PRODUCTION & OPERATIONS MANAGEMENT

STRUCTURE

LEARNING OBJECTIVES

After go through this unit you will be able to-

- Define the term operations management.
- Identify the three major functional areas of organizations and describe how they are interrelate.
- Identify similarities and differences between production and service operations.
- Summarize the two major aspects of process management.
- Briefly describe the historical evolution of operations management.
- Characterize current trends in business that impact operations management.

1.1 INTRODUCTION

Operations is that part of a business organization that is responsible for producing goods and/ or services. Goods are physical items that include raw materials, parts, sub assemblies such as motherboards that go into computers, and final products such as cell phones and automobiles.

Services are activities that provide some combination of time, location, form, or psychological value. Examples of goods and services are found all around you. Every book you read, every video you watch, every e-mail you send, every telephone conversation you have, and every medical treatment you receive involves the operations function of one or more organizations. So does everything you wear, eat, travel in, sit on, and access the Internet with. The operations function in business can also be viewed from a more far-reaching perspective. The collective success or failure of companies' operations functions has an impact on the ability of a nation to compete with other nations, and on the nation's economy.

The ideal situation for a business organization is to achieve a match of supply and demand. Having excess supply or excess capacity is wasteful and costly; having too little means lost opportunity and possible customer dissatisfaction. The key functions on the supply side are operations and supply chains, and sales and marketing on the demand side.

While the operations function is responsible for producing products and/or delivering services, it needs the support and input from other areas of the organization. Business organizations have three basic functional areas: finance, marketing, and operations. It doesn't matter whether the business is a retail store, a hospital, a manufacturing firm, a car wash, or some other type of business; all business organizations have these three basic functions.

Finance is responsible for securing financial resources at favourable prices and allocating those resources throughout the organization, as well as budgeting, analyzing investment proposals, and providing funds for operations. Marketing and operations are the primary, or "line," functions. Marketing is responsible for assessing consumer wants and needs, and selling and promoting the organization's goods or services. Operations is responsible for producing the goods or providing the services offered by the organization. To put this into perspective, if a business organization were a car, operations would be its engine.
And just as the engine is the core of what a car does, in a business organization, operations is the core of what the organization does.

Operations management is responsible for managing that core. Hence, operations management is the management of systems or processes that create goods and/or provide services. Operations and supply chains are intrinsically linked and no business organization could exist without both. A supply chain is the sequence of organizations—their facilities, functions, and activities—that are involved in producing and delivering a product or service. The sequence begins with basic suppliers of raw materials and extends all the way to the final customer.

Facilities might include warehouses, factories, processing centres, offices, distribution centres, and retail outlets. Functions and activities include forecasting, purchasing, inventory management, information management, quality assurance, scheduling, production, distribution, delivery, and customer service.

Supply chains are both external and internal to the organization. The external parts of a supply chain provide raw materials, parts, equipment, supplies, and/or other inputs to the organization, and they deliver outputs that are goods to the organization's customers. The internal parts of a supply chain are part of the operations function itself, supplying operations with parts and materials, performing work on products and/or services, and passing the work on to the next step in the process.

The creation of goods or services involves transforming or converting inputs into outputs.

Various inputs such as capital, labour, and information are used to create goods or
Services using one or more transformation processes (e.g., storing, transporting, repairing).

To ensure that the desired outputs are obtained, an organization takes measurements at various points in the transformation process (feedback) and then compares them with previously established standards to determine whether corrective action is needed (control).

Operations management is important. It is concerned with creating the services and products upon which we all depend. And all organizations produce some mixture of services and products, whether that organization is large or small, manufacturing or service, for profit or not for profit, public or private. Thankfully, most companies have now come to understand the importance of operations. This is because they have realized that effective operations management gives the potential to improve both efficiency and customer service simultaneously. But more than this, operations management is everywhere, it is not confined to the operations function. All managers, whether they are called Operations or Marketing or Human Resources or Finance, or whatever, manage processes and serve customers (internal or external). This makes, at least part of their activities 'operations'.

Operations management is also exciting. It is at the centre of so many of the changes affecting the business world – changes in customer preference, changes in supply networks brought about by internet-based technologies, changes in what we want to do at work, how we want to work, where we want to work, and so on. There has rarely been a time when operations management was more topical or more at the heart of business and cultural shifts.

Operations management is also challenging. Promoting the creativity which will allow organizations to respond to so many changes is becoming the prime task of operations managers. It is they who must find the solutions to technological and environmental challenges, the pressures to be socially responsible, the increasing globalization of markets and the difficult-to define areas of knowledge management.

1.2 Meaning of Operation Management

Operations are what must be done internally in order to deliver value to the customer, whether in goods or services. Thus, from an organizational perspective, operations management may be defined as the management of direct resources that are required to produce and deliver value via the organization's goods and services. So, basically Operations Management is the management of the conversion process that transforms inputs such as raw material and labour into outputs in the form of finished goods and services. Every function in the organization—whether marketing, finance and accounting, production, purchasing, or human resources—adds value to the customer. Keep in mind as you read through this textbook that operations management concepts can be used productively in every function of the organization.

Operations management, just as every functional area within an organization, can be defined from several perspectives: one with respect to its overall role and contribution within an organization; another focusing more on the day-to-day activities that fall within its area of responsibility.

Within the operations function, management decisions can be divided into three broad areas:

- Strategic (long-range) decisions
- Tactical (medium-range) decisions
- Operational planning and control (short-range) decisions. These three areas can be viewed as a top-down (hierarchical) approach to operations management, with the decisions made at the lower level(s) depending on those made at the higher level(s).

The strategic issues usually are very broad in nature, addressing such questions as:

- How will we make the product?

- Where should we locate the facility or facilities?
- How much capacity do we need?
- When should we add more capacity?

Consequently, by necessity, the time frame for strategic decisions typically is very long, usually several years or more, depending on the specific industry.

Operations management decisions at the strategic level impact the long-range effectiveness of the company in terms of how well it can address the needs of its customers. Thus, for the firm to succeed, these decisions must be closely aligned with the corporate strategy. Decisions made at the strategic level then define the fixed conditions or constraints under which the firm must operate in both the intermediate and short term. For example, a decision made at the strategic level to increase capacity by building a new plant becomes a capacity constraint with respect to tactical and operational decisions.

At the next level in the decision-making process, tactical planning primarily addresses the issue of how to efficiently schedule material and labour over a specific time horizon and within the constraints of the strategic decisions that were previously made. Thus, some of the OM issues at this level are:

- How many workers do we need?
- When do we need them?
- Should we work overtime or put on a second shift?
- When should we have material delivered?
- Should we have a finished goods inventory?

These tactical decisions, in turn, define the operating constraints under which the operational planning and control decisions are made.

Management decisions with respect to operational planning and control are very narrow and short term, by comparison. For example, issues at this level include:

- Which jobs do we work on today or this week?
- To whom do we assign which tasks?
- Which jobs have priority?

1.3 Production of Goods vs. Delivery of Services

Although goods and services often go hand in hand, there are some very basic differences between the two, differences that impact the management of the goods portion versus management of the service portion. There are also many similarities between the two. Production of goods results in a tangible output, such as an automobile, eyeglasses, a golf ball, a refrigerator—anything that we can see or touch. It may take place in a factory, but can occur elsewhere. For example, farming produces nonmanufactured goods. Delivery of service, on the other hand, generally implies an act. A physician's examination, TV and auto repair, lawn care, and the projection of a film in a theater are examples of services. The majority of service jobs fall into these categories:

- Professional services (e.g., financial, health care, legal).
- Mass services (e.g., utilities, Internet, communications).
- Service shops (e.g., tailoring, appliance repair, car wash, auto repair/maintenance).
- Personal care (e.g., beauty salon, spa, barbershop).
- Government (e.g., Medicare, mail, social services, police, fire).
- Education (e.g., schools, universities).
- Food service (e.g., restaurants, fast foods, catering, bakeries).
- Services within organizations (e.g., payroll, accounting, maintenance, IT, HR, janitorial).
- Retailing and wholesaling.
- Shipping and delivery (e.g., truck, railroad, boat, air).
- Residential services (e.g., lawn care, painting, general repair, remodelling, interior design).
- Transportation (e.g., mass transit, taxi, airlines, ambulance).
- Travel and hospitality (e.g., travel bureaus, hotels, resorts).
- Miscellaneous services (e.g., copy service, temporary help).

Manufacturing and service are often different in terms of what is done but quite similar in terms of how it is done.

Consider these points of comparison:

Degree of customer contact. Many services involve a high degree of customer contact, although services such as Internet providers, utilities, and mail service do not. When there is a high degree of contact, the interaction between server and customer becomes a "moment of truth" that will be judged by the customer every time the service occurs.

Labour content of jobs. Services often have a higher degree of labour content than manufacturing jobs do, although automated services are an exception.

Uniformity of inputs. Service operations are often subject to a higher degree of variability of inputs. Each client, patient, customer, repair job, and so on presents a somewhat unique situation that requires assessment and flexibility. Conversely, manufacturing operations often have a greater ability to control the variability of inputs, which leads to more-uniform job requirements.

Measurement of productivity. Measurement of productivity can be more difficult for service jobs due largely to the high variations of inputs. Thus, one doctor might have a higher level of routine cases to deal with, while another might have more difficult cases. Unless a careful analysis is conducted, it may appear that the doctor with the difficult cases has a much lower productivity than the one with the routine cases.

Quality assurance. Quality assurance is usually more challenging for services due to the higher variation in input, and because delivery and consumption occur at the same time. Unlike manufacturing, which typically occurs away from the customer and allows mistakes that are identified to be corrected, services have less opportunity to avoid exposing the customer to mistakes.

Inventory. Many services tend to involve less use of inventory than manufacturing operations, so the costs of having inventory on hand are lower than they are for manufacturing. However, unlike manufactured goods, services cannot be stored. Instead, they must be provided "on demand."

Wages. Manufacturing jobs are often well paid, and have less wage variation than service jobs, which can range from highly paid professional services to minimumwage workers.

Ability to patent. Product designs are often easier to patent than service designs, and some services cannot be patented, making them easier for competitors to copy.
There are also many similarities between managing the production of products and managing services. Here are some of the primary factors for both:

a) Forecasting and capacity planning to match supply and demand.
b) Process management.
c) Managing variations.
d) Monitoring and controlling costs and productivity.
e) Supply chain management.
f) Location planning, inventory management, quality control, and scheduling.

Note that many service activities are essential in goods-producing companies. These include training, human resource management, customer service, equipment repair, procurement, and administrative services.

1.4 PROCESS MANAGEMENT

A key aspect of operations management is process management. A process consists of one or more actions that transform inputs into outputs. In essence, the central role of all management is process management. Businesses are composed of many interrelated processes.

Generally speaking, there are three categories of business processes:
1. Upper-management processes. These govern the operation of the entire organization. Examples include organizational governance and organizational strategy.

2. Operational processes. These are the core processes that make up the value stream. Examples include purchasing, production and/or service, marketing, and sales.
3. Supporting processes. These support the core processes. Examples include accounting, human resources, and IT (information technology).

Business processes, large and small, are composed of a series of supplier– customer relationships, where every business organization, every department, and every individual operation is both a customer of the previous step in the process and a supplier to the next step in the process. Figure 1.1 illustrates this concept.

A major process can consist of many sub processes, each having its own goals that contribute to the goals of the overall process. Business organizations and supply chains have many such processes and sub processes and they benefit greatly when management is using a process perspective. Business process management (BPM) activities include process design, process execution, and process monitoring. Two basic aspects of this for operations and supply chain management are managing processes to meet demand and dealing with process variability.

Managing a Process to Meet Demand

Ideally, the capacity of a process will be such that its output just matches demand.

Excess capacity is wasteful and costly; too little capacity means dissatisfied customers and lost revenue. Having the right capacity requires having accurate forecasts of demand, the ability to translate forecasts into capacity requirements, and a process in place capable of meeting expected demand. Even so, process variation and demand variability can make the achievement of a match between process output and demand difficult. Therefore, to be effective, it is also necessary for managers to be able to deal with variation.

Process Variation

Variation occurs in all business processes. It can be due to variety or variability.

For example, random variability is inherent in every process; it is always present. In addition, variation can occur as the result of deliberate management choices to offer customers variety.

There are four basic sources of variation:

1. The variety of goods or services being offered. The greater the variety of goods and services, the greater the variation in production or service requirements.

2. Structural variation in demand. These variations, which include trends and seasonal variations, are generally predictable. They are particularly important for capacity planning.

3. Random variation. This natural variability is present to some extent in all processes, as well as in demand for services and products, and it cannot generally be influenced by managers.

4. Assignable variation. These variations are caused by defective inputs, incorrect work methods, out-of-adjustment equipment, and so on. This type of variation can be reduced or eliminated by analysis and corrective action.

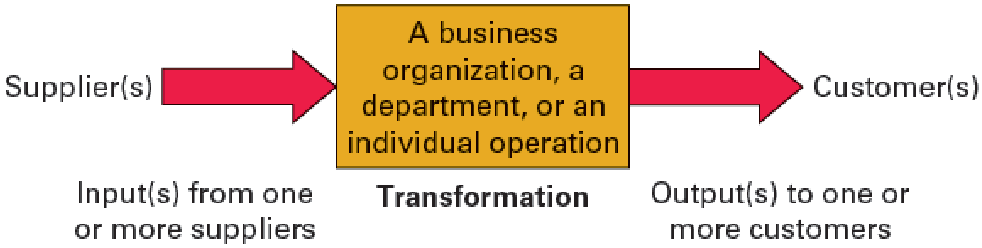


Fig 1.1: **Business Processes form a sequence of suppliers and customers**

Variations can be disruptive to operations and supply chain processes, interfering with optimal functioning. Variations result in additional cost, delays and shortages, poor quality, and inefficient work systems. Poor quality and product shortages or service delays can lead to dissatisfied customers and damage an organization's reputation and image. It is not surprising, then, that the ability to deal with variability is absolutely necessary for managers. An important aspect of being able to deal with variation is to use metrics to describe it. Two widely used metrics are the mean (average) and the standard deviation. The standard deviation quantifies variation around the mean.

1.5 AN OPERATIONAL PERSPECTIVE

The day-to-day activities within the operations management function focus on adding value to the organization through a transformation process (as illustrated in Fig 1.2), sometimes referred to as the technical core, especially in manufacturing organizations.

Some examples of the different types of transformations are:

- Physical, as in manufacturing
- Locational, as in transportation
- Exchange, as in retailing

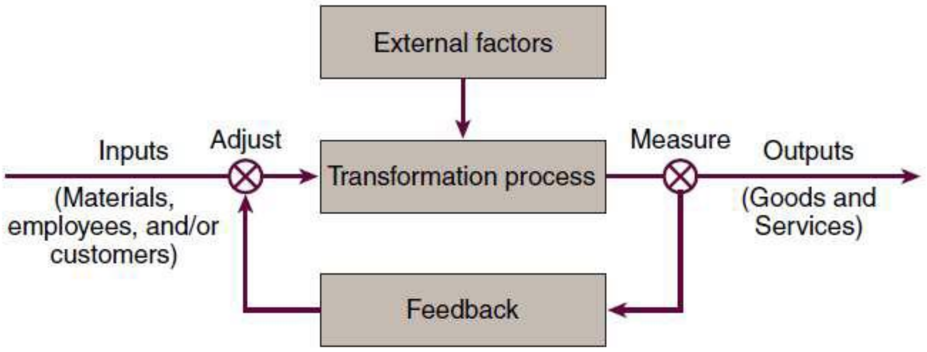


Fig 1.2: **The Transformation Process within OM**

System	**Primary Inputs**	**Resources**	**Primary Transformation Functions**	**Typical desired Output**
Hospital	Pateints	MDs, nurses, medical sipplies, euipments	Health care	Healthy individual
Resturants	Hungry Customers	Food, chef, wait-staff, environment	Well-prepared, well-served food; agreeable environment (physical & exchange)	Satisfied customers
College or University	High school graduates	Teachers, books, lecture halls	Imparting knowledge & skills (informational)	High-quality cars
Automobile	Sheet steel,	Tools,	Fabrication &	Educated

factory	engine parts	equipment, workers	assembly of cars (physical)	individuals
Department Store	Shopper, stock of goods	Displays, salesclerks	Attract shoppers, promote products, fill orders (exchange)	Sales to satisfied customers
Distribution Center	Stockkeeping units (SKU)	Storage bins, stockpickers	Storage and redistribution	Fast delivery, availability of SKUs

- Storage, as in warehousing
- Physiological, as in health care
- Informational, as in telecommunications

The inputs are customers and/or materials which undergo the transformation. Also part of the transformation process is a variety of components supplied by the organization, such as labour, equipment, and facilities, which convert the inputs into outputs. Every transformation process is affected by external factors, which are outside the control of management. External factors include random, unexpected events such as natural disasters, economic cycles, changes in government policies and laws, as well as changes in consumer preferences and tastes. These external factors can also include anticipated changes, such as seasonality, over which management has little or no control.

Another important role of the operations management function is the measurement and control of the transformation process. This consists of monitoring the outputs in various ways, including quality and quantity, and then using this information as feedback to make the necessary adjustments that will improve the process.

The various transformations that take place are not mutually exclusive. For example, a department store can (a) allow shoppers to compare prices and quality (informational), (b) hold items in inventory until needed (storage), and (c) sell goods (exchange). Exhibit 1.3 presents sample input–transformation–output relationships for a wide variety of processes. Note that only the direct components are listed; a more complete system description would also include managerial and support functions.

1.6 THE HISTORICAL EVOLUTION OF OPERATIONS MANAGEMENT

Systems for production have existed since ancient times. The production of goods for sale, at least in the modern sense, and the modern factory system had their roots in the Industrial Revolution.

The Industrial Revolution: The Industrial Revolution began in the 1770s in England and spread to the rest of Europe and to the United States during the 19th century. Prior to that time, goods were produced in small shops by craftsmen and their apprentices. Under that system, it was common for one person to be responsible for making a product, such as a horse-drawn wagon or a piece of furniture, from start to finish. Only simple tools were available; the machines in use today had not been invented.

Then, a number of innovations in the 18th century changed the face of production forever by substituting machine power for human power. Perhaps the most significant of these was the steam engine, because it provided a source of power to operate machines in factories. Ample supplies of coal and iron ore provided materials for generating power and making machinery. The new machines, made of iron, were much stronger and more durable than the simple wooden machines they replaced.

In the earliest days of manufacturing, goods were produced using craft production: highly skilled workers using simple, flexible tools produced goods according to customer specifications. Craft production had major shortcomings.

Because products were made by skilled craftsmen who custom fitted parts, production was slow and costly. And when parts failed, the replacements also had to be custom made, which was also slow and costly. Another shortcoming was that production costs did not decrease as volume increased; there were no economies of scale, which would have provided a major incentive for companies to expand. Instead, many small companies emerged, each with its own set of standards. A major change occurred that gave the Industrial Revolution a boost: the development of standard gauging systems. This greatly reduced the need for custom-made goods. Factories began to spring up and grow rapidly, providing jobs for countless people who were attracted in large numbers from rural areas.

Despite the major changes that were taking place, management theory and practice had not progressed much from early days. What was needed was an enlightened and more systematic approach to management.

Scientific Management: The scientific management era brought widespread changes to the management of factories. The movement was spearheaded by the efficiency engineer and inventor Frederick Winslow Taylor, who is often referred to as the father of scientific management. Taylor believed in a "science of management" based on observation, measurement, analysis and improvement of work methods, and economic incentives. He studied work methods in great detail to identify the best method for doing each job. Taylor also believed that management should be responsible for planning, carefully selecting and training workers, finding the best way to perform each job, achieving cooperation between management and workers, and separating management activities from work activities.
Taylor's methods emphasized maximizing output. They were not always popular with workers, who sometimes thought the methods were used to unfairly increase output without a corresponding increase in compensation. Certainly some companies did abuse workers in their quest for efficiency. Eventually, the public outcry reached the halls of Congress, and hearings were held on the matter. Taylor himself was called to testify in 1911, the same year in which his classic book, The Principles of Scientific Management, was published. The publicity from those hearings actually helped scientific management principles to achieve wide acceptance in industry.

A number of other pioneers also contributed heavily to this movement, including the following:
Frank Gilbreth was an industrial engineer who is often referred to as the father of motion study. He developed principles of motion economy that could be applied to incredibly small portions of a task.

Henry Gantt recognized the value of nonmonetary rewards to motivate workers, and developed a widely used system for scheduling, called Gantt charts.

Harrington Emerson applied Taylor's ideas to organization structure and encouraged the use of experts to improve organizational efficiency. He testified in a congressional hearing that railroads could save a million dollars a day by applying principles of scientific management.

Henry Ford, the great industrialist, employed scientific management techniques in his factories. During the early part of the 20th century, automobiles were just coming into vogue in the United States. Ford's Model T was such a success that the company had trouble keeping up with orders for the cars. In an effort to improve the efficiency of operations, Ford adopted the scientific management principles espoused by Frederick Winslow Taylor. He also introduced the moving assembly line, which had a tremendous impact on production methods in many industries.

Among Ford's many contributions was the introduction of mass production to the automotive industry, a system of production in which large volumes of standardized goods are produced by low-skilled or semiskilled workers using highly specialized and often costly, equipment.

Ford was able to do this by taking advantage of a number of important concepts. Perhaps the key concept that launched mass production was **interchangeable parts**, sometimes attributed to Eli Whitney, an American inventor who applied the concept to assembling muskets in the late 1700s. The basis for interchangeable parts was to standardize parts so that any part in a batch of parts would fit any automobile coming down the assembly line. This meant that parts did not have to be custom fitted, as they were in craft production. The standardized parts could also be used for replacement parts. The result was a tremendous decrease in assembly time and cost. Ford accomplished this by standardizing the gauges used to measure parts during production and by using newly developed processes to produce uniform parts.

A second concept used by Ford was the division of labour, which Adam Smith wrote about in The Wealth of Nations (1776). Division of labour means that an operation, such as assembling an automobile, is divided up into a series of many small tasks, and individual workers are assigned to one of those tasks. Unlike craft production, where each worker was responsible for doing many tasks, and thus required skill, with division of labour the tasks were so narrow that virtually no skill was required.

Together, these concepts enabled Ford to tremendously increase the production rate at his factories using readily available inexpensive labour. Both Taylor and Ford were despised by many workers, because they held workers in such low regard, expecting them to perform like robots. This paved the way for the human relations movement.

The Human Relations Movement: Whereas the scientific management movement heavily emphasized the technical aspects of work design, the human relations movement emphasized the importance of the human element in job design. Lillian Gilbreth, a psychologist and the wife of Frank Gilbreth, worked with her husband, focusing on the human factor in work. (The Gilbreths were the subject of a classic 1950s film, Cheaper by the Dozen.) Many of her studies in the 1920s dealt with worker fatigue. In the following decades, there was much emphasis on motivation.

During the 1930s, Elton Mayo conducted studies at the Hawthorne division of Western Electric. His studies revealed that in addition to the physical and technical aspects of work, worker motivation is critical for improving productivity. During the 1940s, Abraham Maslow developed motivational theories, which Frederick Hertzberg refined in the 1950s. Douglas McGregor added Theory X and Theory Y in the 1960s. These theories represented the two ends of the spectrum of how employees view work. Theory X, on the negative end, assumed that workers do not like to work, and have to be controlled—rewarded and punished—to get them to do good work. This attitude was quite common in the automobile industry and in some other industries, until the threat of global competition forced them to rethink that approach. Theory Y, on the other end of the spectrum, assumed that workers enjoy the physical and mental aspects of work and become committed to work. The Theory X approach resulted in an adversarial environment, whereas the Theory Y approach resulted in empowered workers and a more cooperative spirit.

In the 1970s, William Ouchi added Theory Z, which combined the Japanese approach with such features as lifetime employment, employee problem solving, and consensus building, and the traditional Western approach that features short-term employment, specialists, and individual decision making and responsibility.

Decision Models and Management Science: The factory movement was accompanied by the development of several quantitative techniques. F. W. Harris developed one of the first models in 1915: a mathematical model for inventory order size. In the 1930s, three coworkers at Bell Telephone Labs, H. F. Dodge, H. G. Romig, and W. Shewhart, developed statistical procedures for sampling and quality control. In 1935, L.H.C. Tippett conducted studies that provided the groundwork for statistical-sampling theory.

At first, these quantitative models were not widely used in industry. However, the onset of World War II changed that. The war generated tremendous pressures on manufacturing output, and specialists from many disciplines combined efforts to achieve advancements in the military and in manufacturing. After the war, efforts to develop and refine quantitative tools for decision making continued, resulting in decision models for forecasting, inventory management, project management, and other areas of operations management.

During the 1960s and 1970s, management science techniques were highly regarded; in the 1980s, they lost some favour. However, the widespread use of personal computers and user-friendly software in the workplace contributed to resurgence in the popularity of these techniques.

The Influence of Japanese Manufacturers: A number of Japanese manufacturers developed or refined management practices that increased the productivity of their operations and the quality of their products, due in part to the influence of Americans W. Edwards Deming and Joseph Juran. This made them very competitive, sparking interest in their approaches by companies outside Japan. Their approaches emphasized quality and continual improvement, worker teams and empowerment, and achieving customer satisfaction. The Japanese can be credited with spawning the “quality revolution” that occurred in industrialized countries, and with generating widespread interest in lean production. The influence of the Japanese on U.S. manufacturing and service companies has been enormous and promises to continue for the foreseeable future. Because of that influence, this book will provide considerable information about Japanese methods and successes. Table 1.4 provides a chronological summary of some of the key developments in the evolution of operations management.

1.7 OPERATIONS TODAY

Advances in information technology and global competition have had a major influence on operations management. While the Internet offers great potential for business organizations, the potential as well as the risks must be clearly understood in order to determine if and how to exploit this potential. In many cases, the Internet has altered the way companies compete in the marketplace. Electronic business, or e-business, involves the use of the Internet to transact business. E-business is changing the way business organizations interact with their customers and their suppliers. Most familiar to the general public is ecommerce, consumer–

business transactions such as buying online or requesting information. However, business-to-business transactions such as e-procurement represent an increasing share of e-business. E-business is receiving increased attention from business owners and managers in developing strategies, planning, and decision making.

The word technology has several definitions, depending on the context.
Generally, technology refers to the application of scientific discoveries to the development and improvement of goods and services. It can involve knowledge, materials, methods, and equipment. The term high technology refers to the most advanced and developed machines and methods. Operations management is primarily concerned with three kinds of technology: product and service technology, process technology, and information technology (IT). All three can have a major impact on costs, productivity, and competitiveness.

Product and service technology refers to the discovery and development of new products and services. This is done mainly by researchers and engineers, who use the scientific approach to develop new knowledge and translate that into commercial applications

Approximate Date	Contribution/Concept	Originator
1776	Division of labor	Adam Smith
1790	Interchangeable parts	Eli Whitney
1911	Principles of scientific management	Frederick W. Taylor
1911	Motion study, use of industrial psychology	Frank and Lillian Gilbreth
1912	Chart for scheduling activities	Henry Gantt
1913	Moving assembly line	Henry Ford
1915	Mathematical model for inventory ordering	F. W. Harris
1930	Hawthorne studies on worker motivation	Elton Mayo
1935	Statistical procedures for sampling and quality control	H. F. Dodge, H. G. Romig, W. Shewhart, L.H.C. Tippett
1940	Operations research applications in warfare	Operations research groups
1947	Linear programming	George Dantzig
1951	Commercial digital computers	Sperry Univac, IBM
1950s	Automation	Numerous
1960s	Extensive development of quantitative tools	Numerous
1960s	Industrial dynamics	Jay Forrester
1975	Emphasis an manufacturing strategy	W. Skinner
1980s	Emphasis on flexibility, time-based competition, lean production	T. Ohno, S. Shingo, Toyota
1980s	Emphasis on quality	W. Edwards Deming, J. Juran, K. Ishikawa
1990s	Internet, supply chain management	Numerous
2000s	Applications service providers and outsourcing	Numerous

Fig 1.4: **Historical Summary of Operations Management**

Process technology refers to methods, procedures, and equipment used to produce goods and provide services. They include not only processes within an organization but also supply chain processes. Information technology (IT) refers to the science and use of computers and other Electronic equipment to store, process, and send information. Information technology is heavily ingrained in today's business operations. This includes electronic data processing, the use of bar codes to identify and track goods, obtaining point-ofsale information, data transmission, the Internet, e-commerce, e-mail, and more. Management of technology is high on the list of major trends, and it promises to be high well into the future. For example, computers have had a tremendous impact on businesses in many ways, including new product and service features, process management, medical diagnosis, production planning and scheduling, data processing, and communication. Advances in materials, methods, and equipment also have had an impact on competition and productivity. Advances in information technology also have had a major impact on businesses. Obviously there have been—and will continue to be—many benefits from technological advances. However, technological advance also places a burden on management. For example, management must keep abreast of changes and quickly assess both their benefits and risks. Predicting advances can be tricky at best, and new technologies often carry a high price tag and usually a high cost to operate or repair. And in the case of computer operating systems, as new systems are introduced, support for older versions is discontinued, making periodic upgrades necessary. Conflicting technologies can exist that make technological choices even more difficult. Technological innovations in both products and processes will continue to change the way businesses operate, and hence require continuing attention.

1.8 KEY ISSUES FOR TODAY'S BUSINESS OPERATIONS

There are a number of issues that are high priorities of many business organizations. Although not every business is faced with these issues, many are.

Chief among the issues are the following:

Economic conditions. The lingering recession and slow recovery in various sectors of the economy has made managers cautious about investment and rehiring workers that had been laid off during the recession.

Innovating. Finding new or improved products or services are only two of the many possibilities that can provide value to an organization. Innovations can be made in processes, the use of the Internet, or the supply chain that reduce costs, increase productivity, expand markets, or improve customer service.

Quality problems. This relates to product design and testing, oversight of suppliers, risk assessment, and timely response to potential problems.

Risk management. The need for managing risk is underscored by recent events that include the crisis in housing, product recalls, oil spills, and natural and manmade disasters, and economic ups and downs. Managing risks starts with identifying risks, assessing vulnerability and potential damage (liability costs, reputation, demand), and taking steps to reduce or share risks.

Competing in a global economy. Low labour costs in third-world countries have increased pressure to reduce labour costs. Companies must carefully weigh their options, which include outsourcing some or all of their operations to low-wage areas, reducing costs internally, changing designs, and working to improve productivity.

Three other key areas require more in-depth discussion: environmental concerns, ethical conduct, and managing the supply chain.

(i) Environmental Concerns

Concern about global warming and pollution has had an increasing effect on how businesses operate. Stricter environmental regulations, particularly in developed nations, are being imposed. Furthermore, business organizations are coming under increasing pressure to reduce their carbon footprint (the amount of carbon dioxide generated by their operations and their supply chains) and to generally operate sustainable processes.

Sustainability refers to service and production processes that use resources in ways that do not harm ecological systems that support both current and future human existence. Sustainability measures often go beyond traditional environmental and economic measures to include measures that incorporate social criteria in decision making.

All areas of business will be affected by this. Areas that will be most affected include product and service design, consumer education programs, disaster preparation and response, supply chain waste management, and outsourcing decisions. Note that outsourcing of goods production increases not only transportation costs, but also fuel consumption and carbon released into the atmosphere. Consequently, sustainability thinking may have implications for outsourcing decisions. Because they all fall within the realm of operations, operations management is central to dealing with these issues. Sometimes referred to as “green initiatives,” the possibilities include reducing packaging, materials, water and energy use, and the environmental impact of the supply chain, including buying locally. Other possibilities include reconditioning used equipment (e.g., printers and copiers) for resale, and recycling.

(ii) Ethical Conduct

The need for ethical conduct in business is becoming increasingly obvious, given numerous examples of questionable actions in recent history. In making decisions, managers must consider how their decisions will affect shareholders, management, employees, customers, the community at large, and the environment. Finding solutions that will be in the best interests of all of these stakeholders is not always easy, but it is a goal that all managers should strive to achieve. Furthermore, even managers with the best intentions will sometimes make mistakes. If mistakes do occur, managers should act responsibly to correct those mistakes as quickly as possible, and to address any negative consequences.

Operations managers, like all managers, have the responsibility to make ethical decisions. Ethical issues arise in many aspects of operations management, including

- **Financial statements:** accurately representing the organization’s financial condition.
- **Worker safety:** providing adequate training, maintaining equipment in good working condition, maintaining a safe working environment.
- **Product safety:** providing products that minimize the risk of injury to users or damage to property or the environment.
- **Quality:** honouring warranties, avoiding hidden defects.
- **The environment:** not doing things that will harm the environment.
- **The community:** being a good neighbour.
- **Hiring and firing workers:** avoiding false pretences (e.g., promising a long-term job when that is not what is intended).
- **Closing facilities:** taking into account the impact on a community, and honouring commitments that have been made.

- **Workers' rights:** respecting workers' rights, dealing with workers' problems quickly and fairly.

Many organizations have developed *codes of ethics* to guide employees' or members' conduct.

Ethics is a standard of behavior that guides how one should act in various situations.
The Markula Center for Applied Ethics at Santa Clara University identifies five principles for thinking ethically:

The **Utilitarian Principle** is that the good done by an action or inaction should outweigh any harm it causes or might cause. An example is not allowing a person who has had too much to drink to drive.

- The **Rights Principle** is that actions should respect and protect the moral rights of others. An example is not taking advantage of a vulnerable person.
- The **Fairness Principle** is that equals should be held to, or evaluated by, the same standards. An example is equal pay for equal work.
- The **Common Good Principle** is that actions should contribute to the common good of the community. An example is an ordinance on noise abatement.
- The **Virtue Principle** is that actions should be consistent with certain ideal virtues. Examples include honesty, compassion, generosity, tolerance, fidelity, integrity, and self-control.

The center expands these principles to create a framework for ethical conduct. An **ethical framework** is a sequence of steps intended to guide thinking and subsequent decisions or actions. Here is the one developed by the Markula Center for Applied Ethics:

1. Recognize an ethical issue by asking if an action could be damaging to a group or an individual. Is there more to it than just what is legal?
2. Make sure the pertinent facts are known, such as who will be impacted, and what options are available.
3. Evaluate the options by referring to each of the preceding five ethical principles.
4. Identify the "best" option and then further examine it by asking how someone you respect would view it.
5. In retrospect, consider the effect your decision had and what you can learn from it.

1.9 LET'S SUM UP

Operations management is a multi-disciplinary field that focuses on managing all aspects of an organization's operations. "The typical organization consists of the integration of many different functions," wrote Howard J. Weiss and Mark E. Gershon in Production and Operations Management. "The two most obvious functions are to provide the product or service and to sell the product or service.

Operations management focuses on the function of providing the product or service. It is concerned with the planning and controlling of all activities necessary for the provision of the firm's product or service." Aspects of operations management, then, include products or services to emphasize; facility size and location with respect to customers and suppliers; marketing strategies to attract clients/customers; techniques and equipment to use to make the goods or to provide the services; work force management and training; and measurements of quality assurance. Operations managers apply ideas and technologies to increase productivity and reduce costs, improve flexibility to meet rapidly changing customer needs, enhance product quality, and improve customer service.

To understand operations and how they contribute to the success of an organization, it is important to understand the strategic nature of operations; the value-added nature of operations, the impact technology can have on performance, and the globally competitive marketplace.

Efficient organization operations are a vital tool in achieving competitive advantage in the daily contest for customers/clients. What factors influence buying decisions for these entities? For most services and goods, price, quality, product performance and features, product variety, and availability of the product are critical. All these factors are substantially influenced by actions taken in operations. For example, when productivity increases, product costs decline and product price can be reduced. Similarly, as better production methods are developed, quality and variety may increase.

By linking operations and operating strategies with the overall strategy of the organization (including engineering, financial, marketing, and information system strategy) synergy can result. Operations become a positive factor when facilities, equipment, and employee training are viewed as a means to achieve organizational objectives, rather than as narrowly focused departmental objectives. In recognition of this evolving viewpoint, the criteria for judging operations is changing from cost control (a narrowly defined operating objective) to global performance measurements in such areas as product performance and variety, product quality, delivery time, customer service, and operational flexibility.

In today's business environment, a key component of operational flexibility in many industries is technological knowledge. Advances in technology make it possible to build better products using fewer resources. As technology fundamentally changes a product, its performance and quality often increases dramatically, making it a more highly valued commodity in the marketplace. But the growth in high-tech business applications has created new competitors as well, making it important for businesses to try to register advantages in any and all areas of operations management.

Over time, operations management has grown in scope and increased in importance. Today, it has elements that are strategic, it relies on behavioural and engineering concepts, and it utilizes management science/operations research tools and techniques for systematic decision making and problem-solving. As operations management continues to develop, it will increasingly interact with other functional areas within the organization to develop integrated answers to complex interdisciplinary problems. Indeed, such interaction is widely regarded as essential to long-term business success for small business establishments and multinational corporations alike.

1.10 KEY TERMS

Craft production - System in which highly skilled workers use simple, flexible tools to produce small quantities of customized goods.

Division of labour - The breaking up of a production process into small tasks, so that each worker performs a small portion of the overall job.

E-business - Use of the Internet to transact business.

E-commerce - Consumer-to business transactions.

Ethical framework - A sequence of steps intended to guide thinking and subsequent decision or action.

Ethics - A standard of behaviour that guides how one should act in various situations.

Goods - Physical items produced by business organizations.

Interchangeable parts - Parts of a product made to such precision that they do not have to be custom fitted.

Mass production - System in which low-skilled workers use specialized machinery to produce high volumes of standardized goods.

Operations management - The management of systems or processes that create goods and/ or provide services.

Process - One or more actions that transform inputs into outputs.

Services - Activities that provide some combination of time, location, form, and psychological value.

Supply chain - A sequence of activities and organizations involved in producing and delivering a good or service.

Sustainability - Using resources in ways that do not harm ecological systems that support human existence.

Technology - The application of scientific discoveries to the development and improvement of goods and services.

1.11 SELF ASSESSMENT QUESTIONS

1. Briefly describe the term *operations management.*
2. Identify the three major functional areas of business organizations and briefly describe how they interrelate.
3. List five important differences between goods production and service operations; then list five important similarities.
4. Briefly discuss each of these terms related to the historical evolution of operations management:
    a. Industrial Revolution
    b. Scientific management
    c. Interchangeable parts
    d. Division of labour
5. Describe each of these systems: craft production, mass production.
6. List and briefly explain the four basic sources of variation, and explain why it is important for managers to be able to effectively deal with variation.
7. Why do people do things that are unethical?
8. Explain the term *value-added.*
9. Discuss the term *sustainability,* and its relevance for business organizations.

1.11 FURTHER READINGS

- Krajewski, L.J., and L.P. Ritzman. *Operations Management: Strategy and*
- *Analysis.* Addison-Wesley Publishing, 1993.
- Nie, winter. "Waiting: Integrating Social and Psychological Perspectives in
- Operations Management." *Omega.* December 2000.
- Ruffini, Frans A.J., Harry Boer, and Maarten J. Van Riemsdijk. "Organization
- Design in Operations Management." *International Journal of Operations and*
- *Production Management.* July 2000.
- Weiss, Howard J., and Mark E. Gershon. *Production and Operations*
- *Management.* Allyn and Bacon, 1989.

UNIT 2: OPERATION STRATEGIES

STRUCTURE

LEARNING OBJECTIVE

After you go through this unit, you will be able to know-

- Meaning of Operation Strategies
- Different Perspectives of Operations Strategy
- Relevance of Operations Strategy
- Strategy Formulation Process
- Order Qualifiers
- Order Winners

2.1 INTRODUCTION

In the growing competitive business environment, every organisation needs to implement some strategy to get a competitive advantage over others to survive, compete and prosper in this competition. The word strategy might have used many times by us but what is the exact meaning of strategy? Amazingly, it is quite difficult to answer this question. Linguistically this word came from the Greek word ‘strategos’, it means “leading an army”. Though there is no connection between army practice and the ideas of strategy, the army metaphor is powerful. But both army and business strategy can be seemed in similar passion with common points like;

- Setting an objectives which direct an organisation towards its overall goal
- Planning the way which can help to achieve these goals
- Highlighting long term objectives rather short term
- Dealing with the broader picture than focusing on individual activities

2.2 MEANING AND EXAMPLES OF OPERATION STRATEGIES

The word operations means, part of an organisation which creates and delivers the products. All the operations use the resources and processes to convert the inputs into outputs which satisfy the need of the customer. This process is called as the 'input-transformation-output' model of operations. In the operations management, the manager is needed to transform the inputs of the organisations into finished goods by the help of some processes.

Operations strategy is nothing but one part of overall business strategy, however, it is important for success. Without this strategy the organisations fails to keep up with the market change and lose from the strategic competitors. So many organisations have struggled with this operation strategy even they lacking in compete with the technological sound competitors. Like Amazon, trying and using advanced technologies like drones for the delivery, which pushed the brick and mortar retailers back. Operation strategy is not only a part of organisational strategy but also it supports it. It is a part of planning process which helps to achieve operational objectives of the company. In other words we can say it is an integrated plan for getting competitive advantage or make the business effective. It is primarily concerned with the setting up the policies and plans for the optimum utilisation of the resources to increase the productivity. Operation strategy should be formulated and implemented in such a way that it can maximise the customer satisfaction, minimise the cost and better resource utilisation.

Examples of operations strategies by different company:
In recent years, some companies have managed to adapt with the rapidly changing market by the help of their operations strategies. Like Apple computers: this company is recognised for its excellence in operations and in SCM.

Amazon: at the beginning, it known for books only but now it is well known for the online shopping of any product.

Wall Mart: this company managed to disestablish many of its competitors by price and variety of products.

FedEx: it is well known for its speedy delivery by excellent operations.

2.3 DEFINITIONS OF OPERATION STRATEGY

Operational strategy is necessity for an organisation to achieve the operational goals of the organisation in addition with overall objectives of the organisation. It is design to achieve competitive advantage.

Operational strategy is planning process which aligns the followings:

The organisational goals need to change from time to time in accordance to the competitive market environment. So, the operation strategy has to be dynamic in nature. A consistent SWOT analysis makes sure that the organisation is able to not only get a competitive advantage but also maintain that edge.

According to Slack and Lewis, "Operations strategy is the total pattern of decisions which shape the long-term capabilities of any type of operations and their contribution to the overall strategy, through the reconciliation of market requirements with operations resources."

2.4 DIFFERENT PERSPECTIVES OF OPERATIONS STRATEGY

It is very difficult to define the operations strategy in some specific words or sentences. As this is a dynamic process and there is no overall agreement about what actually this operation strategy means. There is no statement of operations strategy having universal agreement on how the operation strategy should be described. Different people perceive differently about the concept of operations strategy. The views of different authors are slightly different on the basis of the views there are four perspectives emerge like:

- it is a top-down thinking of what the entire business organisation wants to do

- it is a bottom-up function where operations improvements build strategy
- Operations strategy means translating market requirements into operations decisions
- It involves exploiting the capabilities of operations resources in a given markets.

None of these above mentioned perspectives alone narrates the complete picture of what actually the operations strategy is. However, collectively these four perspectives can give some clear idea about the pressure that forms the contents of an operations strategy.

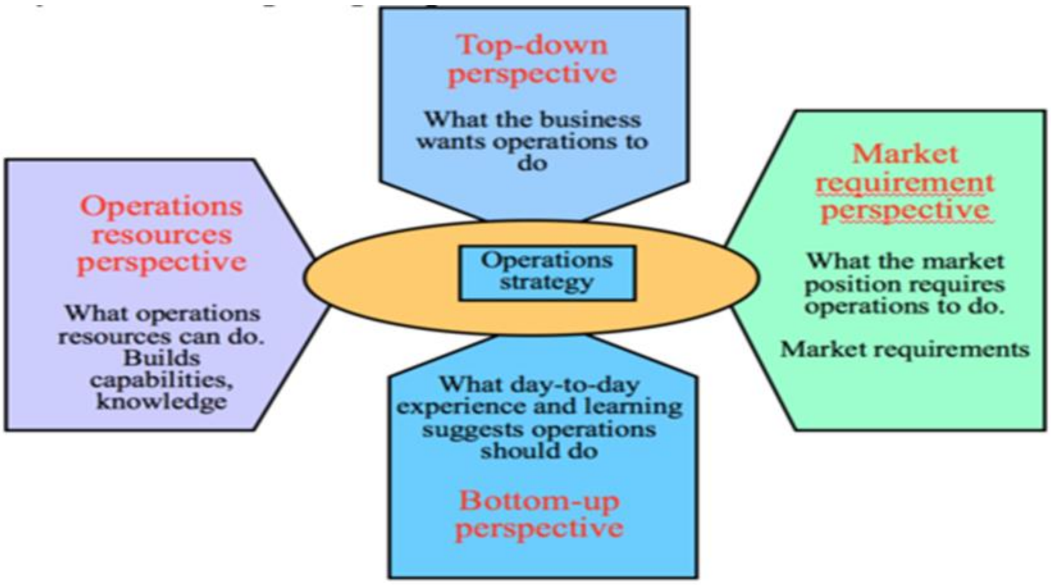


Fig 2.1: **Different Perspectives of Operations Strategy**

How should operations strategy reflect higher-level strategy? The top-down perspective:

An operations strategy should reflect the decisions taken by the top level of the organisation and that set the complete strategic direction of the organisation. This approach is called as 'top-down' perspective of operations strategy. So, if an organisation is a big, diversified then, its corporate strategy will be of decisions regarding some questions like; what types of business the organisation wants to be in, which part of World it wants to operate, which businesses to acquire and what to not, how to apportion its cash between various businesses, and so on. In the corporate, each business house needs to organise its own business strategy that sets out its mission and objectives as well as outlining how it expects to compete in the markets. Likewise, within the business every function need to consider which part of it should contributing to the strategic and competitive purposes of the business by formulating a functional strategy that can guides its actions inside the business. So, in this 'top-down' approach, all the three levels of strategy – corporate, business and functional – form a hierarchy, with business strategy establishing the context of functional strategies and corporate strategy forming the framework of business strategies.

For example, a manufacturer has decided to compete with the other manufacturers in the same industry consisting of high tech companies by being the first company in the industry to introduce every possible new product innovation by the help of its operations functions. So it needs to be competent enough to cope up with the market changes that may come due to the innovation. Therefore, the manufacturer needs to develop the processes in such a way that it must be flexible to produce novel parts/products. The manufacturer should give training to its staff regarding the new process of developing products so that they can implement the necessary changes to the operation. Apart from that it must improve the relationship with the suppliers which may help them to respond quickly. So the operations is all about its technology, employees and the systems, procedures should be must in the short term and nothing to do with the competitive strategy.

How can operations strategy learn from day-to-day experience? The bottom-up perspective:

Practically the relationship between the levels in the strategy is more complex in nature than the top-down perspective of operation strategy suggests and indeed does not represent the way these strategies are formulated. Organisations, when analysing their strategies, hopefully it consult the individual functions in the business. By doing so it may also combine the ideas that come from each function's experience. Therefore another view to this top-down perspective is that various strategic ideas materialise over time from real experiences. Occasionally companies move in a particular direction because the on -going experience of giving the products and services to customers at an operational level assures them that this is the right thing to do. There may be no high-level decisions inspecting alternative strategic possibilities and choosing the one that provides the best one. Instead, a general consent emerges from the operational level of the organisation. The 'high- level' strategic decision making, if occurs then it may confirm the agreement and provide the resources to make it effective. This awareness of strategy being designed by experience over time is called the concept of growing strategies. Over the time the strategy becomes more clear and based on the real life experience not only the theoretical positioning. Certainly, the strategies are often designed in a moderately unstructured and uneven manner to reveal the fact that the future is unknown and unpredictable. This may look like it is not a useful guide for a specific decision making. However, the evolving strategies are difficult to categorise, the principle of governing a bottom-up perspective of operation strategy is clear: 'shape the operation's objectives and action on the basis of the knowledge from the day to day activities. The key features required for doing this are like ability to learn from experience, philosophy of continual and incremental progress that is made into the strategy-making process.

For example, consider the case of the manufacturer that discussed earlier, realises that continual innovation in product may increases the costs as well as it confuses the customers. Therefore, The Company's designers find out a way of 'modularising' their product designs so that one part of the product can be modernised without interfering the design of the main body of the product. This becomes standard design practice in the company. Remember that, this strategy has developed from the company's experience. No top-level decision was perhaps ever taken to approve this practice, but yet it emerges as the approach in which the company shapes its designs.

How do the requirements of the market influence operations strategy? The market requirements perspective:

Operations exist to serve markets. So, whatever the operations strategy of an organisation, it must reflect the requirements of the organisation's markets. Actually, a sensible starting point for any operations strategy is to look in to its markets and ask the simple/ important question, 'How operations could help the organisation to compete in the market?' Note that the organisations usually have some impact on its market demand, if for there is other reason than that the organisation has chosen to be there in some particular market rather than the others. Therefore, by choosing to reside in a particular market position, the organisation is influencing how easy it is for the operations function to support the position. This opens up the options that, in some situations, it may be workable to shift the markets in which the organisation is trying to enter in order to reproduce what its operation is good at. This can be discussed in details later; buy now it is important to note that operations strategy must reveal the organisation's market position. And the initial point for this is to understand that what is required from the operation in-order to support the market position. The problem with this is the concepts, the language and the philosophy used by the marketing functions to help them to understand the markets are not useful always in guiding the operation activities. Therefore, descriptions of market needs descriptions of market needs established by marketing professionals generally need ‘translating’ before it can be used in an operations strategy analysis.

For example, the business of a medium-sized theatre lighting company was dedicated to designing the lighting activities and hiring the necessary tools for stage and entertainment events, exhibitions and conferences. The company could supply any lighting kit, partly as it held a wide range, and partly because it developed a close relationship with other equipment leasing firms. It also concentrated on the ‘top end’ of the market and also targeting the customers who wants less-price. This becoming a problem in the case of theatre lighting and exhibition markets because the competition was imposing margins lower as the competitors undercut prices. Shortly they understood that the ultimate potential for growth in the conference market, where competition was not yet as aggressive, and where its expensive service levels, capacity to give exhibition advice and innovation were valued.

How can the intrinsic capabilities of an operation’s resources influence operations strategy? The operations resource perspective:

The resources and processes in an operation are not inactive elements; they have presence and also a role that need to be part of any operations strategy. The long-term resource management is frequently regarded as the essential basis for operations strategy. One of the problems in this perspective is the translation, because the approach and terms that are useful for understanding a firm’s resources are not certainly appropriate to clarify the nature of the decisions that form those resources. The first step is to understand ‘what we have’ – that is, the whole resources held by, or available to, the operation. Next, step to link the comprehensive understanding of resources and processes with the definite operations strategy decisions like ‘what actions we are going to take’. To achieve this relationship the organisation need a concept to channel the gap between the understanding of ‘what is there’ and more specific ‘what should we do?’ stages. In the operations resource perspective the organisations use the concept of operations capabilities.

2.5 RELEVANCE OF OPERATIONS STRATEGY

Operations strategy was not come to front until the year 1970s. At that point of time, the companies were only give importance to mass production of product with standard designs. There were no such competitors available in the market, therefore, the companies able to sell whatever they produced. But that trend was broken in the year 1970s and 80s. Some foreign companies like Japanese companies started producing the standard products with superior design and quality with cheaper price. So the companies lost the market share. In order to survive and progress in the market the companies started copy the Japanese approaches. Unluckily, the idea of copying the approach was proved failure; because of the time taken to understand the Japanese operations. Now from this, it could be conclude that the Japanese companies were successful and enjoyed the competitive advantage because of their superior operations strategy.

The role of operations strategy is to ensure that all the work will be performed by the operations functions right.

2.6 STRATEGY FORMULATION

Strategy formulation is practically always critical to the success of a strategy. Walmart learned that when it open stores in Japan. Even though Walmart flourished in many countries on its reputation for low-cost stuffs, Japanese consumers linked low cost with low quality, triggering Walmart to reconsider its strategy in the Japanese market. In other cases like many sensed that Hewlett-Packard (HP) done a strategic error when it buy Compaq Computers at a cost of $19 billion. HP's share in the market was less after the merger than the total shares of the separate companies before the merger. Another example, U.S. automakers implemented a strategy in the year 2000s of providing discounts and rebates on a range of cars and SUVs, which were on low-margin cars. The strategy put a stress on profits, but customers expect those incentives, and the companies continued them to keep from losing the extra number of market share.

Further, the leading leather hand bags and purses manufacturer like Coach effectively changed its strategy to raise its market by producing new products. Whereas Long well-known for its highly durable leather goods in the market where women usually owned few handbags, Coach twisted a new market by changing women's opinion about handbags by promoting handbags for different occasions like party bags, clutches, overnight bags, day bags and purses. And Coach announced many styles and colours. To develop an effective strategy, the top level managers must consider the core capabilities of the organizations, and must examine the environment. They must know what the competitors are doing, or prepare to do and consider for the strategy. They must critically study other factors that could have any effects. This is referred as the SWOT (strengths, weaknesses, opportunities, and threats) analysis. Strengths and weaknesses focuses the internal matter which are generally evaluated by the operations people where as the Threats and opportunities are focused on the external matters and evaluated by the marketing peoples. This SWOT analysis is often viewed as the link between organizational and operations strategy. There is an alternative to SWOT analysis that is Michael Porter's five forces model, which considers the threat of new competition, threat of substitute products, the bargaining power of customers, bargaining power of suppliers, and the intensity of competition.

In the process of formulating a successful strategy, the organizations must consider both the order qualifiers and order winners. Generally, Order qualifiers are those potential customers perceive characteristics as minimum standards of satisfactoriness for a product to be considered for buying. But, that may not be enough to get a potential customer to buying from the organization. Order winners are the characteristics of an organization's products that may cause them to be observed as better than the competitors. The characteristics like price, reliable delivery, fast delivery and the quality of the product can be order qualifiers or order winners. Therefore, quality may be an order winner in some cases, but in other situations it is only an order qualifier. Further, a characteristic once treated as an order winner may convert to an order qualifier, and vice versa.

Apparently, it is vital to decide the set of characteristics of an order qualifier and the set of order winner characteristics. This is also needed to agree on the relative significance of each characteristic as appropriate attention could be given to the different characteristics. Marketing must determine and communicate to the operations. Environmental scanning is the checking of events and tendencies which represent either threats or opportunities for the organization. Mostly these includes competitors' activities, changing in consumer needs, legal factors, economic factor, political issues, environmental issues, the possibility for new markets and so on.

Another crucial factor to be considered while developing strategies is the changes in technology that can present exact opportunities and threats to the organization. Technological changes take place in goods like: HD- TV, developed computer chips, value-added telephone systems, and better-quality designs for earthquake-proof structures, in services such as speedy order processing, fast- delivery etc. and in processes like introduction of robotics, automation, computer-aided processing, scanners, and flexible work systems etc. The noticeable benefit is the competitive edge and the risk involves like wrong choices, poor execution, and higher operating costs will make competitive disadvantages.

2.7 FACTORS TO BE CONSIDERED WHILE FORMULATE THE OPERATION STRATEGY

Important factors may be internal or external. The following are key external factors:

1. **Economic conditions:** This consisting of the status of the inflation, deflation, taxation laws and tariffs etc.
2. **Political conditions:** It includes the favourable or unfavourable approaches toward business, political stability or instability, and wars.
3. **Legal environment:** This indicates towards the government regulations, antitrust laws, trade restrictions, laws of minimum wage, and laws of product liability, labour laws, patents and recent court experiences.
4. **Technology:** This includes the rate of product innovations, current and future process technology, and design technology.
5. **Competition:** This includes the number as well as the strength of competitors, basis of competition like price, quality etc., and the easiness of market entry.
6. **Markets:** This includes market size, location, brand loyalties, easiness of entry of new entrants, and prospective for growth, and demographics.

The organizations also consider various internal factors that relate to probable strengths or weaknesses. The key internal factors are:

1. **Human resources:** This factor consisting of the skills and abilities of managers and employees, specific talents like creativity, designing, problem solving etc., loyalty of the employees towards the organization, expertise employees, their dedication, and experience.
2. **Facilities and equipment:** this indicates towards the Capacities, location, age, and maintenance cost can have a noteworthy impact on operations.
3. **Financial resources:** This includes cash flow, access to other funding, existing debt, and cost of capital is key considerations.
4. **Customers:** This consisting of customers loyalty, customer relationships, and knowing the wants and needs are important.
5. **Products and services:** it indicates to the existing products and scope for new products and services.

6. **Technology:** This means existing technology, the capability to adopt new technology, and the possible impact of technology on current and future operations.
7. **Suppliers:** The organisations need to maintain the relations with the Supplier determine the dependability of suppliers, its quality, and flexibility are main considerations.
8. **Other:** Other factors like patents, labour relations, image of company and its products, the distribution channels, connections with distributors, upkeep of facilities and equipment, access to resources, and access to markets.

After considering the internal and external factors and the unique competencies of the organization the strategy should be formulated which will give the organization the best way of getting success. The organisations need to solve some of the important questions like:

- What role the Internet play in the success, if any?
- Will the organization have a global existence?
- To what extent outsourcing will be used?
- What will be the supply chain strategy?
- To what extent will new products or services be introduced?
- What will be the sustainable rate of growth?
- What emphasis should be given to lean production?
- How will the organization differentiate its products from the competitors'?

The organization may pick to have a single, leading strategy (e.g., be the price leader) or to have many strategies. Single strategies allow the organization to focus on one certain strength or market condition and the multiple strategies are required to focus on a particular set of conditions. Several companies are using the outsourcing concepts to decrease the overheads, to become flexible and use the supplier's expertise. We can consider the case of Dell computers as an example of how it uses the benefits of outsourcing as the part of its business strategy. Growth is every so often an element of strategy, particularly for new firms. A key characteristic of this strategy is the need to pursue a growth rate which is sustainable. In the year 1990s, one of the fast-food company Boston Market stunned investors and the consumers equally. Because of its success, it started rapid expansion. But at the end of the decade, the company was approximately ruined due to over expanded. In the year 2000, it was taken over by McDonald. Generally the companies' fails not because of incomplete or missing strategies but also due to wrong execution of the strategies. Sometimes due to some factors which are beyond their control like natural disasters or artificial disasters (man-made), changes in economic or political changes, or the competitors having advantage like low labour costs, deep pockets etc.

2.8 STRATEGY FORMULATION PROCESS

Strategy formulation means the process of picking the most appropriate way for the recognition of organizational goals and achieving the organizational vision. This process mainly involves six main steps. However these steps do not follow any rigid chronological order, but they are very lucid and can be easily monitored in this order.

Fig 2.2: **Strategy Formulation Process**

Step-1(establishing Organizational objectives):

The vital component of any strategy is to establish the long-term objectives of the organization. It is well-known that strategy is a medium for understanding of organizational objectives. Objectives focus on the state of being there while Strategy focuses on the process of reaching there. Strategy contains both the fixation of objectives and the medium to realize those objectives. Therefore, strategy is a broader term which considers the manner of disposition of resources for achieves the objectives.at the time of setting the organisational objective, the factors must be analysed which influence the fixation of the objectives. Once the factors affecting the strategic decisions and the objectives have been fixed, it is easy to take the strategic decisions.

Step-2(analysis of organisational environment):

The next step of strategy formulation is to analyse the environment in which the organisation functions. This step consist the review of organisation's competitive status. It is necessary to do both the quantitative and qualitative review of the existing product line of the organisation. The main purpose of those reviews are to make sure that the factors which are important for competitive success can be identified so that the organisation can detect their own strengths and weaknesses and their competitors' strengths and weaknesses. After knowing the strengths and weaknesses, the organisation should track the competitor's actions to determine likely opportunities and threats to its market or supply sources.

Step-3(forming quantitative goals):

In this 3rd step, the organisation must fix the quantitative goals values for some of the organisational goals. The notion behind this is to equate with long term customers, so as to assess the contribution that might be ended by various product zones or operating departments.

Step-4(objectives in context with the divisional plans):

In this step, the organisations identify the contributions of every department or division or category of products to the organisations and strategic planning can be done for every division accordingly. The process needs a careful analysis of macroeconomics trends.

Step-5 (performance analysis):

This analysis comprises noticing and examining the gap between the scheduled or preferred performance. A critical assessment of the organizations past performance, present situation and the preferred future situations must be done by the organization. This evaluation finds the degree of gap that keep on between the actual reality and the long-term goals of the organization. An effort is made by the organization to guess its future condition if the current trends continue.

Step-6(selection of strategy):

This is the final step in the process of strategy formulation. The best option will be chosen after considering the organisational objective, its strengths, weaknesses and the external opportunities as well.

Examples of strategy formulation:

For some organisations, strategy formulations means not just doing well, it is about doing good for the society or the community like Lipton Brand of HUL decided to restructure its strategy around manufacturing viable tea. This decision helps HUL to become more environment friendly product and so it becomes a popular choice of consumers having environmentally conscious and provides a competitive advantage over the competitors.

Another company like Nike a sports manufacturing company set an example of strategy formulation. In the year 2010, Nike uses the cross-endorse strategy to regain its position in the market As Nike beginning to lose its position in the endorsements with the footballers by the competitors like puma and Adidas. The cross endorse strategy means use an athlete from one sport to promote the products of another sports. Nike used the legendary basketball player Michael Jordan for promoting the football kits and merchandises.

2.9 ORDER QUALIFIERS

Order qualifiers:

Competitive advantage is quite essential for an organisation to make profit. It is the ability of an organisation to do more sales and earnings than its competitors. This competitive advantage starts with the companies having order qualifiers. These are such competitive edge an organisation should prove to be competent as a competitor. To penetrate in the market, the organisations should have critical features in their goods and services which make them competent enough to compete with other products. There are some specific product characteristics which perceived as vital by the customers. One of the vital required characteristics of products to enter into the market is quality. That product not having the bare minimum quality in it cannot enter to the competitive market. That is why order qualifiers are otherwise named as competitive standards.

Examples of order qualifier:

The quality is the one of the most common order qualifier. This is the basic requirement for all the products to enter in to the market. For instance, an organisation intends to send apples to the foreign market would need quality as an order qualifier. These apples need to pass the quality check by the agencies like FDA (food and drug administration) agency. If the apples were able to meet the expected standard then only it would qualify the organisation to penetrate the foreign market and able to compete with the other companies dealing with the same business.

2.10 ORDER WINNERS

Order winners:

After the penetration the market by the product, it needs to have some specific characteristics to help them to have a competitive advantage. Order winners are those characteristics which help the products to win a customers buy. These order winners always influence the customers to choose the products of an organisation. The order winner's characteristics may include:

- Reliability
- Image
- Flexibility
- Fast delivery
- quality

Firms use order winners to be superior to their competitors. For example, organisations can define the quality of other competitors in the market. They can enhance the quality to have an advantage over them. Generally, Car producers often do this.

Examples of order winners:

Delivery and transport businesses gain an advantage over their competitors for the fast deliveries. Like; DHL has fleets of aircrafts which make the international deliveries faster and more convenient. DHL provides international deliveries of products within three working days over 220 companies. The organisations like, Nike, Puma and Adidas appeals and win over customers for their unique design of their products and their brand image. Moreover, athlete and endorsement supports these organisations turn out to be more attractive to the consumers. Most online companies like; Amazon, line up order winners such as flexibility, especially with payment systems. They also offer the reliability of their products to win over consumers to turn them into loyal customers.

2.11 MODEL QUESTIONS

I. Short type Questions:

1) What do you mean by order qualifier?
2) What is operation strategy?
3) What is SWOT analysis?

II. Long type Questions:

1) Explain different perspectives on operation strategy.
2) Explain the strategy formulation process in detail.

2.12 FURTHER READING

1) Nigel Slack and Michel Lewis (2011), operation strategy, 3rd edition, Prentice Hall Publication, ISBN: 978-0-273-74044-5
2) S N Chary (2012), Production and Operation Management, 5th edition, Tata Mc Graw Hill Education Private limited, New Delhi, India, ISBN 13: 978-1-25-900510-7

UNIT-3: MAINTENANCE MANAGEMENT

Structure

3.1 Concept of Maintenance Management

It is the process of planning, directing, scheduling and organisation of resources like vehicles, parts and other equipment to control the availability and performance of the specific plants to some definite level. It consists forecasting of potential issues and arranging regular maintenance to remove them.

For example: scheduling of oil changes regularly and regular check-up for the vehicle in the organisation. More difficult strategies that using machine learning to foreseen which parts need more focus and required to be changed.

3.2 Definition of Maintenance Management

Maintenance can be defined as the process of the resources consists of spares, tools and men to control its availability and condition of the organisation. This indicates that the main functions of the maintenance are to repair, adjust/modify and replace as required for the smooth operation of the different parts of the firm and its performance. Maintenance confirms the perfect functionality of machinery and plants as well. It significantly reduces downtime of machines, confirming continuous manufacture. With scientific back-up, it also contributes to the profitability of an organization, by considerably reducing costs.

In a plant, the job of maintenance is allotted to a distinct technical team, known as the maintenance team or maintenance department. Generally, the employees' works in the maintenance team are not allotted any job in the operations team. Their services are demanded only when it required, typically when a breakdown happens. Time dependency is the only problem with the maintenance as when it will arise is not known. Therefore, planning for the maintenance of staff is quite difficult. So, all organization has to carry a list of employees for maintenance, whether they are required or not. Because of this, many organizations, do outsourcing this function to adjust the maintenance cost. But, such outsourcing may not feasible always because of the critical nature of maintenance jobs and high cost requirements for machine downtime.

Studies point out that at least one third portion of maintenance cost is avoidable, through proper planning and control. Improper capacity utilization, declined rate of output, failure to maintain quality can be support to the problem of maintenance. This problem becomes a global issue and in India, it is quite more acute. This is acute in India because of some factors like obsolescence in technology, poor planning and focusing more on the break down maintenance only.

The TQM (Total Quality Management) method stresses one the maintenance management issues. It is now compulsory for the organisation to rebuild their maintenance functions to adjust with the latest trends even to get ISO certification.

3.3 Objectives of Maintenance Management

The key objective of maintenance management is to have an efficient and dependable production system. Previously, maintenance activities were done by operators in a manufacturing plant. But, with the increasing awareness of maintenance, several organizations have made separate maintenance departments. The following are the key objectives of maintenance:

(i) Keeping assets in good operating conditions:

It involves protecting the machines and equipment's from unexpected breakdowns, by maintaining an effective flow of production. To keep machines and equipment in good operating conditions, an organization can do some activities like cleaning, lubricating and repairing etc. These activities help the organization to use their machines and equipment for a longer time period.

(ii) Guaranteeing the availability of machines and equipment:

It involves the maintenance of machines and equipment at a standard level so that they can freely be used for the production process. Absence of maintenance may lead to let-down of machines and equipment that leads to wastage of time and other resources.

(iii) Enabling a safe working environment:

This refers to the foremost objective of maintenance management. Active maintenance management stops the industrial accidents which may happen due to unexpected breakdowns of machines and equipment. Therefore, it ensures a safe working environment for the employees.

(iv) Preventing wastage:

It indicates toward any type of breakdown or failure in machines or equipment may lead to avoidable wastage of valuable resources, like men, material, machines and time. Appropriate maintenance of machines and equipment can avoids wastage, leads to reducing the total cost of an organization.

(v) Attaining higher operational efficiency:

This objective says that maintenance turns the production system more dependable by making the assets available readily for the operations. This enhances the operational efficiency of a plant.

(vi) Boosting automation:

This objective of maintenance management aims at using the automation in the production system can help to maintain an uninterrupted flow of operations. Automated maintenance management reduces the manual inspection work. So the maintenance management promotes to use automation in the production system.

3.4 Impact of Poor Maintenance

Maintenance actions include all hard work to keep production systems and equipment's in an adequate operating state. Failure or break down of machines and equipment's in the company has a direct effect on the followings:

1. **Production capacity:** Break down of machines impact the production so the production capacity of the system will be reduced.

2. **Production costs:** Poor maintenance has an impact on the cost. Labour cost will increase because of the idle labour caused by the machine failure or break down. Moreover, the machine mal functions results in scrap, increase in material cost as well as in labour cost. Further, cost of maintenance that includes such costs as costs of repair facilities, repair staffs, preventive inspections and spare parts will rise as machines break down frequently.
3. **Product and service quality:** Machines will produce low quality products if the equipment's are not properly maintained. As the equipment's are poorly maintained may cause frequent break downs and so it cannot give proper service to the customers. For example, in air craft fleets of the airline, rail transport and road transport services are not properly maintained leads to poor customer service and satisfaction.
4. **Employee or customer safety:** Damaged equipment or machines expected to be fail at moment that can cause injuries to the employees working on it. Particularly the products like automobiles or two wheelers can break down unexpectedly to cause injuries to the people, if they not serviced properly and regularly.
5. **Customer satisfaction:** If the equipment used for production break down then the products cannot be produced as per the production schedules. Some time it stops the work that leads to the delayed in delivery of the product to the customer.

3.5 Types of Maintenance

Maintenance can be studied under these categories:

- Breakdown maintenance
- Preventive maintenance
- Corrective maintenance
- Routine maintenance
- Planned maintenance
- Statutory maintenance
- Deferred maintenance
- Backlog maintenance

Breakdown (reactive) maintenance:

In this system the equipment is allowed to function / operate till no failure or break down happens that means no maintenance is done in advance to stop the break down. This maintenance happens when the equipment fails and need repair. This type of maintenance could be used when the failure or break down does not impact the operation or the production significantly or because any loss other than the repair cost. This maintenance is made to restore the equipment to its satisfactory level of performance. This is also known as firefighting maintenance or operates to failure maintenance.

Objectives of breakdown maintenance:

- To get the equipment back into action as quickly as possible to curtail the breaks to production.
- To Control the costs of repair crews and cost of operations of repair shops
- To regulate the investments in replacement of spare parts and machines.
- to work appropriate amount of repairs at each malfunction

Advantages

1. It requires low cost for maintenance.
2. To do this maintenance less number of staff is needed.

Disadvantages

1. Cost will be increased because of unplanned breakdown of equipment.
2. Labour cost may increase when the overtime is required for the production.
3. Likely secondary equipment or process may get damage due to equipment failure.
4. Inefficient use of staff resources.

Preventive maintenance:

This type of maintenance program is dedicated to the removal or prevention of breakdown maintenance. A complete preventive program contains regular evaluation of critical equipment and machineries to find out the problem and also scheduling the maintenance work to avoid the degradation in the condition of the machineries. Simply, we can say it is a daily duty (cleaning, oiling, inspecting and re tightening) to keep the healthy/operational condition of machines and equipment.

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.”

Further, this maintenance is divided into two parts like periodic maintenance and predictive maintenance.

- ✓ **Periodic maintenance:**

  This maintenance involves periodically checking, repairing and cleaning equipment and changing parts to avoid unexpected failure and process problems.

- ✓ **Predictive maintenance**

  In This type of maintenance, the service life of vital part is anticipated based on check-up or diagnosis, so as to use the parts up to their service life. In compare to periodic maintenance, predictive maintenance is situation based maintenance. It uses trend values, by assessing and analysing data about breakdown and engages a surveillance system, aimed to observe conditions over an on-line system.

  It's a Modern method of preventive maintenance which uses sensitive instruments like amplitude meters, optical tools, temperature gauges, pressure gauges, vibration analysers and audio gauges to predict foreseen failure of equipment and machines. Conditions can be checked continuously or periodically to help the maintenance department to plan for renovation. This will help to extend the service life of the machines without fear to failure.

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 of preventive maintenance:

- More safety for employees
- Better control the production downtime
- Less repetitive repairs and decrease the large scale repairs
- Maintenance cost will be less as simple repairs saves the machine from breakdown
- Less number of standby equipment/machine required
- Better control over the spare parts
- Easily identify the equipment with high maintenance cost
- Decrease in unit cost of manufacture

Disadvantages:

- Disastrous breakdowns still likely to occur
- Labour intensive
- Unneeded maintenance work is included
- Risk of incidental damage to the equipment while doing unneeded maintenance.

Corrective maintenance:

It recovers equipment and its components so that preventive maintenance can be approved reliably. Tools with design fault must be remodelled to increase reliability or refining maintainability or corrective maintenance that happens when equipment/machines break down and must be restored on an urgent basis.

Routine Maintenance

This type of maintenance work involves the tasks like periodic inspection, cleaning, lubrication, and repair of equipment used in production after their service life. Routine maintenance may be classified as:

- ✓ **Running maintenance:** in this type the maintenance work is done at the time of running of the machines. For an example: oiling or greasing of machines while it is running.
- ✓ **Shut down maintenance:** in this case the maintenance work is done when the equipment or machines are out of service that means when the machine or equipment is not in used or out of service after close down that machine. For example: repairing /descaling boiler tubes of a boiler machine.

Planned maintenance:

This type of maintenance indicates that the Maintenance work is planned well in advance and the activities are done according to a predetermined schedule. That is why this method of maintenance is otherwise named as scheduled maintenance. It includes check-up of all plants, equipment, machinery, in order to lubricate or repair before real breakdown or decline in service arises. This maintenance goal is to decrease machine slowdown due to unexpected breakdowns demanding emergency care. This method helps to reduce the down time of machine or equipment, cuts the maintenance cost and increases productivity as compared to the unplanned maintenance.

Statutory Maintenance:

The maintenance that must be carried out to meet the statutory requirements falls in the category of statutory maintenance.

Deferred Maintenance:

The maintenance which is due to be carried out in the current financial year but which will not be carried out because of shortage of funds or unavailability of parts is termed as deferred maintenance. Such maintenance should be added to the backlog of maintenance items awaiting attention.

Backlog Maintenance:

The maintenance which has not been carried out but which is necessary to prevent the deterioration of an asset or its function is known as backlog maintenance.

3.6 Areas of maintenance

- **Civil maintenance:** it deal with building construction and its maintenance, it maintaining service amenities like water, gas, steam, air, heating and ventilating, air conditioning, painting, plumbing and carpentry work. Also included in civil maintenance are caretaker, service, house-keeping, scrap clearance, fencing, gardening, drainage, lawns and fire fighting equipment.
- **Mechanical Maintenance**: it involves the maintaining of machines and equipment, transport means of transportation, material control, steam makers, boilers, compressors and furnaces. Greasing the machines is also part of mechanical maintenance work.
- **Electrical maintenance**: it involves the maintaining of electrical equipment like generators, motors, transformers, switch gears, telephone systems, lightening, meters, gauges instruments, control panels and battery charging.
- **Maintenance prevention:** It shows the design of new equipment. Weakness of present machines are adequately studied (on-site information prevent the failure, make the maintenance easier and averts of defects, safety and easy manufacturing) and are started before ordering a new equipment.

Breakdown maintenance is maintenance performed on equipment that has broken down and is unusable. It is based on a breakdown maintenance trigger. It may be either planned or it can be unplanned. An example of planned maintenance is run-to- failure maintenance, while examples of unplanned maintenance include corrective maintenance and reactive maintenance. Breakdown maintenance can be more costly than preventative maintenance.

3.7 Maintenance Policies

Breakdown maintenance is crisis based policy where the plant or equipment is worked until it fails and then repairs them to running condition. The maintenance employees locate any mechanical, electrical and any other error to correct it straightway. Preventive maintenance policy avoids the probable failure and also ensures smooth and continuous production by expecting the failures and taking remedial actions:

The preventive maintenance policy has four forms:

(a) Time based: this means providing maintenance work at a regular basis. This policy is based on time rather on usage.

(b) Work based: Mas per this policy, the maintenance will occur after a particular set of hours or volume of work produced.

(c) Opportunity based: here maintenance works takes place when the equipment or machine is available for repair/maintenance.

(d) Condition based: maintenance frequently depends on a planned check-up to tell when maintenance is required?

Preventive maintenance is used to delays or prevents the breakdown of equipment and also to reduce the seventy of any breakdowns that occur.

Two aspects of preventive maintenance are:

1. **Inspection:** Inspection of important parts will show the need for replacement or repair in advance of probable breakdown. Systematic inspection directed by either by operator or by maintenance department is the most main direct means of growing equipment reliability.
2. **Servicing:** Routine cleaning, lubricating and tuning may considerably reduce wear hence avoid breakdowns. Normally such duties are done by equipment operator or may be by maintenance department.

3.8 Preventive vs Breakdown Maintenance:

Preventive maintenance is the routine check-up and service actions aimed to spot possible failure conditions and do minor changes or repairs that will stop major operating glitches. Whereas the Breakdown maintenance is the emergency repair and it involves higher cost of facilities and equipment that have been used until they fail to operate.

Effective preventive maintenance for equipment needs properly competent personnel, consistent check-up and has to maintain even records. It is planned in such a way that it will not interrupt the normal operations therefore no down time cost of equipment. But Breakdown maintenance halts the normal activities and even the operators are remaining idle till the equipment is back to normal working condition.

3.9 Reliability in maintenance

The concept of reliability has started increasing its use in plants engineering maintenance and management.

Need for reliability of Maintenance:

The reliability of a machine, equipment and product is vital part of quality because of its stable performance over the estimated life time. Reliability is well-defined as the probability that a machine / system, when working under certain condition will perform its anticipated functions adequately for a definite time period. In other way, it refers to the resembling that equipment/machines will not fail during its process. The four significant factors are necessary in the determination of reliability are as follows:

- Reliability stated as probability
- Satisfactory performance requirements
- Duration of satisfactory performance.
- Environmental or operating conditions.

Reliability stated as probability: It is the ratio of the number of times we can expect an event to occur to the total number of trail undertaken. A Reliability factor can be articulated as probability. A reliability factor equal to one means that device performs satisfactorily for the recommended duration under the given environmental condition.

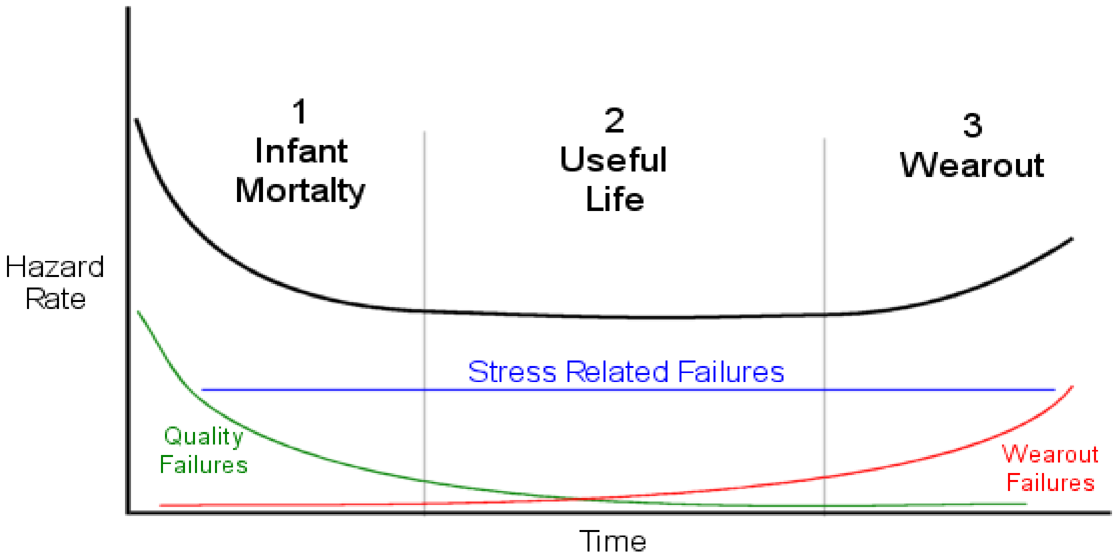
Satisfactory Performance Requirement: A machine/equipment may work satisfactorily yet one or more components may not be working. In reliability analysis there is a necessity to describe the level of satisfactory or adequate performance of the system.

Duration of Satisfactory Performance: The duration of satisfactory performance is used to state the time up to which the wanted performance of the system is attained under the given conditions.

Environmental or Operating condition: Environmental or operational condition shows the usual conditions at which the system is under operation.

3.10 Equipment life cycle/ Failure pattern of equipment (Bathtub curve)

Equipment's performance and life cycle will be different throughout its life period, until it reaches its retirement age and needs to replace. There are several hazard and reliability functions allow monitoring this. One of the hazard functions or the failure rate curve is known as bathtub curve. This look like a household bath tub in it shapes that why it is named so and famous in maintenance. In this bath tub curve diagram there are three phases such as phase I shows the failure pattern innate in a new product because of manufacturing defects. Whereas, Phase II shows the valuable life period of equipment when the failure rates are normally control at the equipment gets set to the working environment. And in Phase III, the failures are justifying due to wear out failure.



Generally bathtub curve is a graph which is used to graphically represent the run to failure strategy of maintenance. This curve represents the overall life cycle of a machine and failure rate of overall machines/equipment over time. This bathtub curve is generally treated as most helpful and vital graphical demonstration of reliability of equipment/machines. By the help of this kind of graph, it is easy to determine and expect when usually failure happens and can identify the root causes of said failure. After finding root causes, one can easily avoid failure from happening by simply solving root causes. It is named bathtub curve because curve look like longitudinal section of bathtub.

Different Sections of Curve:

Basically Bathtub curve is divided into three different phases. Asset mostly faces these three phases all over their lifetime. All the Three different phases of bathtub curve are given below

Infant Mortality phase:

Infant mortality phase is basically stated as early failure period. By observing the curve, one can easily realise that in this phase, asset is being used for the very first time. At first, failure rate i.e. probability of failure incident is very high and by increasing time, there is a regular decrease in failure rate. In this period, failures are generally happened due to manufacturing defects, errors in installation, lack of quality control, inadequate components, design issues, or improper start-up procedures, etc.

How to prevent infant mortality equipment failures:

There are some strategies that can help to decrease infant mortality and avoid early failures. Some steps are:

- **Purging:** do preliminary tests with automatic technologies and sensors. Defective equipment is discarded before leaving the plant.
- **Acceptance and reliability test:** assets revaluations whenever parts are replaced or there are changes to the design, tools or processes.
- **Quality control:** use early fault detection techniques, such as vibration analysis to detect problems.

Normal Life phase (useful life):

At this point of time, the asset is already an adult. The failure rate is constant because everyone knows how to handle it. This stage is known as useful life. Normal life section is basically mentioned as usual life period or steady-state of operation. In other way it can be said that this phase signifies normal working life of assets. By observing the curve, we can easily understand that in this phase, asset is still facing failure but at normal/ low rate. In this phase, failures are commonly happened due to overloading, human errors, over use, accidental breakdowns, hidden defects, collision with other objects etc.

Failure happens generally depends on function and condition of an asset. Therefore, for different assets, failure rate can be different. In this phase an asset can be continuing unchecked for some time because chances of failure low during this phase and the failure rate is almost constant.

Best maintenance strategy during this normal life phase:

The most appropriate maintenance strategy for an adult asset is preventive maintenance or if the operations are prepared for it then predictive maintenance will be the best strategy in this phase.

Wear-out phase (late life):

At this stage, the asset is a senior means basically stated as aging period. From the diagram of the curve, it is understood that there is slow increase in failure rate of assets with increasing time. Number of failures incident experienced by assets normally increases with time. In this phase, failures are typically happened due to fatigue, wear and tear, poor maintenance, gradual deterioration, corrosion, etc. This stage represents the end of life cycle of an asset.

Maintenance strategies for late life asset management:

- **Maintenance and inspection plan:** company need to make a comprehensive plan with periodic maintenance activities that must be done throughout the year. Need to give Priority to the assets that begin to show signs of wear.
- **Preventive replacements:** company should not wait for asset to fail and break down with no change of repair. At this period, the plant should consider preventive replacements of crucial parts like batteries and engines etc.
- **Use high quality spare parts:** from time to time, in older assets, there is the inducement to use parts that are different from the original ones but interchangeable with the equipment. However, the plant investing in repairs, it's better to acquire durable spare parts approved by the manufacturer.
- **Suppression of harmful agents:** try to keep the equipment in the most appropriate conditions, with the recommended temperature and humidity level in the air.

3.11 Measures for maintenance performance (MTBF, MTTR and availability)

Effective maintenance of asset is a key factor in providing quality operations that offer timely resources at a minimal cost. Still, those in the maintenance arena understand that asset reliability does not come easy. Companies need to set quality yardsticks to measure the current effectiveness and forecast future performance and use the data found to understand where to do improvements. To do this there is one way that different maintenance metrics can be used to know the performance of the asset. This metrics are essential because they can show the difference between getting the overall business objectives and revealing how sudden breakdowns can lead to another delay in production.

What are the maintenance metrics?

There are two categories of maintenance key performance indicators such as the leading and lagging indicators. The leading indicators signal future events and the lagging indicators follow the past events.

The leading indicator comprises of metrics like the Estimated vs actual performance and PM Compliance, while the lagging indicator are revealed in maintenance metrics like the Mean Time To Repair (MTTR) , Overall Equipment Effectiveness OEE and Mean time between failure (MTBF).

MTBF (mean time between failures):

MTBF is the measure of the expected time between one break down to the next during normal operation. Actually MTBF tells about the expected lifetime of equipment. Higher value of MTBF indicates that the product /equipment will work longer before its break down. So it is always easy to predict and prepare for a break down, if we know how long equipment will last. MTBF can be calculating by dividing the total operational time by the number of failures.

$$MTBF = \frac{\text{SUM of operational time}}{\text{Total number of failures}}$$

Mean time to repair (MTTR):

It is the measure of the repairable items maintainability. The MTTR regulator starts indicating when the repairs start and it goes on up to the operations are restored. MTTR includes repair time, testing period, and return to the normal operating condition. The goal of every plant is to decrease MTTR as much as possible. Particularly this is vital for critical assets as always additional hour is taken to restore a machine to its working condition caused to huge losses for the plant. MTTR can be calculated by dividing the downtime period by the total number of downtimes.

$$MTTR = \frac{\text{SUM of downtime period}}{\text{Total number of repairs}}$$

Availability:

Availability can be defined as "The proportion of time for which the equipment is able to perform its function". The concept of availability is different from the concept of reliability. Here it takes repair time into consideration. A part of an asset may not be very reliable but it can be repaired quickly when it breaks and its availability could be high. Availability is the ration of the availability of time for the chosen operation service to the total time of maintenance. It can also defined as, the ratio of equipment's uptime to the equipment's uptime and downtime over a certain period of time.

The three types of availability are

- Inherent availability
- Achieved availability
- Operational availability

Inherent availability: It is the probability of a machine that it shall work satisfactorily when it used under given conditions within an ideal environment without any scheduled maintenance at any given point of time. Inherent availability can be calculated as:

$$Inherent\ Availability = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Achieved availability: It is the probability of a machine that work satisfactorily when it used under given conditions within an ideal environment with scheduled preventive maintenance at any given point of time. Achieved availability can be calculated as:

$$Achieved\ Availability = \frac{\text{MTBF}}{\text{MTBF} + \text{M}}$$

Operational Availability: In manufacturing system a definite amount of delay will always occur by time element such as supply downtime and administrative downtime. In this availability concept the Up Time indicates the period when the equipment is available and the down time means the period of time when the equipment is not available or it failed. Here, the mean of Up-time is known as MTBF and the mean down time is named as MDT. Operational availability can be calculated as:

$$\text{Availability} = \frac{\text{Up−Time}}{\text{Total Time}}$$

$$= \frac{Mean\ Up{-}Time}{Mean\ Up{-}Time + Mean\ Down{-}Time}$$

$$Operational\ Availability = \frac{\text{MTBF}}{\text{MTBF} + \text{MDT}}$$

Where MDT is the mean downtime is the satisfied mean of the downtimes including the supply downtime and administrative downtime.

3.12 Model Questions

4) What do you mean by MTBF?
5) What is predictive maintenance?
6) What is MTTR?
7) Explain different types of maintenance.
8) Explain the Bathtub Curve in detail.

3.13 Further Reading:

3) S.C.Agarwal (1968), Maintenance Management, Prabhu Book Service, Newdelhi, India.
4) P.Rama Murthy, Production and operation management, 2nd revised edition, New Age International Publication, New Delhi, India.
5) S N Chary (2012), Production and Operation Management, 5th edition, Tata Mc Graw Hill Education Private limited, New Delhi, India, ISBN 13: 978-1-25-900510-7

UNIT-3: LEAN PRODUCTION

Structure

4.1 Concept of Lean production

Lean production refers to the application of lean principles, tools and practices for the development and manufacturing of products. As the name suggests, lean is aim at cutting “fat” from the manufacturing activities. Most of the manufacturers use lean production principles to optimise processes, improve innovation, decrease costs and reduce time in the volatile and changing market place and to eliminate waste. So, lean production is the systematic way to elimination of waste from the operations in the organisation where waste has been seen as use or loss of resources which does not lead to creating the product to a customer’s wants directly when they want it. In some production processes, these non-values added works can include more than 90 % of a plants total works. Waste is something that customers never believe that it adds value and so not willing to pay for it.

In other words, lean production is a process that aims on minimising waste within production systems while maximise the productivity simultaneously. Lean production is also known as lean manufacturing or simple lean. Some of the benefits of lean production are reduction in lead times, reduction in operating costs and improve the quality of product. Some of the well-known companies like Toyota, John Deere, Nike and Intel use lean. Moreover, many of the concepts in the lean production initiate from the TPS (Toyota production system) and gradually it has been used throughout Toyota’s operations completely which stated in the year 1950. Till 1980’s Toyota become famous for its effectiveness with which it has applied

JIT (Just in time) production systems. This lean production system will also can be benefited to the companies that uses ERP (enterprise resource planning). It is also been successfully implemented to different administrative and engineering activities.

4.2 Three M's of lean

Lean production is a Japanese technique focused on 3M's. These are such as; muda, mura and muri. The meanings of these Japanese words are waste, inconsistency and unreasonableness respectively. Specifically, muda focuses on the activities that need to be eliminated. So, waste can be broadly defined as, "anything that adds cost to the product without adding any value to it".

4.3 Definitions of Lean production

Lean production can be defined as, "It is a systematic method for the elimination of waste (Muda) with in a manufacturing process"

Lean production can also be defined as, "a never ending efforts to eliminate or reduce (waste) in design, manufacturing, distribution, and customer service processes".

Principles of lean production:

There are five principles of lean such as value, the value stream, flow, pull and perfection. Now these are used as the basis for implementation of lean production.

1. **Classify Value from customer's point of view**: Value is generated by the manufacturer; however it is defined by the customer. Corporations need to know the value the customer seeks on their products, which can help them to know how much money the customer is wish to pay. The firm must try to eliminate waste and reduce the cost from its business operations so that the customer's ideal price can be achieved at the highest possible profit to the company.
2. **Plan the value stream**: This principle contains recording and analysing the movement of information or materials necessary to produce a particular product with the intent of finding waste and means of improvement. It encompasses the product's lifecycle, from raw materials to disposal. Firms must study each period of the cycle for waste. Everything that does not increase value must be removed. Lean thinking mentions supply chain configuration as part of this work.

3. **Generate flow: Reduce functional hurdles and find ways to advance lead time**. These aids in confirming the processes should be smooth from the time an order is received up to its delivery. Flow is essential to the removal of waste. Lean engineering relies on stopping disturbances in the making process and assisting a consistent and combined set of procedures in which events move in a continuous stream.
4. **Create a pull system:** This means one starts a new work only when there is a demand for it. Lean production uses a pull system in its place of a push system. Generally, Push systems are used in MRP (manufacturing resource planning) systems. In a push system, requirement of inventory are determined beforehand, and then the product is produced to meet that estimate. However, estimates are normally inaccurate, that can result in fluctuates between excessive inventory and insufficient, as well as interrupted schedules lead to poor customer service. Whereas, lean production is follows pull system where, nothing is produced until there is demand. Pull system depends on the flexibility and communication.
5. **Follow perfection with continual improvement**: Lean production believes on the concept of continuous motivation for perfection that involves targeting the main causes of quality problems and searching out and eliminating waste across the value stream.

4.4 Objectives of Lean production

The main aim of the lean production is to eliminate the waste continuously in the production process. More specifically, some of the objectives of lean production include:

1. To decrease defects and pointless physical wastage, including surplus use of raw materials, cost of repairing defective items and pointless product features which are not required by customers.
2. To reduce production lead times and manufacturing cycle times by dropping waiting times among processing phases, as well as operation preparation times and product conversion times.
3. To reduce inventory levels at all stages of operation, mainly works-in-progress in the middle of production phases. Lesser inventories mean lower working capital requirements.

4. To improve labour efficiency by reducing the idle time of labours and make sure that worker should not involve in unnecessary works/tasks while working and should give their effort as productively as possible.
5. To use machines/equipment and space more efficiently by reducing bottlenecks and increasing the rate of production while curtailing machine downtime.
6. To enhance the ability to manufacture more flexible variety of products with least possible changeover costs and changeover time.

4.5 Lean demand/Pull logic

The traditional method of production management upholds a strong emphasis on machines and utilisation of labour. As per this approach, the manager's point of view was that if he makes sure that employees and machines remains busy then definitely the factory will be efficient and productive. This method is called as the push manufacturing system, where materials and work in progress is always pushed through the plant in the search of high utilisation. The issues with this method are that it generally creates high levels of inventories, lengthy lead times, increase in levels of potential reworks and employees competing rather working cooperatively. In compare to push manufacturing system, JIT advocates a demand – pull system which works on the rule that work should flow to a work centre when there is a demand for more work. If a work centre is occupied with an activity, then the upstream work centre stops its function until the downstream work centre informs a need for material. The focus to maintain high utilisation is absent in a JIT environment. JIT focuses on addressing the tasks that affect the overall effectiveness of the plant i.e, improved quality, reduction in setup time, elimination of waste etc. to meet the strategic goals.

4.6 Waste in Operations

In the beginning 7-9 types of waste were identified as part of the TPS (Toyota Production System). But this numbers has been changed and expanded by different practitioners of lean production. This includes the following types of waste:

1. **Excess production**: excess production means producing more than demanded unnecessarily or producing too early before it is demanded. This results in waste as it detent the resources too early and holds the value which is added till the product sold. In this fast changing marketing scenario, many products manufactured before it can be sold to a particular customer often obsolete before the demand is actually realised.

This enhances the risk of obsolescence and also enhances the risk of manufacturing the wrong items and creates the possibility of sell those items at discount or treats them as scrap. So, manufacturing a product simply to keep the resources busy is not a good practice hence should be avoided. However, in some cases extra volume of semi-finished or finished products is maintained by some of lean manufacturers intentionally.

2. **Defects**: the physical defects in the material/machines can add to the cost of the product. This may consist of defects (error) in paperwork, wrong information regarding the product, defects (late) in delivery, manufacturing with wrong specifications, usage of excess materials or unnecessary scrap etc.
3. **Inventory**: waste in inventory means maintaining unnecessary excess amount of inventories (raw materials, works in process and final products,). Excess amount of inventory leads to high inventory cost, high storing cost and high defect rates. Excess inventory reduces profitability.
4. **Transportation**: it includes the movement of materials which does not increase any value of the product like moving material from one workstation to another. The concept is that movement of materials within the production phases should not be idle, that the output of one phase is instantly used as input for the next. Transportation within the production phases may results in delaying the production cycle time, the wasteful use of labour and space could be the source of production stoppages.
5. **Waiting**: it is the idle time for labourers or machines because of hold ups or in appropriate production process on the plant floor. It also contains small delays within processing of units. Waiting contributing to the cost significantly as it enhance labour cost as well as the depreciation cost per unit of output.
6. **Motion**: it includes any unwanted physical movement by the labourers that may divert them from their actual production work. Like, one worker walking in the floor for searching of a tool might cause in the stoppage of production process, because of poor ergonomics also slow down the workers.
7. **Correction**: the act of correcting/reprocessing is something that has to be done when the work has not done properly for the first time because of inefficient use of labour or equipment. These often cause disturbances in the flow of production and so generate blockages and stoppages. This reworking or correction typically put away noteworthy amount of management time which leads to factory overhead.

8. **Over-processing**: it is an unintentional excess processing work over the requirement by the customers in terms of quality or features of the products like polishing and finishing work in the areas of the products which will not see by the customer.
9. **Information disconnection:** information disconnection will happens when knowledge is not adequate or information is not available at the time of requirement. Knowledge include information regarding the right procedures, right specifications, problem solving process etc. lack of proper knowledge/information may leads to bottlenecks and defects. E.g; non availability of mixing formula may suspend the entire production process or make defective products due to time consuming trial and error methods.

Lean is mostly used in plants which deal with the assembly-oriented or with high amount of monotonous human practices like; garment manufacturing, equipment manufacturing, wood-processing units, electronic assembly and automobile assembly plants. These are such plants where productivity is vastly influenced by the competence and devotion of the workers working physically with tools or equipment. In these kinds of plants, improved systems can remove significant levels of such waste or inefficiency.

From the above points, it should be clear that waste is an endless enemy of production process. Waste elimination should be implemented in continuous basis which can focuses on improving the process regularly. Continuous reviews and worker involvement should be done as often as allowable.

4.7 Elements that address elimination of waste

In each case, it is predictable that even increasing developments can help to enhance the industries efficiency and decrease its costs. Typically, these improvements are recognised in a better proportion of improved quality product, means that even a small amount of improvements can have a large positive result.

- It is also noted that all these types of waste can be tied to different types of organisational or interrelated processes. For example: Better inventory and supply chain management can decrease the requirement for excess-production and to maintain inventory stock is also related to the principal JIT (Just in Time). Here, no need to carry too much inventory unnecessarily or to wait unreasonably for inventories.

- From engineering or a manufacturing point of view, better management of unnecessary operation and re processing not only saves time in planning and preparation but also saves cost and resources.
- From an functioning layout point of view, a more well-organized production line decreases unnecessarily usage, unnecessary motion and possibly unnecessary rework.
- Co-operatively, even minor improvements at every phase of the procedure results in output known as the increase in incremental improvements.

Recently, there has been talking about more types of waste, though these are generally related to the intangible types of waste associated to service environments. These include the underutilisation of human resources and do not take full advantage of opportunities presents. Therefore the companies need to be very careful if it is not measuring the wrong events and the waste in the production.

Eliminating wastes:

Surprisingly, large number of waste can be unseen or remain hidden in the process. Often many companies may have failed to modernize their operational processes for many years. So, in order to control or tackle with the types of waste, identifying and adopting a continuous improvement mind set can help them to reduce and eliminate these issues. There are some useful steps to reducing waste in basic processes. All of these can be related with the main lean principles and the purpose of reducing and removing waste in production. These basic practices are as follows:

1. **Discipline**: it means work standards that are obeyed to and are fundamental to the organisational outputs. Not only these it assists with maintain the quality during the operational process but also it has health and safety effects. Everybody should follow this discipline all the time to have the desired output. Failing of which may increase the risk of defects and cost.
2. **Flexibility**: organisational processes though well-defined, buy need to put up a measure of flexibility. This norm is connected with the usual factors of a work, means that if it is more practical for different part of the plant for a different individual take on the role, then this should be allowed. Eventually this leads to more autonomy, and repeatedly in practice interprets to individuals on the works floor who are usually very efficient in their jobs, being allowed to familiarise with the efficient ways of doing works.

3. **Equality**: equality is very important for a company as it recognise the contribution of all the employees irrespective of their job role in the company. Everybody has a work to do, and lacking in cooperation and collaboration with all it is doubtful that the company will do well in the long run. Several organisations decide on to achieve this by bring together uniform rules irrespective of an employee’s role whether it is management role or others.
4. **Autonomy**: there is common agreement in the research areas of HR that giving autonomy to the employees in their daily lives intensely grow in their commitment towards the organisation and develops their motivation and engagement, as well as their productivity and efficiency. Managers have to have the self-confidence to delegate as much as probable involving employees in problem-solving on their own account. However, this must be tied with the principles of flexibility and equality in the sense that firms must will to admit that are times when employees will do mistakes.
5. **Employee development**: in long term, a company should continue to capitalise in its employees so that they bring together more efficiency and more innovative ideas leads to increase efficiency and competitiveness. A highly skilled and trained workforce aids to increase the standard in an organisation.
6. **Working quality**: it is also stated as the quality of working life. There is accountability of the firm to make safe working conditions so that workers can focus on their job to the top of their ability rather than disturbing about facets like job security and in the process they unfocused in their daily work. This is particularly relevant in an era of zero hours contracts as there is a direct relation between job insecurity and reduced productivity.
7. **Creativity:** if possible, companies should try to give employees the chance to work creatively, as this increases motivation and work commitment, but also helps to provide suggestions for improve efficiency.
8. **Total involvement:** if workers are involved in all phases of the company according to their role and skills, they are more likely to be committed to the organisation, and give suggestions for organisational development and also improves internal organisational communication.

Generally it can be understood that these working guidelines are might be termed as best practice and they are more effective when they used in combining with one another, appreciating the input of employees at different levels. Lacking of these practices, it is unlikely that a company will see substantial productivity. However, it is also clear that it will take time for a company to apply these policies.

4.8 2 card Kanban Production Control system

A Kanban is a way of monitoring organisational processes. It normally controls the movement of inventory over an organisational process. In certain ways it can be understood as knowingly controlling, but the notion behind Kanban is that the company will works with what exactly it needs to not more and less. It decreases disorder and excessive inventory, raises transparency, and cuts the various types of wastes. A kanban system is a multiphase production programing and inventory control system. Here Kanban cards have been used to control the production flow and the raw materials, by keeping a low manufacturing lead time and work in progress.

Different types of Kanban hint the movement of things over the process, and examples are likely to contain movement of parts to the next step in production, or work for raw materials to initiate the process of production. Various organisations select to knowingly and tangibly prevent the opportunity for stock inventory by reducing stock holding capacity. In an example, small shops in the cities like supermarkets, regularly holds little inventory other than what is on sale on the shelves. When it is sold it is gone and there is no replacement until the next morning, but this stops food waste. It also means that as much of the costly city centre retail space is available for generating profit from sales rather than serving as a very expensive form of short-term warehouse.

Other kinds of Kanban might consist of those external to the organisation, e.g, signalling to sellers or suppliers that it is time to refill stock. Now this could be possible with the software like vendor managed inventory where the transparency between the suppliers and the vendor will be maintained so as to achieve true stock levels that initiate the next order point and delivery on an automated basis. Electronic Point of Sale (EPOS) is the other way to achieve it, when the suppliers fill in their order records by scanning the barcodes at the point of sale, this helps to maintain the accurate real time information about the demand and drives a pull supply chain by reducing unnecessary waste in the process of ordering and preventing the organisation from ordering the amount of stock that may not be able to sell.

Noticeably, a kanban is not essentially a physical card (paper/plastic), it can be either electronic or denoted by the container itself. Since it was considered as an easy and economical way to control raw material levels, different applications of kanban systems have been tested in different manufacturing firms all over the world. In the next paragraphs, the most usually used kanban system cards like one or two card systems has been explained.

The 2 card kanban system uses two types of cards or kanbans like, POK (Production Order Kanbans) and WK (Withdrawal Kanbans). A WK contains information on how much material (raw materials / semi-finished materials) the succeeding process should withdraw. A production card is being used to approve the production of one filled container of a portion at one station, while a withdrawal card is being used to approve the transfer of one filled container of inventory of a portion from an upstream station to the next downstream station. With the allowance of the last station, that has one outward withdrawal card post, the Dual-kanban system requires one production card post, one inward withdrawal card post, and one outward withdrawal card post for respectively station. These card posts are used for storage the production, inward withdrawal, and outward withdrawal cards respectively. At times, a material handler will take out all the withdrawal cards posted on the outward withdrawal card post of station and take the withdrawal cards to the production storage point of station. However moving the withdrawal cards from station 1 to station 2, the material manager is expected to maintain the withdrawal cards in the same order as they are posted on the outward withdrawal card post of station 1. At station 1, the material manager will examine the parts requested by the withdrawal cards got from station 1. If a filled container of a demanded portion is available at the production storage point of station 1, then the material manager will remove the output card that is tagged to the filled container, and post the output card on the station1’s card post. For each filled container with a removed production card, the material manager changes the removed output card with the equivalent withdrawal card. Once several production cards have been removed, the output cards are also posted on the station 1’s output card post in the same order as they are detached from the filled containers of the portion. If the portions matching to the inward withdrawal cards are not present at the output storage point of station 1, the withdrawal cards are posted on the station 1’s inward withdrawal card post. These withdrawal cards signify portions that cannot be fulfilled immediately from the output storage point of station 1. The material manager will then move the filled containers with tagged withdrawal cards from the output storage point of station 1 back to the input storage point of station 2. When station 1 becomes idle, its operator will pick and produce a portion demanded by the withdrawal or production cards posted on the station 1's inward withdrawal and production card posts. Since the withdrawal cards on the inward withdrawal card post signify the requirements to transfer portions to the downstream station 2, these withdrawal cards signify orders that are urgent than the production cards.

There are lots of circumstances where it is well to add a kanban type: for examples when work centres are far from one another or while materials are difficult to move because of their weight; so it is handy to use kanban to check materials moving also. Companies introduce cards to approve production (production kanban), and to approve withdrawal and moving (withdrawal kanban). In this case all work centre will have two stock areas that are inbound (for arrival) and outbound (for exit), where there are the containers of work in process or components produced by the centre itself. The working of this checking type is not different from one card kanban system.

Let's consider a company with two stations like 1 and 2, all have its input and output store (inbound and outbound).The operations made can be summarized as follows:

- In station 2, the company have an unfilled container that needs to be filled. That means it has its withdrawal kanban.
- The container and the withdrawal kanban are taken from store no 2 to store 1 of input to station 1.
- When from store 1 a full kanban is withdrawn, company take out the production kanban and send it to the kanban collection box. So it is replaced with the withdrawal kanban of the empty container.
- The filled container is sent to store 2 with its withdrawal kanban
- Production kanban are taken from the collection box and put in the same order on the production kanban "picture" in station 1.
- When the company take the card from the picture of production kanban, production in station 1 starts.
- Company start to fill an unfilled container coming from store 1. When it is filled it gets the production kanban and is sent to store 1 waiting to be sent.

Materials and operations flows are ruled by the lower station (2) that through the flow of ithdrawal/production kanban orders what must be made in the higher station (1). The constant link between kanban and containers allow checking requested production in real necessary lots.

Both production and transport are certified by a kanban. Production kanban flows inside a centre while withdrawal kanban flows between two different phases. In practice transport is not necessary started when the container is empty; the mechanism can be of reorder point type (transport is activated when there is a certain number of kanban queuing), or of periodic review type (at fixed moments the withdrawal cards are collected and relative transport requests fulfilled).

4.9 Model Questions

Short type Questions:

9) What do you mean by Lean Production?
10) What are 3M's of Lean?
11) What is Kanban?

Long type Questions:

3) Explain different types of waste in operation.
4) How to eliminate wastes in operation?

4.10 Further Reading

1) Pascal Dennis (2015), Lean Production Simplified, 3rd edition, CRC publication,(Taylor & Fransis Group), New York, ISBN: 3: 978-1-4987-0888-3
2) P.Rama Murthy, Production and operation management, 2nd revised edition, New Age International Publication, New Delhi, India.
3) S N Chary (2012), Production and Operation Management, 5th edition, Tata Mc Graw Hill Education Private limited, New Delhi, India, ISBN 13: 978-1-25-900510-7

Block-2

Forecasting, Scheduling, Selection

Unit No.	**Unit Name**
Unit 5	Forecasting
Unit 6	Scheduling
Unit 7	Process Selection
Unit 8	Product-process design Matrix and Services design matrix

UNIT-5: FORECASTING

STRUCTURE

LEARNING OBJECTIVES

After reading this unit you will understand:

1. Understand the Forecasting.
2. To discuss different types of forecasting.
3. Find out the importance of Delphi Technique of forecasting.

5.1 INTRODUCTION

Demand forecasts are first approximations to production planning. A prediction, projection, or estimate of some future activity, event, or occurrence. There are literally two types of forecasting such as : *Short Term Forecasting and Long Term Forecasting*. *Short Term forecasting* is the forecasting that made for short term objectives covering less than one year. **Example-** Material Requirement Planning (MRP), scheduling, sequencing, budgeting etc. *Long Term Forecasting* is the forecasting that made for that made for long term objectives covering more than five years. Ex. Product diversification, sales and advertisement.

5.2. WHY DO WE FORECAST?

Since forecasting activity typically precedes a planning process one can identify specific reasons for the use of forecasting in organizations. Organizations face a different set of issues while they engage in planning and in each of these, forecasting plays an important role as a tool for planning process. The key areas of application of forecasting are summarized below:

a) Forecasting plays an important role in long term strategic decision making. This includes planning for product line decisions.
b) A good forecasting system will be able to predict the occurrence of short fluctuations in demand.
c) Since the impending events in an organization are predicted through a forecasting system, organizations can benefit from better material management and ensure better resource availability.
d) A forecasting system provides useful information on the nature of resources required, their timing and magnitude. Therefore, organizations could minimize hiring and lying off decisions. Moreover, better planning on overtime and idle time could also be done based on this information.

5.3. IMPORTANCE OF FORECASTING

i. Production and distribution are two main activities of a business enterprise.
ii. Demand forecasts tries to maintain a balance between production and distribution policies of the enterprise.
iii. As the decentralization of functions and increase in the size of the organizations, forecasting of demand is of great value for proper control and coordination of various activities.
iv. Demand forecast helps the management to take suitable decisions regarding plant capacity, raw material requirements space and building needs and availability of labor and capital. Production schedules can be prepared in conformity with demand requirements minimizing inventory, production and other related costs.
v. Demand forecasting also helps evaluating the performance of the sales department.
vi. Demand forecasting is a necessary and effective tool in the hands of management of an enterprise to have finished goods of right quality and quantity at right time with minimum cost.

5.4. TYPES OF FORECASTS

1. **Economic forecasts:** Predict a variety of economic indicators, like money supply, inflation rates, interest rates, etc.

2. **Technological forecasts**: Predict rates of technological progress and innovation.

3. **Demand forecasts**: Predict the future demand for a company's products or services. main steps in demand forecasting: (i) Determine the objective of forecast, (ii) Select the period over which the forecast is to be made, (iii) Select the technique to be used for forecasting, (iv) Collect the information to be used, (v) Make the forecast. The elements of Forecasting: Forecasting consists basically of analysis of the following elements; (a) Internal **factors**: Past, Present and Proposed or future (b) **External Factors**: such as Controllable: (a) Past (b) Present (c) Future; Non controllable: (a)Past (b) Present (c) Future.

5.5. FORECASTING MODELS

One can classify the various models available for forecasting into three categories:

1. **Extrapolative models**: They make use of past data and essentially prepare future estimates by some methods of extrapolating the past data. ***For example***, the demand for soft drinks in a city or a locality could be estimated as 110 percent of the average sales during the last three months. Similarly, the sale of new garments during the festive season could be estimated to be a percentage of the festive season sales during the previous year.

2. **Casual models:** It analyses data from the point view of cause-effect relationship. For instance, to the process of estimating the demand for the new houses, the model will identify the factors that could influence the demand for the new houses and establish the relationship between these factors. The factors, for example, may include real estate prices, housing finance options, disposable income of families, and cost of construction and befits derived from tax laws. Once tea relationship between these variables and the demand is established, it is possible to use it for estimating the demand for new houses.

3. **Subjective judgments**: Another set of models consist of subjective judgment using qualitative data. In some cases, it could be based on quantitative and qualitative data. In several

of these methods special mechanisms incorporated to draw substantially from the expertise of group of senior managers using some collective decision-making framework.

5.6. TYPES OF FORECASTING METHODS

1. **Qualitative methods**: These types of forecasting methods are based on judgments, opinions, intuition, emotions, or personal experiences and are subjective in nature. They do not rely on any rigorous mathematical computations.
2. **Quantitative methods**: These types of forecasting methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations.

QUALITATIVE FORECASTING METHODS

a) **Executive Opinion**: Approach in which a group of managers meet and collectively develop a forecast. In this method, the experts on the particular product whose demand is understudies are requested to give their opinion about the likely share in the future period. These are the persons who have been dealing in this and related products for the year and are thus able to predict the likely level of sales in future periods under different conditions, based on their experience. If the no. of such expert is large and their expectations are different than an average simple or weighted is found to lead the unique forecast.

b) **Market Survey**: Approach that uses interviews and surveys to judge preferences of customer and to assess demand. survey data is that survey responses may not translate into actual consumer behavior. That is, consumers do not necessarily do what they say they are going to do. This weakness can be partially overcome by the use of market experiments designed to generate data prior to the full-scale introduction of a product or implementation of a policy. To set up a market experiment, the firm first selects a test market. This market may consist of several cities; a region of the country, or a sample of consumers taken from a mailing list.

Once the market has been selected, the experiment may incorporate a number of features. It may involve evaluating consumer perceptions of a new product in the test market. In other cases, different prices for an existing product might be set in various cities in order to determine demand elasticity. A third possibility would be a test of consumer reaction to a new advertising campaign.

There are several factors that managers should consider in selecting a *test market.* **First**, the location should be of manageable size. If the area is too large, it may be expensive and difficult to conduct the experiment and to analyze the data. ***Second,*** the residents of the test market should resemble the overall population of India in age, education, and income. If not, the results may not be applicable to other areas.

Market Research is systematic approach to determine external consumer interest in a service or product by creating and testing hypothesis through data-gathering surveys. It includes all research activities in marketing problem such as (a) Gathering, recording and analyzing the utility and marketability of the product; (b) The nature of the demand; (c) The nature of competition, (d) The methods of marketing; (e) Other aspects of movements of product from the stage of to the point where they get consumed. Market research gathers records and analysis all facts about problems relating to the transfer and sale of goods and services from producer to consumer. It may be used to forecast demand for the short, medium and long-term. Accuracy is excellent for the short term, good for the medium term and only fair for the long term.

c) **Sales Force Composite**: Approach in which each salesperson estimates sales in his or her region. Under this method, Salesmen are required to estimate expected sales in their respective territories and sections. The advantage of this method is that salesman being the closest to the customers are likely to have the most intimate idea of the market. i.e, customer reaction to the products of the firm and their sales trend.

   Advantages:

   - This method is simple to understand.
   - This method is free from the heavy costs of survey.
   - It is also useful when a firm introduces a new product in the market.

   Limitations:

   - The opinion of the experts many a times may be biased.
   - They may not aware of other demand determinants.

d) **Delphi Method**: Approach in which consensus agreement is reached among a group of experts. The Delphi method is a process of gaining consensus from a group of experts

While maintaining their anonymity. *A variant of the opinion poll and survey method is Delphi method.* It consist of an attempt to arrive at a collective or general opinion in an uncertain area, by questioning a group of experts. Each expert is given the opportunity to react to the information or consideration advanced by others but interchange is anonymous so as to avoid or reduce the *"halo effect", "band wagar effect" and "ego involvement"* associated with publicity expressed opinion.

- It is forecasting techniques applied to subjective nature demand values.
- It is useful when there is no historical data from which to develop statistical models and when managers inside the firm have no experience. σ Several knowledgeable persons are asked to provide estimates of demand or forecasts of possible advances of technology.
- A coordinator sends questions to each member of the panel of outside experts, and they are unknown to each other.
- Anonymity is important when some members of the tend to dominate discussion or command a high degree of respect in their field. The members tend to respond to the questions and support their responses freely. The coordinator prepares a statistical summary of the responses along with a summary of arguments for a particular response.
- If the variation among the opinions too much the report is sent to the same group for another round and the participants may choose to modify their previous responses. This process will be continuing until consensus is obtained. So Delphi method is a iterative process.

QUANTITATIVE FORECASTING METHODS

a) **Time-Series Models:** Time series models look at past patterns of data and attempt to predict the future based upon the underlying patterns contained within those data.

b) **Associative Models**: Associative models (often called causal models) assume that the variable being forecasted is related to other variables in the environment. They try to project based upon those associations.

TIME SERIES MODELS

- ✓ **Naïve:** Uses last period's actual value as a forecast.
- ✓ **Simple Mean (Average):** Uses an average of all past data as a forecast.
- ✓ **Simple Moving Average**: Uses an average of a specified number of the most recent observations, with each observation receiving the same emphasis (weight).
- ✓ **Weighted Moving Average**: Uses an average of a specified number of the most recent observations, with each observation receiving a different emphasis (weight).
- ✓ **Exponential Smoothing**: A weighted average procedure with weights declining exponentially as data become older.
- ✓ **Trend Projection**: Technique that uses the least squares method to fit a straight line to the data. Under the trend projection method which is one of the indirect methods of demand forecasting, past data is used to project the sales in the coming years. A firm which has been in existence for a long period has its disposal considerable data on sales pertaining to different time periods. Forecast for the future involves gathering of the past information on the subject which calls for the uses of statistical data which is collected at regular intervals of time. This type of data is known as *"time series*".

Thus, When data for different points of time are collected for sales, production, imports, exports etc. say for a period of five years, such data constitute time series. A firm with a long standing may collect time – series data on sale from its own sales department. New firms can obtain similar data from other established firms in the same industry. The time- series data can be used to project the demand for a product through a graph or least square method. Such data can be presented graphically or in a tabular form for further analysis.

In trend analysis past data about the dependent and independent variables is used to project the sales in the coming years assuming that factors responsible for the past trends will continue to behave in similar manner in future also as they did in the past in determining the magnitude and trend of sales of a product. In this method a data set of past sales are taken at specified time, generally at equal intervals to depict the historical pattern under normal conditions.

On the basis of derived historical pattern, the future sales of a company are project. The main aspect of this method lies in the use of time series and changes in time series occur due to following reasons:

1. **Secular Trend**: Secular Trend also known as long term trend indicate the general tendency and direction in which graph of a time series move in relatively over a long period of time. This can be upward or downward trend, depending upon the behaviour.

2**. Seasonal Trends**: This trend reflects the changes in sales a company due to change in various seasons or climates or due to festival season or sales clearance season etc. These changes are repetitive in nature and related to twelve months period.

3. **Cyclical Trends**: These trends reflect the change in the demand for a product during diverse phases of a business cycle i.e growth, boom, maturity, depression, revival, etc.

4**. Random or irregular trends**: These changes arise randomly or irregularly due to unforeseen events such as famines, earth quakes, floods, natural calamities, strikes, elections and crises. These changes take place only in the short run and have their own impact on the sales of a firm. These trends cannot be predicted.

Linear regression analysis

This is a forecasting technique that establishes a relationship between variables. One variable is known or assumed, and used to forecast the value of an unknown variable. Past data establishes a functional relationship between the two variables. We will consider the simplest regression situation between the two variables and the linear relationship.

Multiple Regression

In multi regression analysis, the regression equation is used where demand for commodity is deemed to be the functions of many variables; the process of multi regression analysis may be briefly described as:

a) The first step in multiple regression analysis is to specify the variables that are supposed to explain the variations in demand for the product under reference. The explanatory variables are generally chosen from the determinants of demand, viz. price of the product, price of its substitute, consumer's income and their tastes and preference. For estimating the demand for durable consumer goods (e.g. TV sets refrigerators, houses etc,), the explanatory variables which are considered are availability of credit and rate of interest. For estimating the demand of capital goods (e.g. machinery, and equipment) the relevant variables are additional corporate investments, rate of depreciation, cost of capital goods cost of other inputs (e.g., labor and raw materials) market rate of interest etc.
b) Once the explanatory or independent variable is specified, the second step is to collect time-series data on the independent variables.
c) After necessary data is collected, the next step is to specify the form of the equation which can appropriately describe the nature and extent of relationship between the dependent and the independent variables.
d) The final step is to estimate the parameters in the chosen equations with the help of statistical techniques. The multivariate equation cannot be easily estimated manually. They have to be estimated with the help of computers.

The reliability of the demand forecast depends to a large extent on the form of equation and degree of consistency of the explanatory variables in the estimated demand function. The greater the degree of consistency, the higher the reliability of the estimated demand and vice versa. Adequate precautions should, therefore, be taken in specifying the equation to be estimated

5.7. LET US SUM UP

There are literally two types of forecasting such as : Short Term Forecasting Long Term Forecasting Short Term forecasting is the forecasting that made for short term objectives covering less than one year. Ex. Material Requirement Planning (MRP), scheduling, sequencing, budgeting etc. Long Term Forecasting is the forecasting that made for that made for long term objectives covering more than five years. Ex. Product diversification, sales and advertisement. Since forecasting activity typically precedes a planning process one can identify specific reasons for the use of forecasting in organizations. Organizations face a different set of issues while they engage in planning and in each of these, forecasting plays an important role as a tool for planning process. The types of Forecasting such as : (a) Qualitative methods; (b) Quantitative methods.

5.8. KEY TERMS

- ✓ **Qualitative methods of forecasting:** These types of forecasting methods are based on judgments, opinions, intuition, emotions, or personal experiences and are subjective in nature. They do not rely on any rigorous mathematical computations.
- ✓ **Quantitative methods of forecasting:** These types of forecasting methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations.
- ✓ **Economic forecasts** : Predict a variety of economic indicators, like money supply, inflation rates, interest rates, etc.
- ✓ **Technological forecasts**: Predict rates of technological progress and innovation.
- ✓ **Demand forecasts**: Predict the future demand for a company's products or services.

5.9. SELF – ASSESSMENT QUESTIONS

1) What is the Meaning of Forecasting ? What are Elements of Forecasting ?

2) Discuss the different Forms of Forecasting?

5.10. FURTHER READINGS

1) Jay Heizer and Barry Render, *Operations Management* , Pearson Publications
2) Amol Palekar and Shreekant Shiralkar, *Supply Chain Analytics with SAP NetWeaver Business Warehouse.*
3) Muthu Mathirajan and Chandrasekharan Rajendran., *Analytics in Operations/Supply Chain Management.*
4) Chopra, Sunil, Meindl, Peter and Kalra, D. V.; *Supply Chain Management: Strategy, Planning and Operation; P*earson Education

5) Altekar, Rahul V.; *Supply Chain Management: Concepts and Cases*; PHI Learning
6) Ballou, Ronald H.; *Supply Chain Management*; Pearson Education
7) Sahay, B.S.; *Supply Chain Management*; Macmillan
8) Ballou, R.H. Business *Logistics Management.* Prentice-Hall Inc.
9) Bowersox D.J. ,Closs D.J. , *Logistical Management*, McGraw-Hill, 1996

UNIT-6: SCHEDULING

STRUCTURE

LEARNING OBJECTIVES

After reading this unit you will understand :

a) Understand the Scheduling
b) To discuss different forms of and elements of Scheduling.
c) Find out the process and stages of Scheduling.
d) Discuss about the Managerial Considerations in Scheduling.

6.1. INTRODUCTION

'Scheduling' is the next important function of production planning and control. It determines the starting and the completion timings for each of the operations with a view to engage every machine and operator of the system for the maximum possible time and; without imposing unnecessary burden over them.

Scheduling is the determination of the time that should be inquired to perform each operation and also the time that should be required to perform the entire series as routed. Scheduling involves establishing the amount of work to be done and the time when each element of the work will start or the order of the work.

Scheduling technique is an important technique of determining the starting and the completion timings of each operation and that of the total manufacturing process so that the man and machines can be utilised to the maximum. Scheduling depends upon a number of factors, e.g., routing, the method of production, quantity of production, transportation of raw materials, production capacity, the probable data of delivery specified by customers in their orders and the past records.

6.2. MEANING OF SCHEDULING

Scheduling pertains to establishing the time of the use of specific resources within an organisation. It relates to the use of equipment, machines, facilities and human activities. Scheduling is necessary in every organisation regardless of the nature of its activities. For example, in manufacturing organisations, production must be scheduled, which means developing schedules for workers, machines, equipments, maintenance etc. In service organisations such as hospitals, admission, surgery, nursing assignments and support services such as cleaning, maintenance, security, meal preparation etc., must be scheduled. In educational institutions, classrooms, instruction and students must be scheduled.

Scheduling, means organising a production line to produce products in time efficiently with least use of time and maximum utilisation of resources (especially men and machines).

6.3. OBJECTIVES OF SCHEDULING

i. To prevent unbalanced use of time among departments and work centres or to evenly load all machines in the production line.

ii. To utilise machines and labour in such a way that the output is produced within the established lead time so as to (a) deliver the products/services in time and (b) complete production in the shortest cycle time possible at minimum total cost of production.

iii. To reduce idle time of labour and machines, which might be caused due to waiting for materials, waiting for movement, waiting for inspection and waiting for want of work.

iv. To fix up delivery dates for various manufacturing activities and for the finished products.

v. To increase the efficiency of production or productivity.

6.4. MANAGERIAL CONSIDERATIONS IN SCHEDULING

Scheduling in production and operations management helps to allocate scarce resources. For example, machine time is a scarce resource that is allocated to different jobs, labour (or employee) time is allocated to different activities and facilities are scheduled for a given activity at a particular time period. In all these scheduling tasks, different criteria may be used in deciding which of several schedules is best. Those criteria may relate to the amount of time the machine or equipment might idle, the importance of a certain order or a certain customer, or the level at which the resource is utilised. In general there are **six criteria** that may be used in **evaluating different possible schedules.** They are:

i. Providing the product or service when the customer wants it.
ii. Minimising the length of time taken to produce that product or service (referred to as flow time)
iii. Minimising the level of work-in-progress (WIP) inventories
iv. Minimising the amount of idle time of equipment or machine.
v. Minimising the amount of idle time of employees and
vi. Minimising costs

6.5. ELEMENTS OF SCHEDULING

i. ***Demand forecasts/customer's firm orders: D***etermine the delivery dates for finished products.

ii. ***Aggregate scheduling:*** Tentative schedule based on demand for quarterly or monthly requirements. Enables employment of available resources in meeting the demand by adjusting the capacity. Needs rough-cut capacity planning.

iii. ***Production plan:*** Showing output levels planned, resource requirements, and capacity limitations and inventory levels.

iv. ***Master production schedule :*** Dates committed and desired quantity to be produced on a daily, weekly, monthly or quarterly basis.

v. ***Priority planning***: Master schedule is exploded into components and parts that are required to produce the product.

vi. ***Capacity planning:*** Regulates loading of specific jobs on specific work centres or machines for specific periods of time.

vii. ***Facility loading or machine loading***: Loading work centres/Machines after deciding which job to be assigned to which ork centre/machine i.e., actual assignment of jobs to machines taking into consideration priority sequencing and machine utilisation.

viii. ***Evaluation of workload:*** To balance the workload on various work centres /machines when resources are scarce or limited. Excess load in one work centre or machine has to be transferred to other work centre or machine having spare capacity.

ix. ***Sequencing:*** Priority sequencing of jobs is done to maximise workflow through work-centres or machines to minimise delay and cost of production.

6.6. FORMS OF SCHEDULES

The Schedules can be prepared in different forms.

A Production Flow Program: If a number of components or assemblies have to be manufactured for the final assembly line and those components are to be made concurrently, the production master flow program is prepared taking into account the sequence of operations and the time of starting and ending of each component in order to comply with the required date of completion of the product. The necessary document for this is Operation Process Chart and the Sequence of Operation. Scheduling Systems:

Scheduling Systems may be classified into various groups as shown below:

(i) **Unit Scheduling System**: This is used for scheduling when jobs are produced one by one and are of different types that is for job production.

(ii) **Batch Scheduling System**: When jobs are produced to order, in batches, this is used.
(iii) **Mass Scheduling System**: When large number of items of similar type are produced that is in mass production, this is used.

Unit Scheduling System: Here we have two types of scheduling, one is Project scheduling and the other is Job Shop Scheduling.

Project Scheduling: Generally, a project consists of number of activities managed by different Apartments or individual supervisors. It can also be considered as a complex output made up of many interdependent activities. Examples are: Railway coach building, Shipbuilding etc. The scheduling methods used are: (i) Project Evaluation and Review Technique (PERT), (ii) Critical Path Method (CPM), (iii) Graphical Evaluation and Review Technique (GERT). We can also use Bar charts, GANTT charts, Milestone chart, but these are less superior to the above.

Job Shop Scheduling: In Job shop scheduling, we come across varieties of jobs to be processed on different types of machines. Separate records are to be maintained for each order. Only after receiving the order, one has to plan for production of the job. The routing is to be specified only after taking the order. Scheduling is done to see that the available resources are used optimally.

The following are some of the factors taken into consideration for job shop scheduling. (i) Arrival pattern of the job, (ii) Processing pattern of the job, (iii) Depending on the type of machine used, (iv) Number of workers available in the shop, (v) Order of sequencing.

Arrival pattern of the job: This is done in two ways. Firstly, as and when the order is received, it is processed on the principle of First in First Out (FIFO). Otherwise, if the orders are received from single customer at different points of time in a week/month, then the production manager pile up all the orders and starts production depending on the delivery date and convenience (This situation is generally known as static situation).

Processing Pattern of the Job: As the layout of Job shops is of Process type and there may be duplication of certain machines, the production planner, after receiving the order thinks of the various methods of converting the requirement of customer / order into a production plan to suit the available facilities. Depending on the process required, there may be backtracking, which is unavoidable. When facilities are busily engaged, in process

6.7. INFORMATION NEEDED FOR SCHEDULING PROCESS

Before starting scheduling process it is necessary to collect sufficient information about jobs, activities, employees, equipment, machines or facilities that are to be scheduled. Depending on the scheduling situation, various types of data must be collected. They are:

i. **Jobs:** (a) Due dates, (b) Routings with standard set up and processing times, (c) material requirements, (d) Flexibility of due dates, (e) Importance of completing the job by due date.

ii. **Activities:** (a) Expected duration, (b) Precedence relationships, (c) Desired time of completion.

iii. **Employees:** (a) Availability, (b) Job capabilities, (c) Efficiency at various jobs, (d) Wage rates.

iv. **Equipment/Machine:** (a) Machine or work centre capacities, (b) Machine or work centre capabilities, (c) Cost of operation, (d) Availability

v. **Facilities:** (a) Capacities, (b) Possible uses, (c) Cost of Use, (d) Availability.

6.8. PROBLEMS OF SCHEDULING

i. Lack of correct and upto date information concerning lead time, operation or processing time, lot size and prevailing load on machines and work centres.

ii. Resource constraints capacity shortfall and delay in supply of materials.

iii. Absenteeism, lack of skill and experience in labour and inefficiency of labour

iv. Type of production viz., Job production, Batch production, Mass production and Continuous production.

v. Problems in machine loading and line balancing.

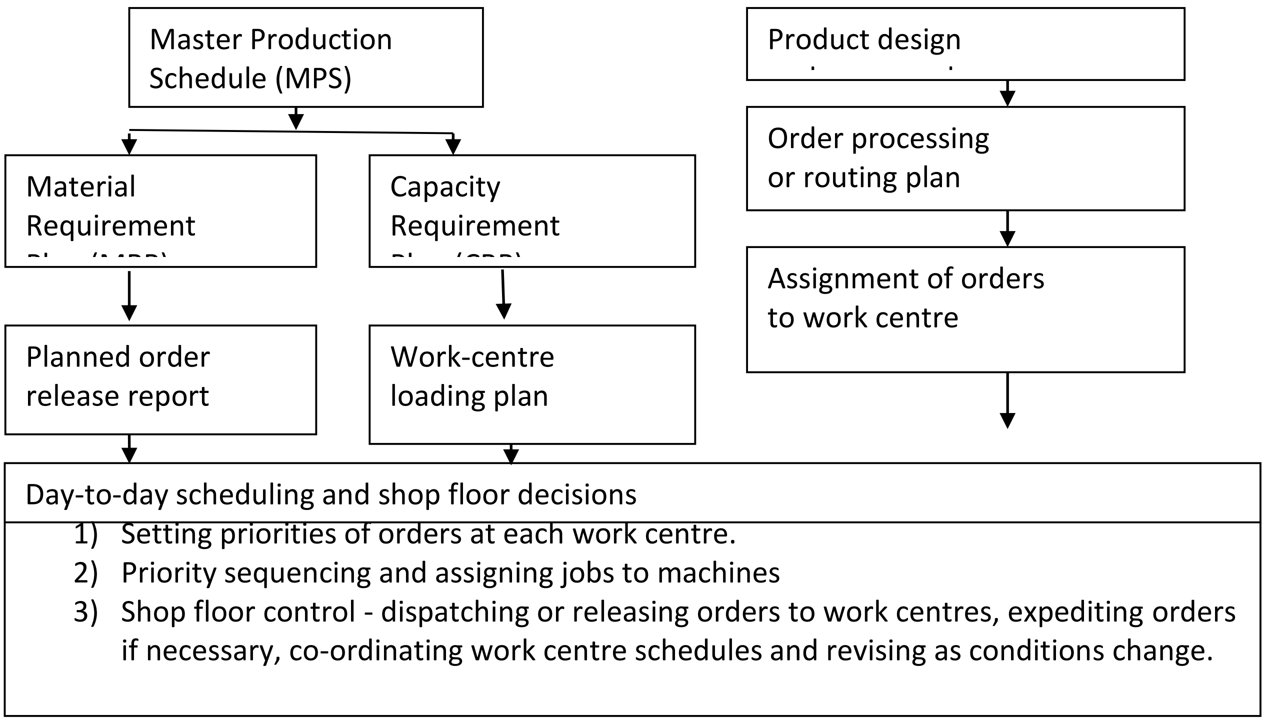
6.9. SCHEDULING PROCESS - FOCUSED PRODUCTION SYSTEMS

Process-focused production systems produce many non-standard products in relatively small batches that flow along different routes or paths through the production facility and require frequent machine change-overs. Such production systems are also known as intermittent production systems or job shops.

In such production systems the departments or work centres are organized around the type of equipment's or operations. (e.g., drilling, welding, soldering, etc.) Products flow through work centres in batches corresponding to individual customer orders or batches of economic batch quantities in produce - to stock situations.

Scheduling and shop-floor decisions in process-focused operations or job shops.

Scheduling and Shop Floor Decisions in Process - Focused Production System



Scheduling in job shop or process focused production systems is quite complex because of the following reasons:

(a) Job shops have to produce products against customer orders for which delivery dates have to be promised.

(b) Production lots tend to be quite small and may require numerous machine change-overs.

(c) Possibility of assigning and reassigning workers and machines to many different orders due to flexibility.

(d) In such a flexible, variable and changing environment, schedules must be specific and detailed work centre wise to bring orderliness.

Scheduling Techniques for Job Shop

The type of scheduling technique used in job shop depends on the volume of orders, the nature of operations and the job complexity. Two types of scheduling techniques used are:

1. Forward scheduling
2. Backward scheduling

A combination of forward and backward scheduling may often be used in practice.

Forward scheduling: In this approach, each task is scheduled to occur at the earliest time that the necessary material will be on hand and capacity will be available. It assumes that procurement of material and operations start as soon as the customers' requirements are known. The customers place their orders on a "needed-as-soon-as possible" basis. The earliest completion date, assuming that everything goes as planned, could be quoted to the potential customer. Some buffer time may be added to determine a date that is more likely to be achievable, if it is acceptable to the customer. Forward scheduling is used in many companies such as steel mills and machine tool manufacturers where jobs are manufactured to customer orders and delivery is requested on "as early as possible." basis. Forward scheduling is well suited where the supplier is usually not able to meet the schedules. This type of scheduling is simple to use, gets jobs done in shorter lead times but accumulates high work in process inventories. Exhibit 11.4 illustrates forward scheduling.

Backward scheduling: This scheduling technique is often used in assembly-type industries and in job shops that commit in advance to specific delivery dates. After determining the required schedule dates for major sub-assemblies, the schedule uses these required dates for each component and works backward to determine the proper release date for each component manufacturing order. The job's start date is determined by "setting back" from the finish date the processing time for the job. By assigning jobs as late as possible, backward scheduling minimizes inventories since each job is not completed until it is due but not earlier. Backward scheduling is also known as reverse scheduling.

6.10. STAGES IN SCHEDULING

Scheduling is performed in two stages, viz.

1. Loading,
2. Dispatching

Loading: Loading or shop loading is the process of determining which work centre receives which job. It involves assigning a job or task to a particular work centre to be performed during a scheduling period (such as a week). Loading of work centres depends on the available capacity (or determined by load schedules) and the expected availability of the material for the job. The jobs are assigned to machines on work centres taking into consideration the priority sequencing and machine or work centre utilization.

Dispatching: Dispatching is sequencing and selecting the jobs waiting at a work centre (i.e., determining which job to be done next) when capacity becomes available. It is the actual authorizing or assigning the work to be done. The dispatch list is a means of priority control. It lists all jobs available to a work centre and ranks them by a relative priority. When priorities have been assigned to specific jobs, scheduling gets implemented through the dispatch list.

Finite Loading and Infinite Loading: Loading procedures are categorized as either finite loading or infinite loading. In finite loading, jobs are assigned to work centres by comparing the required hours for each operation with the available hours in each work centre for the scheduling period. In infinite loading, jobs are assigned to work centres without regard to capacity (as if the capacity were infinite).

(a) Finite loading: Finite loading systems start with a specified capacity for each work centres and a list of jobs to be processed at the work centre (sequencing). The work centre's capacity is allotted to the jobs by simulating job starting times and completion times. The finite loading system combines, loading, sequencing and detailed scheduling. It creates a detailed schedule for each job and each work centre based on the capacity of the work centre.

(b) Infinite loading: The process of loading work centres with all the jobs when they are required without regard to the actual capacity available at the work centre is called infinite loading. Infinite loading indicates the actual released order demand (load) on the work centre so as to facilitate decision about using overtime, sub-contracting or using alternative routings, delaying selected orders.

Load Charts and Machine Loading Charts

(a) Load chart or load schedule : A load schedule or load chart is a device for comparing the actual load (labour hours and machine hours) required to produce the products as per the MPS against the available capacity (labour hours and machine hours) in each week.

(b) Machine loading chart (Gantt load chart): Gantt Charts are used to display graphically the work loads on each machine or in each work centre. There are two types of Gantt charts (i) Gantt load chart (ii) Gantt scheduling chart or program chart.

6.11. LET US SUM UP

Scheduling is the determination of the time that should be inquired to perform each operation and also the time that should be required to perform the entire series as routed. Scheduling involves establishing the amount of work to be done and the time when each element of the work will start or the order of the work. Scheduling in production and operations management helps to allocate scarce resources.

For example, machine time is a scarce resource that is allocated to different jobs, labour (or employee) time is allocated to different activities and facilities are scheduled for a given activity at a particular time period. In all these scheduling tasks, different criteria may be used in deciding which of several schedules is best. Before starting scheduling process it is necessary to collect sufficient information about jobs, activities, employees, equipment, machines or facilities that are to be scheduled.

Depending on the scheduling situation, various types of data must be collected. Loading of work centres depends on the available capacity (or determined by load schedules) and the expected availability of the material for the job. The jobs are assigned to machines on work centres taking into consideration the priority sequencing and machine or work centre utilization.

Dispatching is sequencing and selecting the jobs waiting at a work centre (i.e., determining which job to be done next) when capacity becomes available. It is the actual authorizing or assigning the work to be done. The dispatch list is a means of priority control. It lists all jobs available to a work centre and ranks them by a relative priority. When priorities have been assigned to specific jobs, scheduling gets implemented through the dispatch list.

6.12. KEY TERMS

- ✓ **Scheduling Technique**: is an important technique of determining the starting and the completion timings of each operation and that of the total manufacturing process so that the man and machines can be utilised to the maximum.

- ✓ **Scheduling**: means organising a production line to produce products in time efficiently with least use of time and maximum utilisation of resources (especially men and machines).

- ✓ **Aggregate Scheduling**: Tentative schedule based on demand for quarterly or monthly requirements.

- ✓ **Capacity Planning**: Regulates loading of specific jobs on specific work centres or machines for specific periods of time.

- ✓ **Forward Scheduling**: In this approach, each task is scheduled to occur at the earliest time that the necessary material will be on hand and capacity will be available.

- ✓ **Backward Scheduling**: This scheduling technique is often used in assembly-type industries and in job shops that commit in advance to specific delivery dates.

- ✓ **Loading**: Loading or shop loading is the process of determining which work centre receives which job. It involves assigning a job or task to a particular work centre to be performed during a scheduling period (such as a week).

- ✓ **Dispatching**: Dispatching is sequencing and selecting the jobs waiting at a work centre (i.e., determining which job to be done next) when capacity becomes available. It is the actual authorizing or assigning the work to be done.

6.13. SELF – ASSESSMENT QUESTIONS

1) What is the Meaning of Scheduling ? What are Elements of Scheduling ?

2) Discuss the different Forms of Schedules? Discuss the problems of Scheduling?

3) Discuss the Scheduling Process and its stages as related to Production Systems

6.14. FURTHER READINGS

1. Jay Heizer and Barry Render, *Operations Management* , Pearson Publications

2. Amol Palekar and Shreekant Shiralkar, *Supply Chain Analytics with SAP NetWeaver Business Warehouse.*

3. Muthu Mathirajan and Chandrasekharan Rajendran., *Analytics in Operations/Supply Chain Management.*

4. Chopra, Sunil, Meindl, Peter and Kalra, D. V.; *Supply Chain Management: Strategy, Planning and Operation; P*earson Education

5. Altekar, Rahul V.; *Supply Chain Management: Concepts and Cases*; PHI Learning

6. Ballou, Ronald H.; *Supply Chain Management*; Pearson Education

7. Sahay, B.S.; *Supply Chain Management*; Macmillan

8. Ballou, R.H. Business *Logistics Management.* Prentice-Hall Inc.

9. Bowersox D.J. ,Closs D.J. , *Logistical Management*, McGraw-Hill, 1996

UNIT-7: PROCESS SELECTION

STRUCTURE

LEARNING OBJECTIVES

After reading this unit you will understand:

1. Understand the Process.
2. To discuss scope and process Design.
3. Find out the Process Management.
4. Find out the Major Process Decisions.

7.1. INTRODUCTION

At the time of designing and developing a product, due consideration is given for the manufacturability or producibility of the product using the current process technology and the capability of the firm to manufacture the product. If the firm already has the required technology, the facilities (machines and equipment's) and the manufacturing process, and the firm has sufficient capacity or can acquire the needed capacity to manufacture the product, then decision is taken to go ahead with the product design. Otherwise, the design effort may be terminated.

After the final design of the product has been approved and released for production, the Production Planning and Control department takes the responsibility of **Process Planning** and **Process Design** for converting the product design into a tangible product. As the process plans are firmly established, the processing time required to carryout the production operations on the equipments and machines selected are estimated. These processing times are compared with the available machine and labour capacities and also against the cost of acquiring new machines and equipments required, before a final decision is made to manufacture the product completely in house or any parts or subassemblies must be outsourced.

7.2. WHAT IS A PROCESS?

A **process** is a sequence of activities that is intended to achieve some result, typically to create **added value** for the customers. A process converts inputs into outputs in a production system. It involves the use of organisation's resources to provide something of value. No product can be made and no service provided without a process and no process can exist without a product or service.

Processes underlie all work activities and are found in all organisations and in all functions of an organisation. Deciding what processes to use is an essential issue in the design of a production system. Process decisions involve many different choices in selecting human resources, equipment and machinery, and materials. Process decisions are strategic and can affect an organisation's ability to compete in the long run.

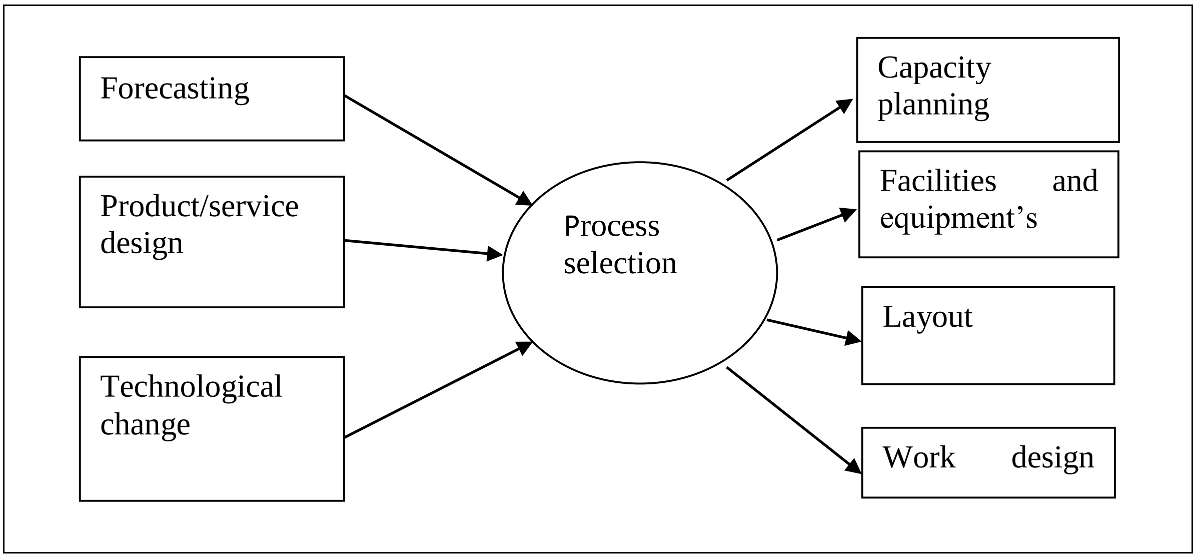
7.3. PROCEDURE FOR PROCESS PLANNING AND DESIGN

1. The inputs required comprises the product design information, production system information and product strategy decisions.

2. Process planning and design starts with selection of the types of processes, determining the sequence of operation, selection of equipment, tooling, deciding about the type of layout of facilities and establishing the control system for efficient utilisation of resources to achieve most economical production of the product.

3. The outputs are specific process plans, route sheets, flow charts, assembly charts, installation of equipments, machinery, material handling systems and providing trained, skilled employees to carryout the production processes to achieve the desired results.

Factors Influencing Process Selection



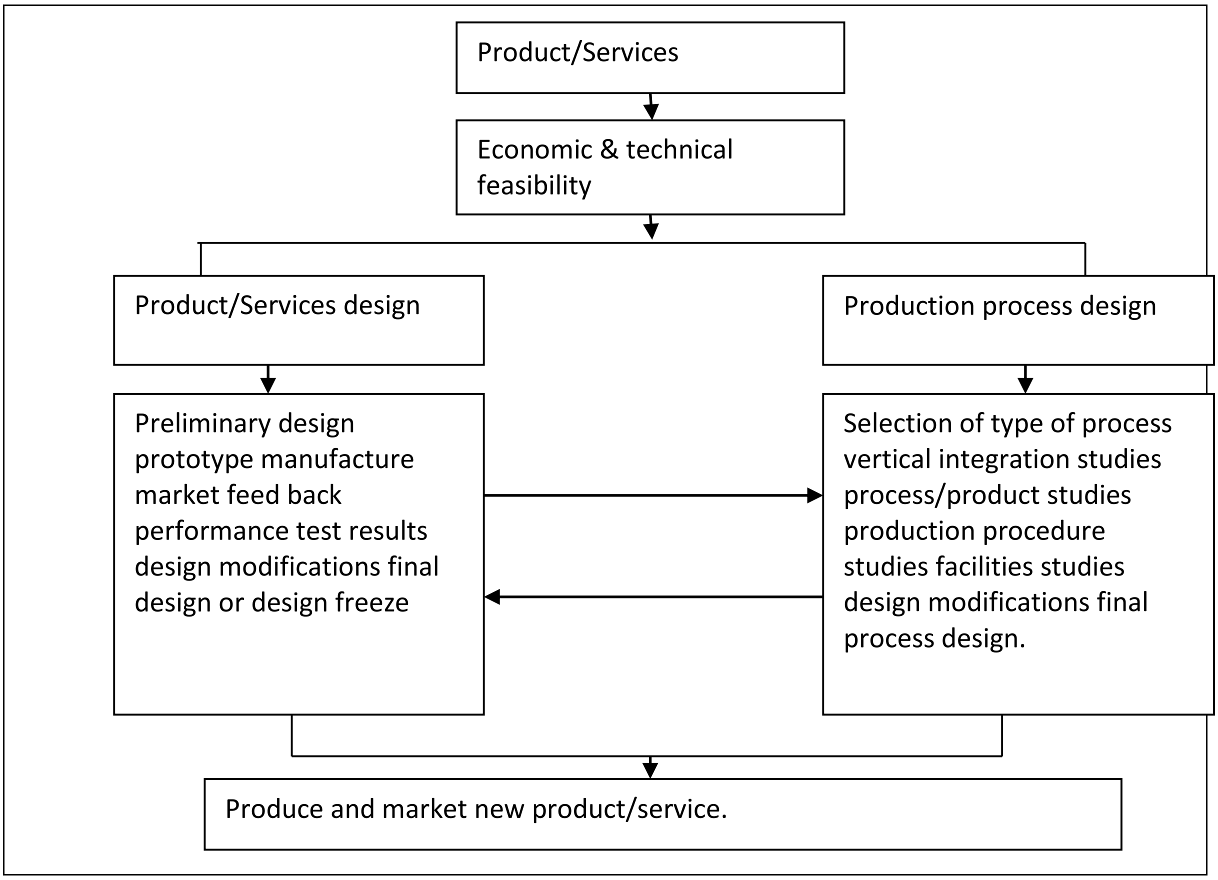
Selection of Specific Equipments

The choice of specific equipment follows the selection of the general type of processes. The Table shows some key factors to be considered in the equipment selection decision. Firms may have both general purpose and special purpose equipments. But if the firm uses advanced manufacturing technology using NC/CNC machines and automation, the distinction between general purpose and special purpose machines may not exist.

Factors to be considered for Equipment Selection	
Decision Variable	Factors to be Considered
(i) Initial investment	Price, manufacturer, space requirements, need for support equipments.
(ii) Output rate	Actual versus rated capacity.
(iii) Output quality	Consistency in meeting specifications, Scrap rate.
(iv) Operating requirements	Ease of use, safety, human factors impact.
(v) Labour requirements	Skills and training, direct labour versus indirect labour ratio.
(vi) Flexibility	General purpose versus special purpose equipment, special tooling.
(vii) Set up requirement	Complexity, Change over time.
(viii) Maintenance	Complexity, frequency, availability of spare parts.
(ix) Obsolescence	State of the art, modification for use in other situations.
(x) In-process inventory	Timing and need for buffer stocks.
(xi) System-wide impact	Tie-in with existing equipments, control activities, fit with manufacturing strategy.

7.4. PROCESS DESIGN

The process design determines the overall sequence of operations required to achieve the product specifications. It specifies the workstations to be used, the machines and equipment's needed to carryout the operations and also the sequence of these operations. **The interaction between product design and process design.**



The design of the product (i.e., product design) and design of production processes (or process design) are interrelated. In the simultaneous engineering or concurrent engineering approach to product design, the product design proceeds at the same time as process design with continuous interaction

7.5. SCOPE OF PROCESS DESIGN:

Design of manufacturing process starts with the receipt of product specifications and ends with the final plan for the manufacture of the product. The steps involved in process design are:

1. A careful review of the product design and product specifications to ensure that economical manufacture is feasible.

2. Determination of the methods of manufacture that will result in the optimum manufacturing cost.

3. Selection or development and procurement of all machines, tools, jigs and fixtures, material handling equipments and machine accessories required for the manufacture of the product at the required quality level and at the rate of production.

4. Layout of the production area and auxiliary spaces and installation of the manufacturing facilities.

5. Planning for and establishing the necessary control of materials, machines and manpower to ensure the effective utilization of the manufacturing facility for the economical production of the product.

The above steps may be identified as functions or activities such as manufacturing, engineering, process engineering, methods engineering and tools engineering. The scope of process design activity can be identified as **"all the work that is necessary to arrange for the manufacture of the product by the most economical means and the compliance with all safety regulations.**

7.6. BASIC FACTORS AFFECTING PROCESS DESIGN

The basic factors that affect the design of manufacturing processes are :

1. The volume or quantity of the product to be manufactured.

2. The required quality of the product.

3. The equipment that is available or that can be procured for the manufacture of the product.

Major factors affecting Process Design Decisions

1. *Nature of product/service demand,*

2. *Degree of vertical integration,*

3. *Product/service and volume flexibility,*

4. *Degree of automation,*

5. *Level of product/service quality and*

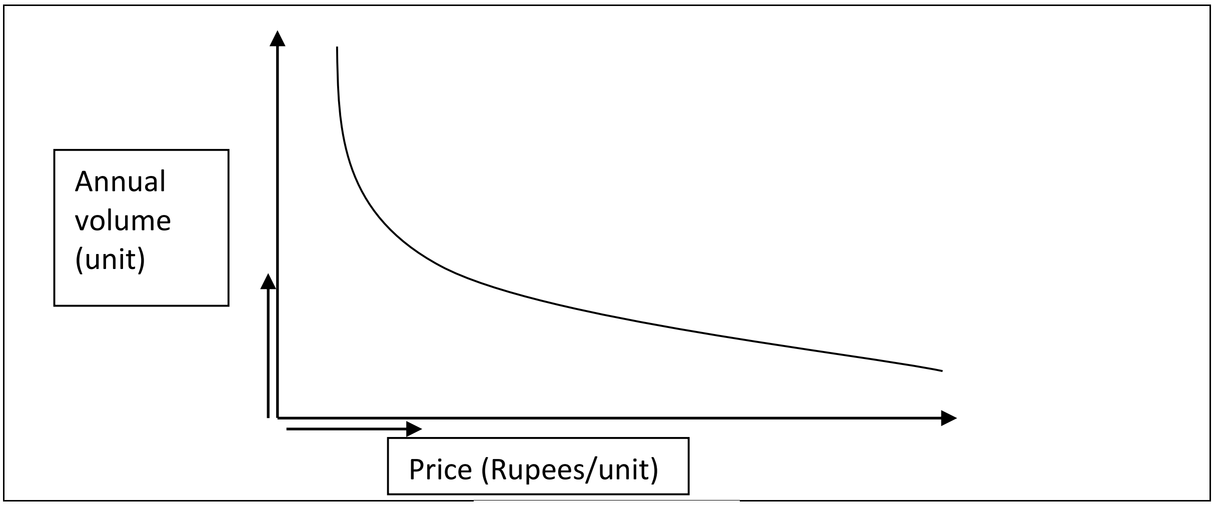
6. *Degree of customer contact.*

1. Nature of Product/Service Demand

The operations management has to design the production systems to produce products/services of the kind the customers want, when they want them and at a cost that allows the firm to be profitable. The Production process must have adequate capacity to produce the volume of products/services that customers want. The demand forecast (seasonality of demand, growth trends and other patterns of demand) for the products/services can be the basis for determining the production capacity needed in the future period or the time horizon of the demand forecast. The volume of demand is related to the price of the product/service. The price-volume relationship can be illustrated by means of price-volume curve. It can be seen from ***Chart*** that when price is set at a high level, consumers tend to buy lower volumes of products/services and vice versa. Concepts implicit in price-volume curves having important implications for designing production processes are :

a) Every price along the price-volume curve assumes a combination of elements of marketing efforts such as advertising, sales force, customer services provided, credit terms provided, a particular product/service design, inventory and shipping policies, and quality requirements.

b) At different price levels, different approaches to production must be adopted so that the customer services provided, product/service designs offered (custom built design vs. standard design) inventory and shipping policies, product quality level and production cost requirements can be met..



Price-Volume Curve

2. Degree of Vertical Integration

Vertical integration is the amount of production and distribution chain, from suppliers of raw materials and components to the delivery of finished products/services to the customers, that is bought under the ownership of a company.

Two types of vertical integration are:

a) **Forward integration** which means expanding ownership of production and distribution chain forward towards the market.

b) **Backward integration** which means expanding ownership of the production and distribution chain backward toward the sources of supply.

3. Product/Service and Volume Flexibility

Ability to respond fast to the customer's needs is known as flexibility. Two forms of flexibility are **product/service flexibility** and **volume flexibility**.

The ability of the production system to change quickly from production of one product/service to another is known as product/service flexibility, whereas the ability to quickly increase or reduce the volume of products/services produced is known as volume flexibility. Both forms of flexibility are determined when production processes are designed. For example, when the firm's business strategy calls for many custom- designed products required in small volumes and to be introduced into the market in a short lead time, production processes must be designed to include general purpose machines and flexible work force versatile employees with multiple skills). The Volume flexibility is needed when the demand pattern is fluctuating and production processes must be designed with production capacities that can be quickly expanded without much expenses.

4. Degree of Automation

The degree of automation to be adopted and integrated into the production system is a key issue in process design because of the high expenses involved in automation and also the difficulty involved in integrating automation into existing operations. Automation can reduce labour and related costs but the huge investments required for automation cannot be justified by savings in labour cost alone. The key factors supporting automation are the need to quickly produce products/services of high quality and the ability to quickly change production to other products/services. If the operations strategy calls for high product/service quality, high flexibility and faster production of products/services, automation becomes an important element of operations strategy.

5. Level of Product/Service Quality

In today's marketing environment, mass produced products with high product quality offer a better competitive edge to the manufacturer. The choice of design of production process affects the level of product quality to a considerable extent. The degree of automation integrated into the production processes has an impact on the level of product quality.

6. Degree of Customer Contact

The extent to which customers get involved in the production system has important implications for the design of production processes. In custom-built product/services, the customer is the central focus of the design of production processes. In case of standard products/services, the customer's interaction does not affect the design of production processes in a big way.

7.7. TYPES OF PROCESS MANAGEMENT

Types of Processes: Basically, processes can be categorised as:

Conversion Processes: means converting the raw materials into finished products (for example, converting iron ore into iron and then to steel). The conversion processes could be metallurgical or chemical or manufacturing or construction processes.

Manufacturing Processes: can be categorised into *(a) Forming Processes, (b) Machining Processes and (c) Assembly Processes.*

Testing Processes: which involve inspection and testing of products (some times considered as part of the manufacturing processes).

*Forming Processes***:** include foundry processes (to produce castings) and other processes such as forging, stamping, embossing and spinning. These processes change the shape of the raw material (a metal) into the shape of the workpiece without removing or adding material.

Machining Processes: comprise metal removal operations such as turning, milling, drilling, grinding, shaping, planing, boring etc.

Assembly Processes: involve joining of parts or components to produce assemblies having specific functions. Examples of assembly processes are welding, brazing, soldering, riveting, fastening with bolts and nuts and joining using adhesives.

7.8. PROCESS PLANNING

Process Planning is concerned with planning the conversion processes needed to convert the raw material into finished products. It consists of two parts - (i) **Process design** and (ii) **Operations design**.

Process design is concerned with the overall sequences of operations required to achieve the product specifications. It specifies the type of work stations to be used, the machines and equipments necessary to carryout the operations. The sequence of operations are determined by (a) The nature of the product, (b) the materials used, (c) the quantities to be produced and (d) the existing physical layout of the plant.

Operations design is concerned with the design of the individual manufacturing operation. It examines the **man-machine relationship** in the manufacturing process. Operations design must specify how much labour and machine time is required to produce each unit of the product.

Framework for Process Design

The process design is concerned with the following:

i. Characteristics of the product or service offered to the customers.
ii. Expected volume of output.
iii. Kinds of equipments and machines available in the firm
iv. Whether equipments and machines should be of special purpose or general purpose.
v. Cost of equipments and machines needed.
vi. Kind of labour available, amount of labour available and their wage rates
vii. Expenditure to be incurred for manufacturing processes.
viii. Whether the process should be capital-intensive or labour-intensive.
ix. Make or buy decision.
x. Method of handling materials economically.

7.9. PROCESS MANAGEMENT

Process selection refers to the way production of goods or services is organised. It is the basis for decisions regarding capacity planning, facilities (or plant) layout, equipments and design of work systems. Process selection is necessary when a firm takes up production of new products or services to be offered to the customers. **Process Management** is concerned with the selection of inputs, operations, workflows and methods that transform inputs into outputs

Three primary questions to be addressed before deciding on process selection are:

i. How much variety of products or services will the system need to handle?

ii. What degree of equipment flexibility will be needed?

iii. What is the expected volume of output?

Process Management is concerned with the selection of inputs, operations, workflows and methods that transform inputs into outputs. The starting point of input selection is the make-or-buy decision (i.e.. deciding which parts and components are to be produced in-house and which are to be purchased from outside suppliers). Process decisions are concerned with the proper mix of human skills and equipments needed to produce the parts in-house and which part of the processes are to be performed by each equipment and worker.

Process decision must be made when

iv. a new or modified product or service is being offered.

v. quality must be improved.

vi. competitive priorities have changed.

vii. demand for a product or service is changing.

viii. cost or availability of materials has changed.

ix. competitors are doing better by using a new technology or a new process.

7.10. MAJOR PROCESS DECISIONS

Five common process decisions considered by production/operations managers are: (i) Process choice, (ii) Vertical integration, (iii) Resource flexibility, (iv) Customer involvement and (v) Capital intensity.

Process choice determines whether resources are organised around products or processes in order to implement the flow strategy. It depends on the volumes and degree of customisation to be provided.

Vertical integration is the degree to which a firm's own production system handles the entire supply chain starting from procurement of raw-materials to distribution of finished goods.

Resource flexibility is the ease with which equipments and workers can handle a wide variety of products, levels of output, duties and functions.

Customer involvement refers to the ways in which customers become part of the production process and the extent of their participation.

Capital intensity is the mix of equipment and human skills in a production process. Capital intensity will be high if the relative cost of equipment is high when compared to the cost of human labour.

These major process decisions are discussed in detail in the following paragraphs.

1. **Process Choice:** The production manager has to choose from five basic process types- (i) Job shop, (ii) Batch, (iii) Repetitive or assembly line, (iv) Continuous and (v) Project.

    i. **Job Shop Process:** It is used in job shops when a low volume of high-variety goods are needed, Processing is intermittent, each job requires somewhat different processing requirements. A job shop is characterised by high customisation (made to order), high flexibility of equipment and skilled labour and low volume. A tool and die shop is an example of job shop where **job process** is carried out to produce one-of-a-kind of tools. Firms having job shops often carryout job works for other firms. A job shop uses a flexible flow strategy, with resources organised around the process.

ii. **Batch Process:** Batch processing is used when a moderate volume of goods or services is required and also a moderate variety in products or services. A batch process differs from the job process with respect to volume and variety. In batch processing, volumes are higher because same or similar products or services are repeatedly provided. Examples of products produced in batches include paint, ice cream, soft drinks, books and magazines.

iii. **Repetitive Process:** This is used when higher volumes of more standardised goods or services are needed. This type of process is characterised by slight flexibility of equipment (as products are standardised) and generally low labour skills. Products produced include automobiles, home appliances, television sets, computers, toys etc. Repetition process is also referred to as **line process** as it include **production lines** and **assembly lines** in mass production. Resources are organized around a product or service and materials move in a line flow from one operation to the next according to a fixed sequence with little work-in-progress inventory. This kind of process is suitable to **"manufacture-to-stock"** strategy with standard products held in finished goods inventory. However, **"assemble-to-order"** strategy and **"mass customisation"** are also possible in repetitive process.

iv. **Continuous Process:** This is used when a very highly standardised product is desired in high volumes. These systems have almost no variety in output and hence there is no need for equipment flexibility. A continuous process is the extreme end of high volume, standardised production with rigid line flows. The process often is capital intensive and operate round the clock to maximize equipment utilisation and to avoid expensive shutdowns and start-ups. Examples of products made in continuous process systems include petroleum products, steel, sugar, flour, paper, cement, fertilizers etc.

v. **Project Process:** It is characterised by high degree of job customisation, the large scope for each project and need for substantial resources to complete the project. Examples of projects are building a shopping centre, a dam, a bridge, construction of a factory, hospital, developing a new product, publishing a new book etc. Projects tend to be complex, take a long time and consist of a large number of complex activities. Equipment flexibility and labour skills can range from low to high depending on the type of projects.

2. **Vertical Integration :** Vertical Integration is the amount of the production and distribution chain, from suppliers of components to the delivery of products/services to customers, which is brought under the ownership of a firm. The management decides the level or degree of integration by considering all the activities performed from the acquisition of raw materials to the delivery of finished products to customers. The degree to which a firm decides to be vertically integrated determines how many production processes need to be planned and designed to be carried out in-house and how many by outsourcing. When managers decide to have more vertical integration, there is less outsourcing. The vertical integration is based on **"make-or-buy" decisions**, with **make** decisions meaning more integration and a **buy** decision meaning less integration and more outsourcing.

Two directions of vertical integration are:

(a) **Backward integration** which represents moving upstream toward the sources of raw-materials and parts, for example, a steel mill going for backward integration by owning iron ore and coal mines and a large fleet of transport vehicles to move these raw materials to the steel plant.

(b) **Forward integration** in which the firm acquires the channel of distribution (such as having its own warehouses, and retail outlets)

The advantages of more vertical integration are disadvantages of more outsourcing and similarly, advantages of more outsourcing are disadvantages of more vertical integration.

Advantages of vertical integration are:

i. Can sometimes increase market share and allow the firm enter foreign markets more easily.

ii. Can achieve savings in production cost and produce higher quality goods.

iii. Can achieve more timely delivery.

iv. Better utilisation of all types of resources.

Disadvantages of vertical integration are:

i. Not attractive for low volumes.

ii. High capital investment and operating costs.

iii. Less ability to react more quickly to changes in customer demands, competitive actions and new technologies.

3. **Resource Flexibility:** The choices that management makes concerning competitive priorities determine the degree of flexibility required of a firm's resources - its employees, facilities and equipment. Production managers must decide whether to have flexible workforce which will provide reliable customer service and avoid capacity bottle necks. Flexible workforce is useful with flexible flow strategy to even out fluctuating workloads. Also, when volume flexibility is required, instead of laying off and hiring workforce to match varying demands, it is better to have certain amount of permanent workforce having multiple skills. This will facilitate movement of surplus workforce from low load work centres to higher-load work centres. When a firm's product has a short life cycle and a high degree of customisation, low production volumes mean that the firm should select flexible general purpose machines and equipment’s.

4. **Customer Involvement:** is the extent to which customers interact with the process. A firm which competes on customisation allows customers to come up with their own product specifications or even become involved in the designing process for the product (quality function deployment approach to design for incorporating the voice of the customer)

5. **Capital Intensity:** means the predominant resource used in manufacturing is capital equipment’s and machines rather than labour. Decision regarding the amount of capital investment needed for equipment’s and machines is important for the design of a new process or the redesign of an existing one. As the capabilities of technology increase (for example, automation), costs also will increase and managers have to decide about the extent of automation needed. While one advantage of adding capital intensity is significant increase in product quality and productivity, one big disadvantage can be high investment cost for low-volume operations.

7.11. LET US SUM UP

After the final design of the product has been approved and released for production, the Production Planning and Control department takes the responsibility of Process Planning and Process Design for converting the product design into a tangible product. As the process plans are firmly established, the processing time required to carryout the production operations on the equipment’s and machines selected are estimated.

These processing times are compared with the available machine and labour capacities and also against the cost of acquiring new machines and equipment’s required, before a final decision is made to manufacture the product completely in house or any parts or subassemblies must be outsourced. A process converts inputs into outputs in a production system. It involves the use of organisation's resources to provide something of value. No product can be made and no service provided without a process and no process can exist without a product or service.

7.12. KEY TERMS

- ✓ **Process choice** determines whether resources are organised around products or processes in order to implement the flow strategy. It depends on the volumes and degree of customisation to be provided.
- ✓ **Vertical integration** is the degree to which a firm's own production system handles the entire supply chain starting from procurement of raw-materials to distribution of finished goods.
- ✓ **Process selection** refers to the way production of goods or services is organised. It is the basis for decisions regarding capacity planning, facilities (or plant) layout, equipment’s and design of work systems.
- ✓ **Process Management** is concerned with the selection of inputs, operations, workflows and methods that transform inputs into outputs
- ✓ **Resource flexibility** is the ease with which equipments and workers can handle a wide variety of products, levels of output, duties and functions.
- ✓ **Customer involvement** refers to the ways in which customers become part of the production process and the extent of their participation.
- ✓ **Capital intensity** is the mix of equipment and human skills in a production process. Capital intensity will be high if the relative cost of equipment is high when compared to the cost of human labour.

- ✓ **Backward integration** which represents moving upstream toward the sources of raw-materials and parts, for example, a steel mill going for backward integration by owning iron ore and coal mines and a large fleet of transport vehicles to move these raw materials to the steel plant.
- ✓ **Forward integration** in which the firm acquires the channel of distribution (such as having its own warehouses, and retail outlets)

7.13. SELF – ASSESSMENT QUESTIONS

1) What is a Process? Discuss the procedure for Process Planning and Design ?

2) What is Process Design ? Discuss the scope, Factors Affecting Process Design?

3) What is Process Management ? Discuss the major Process Decisions?

7.14. FURTHER READINGS

1. Jay Heizer and Barry Render, Operations Management , Pearson Publications

2. Amol Palekar and Shreekant Shiralkar, Supply Chain Analytics with SAP NetWeaver Business Warehouse.

3. Muthu Mathirajan and Chandrasekharan Rajendran., Analytics in Operations/Supply Chain Management.

4. Chopra, Sunil, Meindl, Peter and Kalra, D. V.; Supply Chain Management: Strategy, Planning and Operation; Pearson Education

5. Altekar, Rahul V.; Supply Chain Management: Concepts and Cases; PHI Learning

6. Ballou, Ronald H.; Supply Chain Management; Pearson Education

7. Sahay, B.S.; Supply Chain Management; Macmillan

8. Ballou, R.H. Business Logistics Management. Prentice-Hall Inc.

9. Bowersox D.J. ,Closs D.J. , *Logistical Management*, McGraw-Hill, 1996

UNIT-8: PRODUCT-PROCESS DESIGN MATRIX AND SERVICES DESIGN MATRIX

STRUCTURE

LEARNING OBJECTIVES

After reading this unit you will understand:

1. Understand the Product Planning and Development.
2. To discuss New Product Development Strategy.
3. Find out the Product Design, Process Design and Production Design.
4. Discuss the Product Design process as part of Product Development Process.

8.1. INTRODUCTION

Even though the overall responsibility for product planning and development lies with the marketing department of a firm, the research and development (R&D) department (also called product design department) and the production or manufacturing department contribute substantially to the product planning and development effort. The success of manufacturing firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low cost. To achieving these goals is not solely a marketing problem or responsibility nor is it solely a design problem or a manufacturing problem, it is a product development problem involving all these functions.

8.2.WHAT IS A PRODUCT?

A product is something sold by an enterprise to its customers. The product as anything that can be offered to a market for attention, acquisition, use or consumption and that might satisfy a want or need. Products include more than just tangible goods, they include physical objects, (tangibles) services (intangibles), events, persons, places, ideas, organisations or a combination of these entities. However, we use the term product to refer to tangible goods in this book because of its importance in the study of production and materials management.

Levels of Product: Product planners need to think about products and services in three levels.

(i) The core product at the basic level, (ii) The actual product around the core product and (iii) The augmented product around the core and actual product.

Concept of three levels of products.

The core product addresses the question "What is the buyer really buying? Buyers view products as bundle of benefits or those which provide them problem-solving benefits. The marketing department seeks to find out the core benefits that customers seek in the products they buy to satisfy their needs and arrives at the product specifications as input to the designing of products by the research and development or product design department. The product designer must then build an actual product around the core product by producing the product structure design which includes all the desired product features, quality level and the packaging for the product.

Role of Production Department

The production department converts the product design into a reality (a tangible product) ensuring that the output of the production system-a tangible product meets all the design specifications and provides the necessary benefits sought by the customers, These include, quality, cost (producibility or economic production), speed to market and flexibility which offer competitive advantage to the manufacturing firm.

The augmented product includes additional customer services and benefits offered by the marketing department to the customers. These include delivery and credit, installation, after-sales-service and warranty which came under the purview of the responsibilities of marketing department. Hence, we may conclude that product planning and development is a combined effort of three departments namely - marketing, research and development (or design department) and production departments.

Further, products are classified as consumer products (such as convenience products, shopping products, speciality products and unsought, products) and industrial products (such as raw materials and parts, capital items, supplies and services).Product strategy includes product decisions regarding product attributes. Developing a product involves defining the benefits that it will offer and these benefits are communicated and delivered by product attributes such as quality, features, style and design of the products.

Further a firm may offer to the market a **single product** or a **product line** (a group of products that are closely related) or a **product-mix** (a set of all product lines) or a set of **diverse products** (products which are totally unrelated to one another).

Kirloskar Brothers Limited (KBL)KBL opens division for manufacturing high-end technology products

Kirloskar Brothers Limited (KBL) has recently built a new manufacturing division at the company’s mother plant in Kirloskarvadi called ‘Advanced Technology Product Division (ATPD)’. The ATPD has primarily been built as a dedicated manufacturing division for high-end technology products, especially those used for nuclear applications. It is a state-of-the-art facility spread across 6000 sq. mtrs. area and is fully equipped with modern machines and test facilities, including special measuring instruments. The facility is a one-stop-shop for machining, quality control checks, assembly, and testing under high pressure and high temperature.

KBL is among the world leaders in pumping solutions for various critical applications in the nuclear industry. It is the first and leading manufacturer of primary and secondary sodium pumps for Fast Breeder Reactors (FBR) in India. The company is also among the only few providers of primary heat transfer pumps for the nuclear sector. Besides, the company's Concrete Volute Pumps (CVP) form an essential part of various nuclear and thermal power plants across India. Thus, the establishment of the ATPD division is primarily aimed at further consolidating KBL's capabilities as a full-fledged dedicated provider of some of the most advanced fluid management technologies and solutions for a wide range of applications in the nuclear industry.

NEED FOR PRODUCT PLANNING AND DEVELOPMENT

A company has to be good at planning, developing and managing new products. Since every product goes through a **life cycle** (having various phases or stages such as *introduction, growth, maturity, saturation, decline and obsolescence)* new products must be planned, developed and launched to the market to replace existing products which are in the later stages of their life cycles namely saturation, decline or obsolescence. This *Product life cycle* poses two challenges to manufacturers - (i) Because all products eventually have declining demand and eventually become obsolete, the firm must be good at developing new products to replace aging ones (the problem of *new-product development*) and (ii) the firm must be good at its marketing strategies through life cycle stages (the problem of *product-life-cycle strategies*). While the product-life-cycle strategies are purely the responsibilities of the marketing managers, the new-product development is a combined responsibility of marketing, product design and production managers. Further, a sound new-product development strategy will reinforce the marketing managers and leads to their success in formulating the product-life-cycle strategies and managing the marketing of new products.

What is Product Planning and Development?

Product planning and development is the process of searching ideas for new products, screening them systematically, converting them into tangible products and introducing the new products into markets. It also involves formulation of product strategies and policies. It includes improvement in existing products as well as dropping unprofitable products. Product planning and development includes product design and product engineering (or product development).

Product planning includes all activities starting from the concept of product ideas and ending up-with full scale production and introduction of the product in the target market.

What is a New Product?

New product planning and development and product innovation are at the heart of the product planning and development function of an organisation. There are three distorted categories of new products.

i. **Products** that are really innovative - truly unique. For example, cellular phones, palm-top computers and the like. Any new product in this category satisfies a real need that is not being satisfied at the time it is introduced.

ii. **Replacement** that are significantly different from existing products in terms of product features such as function, form, size etc., and most important-benefits provided by the product For example, disposable contact lenses, wall television sets, compact disc players, electric car and the like.

iii. **Imitative products** that are new to a particular company but not new to the market. For example, new models of automobiles, new versions of cereals, chocolates and the like. Ultimately, whether a product is a really new product or slightly new product (i.e., a modified product), what is more important is how the intended market perceives it. If the buyers consider a product to be significantly different from competitive products in some relevant characteristics (such as performance or appearance), then it is truly a new product because perception is reality.

8.3. OBJECTIVES OF PRODUCT PLANNING AND DEVELOPMENT:

The objectives are:

i. To facilitate profitability and growth of business.

ii. To meet the ever changing needs of the customers and achieve maximum possible customer satisfaction.

iii. To enable the firm to face competitive pressures and to diversify risks.

iv. To minimise costs of production and to maximise sales.

On the other hand, the objectives of product planning and development may be classified as :

i. **Immediate Objectives**

ii. **Ultimate Objectives.**

Immediate objectives are short-term objectives such as: (a) immediate satisfaction of customers' needs. (b) better utilisation of available resources. (c) to replace obsolete products and (d) to utilise surplus capacity.

Ultimate objectives are long-term objectives such as:

(a) To create a favourable product image and brand image,

(b) To position the product favourably in the customer's mind (product positioning or brand positioning),

(c) To create brand loyal customers and increase market share,

(d) To diversify business risks,

(e) To increase sales turnover and

(f) To become a market leader by "product innovation".

Why Product Planning and Development is Important?

i. New products hold the answer to most organisation's biggest problems.

ii. Competitors are most threatening when (a) there is so little **product-differentiation** that price cutting takes everyone's margin away and (b) when they have a desirable new item which we don't have.

iii. Profits and sales will diminish when customers no longer prefer our products over the competitor's products.

iv. All successful new products do more good to an organisation than anything else that can happen.

v. To be competitive, what we offer to our customers must be better than what someone else offers.

vi. Business firms can expect and get a high percentage of their sales and profits from new products.

vii. Because of severe competition, managements are under pressure to adapt value as their key guide line - new products now must have quality and be low in price.

viii. New product planning and development are vital to an organisational success. A company cannot successfully sell a bad product over the long run and yet survive.

ix. Product innovations have two significant implications-(a) Every company's products eventually become obsolete as their sales volume and market share are reduced by changing consumer desires and/or superior competing products and (b) As a product ages through its lifecycle, its profits generally decline and introducing a new product at the right time can help maintain a company's profits.

x. A guide line for management is "innovate or perish".

8.4. CHARACTERISTICS OF SUCCESSFUL PRODUCT DEVELOPMENT:

Successful product development results in products that can be produced and sold profitably. That is often difficult to assess quickly and directly. Five specific dimensions, all of which ultimately relate to profit are commonly used to assess the performance of a product development effort, They are:

i. **Product Quality:** Does the product satisfy customer needs? Is it robust and reliable? Product quality is ultimately reflected in market share and the price that customers are willing to pay.

ii. **Product Cost:** What is the manufacturing cost of the product? (including expenditure on capital equipment and tooling as well as incremental cost or variable cost). Product cost determines the per unit profit for a particular sales volume and selling price.

iii. **Development Time :** How quickly did the team complete product development effort?

iv. **Development Cost :** How much did the firm have to spend to develop a product?

v. **Development Capability:** Are the team and the firm better able to develop future products as a result of their experience with the present development project?

8.5. ROLE OF PRODUCTION MANAGEMENT IN PRODUCT DEVELOPMENT

The manufacturing function is primarily responsible for designing and operating the production system in order to produce the product. The production management function is responsible to ensure product quality, cost and delivery to customer at times of demand for the new products from time to time. During the product development stage, the manufacturing people must ensure that the product design has the characteristics of producibility i.e., economic production on a large scale taking advantages of "economies of scale" in the later stages of product life cycle.

THE CHALLENGES OF PRODUCT DEVELOPMENT,

Developing great products is a challenging job for many companies. Few companies are highly successful more than half the time. It is observed that generally about 80 percent of new products fail even though thousands of new products are developed and launched to the market every year. Why do new products fail? Some of the characteristics that make product development challenging may perhaps answer this question. These characteristics are:

i. **Trade Offs:** An aircraft can be made lighter by increase in manufacturing cost. One of the most difficult aspects of product development is recognising, understanding and managing such trade-offs so as to maximise the success of the product.

ii. **Dynamics :** Improvement in technologies, evolution of customer preferences, introduction of new products by competitors and the shifts in macroeconomic environment - are all the factors which make it a formidable task to take new product development decisions in an environment of constant change.

iii. **Details:** Even decisions regarding use of small, low cost items (such as screws, bolts & nuts) can have great economic implications. Developing a product of even modest complexity may require thousands of such decisions. Hence, the product development team should consider even minute details of product design that ensures economic production.

iv. **Time Pressure :** Since it is mandatory to reduce the product development cycle time and to increase the speed to market, product development decisions must usually be made quickly and often without complete information.

v. **Creation:** The product development process begins with an idea and ends with the production of a physical entity. When viewed both in its entirety as well as at the level of individual activities, the product development process is intensely creative.

vi. **Satisfaction of Societal and Individual Needs:** All products are aimed at satisfying the needs of some kind of individuals specifically and of the society in general.

vii. **Team Diversity:** Successful product development needs many different skills and talents. Hence, there is a need to develop teams involving people with a wide range of different training, experience, skills and personalties.

viii. **Team Spirit:** Product development teams must be highly motivated and the team members must develop team spirit in order to be successful.

8.6. NEW PRODUCT DEVELOPMENT STRATEGY

To achieve strong sales and healthy profits, every firm manufacturing goods should have an explicit strategy to develop and evaluate new products. The **new product strategy** should guide the firm in the process of developing a new product.

A new product strategy is a statement identifying the role a new product is expected to play in achieving the goals of the company. For example, a new product might be designed to protect market share or maintain a firm's reputation as an innovator, or a new product's role might be to meet a specific return-on-investment goal or establish a position in a new market.

A firm can obtain new products in two ways: (i) through acquisition i.e., by buying a whole firm, or a licence to produce a product of another firm, or by purchasing the know-how (product design & process) against know-how charges, (ii) through new-product development in the firm's own research and development department.

Many new products fail, companies are anxious to learn how to improve their chances of new product success. One way is to identify successful new products and find out what they have in common. Another is to study new product failures to see what lessons can be learnt to avoid failures in future. New product success depends on developing a unique superior product, one with higher quality, new feature and higher value to the customer in use. Another key success factor is a well-defined product concept prior to development in which the company carefully defines and assesses the target market, the product requirements and the benefits before proceeding with product design and development. In all to create successful new products, a company must understand its customers, markets, the competitors and develop products that deliver superior value to customers.

8.7. NEW PRODUCT DEVELOPMENT PROCESS

A systematic new product development process has eight major steps which are:

Step 1. Idea Generation : New product development starts with idea generation which is a systematic search for new-product ideas. It is necessary to generate many ideas in order to find a few good ones. (For example, thousands of new ideas may have to be generated to develop one or two products). The new ideas many be generated from various sources such as internal sources (employees, executives, R & D engineers, sales people etc.,) and external resources such as customers, competitors, distributors and suppliers. Top management can install an idea management system that directs the flow of new ideas to a central point where they are collected, reviewed and evaluated.

Step 2. Idea Screening: Idea screening is the process of screening new-product ideas in order to spot good ideas and drop poor ones as earlier as possible. The firm must go ahead with those product ideas that will turn into profitable products. The new product ideas are written down on a standard form and reviewed by a new-product committee. The product, the target market and the competition are described in the write- up. A rough estimate of market size, product price, development time, and costs, manufacturing costs and time and rate of return helps the committee to evaluate the ideas against a set of general criteria.

Step 3. Concept Development and Testing: An attractive idea must be developed into a product concept. A product concept is a detailed version of the product idea stated in meaningful consumer terms. For example, Daimler Chrysler which is road testing its NECAR-4 (electric car) has created the following concepts for the fuel-cell electric car : (i) a moderately priced subcompact designed as a second family car, (ii) a medium cost sporty compact appealing to all young people and (iii) an inexpensive subcompact "green" car appealing to environmentally conscious people.

Concept Testing: Calls for testing new product concepts with target customer groups to find out whether the concepts have strong customer appeal. Marketers may present a word or picture description of the product concept or present virtual reality program using computers and sensory devices to stimulate reality. After being exposed to the concept, consumers may be asked to react to it by answering questions in a questionnaire. The answer will help the firm to decide which concept has the strongest appeal.

Step 4. Marketing Strategy Development: This step involves designing an initial marketing strategy for introducing the new product to the market. The marketing strategy statement has three parts: (i) the description of the target market, (ii) the planned product positioning and (iii) the sales, market share and profit goals for the first few years.

Step 5. Business Analysis: Once the company has decided on its product concept and marketing strategy, it can evaluate the business attractiveness of the proposal. Business analysis involves a review of the sales, and profit projections for a new product to find out whether these factors satisfy the company's objectives. If so, the product concept can be moved to the product design and development stage.

Step 6. Product Development: It involves developing the product concept which has existed as a word description or a drawing into a physical product by the R & D or engineering department. One or more physical versions (known as working prototype models) are developed and tested. The objective is to design. a prototype that will satisfy and excite customers and that can be produced quickly and at budgeted costs. The prototype must have the required functional features and also convey the intended psychological characteristics Even, the product may be subjected to consumer test.

Step 7. Test Marketing: If the product passes functional and consumer tests, then test marketing is conducted. In this stage, the products are produced in a small batch (known as pilot batch) and the product and marketing programs are introduced into more realistic market settings. It lets the company test the product in use by customer and also its entire marketing program such as positioning strategy, advertising, distribution, pricing, branding and packaging and budget levels.

Step 8. Commercialisation : Based on the information obtained from test marketing the company can make final decision about whether to launch the new product in full scale to the market or not. Commercialisation involves, full scale manufacturing and marketing of the product which will involve considerable expenditure to the company. The company launching the new product must first decide on introduction timing and also on where to launch the new product - in a single location, region, national or international market.

APPROACHES TO SPEED UP NEW-PRODUCT DEVELOPMENT

The eight steps involved in new product development process, These 8 steps are performed in an orderly sequence and this approach is known as sequential product development approach. In this, approach, one department works individually to complete its stage of the process before passing the new product to the next department and stage. This approach can be very slow resulting in long development cycle time, product failures, lost sales and profits, Today, "speed to market" and "short new product development cycle time" have become pressing concerns for companies to gain competitive advantage.

Hence, in order to get the new products to market more quickly, many firms are adopting a faster, team oriented approached called simultaneous or concurrent (or team based) product development.

It is an approach to developing new products in which various company departments work closely together, overlapping the steps in the product development process to save time and increase effectiveness. A team of people from various relevant departments stays with the new product from start to finish. The team includes members from marketing, finance, design, manufacturing, safety and legal departments and sometimes even supplier and customer firms.

8.8. THE PRODUCT-LIFE CYCLE CONCEPT

After launching a new product, the marketing manager should be aware of the fact that each product will have a life cycle and has to keep track of it in order to make new product development decision (timing) before the existing product completes it saturation stage and enters the decline stage. The various stages in a product-life cycle are: (i) product development, (ii) introduction, (iii) growth, (iv) maturity, (v) saturation, (vi) decline and (vii) obsolescence.

i. **Product development** begins when the firm finds and develops a new-product idea. During the product development period, there is no sales and the company incurs expenditure for investment in product development effort.

ii. **Introduction** is the period of slow sales growth as the product is introduced in the market. Profit is nonexistent in this stage because of heavy expenses for promotion of the product in introduction to market.

iii. **Growth stage** is a period of rapid market acceptance and increasing profits because of higher volume of sales.

iv. **Maturity** is a period of slow down in sales growth because the product has achieved acceptance by most potential customers. Competitors enter the market and profits level off or decline because of increased marketing outlays to defend the product against competition.

v. **Saturation** is a period in which sales level off because of competition and profit decline.

vi. **Decline** is the period when sales fall off and profits drop.

vii. **Obsolescence** is a period in which sales decline deeply to almost zero level because of superior products in the market offered by the competitors.

8.9. FACTORS TO BE CONSIDERED IN PRODUCT DEVELOPMENT

Product planning and development includes the following considerations: (i) Consumer acceptance, (ii) Protection against copying by competitors through patent, copyright and trademarks, (iii) Development costs and manufacturing costs, (iv) Complementary products, (v) Utilising the by-products and wastages resulting from manufacturing processes.

Consumer acceptance is the most important consideration because the sole purpose of developing new products is to satisfy the customers' hither-to unsatisfied needs. The new product should have all the features expected by customers such as performance or use (or benefits), appearance, aesthetics, durability, reliability, service life, maintainability, convenience for use, reasonable price (value for money), stable supply and the like. The manufacturer must carefully weigh the relative importance of various product features and trade-off among them to achieve a balance among these attributes and ensure the same for gaining maximum customer acceptance.

The manufacturing firm must explore the degree of protection that can be obtained by seeking patent rights so that the firm's product design can not be copied by the competitors. Other protection available are trademarks and copy rights (for authors of books, drawings, photographs, painting etc.). Trade marks and brand names may be registered so that other firms may not use the same brand name & trade mark. Since new product development involves heavy development expenditures, the manufacturing firm must estimate as accurately as possible the development cost (time, effort and equipment needed for product development) and also the manufacturing costs so as to envisage the return on investment and the pay-back period. The producibility aspect (i.e., economic production on commercial basis) has to be considered taking into consideration both quality and production cost.

Developing complementary products which support the core or main new product being developed helps in utilisation of existing manufacturing facilities for production of complementary products when the demand for the main product goes down due to the effect of seasonality on the demand. Some examples of complementary products are "tooth brush & tooth paste", "Shaving razor and shaving cream", ball-point pen and refills and the like.

It is also important for management to consider the effect of the new product developed on the sales of existing products offered to the market by the firm. The new product should not compete with the firm's existing products. The new product may fill up a gap in the existing product line, in terms of size, quality level and price, in which case it may not directly compete with the existing products of the product line.

Finally, it is necessary to develop ways and means of utilising the by-products or wastages taking into consideration the safety of the environment also.

Tools for Product Development: Product standardisation, product specialisation, product simplification, product diversification and use of automation in product development are considered as some of the tools and techniques in product development.

PRODUCT DESIGN

Designing new products and getting them to market is the challenge facing manufacturers in industries as diverse as computer chips and potato chips. Whereas computer chip manufactures need to offer more powerful IC chips for their customers (such as computer manufacturers), food producers need to provide their customers new taste sensation to sustain or enlarge their retail market share.

The competitiveness and profitability of firms depend partly on the design and quality of the products and services offered by the firms and also on the cost of production. Hence the relationship between product design to process technology and process design is of considerable interest to production managers. The designing and developing products and production processes are key elements in successful production and operations strategies in today's global economy. Also, design of the productive system depends largely on the design of the product and services to be produced as well as the design and selection of production processes.For all companies, whether high tech, low tech or no tech (i.e., degree of technology used) product design plays an important role in the profitability and their very survival.

The essence of any organisation is the product or services it offers. There is an obvious link between product design and the success of the organisation. Those organisations which have well-designed products are more likely to realise their goals than those with poorly designed products. Hence organisations have a vital stake in achieving good product design.

8.10. PRODUCT DESIGN, PROCESS DESIGN AND PRODUCTION DESIGN

Product Design: One way for manufacturers to satisfy customers and gain a differential advantage is through product design which refers to ***the arrangement of elements that collectively form a good or service.***

Product design is concerned with the **form** and **function** of a product. Form design involves the determination of what a product would look like, i.e., the shape and appearance of the product, what it will be made of (product structure) and how it will be made (process design). **Functional design** deals with what function the product will perform and how it performs.

Functional design is concerned with the first and fore-most requirement of a good product i.e., the product should effectively perform the function for which it is developed. For example, for a television set, the picture quality (video) and the sound quality (audio) are more important than the appearance of the cabinet in which the picture tube is fixed.

Form design is concerned with the appearance and aesthetic considerations and also the size, volume and weight of the product which are secondary to the performance of the product.

Process Design: Process design is concerned with the overall sequences of operations required to achieve the design specifications of the product. It specifies the type of work stations that are to be used, the machines and equipments necessary to carryout the processes to produce the product. The choice of process technology (i.e., manual, mechanised or automated technology) and the process design is related to product design because the manufacturing processes must be capable of achieving the product quality (accuracy, tolerances etc.,) specified in the product design and also the product must be designed for producibility (i.e., economic production).

Production Design: The design of products and services is partially dependent on the productive system design and vice versa. A product or service designed in one way may be costly to be produced, but it may be somewhat less costly when designed another way. The concept of designing products from the point of view of producibility is known as production design.

The producibility and minimum possible production cost of a product are established originally by the product designer and the process technology. Process design and selection of the productive system are governed by the limitations of the product design. Hence, the basic modes of production for products are thought of in the product design stage itself. This conscious effort to design for producibility and low manufacturing costs is referred to as production design.

Importance of Product Design

Production or operations strategy is directly influenced by product design for the following reasons.

i. As products are designed, all the detailed characteristics of each product are established.

ii. Each product characteristic directly affects how the product can be made or produced (i.e., process technology and process design) and

iii. How the product is made determines the design of the production system (production design) which is the heart of production and operations strategy.

Further, product design directly affects product quality, production costs and customer satisfaction. Hence, the design of product is crucial to success in today's global competition.

A good product design can improve the marketability of a product by making it easier to operate or use, upgrading its quality, improving its appearance, and/or reducing manufacturing costs.

A distinctive design may be the only feature that significantly differentiates a product. An excellent design includes usability, aesthetics, reliability, functionality, innovation and appropriateness. An excellent design provides competitive advantage to the manufacturer by ensuring appropriate quality, reasonable cost and the expected product features, Firms of tomorrow will definitely compete not on price and quality, but on product design.

What does product design do?

The activities and responsibilities of product design include the following:

i. Translating customer needs and wants into product and service requirements (marketing).

ii. Refining existing products (marketing).

iii. Developing new products (marketing, product design and production).

iv. Formulating quality goals (quality assurance, production).

v. Formulating cost targets (Accounting).

vi. Constructing and testing prototype (marketing, production).

vii. Documentary specifications (product design).

Reasons for Product Design or Redesign

The most obvious reason for product design is to offer new products to remain competitive in the market. The second most important reason is to make the business grow and increase profits. Some times product design is actually redesign or modification of existing design instead of an entirely new design. The reasons for this include customer complaints, accidents or injuries during product use, excessive warranty claims or low demand. Some times product redesign is initiated to achieve cost reductions in labour and material costs.

Objectives of Product Design

i. The overall objective is profit generation in the long-run.
ii. To achieve the desired product quality.
iii. To reduce the development time and cost to the minimum.
iv. To reduce the cost of the product.
v. To ensure producibility or manufacturability (design for manufacturing and assembly).

8.11. FACTORS INFLUENCING PRODUCT DESIGN

i. Customer Requirements: The designers must find out the exact requirements of the customers to ensure that the products suit the convenience of customers for use. The products must be designed to be used in all kinds of conditions.

ii. **Convenience of the Operator or User:** The industrial products such as machines and tools should be so designed that they are convenient and comfortable to operate or use.

iii. **Trade-off Between Function and Form:** The design should combine both performance and aesthetics or appearance with a proper balance between the two.

iv. **Types of Materials Used:** Discovery of new and better materials can improve the product design. Designers keep in touch with the latest development taking place in the field of materials and components and make use of improved materials and components in their product designs.

v. **Work Methods and Equipments:** Designers must keep abreast of improvements in work methods, processes and equipments and design the products to make use of the latest technology and manufacturing processes to achieve reduction in costs.

vi. **Cost/Price Ratio:** In a competitive market, there is lot of pressure on designers to design products which are cost effective because cost and quality are inbuilt in the design. With a constraint on the upper limit on cost of producing products, the designer must ensure cost effective designs.

vii. **Product Quality:** The product quality partly depends on quality of design and partly. on quality of conformance. The quality policy of the firm provides the necessary guide lines for the designers the extent to which quality should be built in the design stage itself by deciding the appropriate design specifications and tolerances.

viii. **Process Capability:** The product design should take into consideration the quality of conformance - the degree to which quality of design is achieved in manufacturing. This depends on the process capability of the machines and equipments. However, the designer should have the knowledge of the capability of the manufacturing facilities and specify tolerances which can be achieved by the available machines and equipments.

ix. **Effect on Existing Products:** New product design while replacing existing product designs, must take into consideration the use of standard parts and components, existing manufacturing and distribution strategies and blending of new manufacturing technology with the existing one so that the costs of implementing the changes are kept to the minimum.

x. **Packaging:** Packaging is an essential part of a product and packaging design and product design go hand in hand with equal importance. Packaging design must take into account the objectives of packaging such as protection and promotion of the product. Attractive packaging enhances the sales appeal of products in case of consumer products (non durable).

8.12. CHARACTERISTICS OF GOOD PRODUCT DESIGN

A good product design must ensure the following:

i. **Function or Performance:** The function or performance is what the customer expects the product to do to solve his/her problem or offer certain benefits leading to satisfaction. For example, a customer for a motorbike expects the bike to start with a few kicks on the kick pedal and also expects some other functional aspects such as pickup, maximum speed, engine power and fuel consumption etc.

ii. **Appearance or Aesthetics:** This includes the style, colour, look, feel, etc., which appeals to the human sense and adds value to the product.

iii. **Reliability:** This refers to the length of time a product can be used before it fails. In other words, reliability is the probability that a product will function for a specific time period without failure.

iv. **Maintainability:** This refers to the restoration of a product once it has failed. High degree of maintainability is desired so that the product can be restored (repaired) to be used within a short time after it breaks down This is also known as serviceability.

v. **Availability:** This refers to the continuity of service to the customer. A product is available for use when it is in an operational state. Availability is a combination of reliability and maintainability. High reliability and maintainability ensures high availability.

vi. **Producibility:** This refers to the case of manufacture with minimum cost (economic production). This is ensured in product design by proper specification of tolerances, use of materials that can be easily processed and also use of economical processes and equipments to produce the product quickly and at a cheaper cost.

vii. **Simplification:** It refers to the elimination of the complex features so that the intended function is performed with reduced costs, higher quality or more customer satisfaction. A simplified design has fewer parts which can be manufactured and assembled with less time and cost.

viii. **Standardisation :** refers to the design activity that reduces variety among a group of products or parts. For example, group technology items have standardised design which calls for similar manufacturing process steps to be followed. Standard design leads to variety reduction and results in economies of scale due to high volume of production of standard products. However, standardized designs may lead to reduced choices for customers.

ix. **Specification:** A specification is a detailed description of a material, part or product, including physical measures such a dimensions, volume, weight, surface finish etc. These specifications indicate tolerances on physical measures which provide production department with precise information about the characteristics of products to be produced and the process and production equipments to be used to achieve the specified tolerance (acceptable variations). Interchangeability of parts in products produced in large volumes (mass production and flow-line production) is achieved by appropriate specification of tolerances to facilitate the designed fit between parts which are assembled together.

x. **Safety:** The product must be safe to the user and should not cause any accident while using or should not cause/any health hazard to the user. Safety in storage, handling and usage must be ensured by the designer and a proper package has to be provided to avoid damage during transportation and storage of the product. For example, a pharmaceutical product while curing the patient, should not cause some other side effect threatening the user.

8.13. THE PRODUCT DESIGN PROCESS AS PART OF PRODUCT DEVELOPMENT PROCESS

While the potential opportunities to be realised in developing new products are exciting, making them a reality is a big challenge. New product development involves a complex set of activities carried out in the following phases:

Phase 1: Concept development involving product architecture, conceptual design and target market considerations.

Phase 2: Product planning involving market identification, and business analysis regarding technical feasibility and economic viability of the new product.

In the above two phases - *concept development and product planning,* the information about market opportunities, competitive actions, technical possibilities and production requirements must be combined to arrive at the definition of the product architecture for the new product. The various factors involved are conceptual design, target market, desired level of performance, investment requirements and impact of financial commitments. In this phase, a prototype model of the product may be built based on preliminary design to prove technical feasibility of the new product development and also check with potential customers about its acceptability.

Phase 3: Product/Process Engineering: Once the new product prototype model is approved, the detailed engineering is taken up. This involves the design and construction of working prototypes based on provisional design (i.c.. preliminary design modified based on testing of first prototype model) and development of tools and equipments to be used in commercial production. The working prototype model is built and tested in conditions that simulate product use. If the model fails to deliver the desired performance characteristics, design engineers search for design changes to over-come the short comings of the model and the cycle of "*design-build-test"* is repeated until the working of the prototype model is satisfactory. At the end of this phase, the design drawings are approved and released with signature of competent managers of design department and this signifies that the final design meets the requirement and the design is frozen (known as "design-freeze" stage).

Phase 4: Pilot Production: In this phase, the development project moves up to pilot manufacturing phase, during which the product is produced and tested in the existing production system for regular production. During pilot production the producibility aspect of the product design is checked and the ability of the -manufacturing process to execute at a commercial production rate is tested. At this stage, all tooling and equipments should be in place and all suppliers and sub-contractors should be ready for volume production. At this stage, the total system including design, detailed engineering, tools and equipment, parts, assembly sequences, production supervisors, technicians and operators come together to execute pilot production.

Phase 5: The final phase of development is bulk production or commercialisation. In this phase, production starts at a relatively low volume and as the organisation develops confidence in its abilities to execute production consistently, and marketing establishes its abilities to sell the products, the volume of production is increased to meet the market demand.

SOURCES OF IDEAS FOR DESIGNING NEW PRODUCTS OR REDESIGNING THE PRODUCTS

Ideas for new and improved products may come both from within the organisation and from outside. Internal sources include employees, sales people, purchasing agents etc., whereas external sources include customers, competitors and suppliers. One approach to include "voice of the customer" in product design is known as *"Quality Function Deployment*" Customer complaints, product failures and warranty claims provide valuable insight into areas that need improvement. Also, ideas can be obtained by studying competitor's products and their operations (pricing policies, warranties, location strategies, processing strategies etc.). "*Reverse engineering*" is the process in which some companies buy competitor's product and dismantle and inspect it and then adapt that design to improve their own product.

Research and Development (R & D) refers to the organised efforts of an organisation directed towards increasing scientific knowledge and product innovation. R & D efforts may involve basic research, applied research or development. Basic research advances the state of knowledge about a field of knowledge (product technology) and applied research attempts to achieve commercial applications for basic research, Development converts the results of applied research into useful commercial applications (i.e., products and services).

Some organisations, instead of investing in their own research and development efforts, enter into collaboration with firms of developed countries and buy their design know-how by paying the know-how charges. This approach for product design is known as *transfer of technology (TOT).* Another way of producing new products is under licence production in which a firm produces a "new product" by obtaining licence for producing the same by entering into licence agreement with a firm of developed country. In such cases the firm producing the product under licence production has to pay royalty for every unit of product produced, to the licencing firm.

8.14. STAGES IN PRODUCT DESIGN

The various stages through which a product design passes are: (i) conception, (ii) acceptance, (iii) execution, (iv) evaluation, (v) translation and (vi) pre-production.

These stages are briefly discussed in the following paragraphs.

i. **Conception:** In this stage a draft copy of product specifications are prepared by the marketing department in consultation with the design department. The purpose of the draft specification is to help designers understand what exactly the customers expect from the product and also to let the marketing people understand the cost of the proposed product. The design specifications should include informations about the product such as requirements regarding performance, aesthetics (appearance) safety, reliability, serviceability, maintainability, delivery and also informations such as maximum price to the customer, estimated volume of demand for the product and maximum acceptable cost of design and development of the product.

ii. **Acceptance:** The draft specification is scrutinised for checking the technical feasibility and economic viability. If the specification is not accepted, it may have to be modified or rejected and such decisions are taken jointly by design and marketing departments.

iii. **Execution:** This stage involves the conversion of design specifications into drawings (preliminary design) to build the prototype model of the product. The prototype model should be a true replica of the proposed new product satisfying all the requirements of the customer. Sometimes it may be necessary to build more models of prototype (For example, 'A' model, 'B' Model, 'C' model etc.,) First 'A' model is built and tested, if not satisfactory, the design is modified and then 'B' model is built and tested and so on till a satisfactory prototype model is built and tested. This stage establishes the feasibility of the proposed product design.

iv. **Evaluation and Review of Design:** The design is evaluated by a cross functional team having representatives from finance, marketing, manufacturing and service departments to achieve **optimal design** (trading off between product quality and cost).

The design is reviewed to ensure that all requirements of the product such as function, aesthetics (appearance), materials and process alternatives, and their costs, economic assembly, repair and maintenance, lead time required for installing the new process and training the labour etc., are met by the product design.

v. **Translation:** In this stage based on the experiences in the previous stages, the detailed engineering drawings for parts, subassemblies, final assemblies, parts lists etc., are prepared. These documents are known as provisional design documents which take into account the producibility aspects of the design. Also, detailed estimates of costs are prepared at this stage.

vi. **Preproduction:** A pilot production run is carried out using the provisional design documents and the producibility aspect is proved in this stage. Based on the experience gained in preproduction, the provisional design is modified into final design which is approved for bulk production later.

8.15. DESIGN DOCUMENTS FOR PRODUCTION

The design documents comprise the product specification in the form of various design drawings and other documents such as product structure tree, bill of materials, parts lists, engineering drawings for bought- out parts, in-house manufactured parts, assembly drawings, assembly charts, inspection procedures, testing procedures, installation and maintenance manuals, recommended spares list etc. The bill of materials lists the components, their description, and the quantity of each required to make one unit of the product. A product structure tree indicates the various levels of sub assemblies and different subassemblies required to build the product. Engineering drawings show the dimensions, tolerances, materials and finishes of a manufactured part. For bought-out items it gives the supplier's reference number for the item and supplier's name. An assembly drawing shows an exploded view of the product. It is usually a three dimensional drawing, known as isometric drawing in which the relative locations of the components are drawn in relation to each other to show how to assemble the unit. Every subassembly has a parts list which lists all the different parts and components used in the assembly or the product. It gives the part number, description, quantity per unit etc...for each part or item that goes into the assembly.

Engineering change notices indicate the correction or modification to an engineering drawing, parts list or bill of material or an assembly drawing.

EFFECT OF PRODUCT DESIGN ON PRODUCT COST

The cost of product is in-built in product design, which means, the production cost and thereby the product cost is decidedly determined by the product design. Product cost is based on cost of materials used, labour cost (direct and indirect), cost of machine hours or equipment hours spent for production, cost of power or energy and overhead costs. Since, product design specifies what raw-materials and components are used for making the product, the designer has to select the most economic materials without affecting the performance specifications of the product. Value engineering approach helps in this effort. Also, the process technology and manufacturing equipment’s and tools to be used to carry out the conversion process depend on.

The type of materials specified in the design and also the tolerances specified on various design parameters. The various approaches to product design such as design for manufacture and assembly, design for producibility, simplification and standardisation, designing for automation, value engineering, modular design, designing for recycling and computer aided design reduces the cost of design and cost of production to the minimum possible without affecting the product performance specifications and other product quality attributes to satisfy the customer needs.Also, since design assures product quality, wastages are reduced to the minimum and productivity increases. Hence, we can conclude that since product quality and cost are in built in the design itself and the process design very much depends on product design, the product cost is determined by the product design.

8.16. LET US SUM UP

A product is something sold by an enterprise to its customers. We define a product as anything that can be offered to a market for attention, acquisition, use or consumption and that might satisfy a want or need. Products include more than just tangible goods, they include physical objects, (tangibles) services (intangibles), events, persons, places, ideas, organisations or a combination of these entities. However, we use the term product to refer to tangible goods in this book because of its importance in the study of production and materials management.

The production department converts the product design into a reality (a tangible product) ensuring that the output of the production system-a tangible product meets all the design specifications and provides the necessary benefits sought by the customers, These include, quality, cost (producibility or economic production), speed to market and flexibility which offer competitive advantage to the manufacturing firm.

A company has to be good at planning, developing and managing new products. Since every product goes through a life cycle (having various phases or stages such as introduction, growth, maturity, saturation, decline and obsolescence) new products must be planned, developed and launched to the market to replace existing products which are in the later stages of their life cycles namely saturation, decline or obsolescence.

Successful product development results in products that can be produced and sold profitably. That is often difficult to assess quickly and directly. Five specific dimensions, all of which ultimately relate to profit are commonly used to assess the performance of a product development effort.

8.17. KEY TERMS

- ✓ **Product:** is something sold by an enterprise to its customers. We define a product as anything that can be offered to a market for attention, acquisition, use or consumption and that might satisfy a want or need.
- ✓ **Product planning and development:** is the process of searching ideas for new products, screening them systematically, converting them into tangible products and introducing the new products into markets
- ✓ **Stages in a product-life cycle:** are: (i) product development, (ii) introduction, (iii) growth, (iv) maturity, (v) saturation, (vi) decline and (vii) obsolescence
- ✓ **Process Design**: Process design is concerned with the overall sequences of operations required to achieve the design specifications of the product.
- ✓ **Functional design:** is concerned with the first and fore-most requirement of a good product i.e., the product should effectively perform the function for which it is developed

- ✓ **Production Design**: The design of products and services is partially dependent on the productive system design and vice versa.

8.18. SELF – ASSESSMENT QUESTIONS

1) What is a Product? Discuss the Characteristics, need and objectives for Product Planning and Development ?

2) Discuss the role of Production Management in Product Development?

3) Discuss the Product-Life Cycle Concept ? Discuss the factors to be considered in Product Development ?

4) Differentiate between Product Design, Process Design and Production Design ?

5) Discuss the factors influencing Product Design ? Discuss the characteristics and stages of Good Product Design ?

8.19. FURTHER READINGS

1. Jay Heizer and Barry Render, Operations Management, Pearson Publications
2. Amol Palekar and Shreekant Shiralkar, Supply Chain Analytics with SAP NetWeaver Business Warehouse.
3. Muthu Mathirajan and Chandrasekharan Rajendran., Analytics in Operations/Supply Chain Management.
4. Chopra, Sunil, Meindl, Peter and Kalra, D. V.; Supply Chain Management: Strategy, Planning and Operation; Pearson Education
5. Altekar, Rahul V.; Supply Chain Management: Concepts and Cases; PHI Learning
6. Ballou, Ronald H.; Supply Chain Management; Pearson Education
7. Sahay, B.S.; Supply Chain Management; Macmillan
8. Ballou, R.H. Business Logistics Management. Prentice-Hall Inc.
9. Bowersox D.J. ,Closs D.J. , *Logistical Management*, McGraw-Hill, 1996

Block-3

Location and Layout

Unit No.	**Unit Name**
Unit 9	Layout Decision
Unit 10	Location Decisions & Models
Unit 11	Capacity Planning
Unit 12	Decision trees analysis

UNIT 9: LAYOUT DECISIONS

STRUCTURE

LEARNING OBJECTIVES

After go through this unit you will be able to-

- Understand the meaning of facility layout and state the objectives of facility layout
- Discuss the factors affecting facility layout
- Enumerate the principles of layout
- Discuss the importance of facility layout

- Discuss the criteria for selection and design of layouts

9.1 INTRODUCTION

After deciding above the proper site for locating an industrial unit, next important point to be considered by an entrepreneur is to decide about the appropriate layout for the plant. Plant layout is primarily concerned with the internal set up of an enterprise in a proper manner. 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. A plant layout study is an engineering study used to analyze different physical configurations for a manufacturing plant. It is also known as Facilities Planning and Layout. Plant layout refers to the physical arrangement of production facilities. It is the configuration of departments, work centers and equipment in the conversion process. It is a floor plan of the physical facilities, which are used in production.

It is concerned with the orderly and proper arrangement and use of available resources viz., men, money, machines, materials and methods of production inside the factory. A well designed plant layout is concerned with maximum and effective utilisation of available resources at minimum operating costs.

The concept of plant layout is not static but dynamic one. It is on account of continuous manufacturing and technological improvements taking place necessitating quick and immediate changes in production processes and designs. A new layout may be necessary because of technological changes in the products as well as simple change in processes, machines, methods and materials". A new layout also becomes necessary when the existing layout becomes ineffective and poor or is not conducive to the changed circumstances. There are certain indications which raise alarm for immediate changes in the existing layout of plant. These indications may be in the form of excessive manufacturing time, improper storage, lack of control over materials and employees, poor customer service, excessive work in progress and work stoppages etc.

9.2 DEFINITIONS OF PLANT LAYOUT

Some of the famous definitions on plant layout are given below.

According to George R.Terry, “Plant layout is the arrangement of machines, work areas and service areas within a factory”.

According to Hurley, “Plant layout involves the development of physical relationship among building, equipment and production operations, which will enable the manufacturing process to be carried on efficiently”.

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”.

9.3 OBJECTIVES OF PLANT LAYOUT

The primary goal of the plant layout is to maximize 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:

1. Streamline the flow of materials through the plant.
2. Facilitate the manufacturing process.
3. Maintain high turnover of in-process inventory.
4. Minimize materials handling and cost.
5. Effective utilization of men, equipment and space.
6. Make effective utilization of cubic space.
7. Flexibility of manufacturing operations and arrangements.
8. Provide for employee convenience, safety and comfort.
9. Minimize investment in equipment.
10. Minimize overall production time.
11. Maintain flexibility of arrangement and operation.
12. Facilitate the organizational structure.
13. To achieve economies in handling of raw materials, work in- progress and finished goods.

The objectives of plant layout have been nicely explained by Shubin and

Madeheim. "Its objective is to combine labour with the physical properties of a plant (machinery, plant services, and handling equipment) in such a manner that the greatest output of high quality goods and services, manufactured at the lowest unit cost of production and distribution, will result."

9.4 PRINCIPLES OF PLANT LAYOUT

There are different principles to make a plant layout an ideal one, and these principles are:

- **a.** ***Principle of integration:*** A good layout is one that integrates men, materials, machines and supporting services and others in order to get the optimum utilization of resources and maximum effectiveness.
- **b.** ***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.
- **c.** ***Principle of cubic space utilization:*** The good layout is one that utilizes both horizontal and vertical space. It is not only enough if only the floor space is utilized optimally but the third dimension, i.e., the height is also to be utilized effectively.
- **d.** ***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.
- **e.** ***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.
- **f.** ***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.
- **g.** ***Principle of minimum handling:*** A good layout is one that reduces the material handling to the minimum.

9.5 NEED OF PLANT LAYOUT

Many situations give rise to the problem of plant layout. Two plants having similar operations may not have identical layout. This may be due to size of the plant, nature of the process and management's caliber. The necessity of plant layout may be feel and the problem may arise when.

i. There are design changes in the product.
ii. There is an expansion of the enterprise.
iii. There is proposed variation in the size of the departments.
iv. Some new product is to be added to the existing line.
v. Some new department is to be added to enterprise and there is reallocation of the existing department.
vi. A new plant is to be set up.

9.6 MAJOR FACTORS AFFECTING PLANT LAYOUT

Some of the major factors which affect plant layout are:

(a) Policies of management

(b) Plant location

(c) Nature of the product

(d) Volume of production

(e) Availability of floor space

(f) Nature of manufacturing process and

(g) Repairs and maintenance of equipment and machines

(h) Types of Machines

(i) Climate

(a) Policies of management:

It is important to keep in mind various managerial policies and plans before deciding plant layout. Various managerial policies relate to future volume of production and expansion, size of the plant, integration of production processes; facilities to employees, sales and marketing policies and purchasing policies etc. These policies and plans have positive impact in deciding plant layout.

(b) Plant location:

Location of a plant greatly influences the layout of the plant. Topography, shape, climate conditions, and size of the site selected will influence the general arrangement of the layout and the flow of work in and out of the building.

(c) Nature of the product:

Nature of the commodity or article to be produced greatly affects the type of layout to be adopted. In case of process industries, where the production is carried in a sequence, product layout is suitable. For example, soap manufacturing, sugar producing units and breweries apply product type of layout. On the other hand in case of intermittent or assembly industries, process type of layout best suited. For example, in case of industries manufacturing cycles, typewriters, sewing machines and refrigerators etc., process layout method is best suited. Production of heavy and bulky items need different layout as compared to small and light items. Similarly products with complex and dangerous operations would require isolation instead of integration of processes.

(d) Volume of production:

Plant layout is generally determined by taking into consideration the quantu of production to be produced. There are three systems of production viz.,

(i) Job production: Under this method peculiar, special or non- standardized products are produced in accordance with the orders received from the customers. As each product is non- standardized varying in size and nature, it requires separate job for production. The machines and equipment's are adjusted in such a manner so as to suit the requirements of a particular job. Job production involves intermittent process as the work is carried as and when the order is received. Ship building is an appropriate example of this kind. This method of plant layout viz., Stationery Material Layout is suitable for job production.

(ii) Mass production: This method involves a continuous production of standardized products on large scale. Under this method, production remains continuous in anticipation of future demand. Standardization is the basis of mass production. Standardized products are produced under this method by using standardized materials and equipment. There is a continuous or uninterrupted flow of production obtained by arranging the machines in a proper sequence of operations. Product layout is best suited for mass production units.

(iii) Batch production: It is that form of production where identical products are produced in batches on the basis of demand of customers or of expected demand for products. This method is generally similar to job production except the quality of production. Instead of making one single product as in case of job production a batch or group of products is produced at one time, It should be remembered here that one batch of products has no resemblance with the next batch. This method is generally adopted in case of biscuit and confectionary manufacturing, medicines, tinned food and hardware's like nuts and bolts etc.

(e) Availability of floor space:

Availability of floor space can be other decisive factor in adopting a particular mode of layout. If there is a scarcity of space, product layout may be undertaken. On the other hand more space may lead to the adoption of process layout.

(f) Nature of manufacturing process:

The type of manufacturing process undertaken by a business enterprise will greatly affect the type of layout to be undertaken.

A brief mention of various processes is given us under:

(i) Synthetic process:

Under this process two or more materials are mixed to get a product. For example, in the manufacture of cement, lime stone and clay are mixed.

(ii) Analytical process:

This is just the reverse of synthetic process. Under this method different products are extracted from one material. For example, from crude oil, petroleum, gas, kerosene and coal tar etc. are extracted.

(iii) Conditioning process:

Under this process the original raw material is given the shape of different products

(iv) Extractive process: This method involves the extraction of a product from the original material by the application of heat or pressure. This involves the process of separation, for example, aluminium is separated from bauxite and nothing is added to it. Jute is an important example of this kind.

(g) Repairs and maintenance of equipment and machines:

The plant layout should be designed in such a manner as to take proper care with regard to repairs and maintenance of different types of machines and equipment being used in the industry. The machines should not be installed so closely that it may create the problems of their maintenance and repairs. It has been rightly said that "Not only should access to parts for regular maintenance such as oiling, be considered in layout but also access to machine parts and components when replacement and repair are fairly common".

(h) Type of machines:

Stationary layout is preferable if machines are heavy and emit more noise. Such heavy machinery can be fitted on the floor. Adequate space should be provided for the location of machines and also there should be sufficient space between them to avoid accidents.

(i) Climate:

Temperature, illumination, ventilation should be considered while deciding on the type of layout. The above factors should be considered in order to improve the health and welfare of employees.

9.7 THE IMPORTANCE OF LAYOUT

The importance of a layout would be better appreciated if one understands the influence of an efficient layout on the manufacturing function: it makes it smooth and efficient. Operating efficiencies, such as economies in the cost of handling materials, minimization of production delays and avoidance of bottlenecks all these depend on a proper layout. An ideally laid out plant reduces manufacturing costs through reduced materials handling, reduced personnel and equipment requirements and reduced process inventory.

The objectives or advantages of an ideal layout are outlined in the paragraphs that follow. The advantages are common to all the plants, irrespective of age; and whether a plant employs 50 workers or 50,000 makes no difference in so far as the applicability of the plant layout advantages is concerned. Some of these advantages are:

(a) Economies in Handling

Nearly 30% to 40% of the manufacturing cost is accounted for, by materials handling. Every effort should, therefore, be made to cut down on this cost.

Long distance movements should be avoided and specific handling operations must be eliminated. A cynic may say that the cheapest way to handle materials is not to handle them at all. But, in a factory, materials have to be handled; and therefore, it all depends on the layout.

(b) Effective Use of Available Area

Every inch of the plant area is valuable, especially in urban areas. Efforts should therefore be made to make use of the available area by planning the layout properly. Some steps for achieving this end are: location of equipment and services in order that they may perform multiple functions; development of up-to-date work areas and operator job assignments for a full utilization of the labor force.

c) Minimization of Production Delays

Repeat orders and new customers will be the result of prompt execution of orders. Every management should try to keep to the delivery schedules. Often, the deadline dates for delivery of production orders are a bug-a-boo to the management. Plant layout is a significant factor in the timely execution of orders. An ideal layout eliminates such causes of delays as shortage of space, long-distance movements of materials, spoiled work and thus contributes to the speedy execution of orders.

(d) Improved Quality Control

Timely execution of orders will be meaningful when the quality of the output is not below expectations. To ensure quality, inspection should be conducted at different stages of manufacture. An ideal layout provides for inspection to ensure better quality control.

(e) Minimum Equipment Investment

Investment on equipment can be minimized by planned machine balance and location, minimum handling distances, by the installation of general purpose machines and by planned machine loading. A good plant layout provides all these advantages.

(f) Avoidance of Bottlenecks

Bottlenecks refer to any place in a production process where materials tend to pile up or are produced at a speed, less rapid than the previous or subsequent operations. Bottlenecks are caused by inadequate machine capacity, inadequate storage space or low speed on part of the operators. The results of bottlenecks are delays in productions schedules, congestion, accidents and wastage of floor area. All these may be overcome with an efficient layout.

(g) Better Production Control

Production Control is concerned with the production of the product of the right type, at the right time and at a reasonable cost. A good plant layout is a requisite for good production control and provides the production control officers with a systematic basis upon which to build organization and procedures.

(h) Better Supervision

A good plant layout ensures better supervision in two ways:

1. Determining the number of workers to be handled by a supervisor and
2. Enabling the supervisor to get a full view of the entire plant at one glance.

A good plant layout is, therefore, the first step to good supervision.

i) Improved Utilization of Labor

Labor is paid for every hour it spends in the factory. The efficiency of a management lies in utilizing the time for productive purpose. A good plant layout is one of the factors in effective utilization of labor. It makes possible individual operations, the process and flow of materials handling in such a way that the time of each worker is effectively spent on productive operations.

(j) Improved Employee Morale

Employee morale is achieved when workers are cheerful and confident. This state of mental condition is vital to the success of any organization.

i. Morale depends on:
ii. Better working condition;
iii. Better employee facilities;
iv. Reduced number of accidents;
v. Increased earnings.

Plant layout has a bearing on all these.

(k) Avoidance of Unnecessary and Costly Changes

A planned layout avoids frequent changes which are difficult and costly. The incorporation of flexibility elements in the layout would help in the avoidance of revisions.

9.8 APPLICABILITY OF PLANT LAYOUT

Plant layout is applicable to all types of industries or plants. Certain plants require special arrangements which, when incorporated make the layout look distinct from the types already discussed above. Applicability of plant layout in manufacturing and service industries is discussed below.

In case of the manufacturing of ‘detergent powder’, a multi-storey building is specially constructed to house the boiler. Materials are stored and poured into the boiler at different stages on different floors. Other facilities are also provided around the boiler at different stations.

Another applicability of this layout is the manufacture of ‘talcum powder’.

Here machinery is arranged vertically i.e. from top to bottom. Thus, material is poured into the first machine at the top and powder comes out at the bottom of the machinery located on the ground floor.

Yet another applicability of this layout is the ‘newspaper plant’, where the time element is of supreme importance, the accomplishment being gapped in seconds. Here plant layout must be simple and direct so as to eliminate distance, delay and confusion. There must be a perfect coordination of all departments and machinery or equipments, as materials must never fail.

Plant layout is also applicable to ‘five star hotels’ as well. Here lodging, bar, restaurant, kitchen, stores, swimming pool, laundry, shaving saloons, shopping arcades, conference hall, parking areas etc. should all find an appropriate place in the layout. Here importance must be given to cleanliness, elegant appearance, convenience and compact looks, which attract customers.

Similarly plant layout is applicable to a ‘cinema hall’, where emphasis is on comfort, and convenience of the cinemagoers. The projector, screen, sound box, fire-fighting equipment, ambience etc. should be of utmost importance.

A plant layout applies besides the grouping of machinery, to an arrangement for other facilities as well. Such facilities include receiving and dispatching points, inspection facilities, employee facilities, storage etc.

Generally, the receiving and the dispatching departments should be at eight end of the plant. The storeroom should be located close to the production, receiving and dispatching centers in order to minimize handling costs. The inspection should be right next to other dispatch department as inspections are done finally, before dispatch.

The maintenance department consisting of lighting, safety devices, fire protection, collection and disposal of garbage, scrap etc. should be located in a place which is easily accessible to all the other departments in the plant. The other employee facilities like toilet facilities, drinking water facilities, first aid room, cafeteria etc. can be a little away from other departments but should be within easy reach of the employees. Hence, there are the other industries or plants to which plant layout is applicable.

9.9 LET'S SUM-UP

An efficient plant layout is one that aims at achieving various objectives like efficient utilization of available floor space, minimizes cost, allows flexibility of operation, provides for employees convenience, improves productivity etc.

The entrepreneurs must possess the expertise to lay down a proper layout for new or existing plants. It differs from one plant to another. But basic principles to be followed are more or less same. Designing of layout is different in all above three categories e.g. manufacturing unit may follow one of Product, Process, and fixed position or combined layout, as the case may be. Traders might go either for self-service or full service or special layouts whereas service establishments such as motels, hotels, and restaurants must give due attention to customer convenience, quality of service, efficiency in delivering the service etc. While deciding for layout for factory or unit or store, a small entrepreneur has to consider the factors like the nature of the product, production process, size of factory building, human needs etc. Plant layout is applicable to all types of industries or plants. At the end, the layout should be conducive to health and safety of employees. It should ensure free and efficient flow of men and materials. Future expansion and diversification may also be considered while planning factory layout.

9.10 KEY TERMS

- Plant Layout
- Work Center

- Material Handling
- Job Production
- Mass Production
- Synthetic Industry

9.11 SELF-ASSESSMENT QUESTIONS

(i) Define the plant layout. What are the various factors influencing the layout of grocery store?

____

____

____

(ii) "Plant Layout involves, besides grouping of machinery, an arrangement of other facilities also". Discuss

____

____

____

9.12 MODEL QUESTIONS

1. What are the principles for planning the layout of a new factory?
2. What is plant layout? Discuss the objectives of a good layout.
3. Point out the differences between product layout and process layout.

9.13 FURTHER READINGS

- Gupta C.B., Operations Management and Control, SSultan Chand and Sons, New Delhi
- Aswathappa K., Productions and Operations Management, Himalaya Publishing House, New Delhi
- Panneerselvam R., Production and Operations Management, PHI Learning Private Ltd, New Delhi
- Bhattacharya Subimal, Operations Management, PHI Learning Private Ltd, New Delhi
- Ahuja K.K, Production Management, CBS Publishers, New Delhi

- Bedi K., Productions and Operations Management, Oxford University Press, New Delhi

UNIT-10: LOCATIONS DCISIONS AND MODELS

Structure

Learning Objectives

The basic objective of this unit is to introduce various concepts of plant location decisions & the relevant models. After going through this unit, a student will be able to:

- Define the plant location
- Elaborate the nature & scope of plant location decision
- Understand the importance of plant location
- Examine the role of different models related to plat location decision

10.1 INTRODUCTION

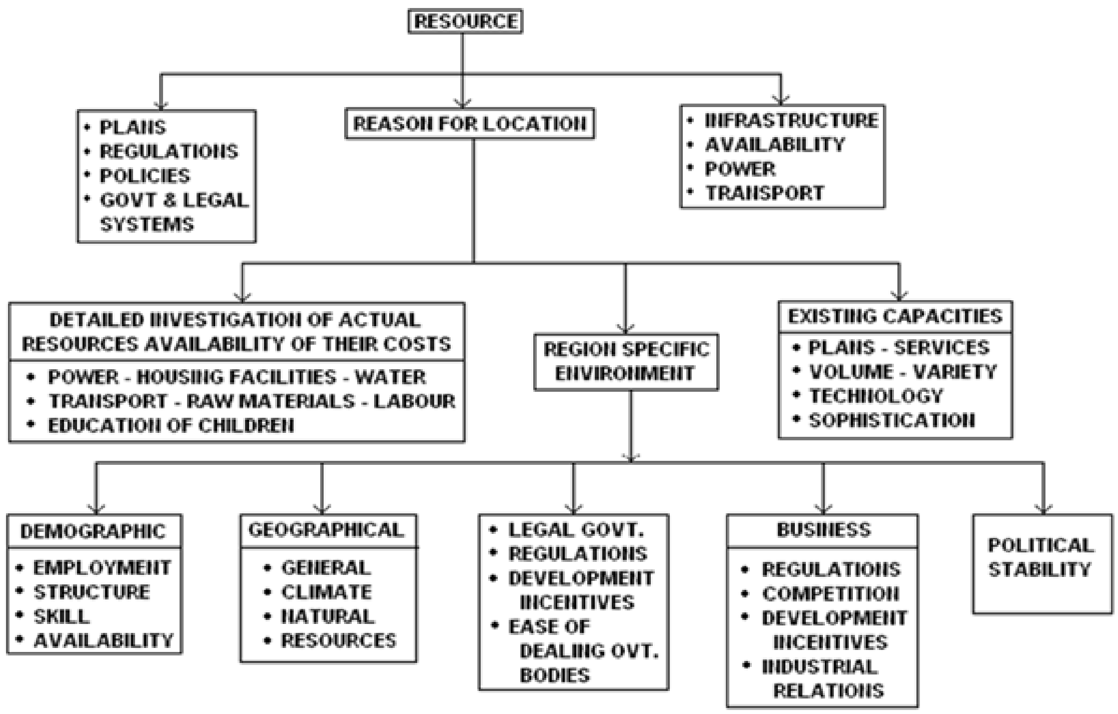
In a rapidly changing environment, the plant location preferences are shifting very fast and the marketers are not in a position to understand them. Today in a competitive market, every organization strive towards the achievement of the organizational target by aligning various types of organizational strategies such as plant location etc. Plant location plays a vital role in the fulfillment of targets as well as it is also helpful to provide quality assured products and services to the prospect customers. The performance of any manufacturing unit is considerably affected by its location. The location of the industry is as important as the choice of location for a Business or a retail outlet. Selection of location for the operations, involves a long-term commitment about the geographical factors that affect any industry.

Plant location is a very important part of any organization & there are so many factors affect ting on it. According to Dr. Visweswarayya, the decision of plant location should be based on the 'Nine M's' namely, Money, Material, Manpower, Market, Motivational power, Management, Machinery, Means of communication and Momentum to early start.

Availability of Raw Materials: An ideal location is one where the main raw material required to manufacture the product is adequately available. This will ensure regular supply of raw material and will also reduce the transport cost, for example, the location of textile mills at Mumbai and Ahmadabad, iron and steel industries at Jamshedpur and jute mills in Kolkata.

1. Nearness proximity to Potential Market: If the plant is located near the market, the management can keep in close touch with the changes in the market environment and formulate its production policies accordingly. Now-a-days, with the expansion of markets, both at the national and the international levels, this aspect is becoming secondary. The transport and other overheads are likely to increase with the increase in distance between the plant and the market. Also, in case of a factory being near to the market, the risk of damage during transportation, loss of demand due to change in fashions, etc., are also reduced, for example, the glass industry as well as the chemical and drug factories.
2. Nearness to power source: Some industries require continuous and adequate supply of power. For example, nylon and fiber plants. Availability of low cost electricity may be more important for industries in such a case the location of the plant near to power stations will provide cheap electricity.
3. Supply of Labour: Labour is one of the most important inputs in an industrial enterprise. There should be regular and cheap supply of labour, especially unskilled labour. This is vital for labour based industries.
4. Transport and Communication Facilities: Transport is very important for bringing raw material and fuel from different places and for marketing the finished goods, etc. The region well connected with rail, road, water and air transport systems is considered to be more appropriate for the location of plants. Similarly, good communication facilities like postal and telecommunication links play a significant role in the success of an enterprise.

5. Integration with other establishments in a group of companies: A new enterprise owned or operated by a single group of companies should be located such that its work can be integrated with the work of the associated establishments.
6. Suitability of land and climate: The subsoil of the location should be able to support the load likely to be placed on it. Similarly, the climatic conditions like humidity, temperature and other atmospheric conditions should be favourable for the plant, for example, a very damp climate may not favour the textile and cotton industries. The climatic conditions also determine the heating and ventilation requirements for the industry.
7. Availability of housing, other amenities and services: A good housing facility with adequate number of shops, theatres, restaurants, local transport system and sufficient supply of gas and water as well as provision for drainage and disposal of waste, etc., can easily attract good staff.
8. Local building and planning regulations: The proposed location should not infringe local regulations and by-laws for the construction of buildings, local taxes, etc.
9. Safety requirements: Industries like nuclear power stations using processes that are explosive in nature and chemical process likely to pollute the atmosphere should be located in remote areas, on the outskirts of a city or village, away from the residential areas.



10.2 Steps in selection of Location

Every business is facing the issue of selecting the suitable location for their factory plant. Units concerning both manufacturing as well as the assembling of the products are on a very large scale affected by the decisions involving the location of the plant. Location of the plant itself becomes a very important factor concerning service facilities, as the plant location decisions are strategic and long-term in nature. Plant location refers to the choice of region and the selection of a particular site for setting up a business or factory.

To be systematic, in choosing a plant location, the enterprises should do well to proceed step by step, like:

1. Within the country or outside;
2. Selection of the region;
3. Selectors of the locality or community;
4. Selection of the exact site.
5. Deciding on Domestic or International Location

6. The choice of a 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.
7. Selection of Region The selection of a particular region out of the many natural regions of a country is the second step in plant location.

In this context, we can take some help from weber's theory of plant location:

(a) **Alfred Weber's Theory of the Location of Industries**

Alfred Weber (1868-1958), with the publication of Theory of the Location of Industries in 1909, put forth the first developed general theory of industrial location. His model took into account several spatial factors for finding the optimal location and minimal cost for manufacturing plants.

The point for locating an industry that minimizes costs of transportation and labour requires analysis of three factors:

1. The point of optimal transportation based on the costs of distance to the 'material index'—the ratio of weight to intermediate products (raw materials) to finished product.
2. The labour distortion, in which more favourable sources of lower cost of labour may justify greater transport distances.
3. Agglomeration and degglomerating.

Agglomeration or concentration of firms in a locale occurs when there is sufficient demand for support services for the company and labour force, including new investments in schools and hospitals. Also supporting companies, such as facilities that build and service machines and financial services, prefer closer contact with their customers.

Degglommeration occurs when companies and services leave because of over concentration of industries or of the wrong types of industries, or shortages of labour, capital, affordable land, etc.

10.3 Advantages and Disadvantages of plant location and its decisions

As we have already observed that for the holistic developmentof an organization, selection of a suitable plant location is very important. Most of the cases, the sustainability of the enterprise also depends on its locational aspects.

10.3.1 Selection of Site in an Urban Area: The advantages and disadvantages of selection of Site in an urban areas:

Advantages:

1. It is sometimes possible to find an existing building which can be used to house the factory.

2. It is easier to sell the building, if it is desired, at later stage.

3. Power and water is easily available.

4. If other factories are also situated in a big city, there will be good opportunity for discussing and having exchange of knowledge.

5. Good market for small manufacturers.

6. It is well served by railways and roads from various parts of the country so that transportation of incoming and outgoing materials is convenient and cheap.

7. It is a good labour market, where all types of labour available. Seasonal labour is also easily obtained than in a smaller centre of population, specially where unskilled labour is required.

8. Workers find easy to change job from one industry to other, if required.

9. Services of repairs and maintenance etc. can be available with existing industries.

10. Large number of government of facilities will be easily available like-Post office, Banks, Railways, Police and Fire protection.

11. Houses for workers are easily available.

12. Education for the children is not a problem.

13. Transport is easy.

Disadvantages:

1. Often sites are limited in area as sufficient land is not available and congested. Hence climate is not healthy.

2. Area being limited, it may not be possible to arrange the equipment to the best of advantages.

3. The cost of land is high and rates are liable to increase further. Land for expansion is not available at reasonable rates. The larger the city, the larger the land value.

4. Because of high standard of living, higher wages of labour will have to be paid.

5. More problems about labour and employer relations.

6. Cost of building factory will be high.

7. High taxes.

10.3.2 Selection of Site in a Rural Area

The advantages and disadvantages of selection of sites in a rural areas has been discussed hereunder:

Advantages:

1. The cost of land is less than in a city area and usually easier to provide space for future expansion.

2. The cheapness of land enables a more efficient layout of works to be made and gives greater freedom in selecting the most economic design for the buildings.

3. Rail or road connection can be arranged easily.

4. Labour supply may be arranged from the nearby areas or by transport from the city. Labour is cheaply available.

5. Housing can be provided by private enterprises or by local authorities.

6. Healthy surrounding and pleasant atmosphere.

7. Less labour trouble.

8. Lesser taxes and restriction.

Disadvantages:

1. Sufficient power and water facilities may not be available.

2. Enough facilities for expansion may not be available.

3. Repairing work may become difficult, because of less industry in the area.

4. Skilled workers are not easily available.

5. No recreational facilities.

6. Facilities for education to children and adults (part time courses) may not be avail-able.

7. Government facilities may not be sufficient.

8. Transport and housing facilities may not be satisfactory.

10.4 Different Models of Plant Location Decision

Plant location is a vital factor for any organization for its growth & development. There are various methods & models which are associated with it. They are explained here as follows:

1. Subjective Techniques:
   (a) Industry precedence,
   (b) Preferential factor and
   (c) Dominant factor.

2. Qualitative Techniques (Factor ranking system)

3. Semi-quantitative Techniques (Factor weight-rating system)

4. Quantitative Techniques (Operation Research Models):

   (a) Break-even analysis.
   (b) Economic/cost analysis, and
   (c) Transportation model

Three subjective techniques used for facility location are Industry Precedence, Preferential Factor and Dominant Factor. In the industry precedence subjective technique, the basic assumption is that if a location was best for similar firms in the past, it must be the best for the new one now. As such, there is no need for conducting a detailed location study and the location choice is thus subject to the principle of precedence - good or bad.

However, in the case of the preferential factor, the location decision is dictated by a personal factor. It depends on the individual whims or preferences e.g. if one belongs to a particular state, he / she may like to locate his / her unit only in that state. Such personal factors may override factors of cost or profit in taking a final decision. This could hardly be called a professional approach though such methods are probably more common in practice than generally recognized.

However, in some cases of plant location there could be a certain dominant factor (in contrast to the preferential factor) which could influence the location decision. In a true dominant sense, mining or petroleum drilling operations must be located where the mineral resource is available. The decision in this case is simply whether to locate or not at the source.

1. Factor-Point Rating Method

Now for a last one, establish a subjective.- scale common to all factors. Assign points against the subjective scale for each factor and assign the factor points of the subjective rating for each factor. For example, five subjective ratings–Poor, Fair, Adequate, Good and Excellent were selected to be used in evaluating each site for each factor. For each of the factors, `adequate' was assigned a value zero and then negative and positive relative worth weights were then assigned the subjective ratings below and above adequate for each factor in Table 5.

Table 5
Factor Point Ratings Sample

		Poor	Fair	Adequate	Good	Excellent
Factor	F_1 water Supply	-15	12	0	6	10
	F_2 Appearance of site	-3	-1	0	1	2

The range between minimum and maximum weights assigned; to a factor in effect weighs that factor against all other factors in a manner equivalent to the method (iii) described just previous to this one. Each location site S1 to S4 were then rated by selecting the applicable subjective rating for each factor for each, location and the equivalent points of that subjective `factor rating assigned to the factor. Thus we can now obtain Table 6.

Table 6
Decision Matrix

Factors	Potential Sites			
	S1	S2	S3	S4
F1	(Adequate) 0	(Fair) 12	(Good) 6	(Adequate) 0
F2	(Adequate) 0	(Poor) 3	(Excellent) 3	(Fair) 1
F3	(Adequate) 0	(Adequate) 0	(Adequate) 0	(Adequate) 0
Site Rating	0	-15	9	-1

*Sample Calculation – 15 = (-12) + (-3) + (0)

Accordingly Site 3 with the highest rating of 9 would be chosen.

2. **Equal Weights Method**

We could assign equal weights to all factors and evaluate each location along the factor scale. For example, Banson, a manufacturer of fabricated metal products selected three factors by which to rate four sites. Each site was assigned a rating of 0 to 10 points for each factor. The sum of the assigned factor points constituted the site rating by which it could be compared to, other sites.

Factor ↓ \ Potential Sites →	S_1	S_2	S_3	S_4
F_1	2	5	9	2
F_2	3	3	8	3
F_3	6	2	7	3
Site Rating	11*	10	24	8
Sample Calculation	11	2 + 3 + 6		

F Factor; F_1 Factor 1; S Site; S_1 Site 1

Looking at Table 2, Site 3 has the highest site rating of 24. Hence, this site would be chosen.

Variable Weights Method

The above method could be utilized on account of giving equal weight age to all the factors. Hence, we could think of assigning variable weights to each of the factors and evaluating each location site along the factor scale. Hence, factor Fi. Might be assigned 300 points, factor 2 might be assigned 100 points and factor 3 might be assigned 50 points. Thus the points scored, out of the maximum assigned to each of the factors, for each possible location site could be obtained and again the site rating could be derived as follows:

Table 3
Decision Matrix

Factor	Max. Pts.	Potential Sites			
		S_1	S_2	S_3	S_4
F_1	(300)	200	250	250	50
F_2	(100)	50	70	80	100
F_3	(50)	5	50	10	40
Site Rating		255*	370	340	190

*Sample Calculation 255 = 200 + 50 + 5

Looking at the Table 3, Site 2 has the highest site rating of 370. Hence, this site would be chosen.

10.5 Location Beak-even Analysis

Location Break-even Analysis helps in finding the most economical location alternative. This technique examines the economic aspect of the prospecting sites.

The location providing a minimum cost of production yielding maximum output is to be selected.

Therefore, we estimate the costs from various factors that significantly affect business. After that, we separate all the costs under operating and fixed costs. And then, plot the break-even analysis for each location on the graph.

Formula: Q= F/ (P-C)

Where,

Q = Break-even quantity

p = Price/unit

c = Variable cost/unit

F = Fixed cost

The procedure to solving transportation problems as outlined in Nwadighoha et.al (2010) are as follows:

Step 1: Formulate the Problem: Formulating the given problem and settling it up in a matrix form. Check whether the problem is a balanced or unbalanced problem. If unbalanced, add a dummy source (row) or dummy destination (column) as required.

Step 2: Obtain the Initial Feasible Solution. The initial feasible solution can be obtained by any of the following three methods.

i) Northwest Corner Method (NWC)

ii) Least Cost Method (LCM)

iii) Vogel‟s Approximation Method (VAM)

Step 3: Check for Degeneracy The solution that satisfies the above said conditions N = m+n-1 is a non-degenerate basic feasible solution. Otherwise, it is a degenerate solution. Degeneracy may occur either at the initial stage or at subsequent interactions. If number of allocations, N=m+n-1, then degeneracy does not exist. If number of allocations, N = m+n-1, the degeneracy does exist.

Step 4: Solving Degeneracy To resolve degeneracy at the initial solution, allocate a small positive quantity d e to one or more unoccupied cell that have lowest transportation costs, so as to make m+n-1 allocations (i.e., to satisfy the condition N=m+n-1).The cell chosen for allocating e must be of an independent position. In other words, the allocation of e should avoid a closed loop and should not have a path.

(i) **<u>Northwest Corner Method</u>**

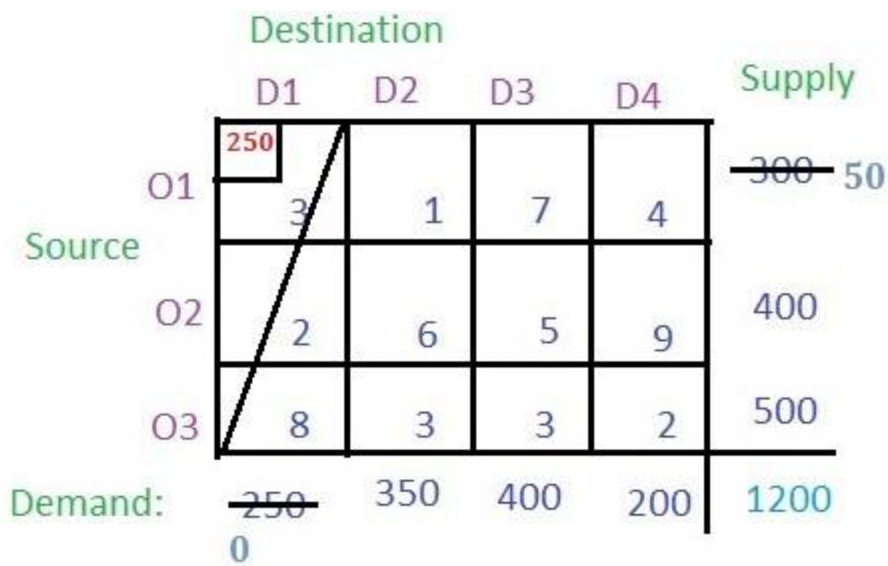
Destination

Source	D1	D2	D3	D4	Supply
O1	3	1	7	4	300
O2	2	6	5	9	400
O3	8	3	3	2	500
Demand:	250	350	400	200	1200

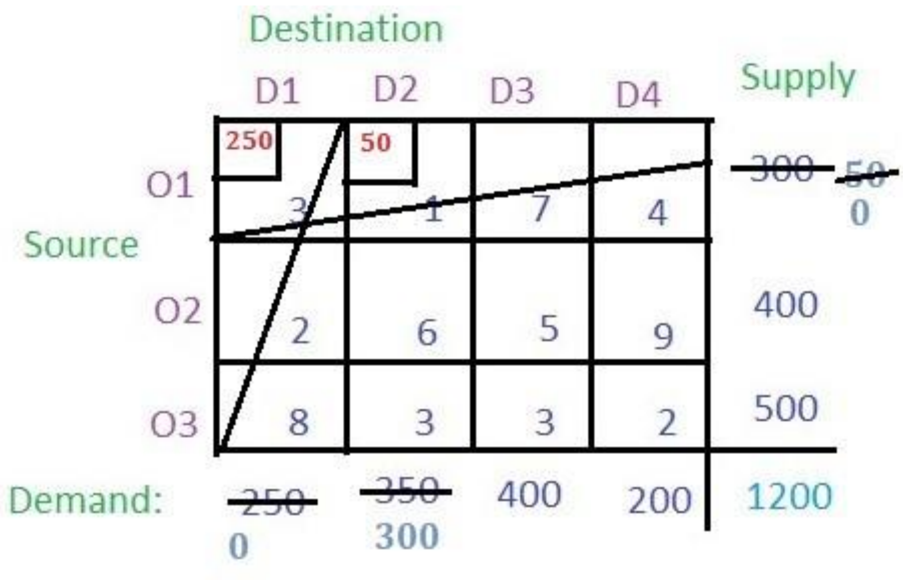
Given three sources **O1**, **O2** and **O3** and four destinations **D1**, **D2**, **D3** and **D4**. For the sources **O1**, **O2** and **O3**, the supply is **300**, **400** and **500** respectively. The destinations **D1**, **D2**, **D3** and **D4** have demands **250**, **350**, **400** and **200** respectively.

Solution: According to North West Corner method, **(O1, D1)** has to be the starting point i.e. the north-west corner of the table. Each and every value in the cell is considered as the cost per transportation. Compare the demand for column **D1** and supply from the source **O1** and allocate the minimum of two to the cell **(O1, D1)** as shown in the figure.

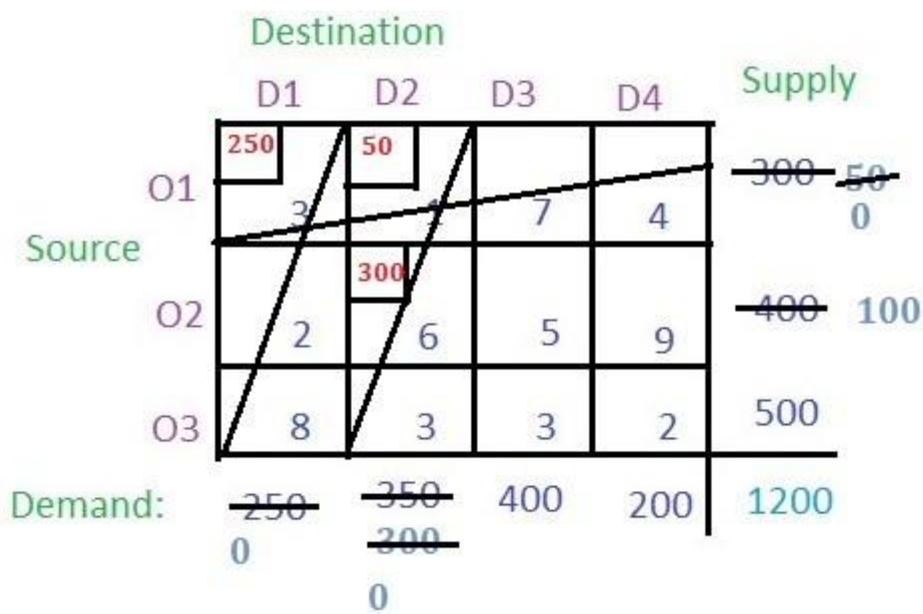
The demand for Column **D1** is completed so the entire column **D1** will be canceled. The supply from the source **O1** remains **300 – 250 = 50**.



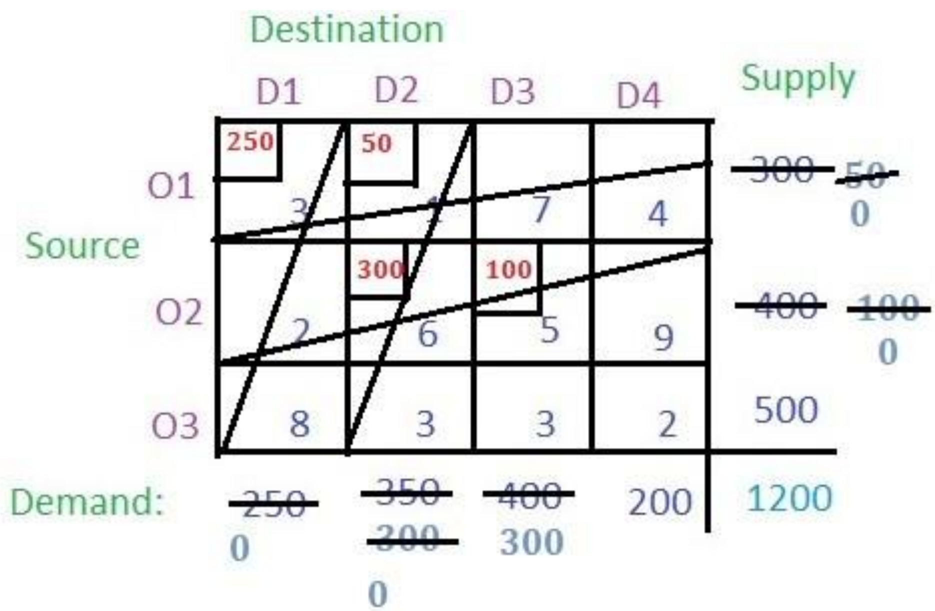
Now from the remaining table i.e. excluding column **D1**, check the north-west corner i.e. **(O1, D2)** and allocate the minimum among the supply for the respective column and the rows. The supply from **O1** is **50** which is less than the demand for **D2** (i.e. 350), so allocate **50** to the cell **(O1, D2)**. Since the supply from row **O1** is completed cancel the row **O1**. The demand for column **D2** remain **350 – 50 = 300**.



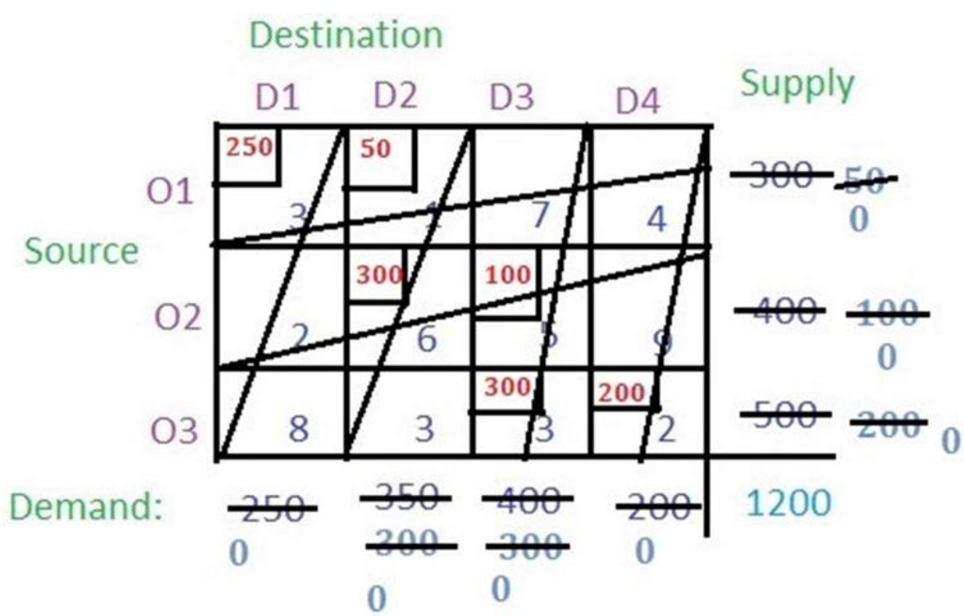
From the remaining table the north-west corner cell is (O2, D2). The minimum among the supply from source O2 (i.e 400) and demand for column D2 (i.e 300) is 300, so allocate 300 to the cell (O2, D2). The demand for the column D2 is completed so cancel the column and the remain



Now from remaining table find the north-west corner i.e. **(O2, D3)** and compare the **O2** supply (i.e. 100) and the demand for **D2** (i.e. 400) and allocate the smaller (i.e. 100) to the cell **(O2, D2)**. The supply from **O2** is completed so cancel the row **O2**. The remaining demand for column **D3** remains **400 – 100 = 300**.



Proceeding in the same way, the final values of the cells will be:



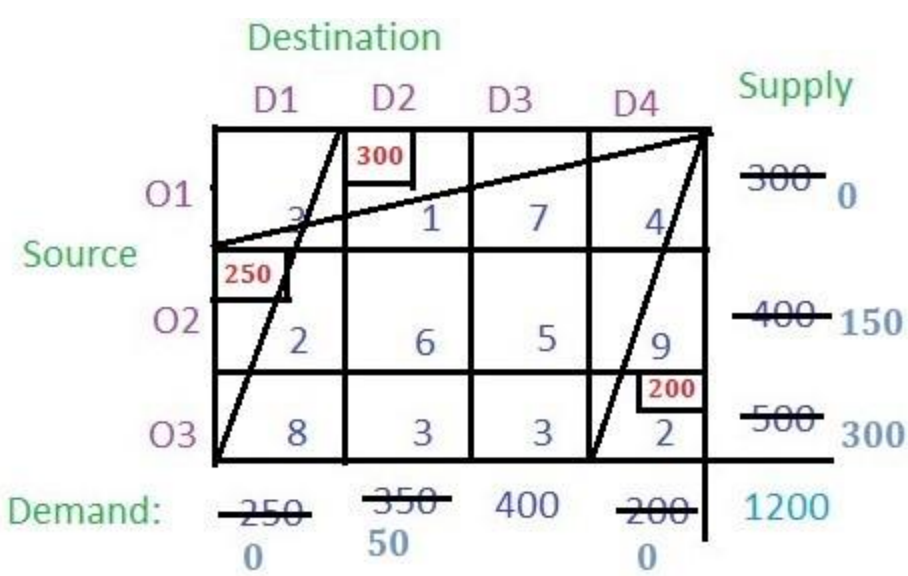
Note: In the last remaining cell the demand for the respective columns and rows are equal which was cell **(O3, D4)**. In this case, the supply from **O3** and the demand for **D4** was **200** which was allocated to this cell. At last, nothing remained for any row or column.

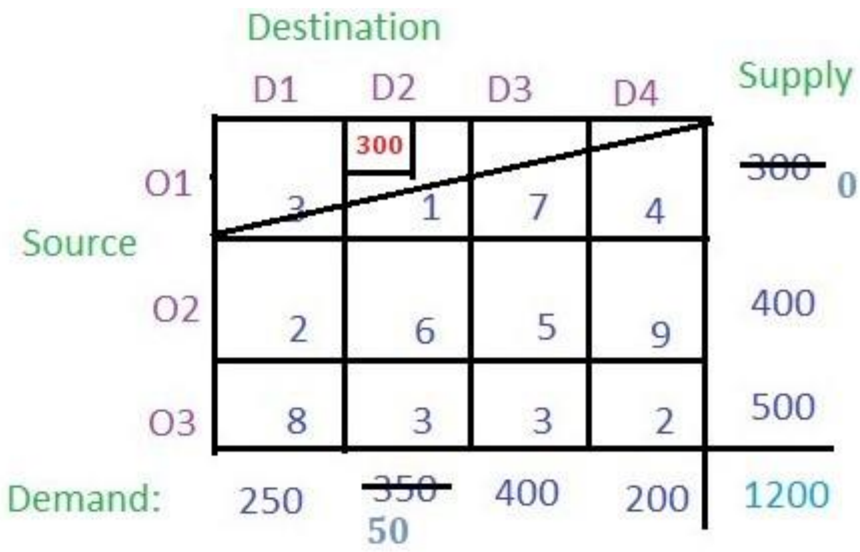
Now just multiply the allocated value with the respective cell value (i.e. the cost) and add all of them to get the basic solution i.e. **(250 * 3) + (50 * 1) + (300 * 6) + (100 * 5) + (300 * 3) + (200 * 2) = 4400**.

(ii) **Least Cost Cell Method**:

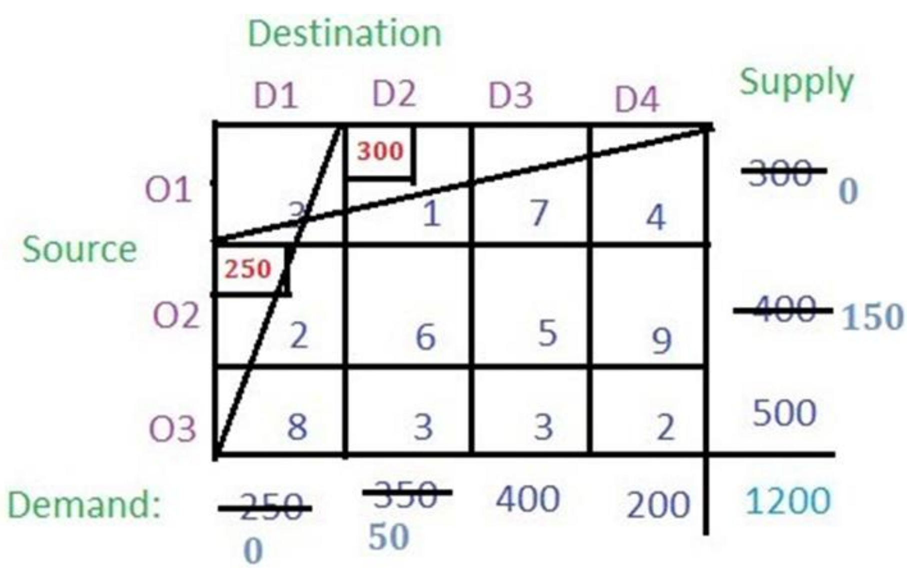
Source	D1	D2	D3	D4	Supply
O1	3	1	7	4	300
O2	2	6	5	9	400
O3	8	3	3	2	500
Demand:	250	350	400	200	1200

Solution: According to the Least Cost Cell method, the least cost among all the cells in the table has to be found which is **1** (i.e. cell **(O1, D2)**). Now check the supply from the row **O1** and demand for column **D2** and allocate the smaller value to the cell. The smaller value is **300** so allocate this to the cell. The supply from **O1** is completed so cancel this row and the remaining demand for the column **D2** is **350 – 300 = 50**.

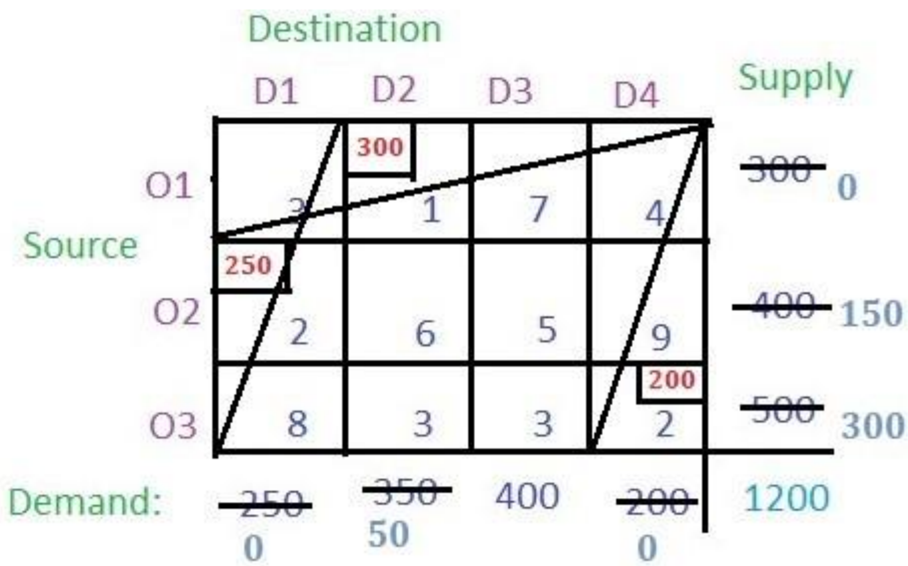




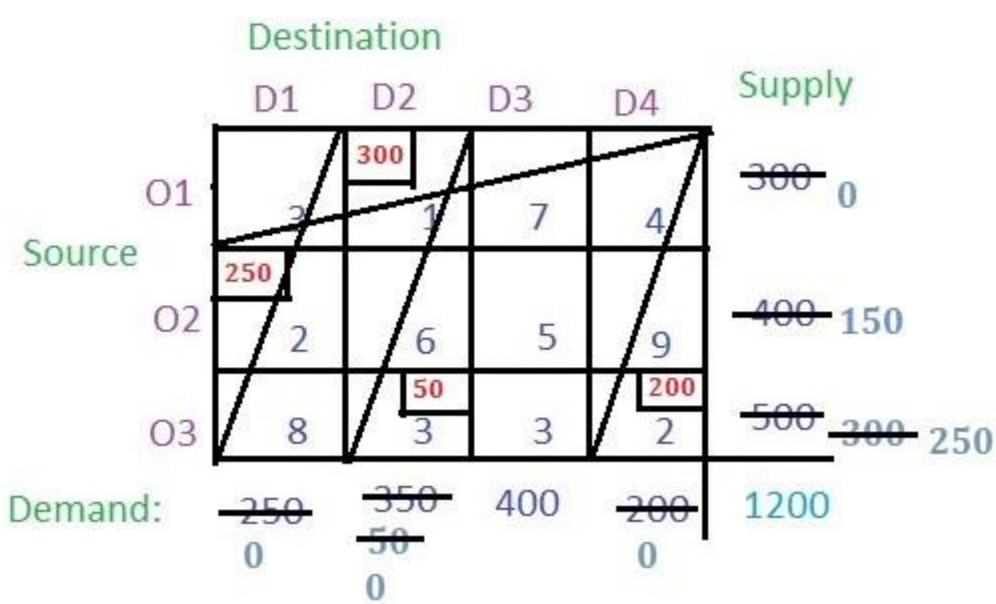
Now find the cell with the least cost among the remaining cells. There are two cells with the least cost i.e. **(O2, D1)** and **(O3, D4)** with cost **2**. Lets select **(O2, D1)**. Now find the demand and supply for the respective cell and allocate the minimum among them to the cell and cancel the row or column whose supply or demand becomes **0** after allocation.



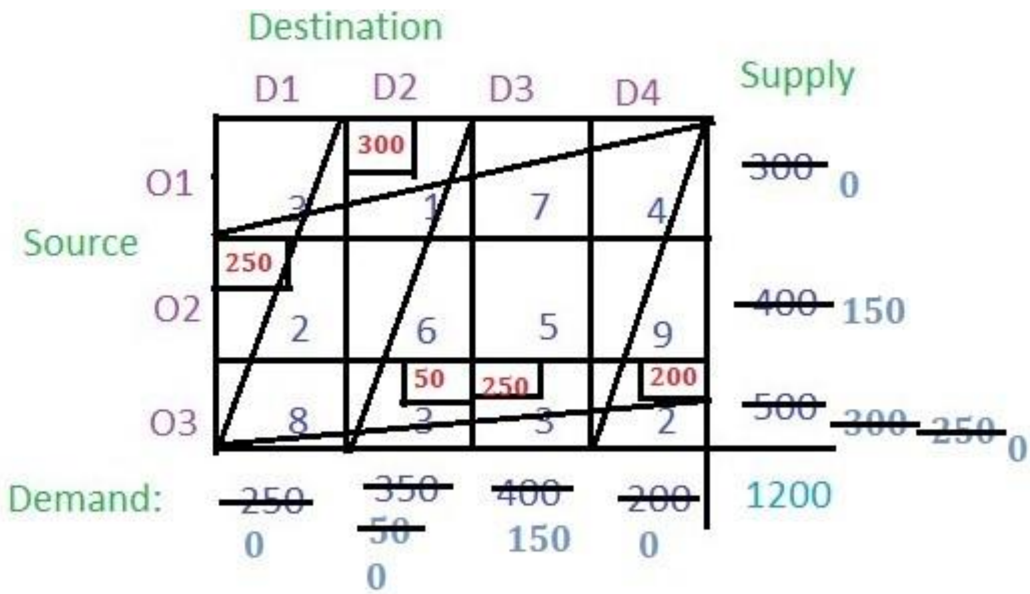
Now the cell with the least cost is **(O3, D4)** with cost **2**. Allocate this cell with **200** as the demand is smaller than the supply. So the column gets cancelled.



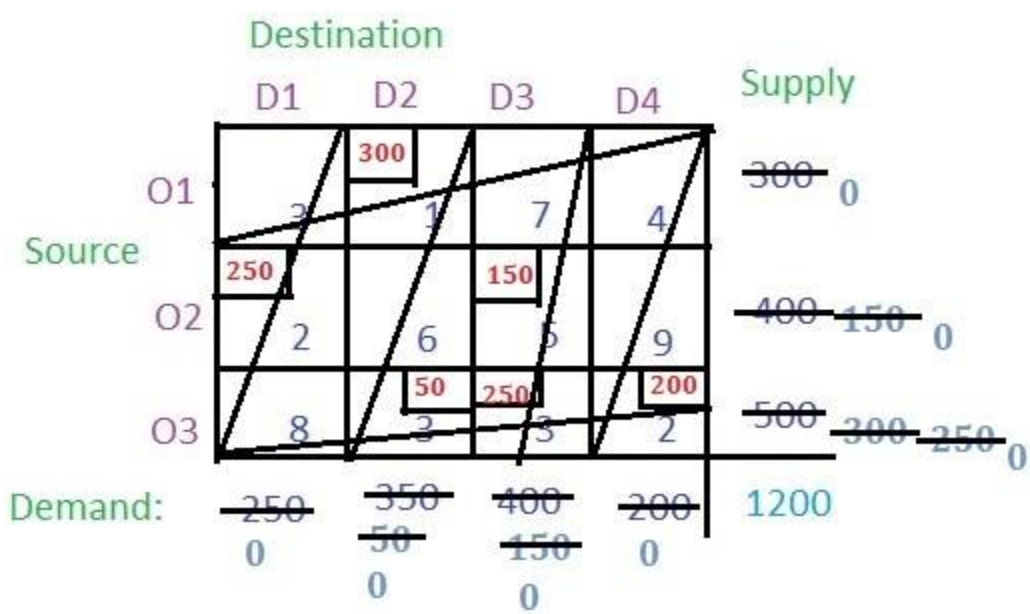
There are two cells among the unallocated cells that have the least cost. Choose any at random say (O3, D2). Allocate this cell with a minimum among the supply from the respective row and the demand of the respective column. Cancel the row or column with zero value.



Now the cell with the least cost is **(O3, D3)**. Allocate the minimum of supply and demand and cancel the row or column with zero value.



The only remaining cell is **(O2, D3)** with cost **5** and its supply is **150** and demand is **150** i.e. demand and supply both are equal. Allocate it to this cell.



Now just multiply the cost of the cell with their respective allocated values and add all of them to get the basic solution i.e. (300 * 1) + (250 * 2) + (150 * 5) + (50 * 3) + (250 * 3) + (200 * 2) = 2850

Now just multiply the cost of the cell with their respective allocated values and add all of them to get the basic solution i.e. (300 * 1) + (250 * 2) + (150 * 5) + (50 * 3) + (250 * 3) + (200 * 2) = 2850.

(iii) **Vogel's Approximation method**:

Source \ Destination	D1	D2	D3	D4	Supply
O1	3	1	7	4	300
O2	2	6	5	9	400
O3	8	3	3	2	500
Demand:	250	350	400	200	1200

Solution:

- For each row find the least value and then the second least value and take the absolute difference of these two least values and write it in the corresponding row difference as shown in the image below. In row O1, 1 is the least value and 3 is the second least value and their absolute difference is 2. Similarly, for row O2 and O3, the absolute differences are 3 and 1 respectively.

• For each column find the least value and then the second least value and take the absolute difference of these two least values then write it in the corresponding column difference as shown in the figure. In column D1, 2 is the least value and 3 is the second least value and their absolute difference is 1. Similarly, for column D2, D3 and D3, the absolute differences are 2, 2 and 2 respectively.

Source \ Destination	D1	D2	D3	D4	Supply	Row Difference
O1	3	1	7	4	300	**2**
O2	2	6	5	9	400	**3**
O3	8	3	3	2	500	**1**
Demand:	250	350	400	200	1200	
Column Difference:	**1**	**2**	**2**	**2**		

These value of row difference and column difference are also called as penalty. Now select the maximum penalty. The maximum penalty is **3** i.e. row **O2**. Now find the cell with the least cost in row **O2** and allocate the minimum among the supply of the respective row and the demand of the respective column. Demand is smaller than the supply so allocate the column's demand then cancel the column D1.

Destination

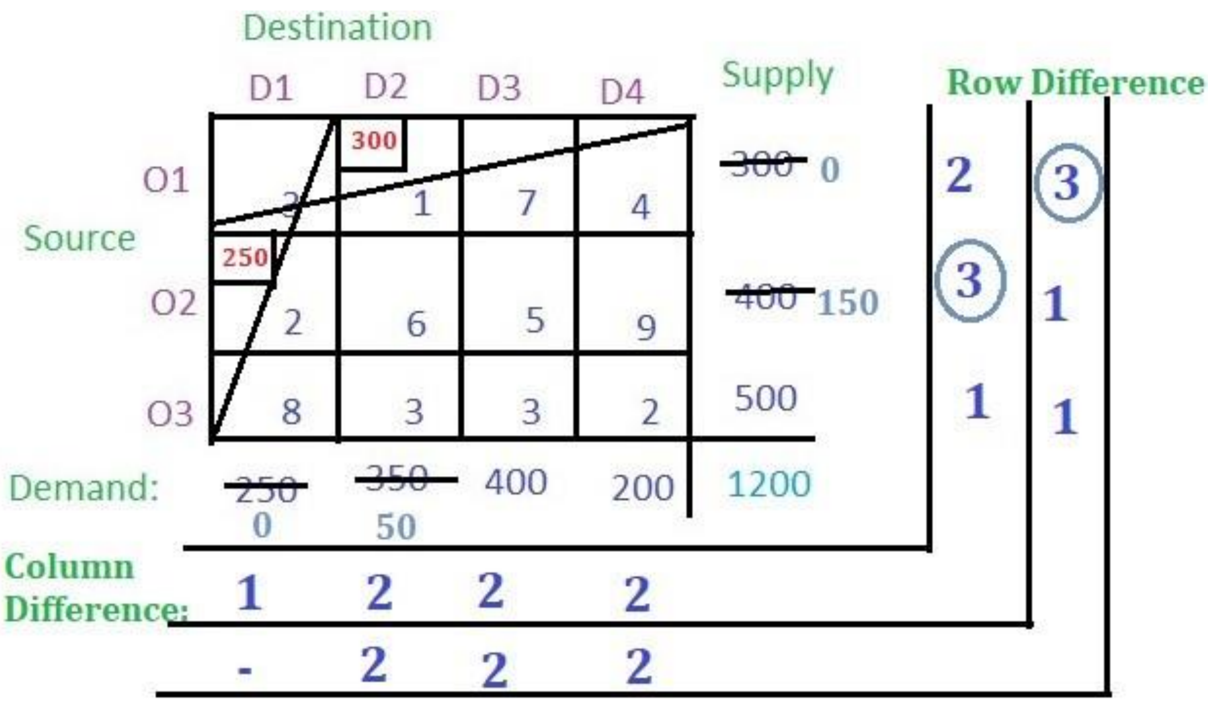
Source	D1	D2	D3	D4	Supply	Row Difference
O1	3	1	7	4	300	2
O2	250 2	6	5	9	~~400~~ 150	3
O3	8	3	3	2	500	1
Demand:	~~250~~ 0	350	400	200	1200	
Column Difference:	1	2	2	2		

From the remaining cells, find out the row difference and column difference.

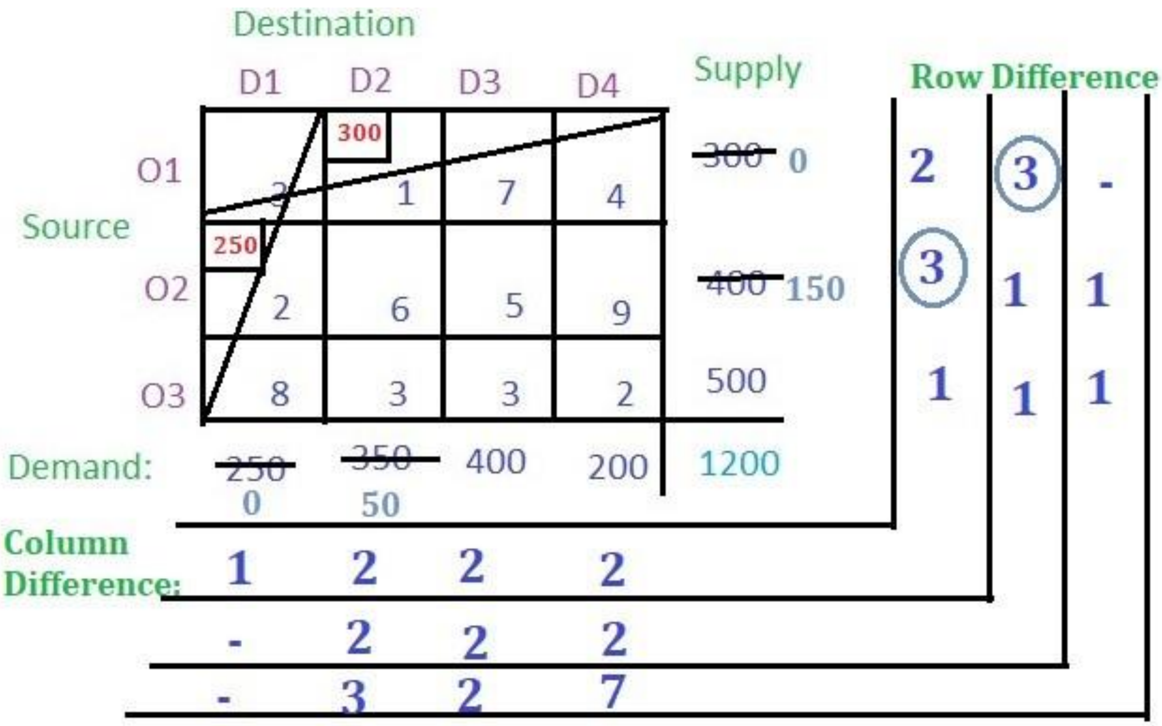
Destination

Source	D1	D2	D3	D4	Supply	Row Difference	
O1	3	1	7	4	300	2	3
O2	250 2	6	5	9	~~400~~ 150	3	1
O3	8	3	3	2	500	1	1
Demand:	~~250~~ 0	350	400	200	1200		
Column Difference:	1	2	2	2			
	-	2	2	2			

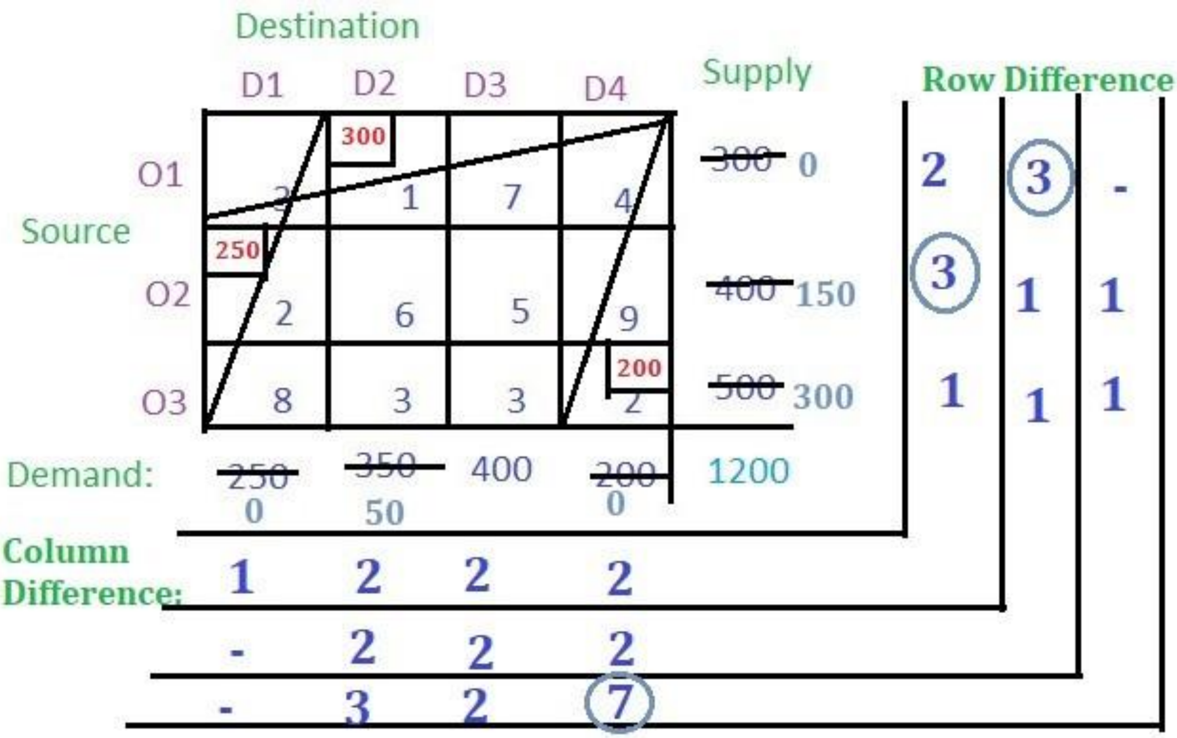
Again select the maximum penalty which is **3** corresponding to row **O1**. The least-cost cell in row **O1** is **(O1, D2)** with cost **1**. Allocate the minimum among supply and demand from the respective row and column to the cell. Cancel the row or coloumn with zero value.



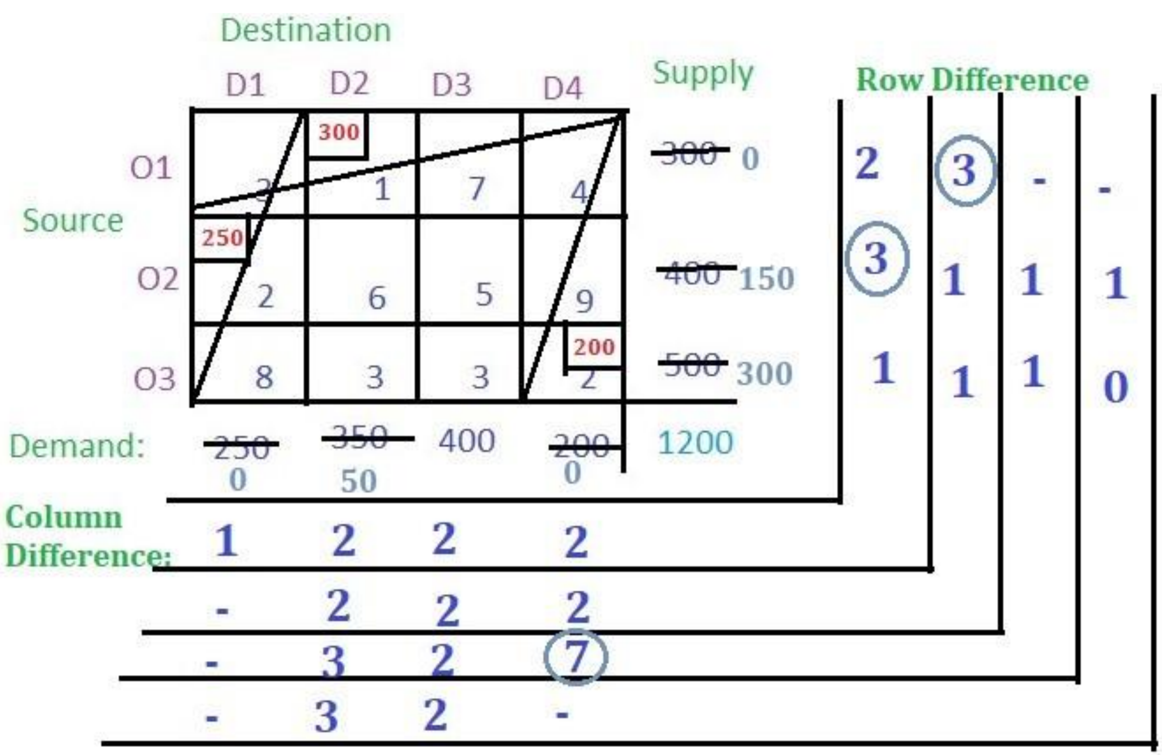
Now find the row difference and column difference from the remaining cells.



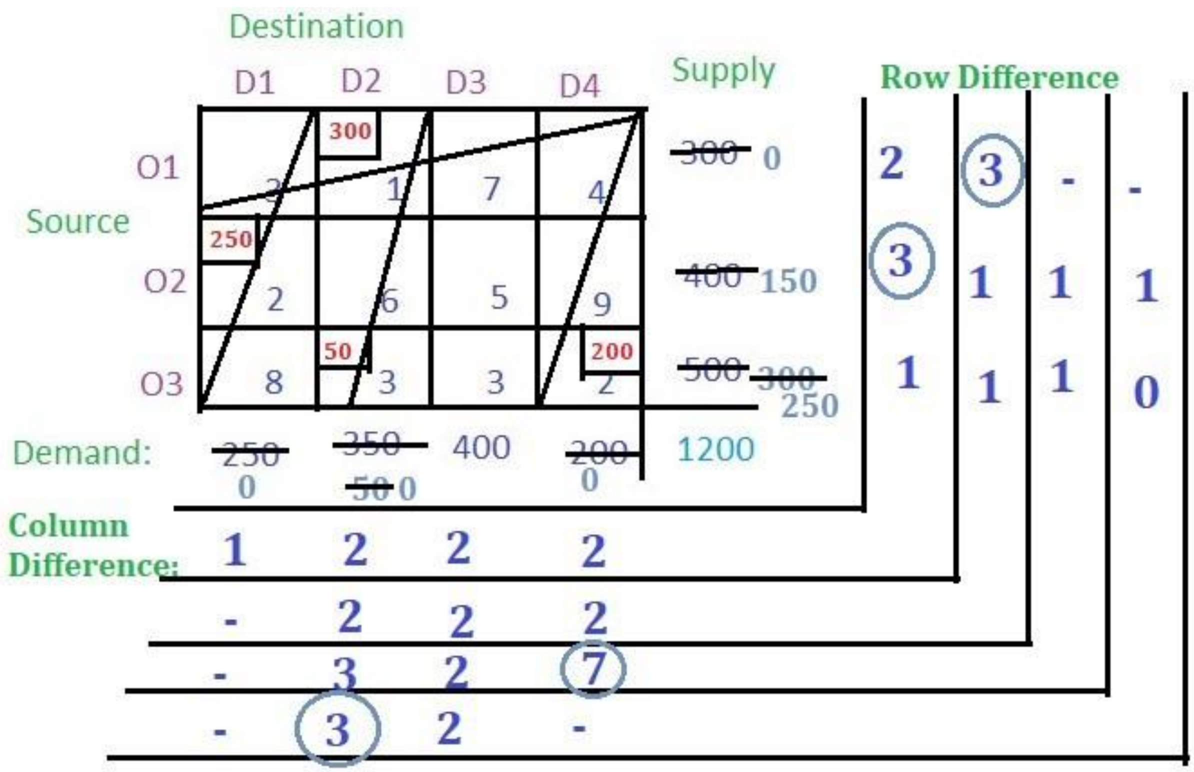
Now select the maximum penalty which is **7** corresponding to column **D4**. The least cost cell in column **D4** is **(O3, D4)** with cost **2**. The demand is smaller than the supply for cell **(O3, D4)**. Allocate **200** to the cell and cancel the column.



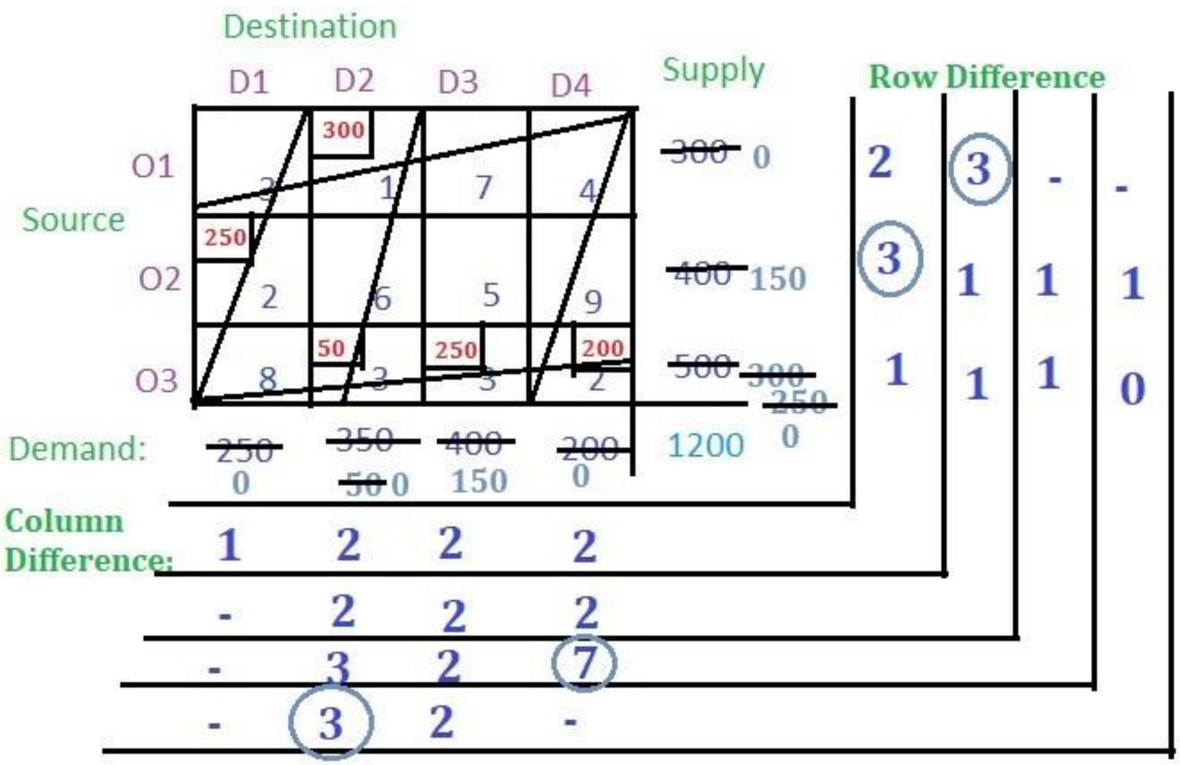
Find the row difference and the column difference from the remaining cells.



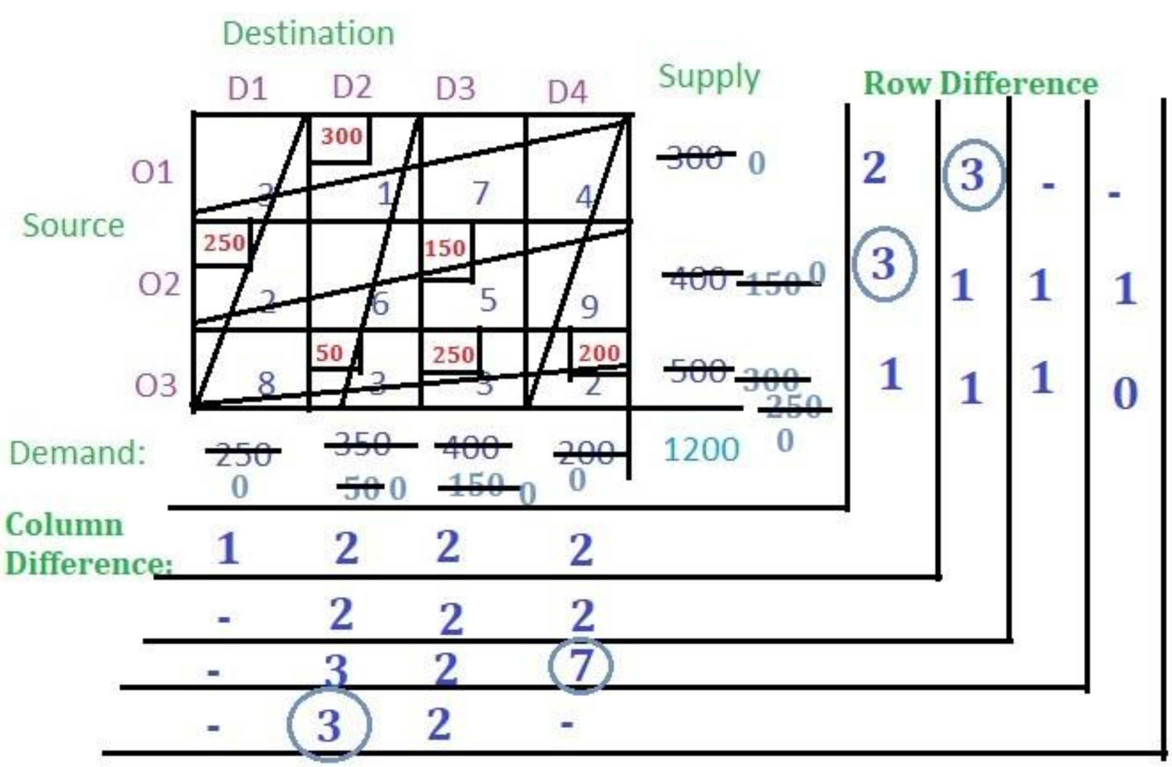
- Now the maximum penalty is **3** corresponding to the column **D2**. The cell with the least value in **D2** is **(O3, D2)**. Allocate the minimum of supply and demand and cancel the column.



Now there is only one column so select the cell with the least cost and allocate the value.



Now there is only one cell so allocate the remaining demand or supply to the cell.



- No balance remains. So multiply the allocated value of the cells with their corresponding cell cost and add all to get the final cost i.e. **(300 * 1) + (250 * 2) + (50 * 3) + (250 * 3) + (200 * 2) + (150 * 5) = 2850**

10.6 Model Questions

1. Define Plant location.
2. Elaborate the factors affecting on plant location decision.
3. Describe the importance of plant location.
4. Practice numerical of different methods of plant location decision

UNIT-11 CAPACITY PLANNING

STRUCTURE

11.1 Introduction

11.2 Defining capacity planning

11.3 Factors Influencing capacity plan

11.4 Capacity planning-how to make a successful plan? the know how.

11.5 Model Questions

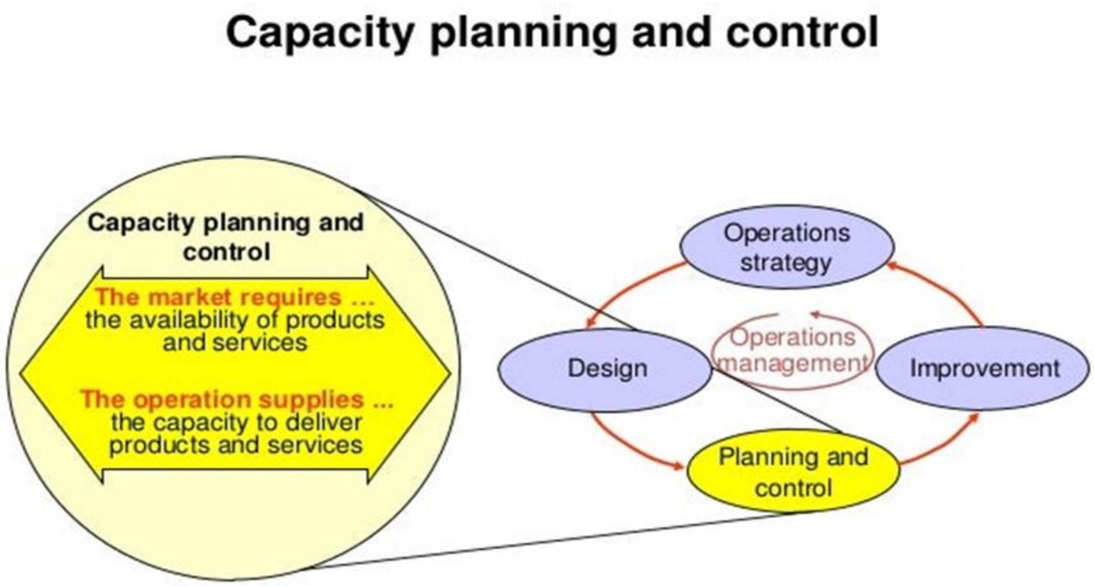
LEARNING OBJECTIVE

The basic objective of this unit is to understand the concept & significance of capacity planning in respect to any organization. After learning this unit, one should be able to:

- Define the concept of capacity planning
- Recognise various factors influencing on capacity planning
- Understand how a successful capacity plan can be prepared.

11.1 INTRODUCTION

Capacity planning is an important aspect of plant location as it denotes the total strength of the enterprise which is an obvious factor behind of a successful organization. Although there are different ways of defining or describing capacity planning, one aspect is common in all the definitions. Capacity planning is globally defined as the ability to deliver something in a specific period of time. The phrase adds different dimensions which cover the skill to hold, receive, store and accommodate in a business (Lam, 2014). Nonetheless, it is not only the skill to achieve the aforementioned properties but also the ability to do so. In simple terms, the capacity refers to the amount of output that a business is capable of producing over a specified amount of time.



11.2 DEFINING CAPACITY PLANNING

A capacity planning process involves determining how much production capacity is required to meet changing demand for products. Design capacity refers to an organization's maximum capacity to accomplish work over a given time period in capacity planning.

Capacity planning is the act of balancing available resources to satisfy customer demand or project capacity needs. In project management and production, capacity refers to the amount of work that can get completed in a given amount of time.

The capacity planning process is crucial in project management knowledge areas such as:

- Resource management
- Time management
- Team management
- Work Management

- Resource capacity planning is the integral part of a firm's visibility into what work can be offered and delivered. Resource capacity at a high level is simply a calculation of number of employees multiplied by expected workable hours available in a given week. For most organizations, there has to be at least a few more considerations for optimal resource capacity planning, things like skill sets, utilization targets and work under management.
- Project capacity planning, takes a view of a given project within an organization and the time and resources it needs. Project capacity planning strategies need to be balanced with strong resource management, ensuring staff aren't overworked (leading to employee stress & burnout) or underworked (leading to lower profits & productivity level).
- Team capacity planning is useful for groups that typically operate or work together. IT teams with specialized skills, for example, may perform work together on one or more projects. Project managers will use team capacity planning to understand how much work can get done from week to week and how those efforts will affect the project timeline.
- HR capacity planning is similar to resource planning but conducted by an HR group who may take into consideration other factors around professional development, ability to hire and onboard new staff and budget for new hires when determining capacity.

11.3 FACTORS INFLUENCING CAPACITY PLAN

This section discusses some of the factors influencing on a plant's capacity planning. Let us discuss then one by one.

Capacity is affected by both external and internal factors.

The external factors include

a) Government regulations- One of the important external factor is Government regulations. We know that for any organization, Government regulations, policies etc. are playing a significant role in various employment factors like- working hours, salary & wage policy, labour laws, organizational policies etc. Based on these things an organization can prepare its own planning regarding its capacity.

b) Union agreements- Another factor influencing on capacity plan is union agreements. Union means the workers' association which works for the development of employee rights & welfare. Agreements are made by the union representatives through various methods like collective bargaining & others regarding the organization's capacity 7 strategies.

c) Supplier capabilities- Supplier capabilities means the ability of suppliers to meet the requirements of a lead firm or buying firm including specifications about quality, timely delivery and environmental and safety standards.

d) Level of demand- The demand level of the customers is also a significant external factor which governs the capacity planning of an enterprise. Based on the customer demand the productivity and supply level of the products/services that offered by the organization.

The internal factors include:

a) Size of the facility/plant- Size and structure of a plant is also a dominating factor affecting on the capacity plan of it. If the organization is big in size then its operational level also will be in a greater extent thus its capacity also will be higher and so on.

b) Human factors- Various human factors like- total strength of manpower of an organization, recruitment policies, Human resource planning of the enterprise etc.are also having a great impact on the firm's capacity.

c) Availability of fund- Another important internal factor of capacity planning is the availability of adequate fund. The successful functions & other operational strategies of an organization mostly depends on the continuous flow of cash & adequate supply of fund.

<table>
<tr><th colspan="2">Factors affecting on capacity planning</th></tr>
<tr><th>Internal factors</th><th>External factors</th></tr>
<tr><td>• Availability of fund.
• Human factors.
• Size of the plant.etc.</td><td>• Demand level of customers.
• Government regulations.
• Union agreements.
• Supplier capabilities,etc.</td></tr>
</table>

11.4 CAPACITY PLANNING FOR AN ENTERPRISE: THE KNOWHOW

Capacity planning- is an important factor for any organization because most of the success quotient of an enterprise depends on it.

To make an organization successful some strategies of capacity planning should be adopted ny the firms,as:

Lead strategy

Lead capacity planning is when you increase your capacity ahead of anticipated future demand to meet that demand as soon as possible.

In lead strategy, you can either add resources to your current system or expand your system. Adding resources is the most common way to increase capacity. However, you can do it as part of resource planning.

Lag strategy

The lag strategy is when you delay expanding capacity until after experiencing demand.

Lag strategy can be problematic since you may find yourself in a situation where demand has increased, and there’s no capacity to meet the demand.

Match strategy

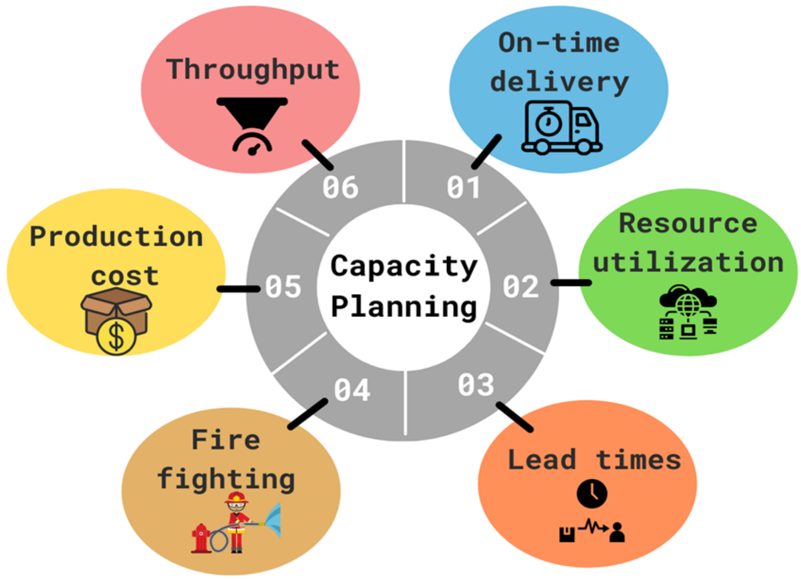
The match strategy is when you add capacity only after the ongoing capacity has been matched with current demand. This is the best for budgeting because you will only be buying capacity when needed.

However, this strategy does not work well with fast-changing demand. If the whole industry is changing, your capacity might not be enough to meet that change in demand, and you will have a bad customer experience.

Adjustment strategy

The adjustment strategy is gradual changes to either capacity or demand based on past performance.

For example, if you notice that you come close to or exceed your capacity during your busiest months, you will adjust by increasing your capacity in preparation. This strategy is an excellent method because it's gradual and doesn't have a lot of negative consequences if it fails.



Capacity Requirements Planning and MRP

Capacity requirements planning (CRP) compares the capacity available across the enterprise in all its work centers to material requirements plans. CRP can help create achievable workloads and can also improve utilization in the face of limited resources.

An MRP system allows a company to use data not just in a historical sense to compare with measurements. It also provides a dynamic framework of near real-time data as well as historical transactions to improve capacity planning to make it more accurate and more predictable. Instead of using rough-cut capacity to gauge a range of what its needed, CRP uses the depth of functionality of an MRP to make it a truly predictive tool and unlock additional capacity through proactive planning with the MRP.

Production Planning

All MRPs have production planning modules that are central to their success. This production planning of course includes functionality such as manufacturing order records and the production schedule. But it also includes workstations, workstation groups, BOMS and routings. These are all elements required for rough-cut capacity planning. By using the accuracy and analytics of the MRP system, capacity planning is easier.

ABC Analysis

As important as capacity planning is, its importance runs parallel to other critical areas of business management such as cost control, optimized purchasing and inventory purchase and valuation. MRP systems can help perform ABC analysis, where the Pareto principal is used to assign weighted valuation to material and components that measure their use and importance to the finished goods, and BOMs, they are used in.

ABC analysis helps decision-makers craft optimized stock levels and purchase plans to maximize the value of the dollar spent. These purchasing plans can be automated to include any changes in BOMs due to substitutes or other issues.

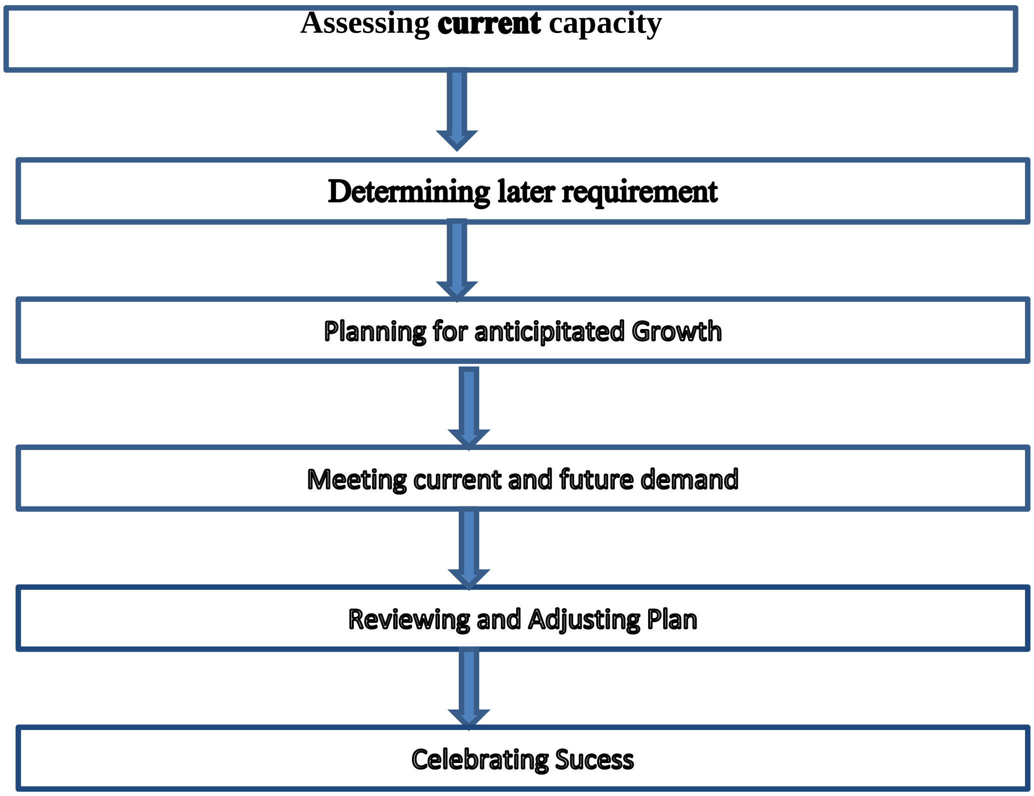
Human Resources

Today's MRP systems carry deep functionality that brings production orders, workloads at all workstations and other factors down to the staff level. This means that HR can calculate the staff needed at each workstation down to the number of employees required. Labor and staffing are an integral part of capacity planning. By utilizing an MRP system's native functionality for labor within HR, capacity planning can include exact staffing requirements that make their plan more accurate.

Production Scheduling

An MRP system will also have a production planning module for scheduling the shop floor. This means that production scheduling tasks are automated, and errors are reduced. Production planners can utilize both forward and backward scheduling to have manufacturing orders scheduled at the first available time and with assurance that the resources will be there to make the finished good. They can also see and edit workstations and even schedule subcontracted services.

6 Steps in Capacity Planning Process



1. **Assessing current capacity**

It is the first step in any capacity planning process. Next, you need to understand what resources you have at your disposal and how they're currently used in resource planning. This can include everything from people and equipment to office space and data storage.

2. **Determining later requirement**

It may seem daunting, but planning for growth is essential. Whether your business is expanding or anticipating more traffic on your website, you need to know what capacity you'll need down the road.

3. **Planning for anticipated growth**

It is essential, but it’s also important to be realistic about potential needs. It’s better to overestimate than underestimate, so don’t be afraid to think big!.

4. **Meeting current and future demand**

It is the ultimate goal of capacity planning. Of course, you want to ensure you have enough resources available at all times, but it’s also important not to waste money on excess capacity.

5. **Reviewing and adjusting plans**

Reviewing and adjusting plans as needed will help your business grow steadily instead of haphazardly. No matter what kind of changes come up — whether they’re related to growth or anything else — you should always be willing and able to adapt!

6. **Celebrating success**

It may seem like an odd part of a process that requires so much focus and attention, but everyone deserves recognition after doing such hard work. Whether this means throwing a party for employees, taking time off with family, or rewarding yourself another way, don’t forget to pause and appreciate all you’ve accomplished!

Although the capacity planning process might differ from business to business, there are a few fundamental elements that are followed in every process:

1. Calculate Current Capacity

It is time to assess how well your present production capacity is positioned to fulfill demand once you have established the capacity needed. This multi-tiered strategy aims to respond to four important queries:

- What is the maximum output my company is capable of producing?
- Does it match the demands of the present?
- Am I already producing to my fullest potential?
- Do I have the bandwidth to accommodate any additional activities?

2. Track Staff Skills

Staff participation in a project is not solely dependent on their availability. It's also about their abilities. Therefore, you must be aware of the capabilities and level of competence of all the resources at your fingertips. This will enable you to choose the best candidates for each project. You will comprehend the "supply" side of the capacity planning equation by tracking and knowing this.

3. Analyze Project Requirements

The next step is to decide the tasks your team will be working on. If you have a lag strategy, take a look at the projects you have on your books right now and make a reasonable critical path for each one of them. If you're utilizing lead strategy, consider upcoming initiatives and project what resources they will likely need. Consequently, you have the "demand" side of the equation.

4. Create Visibility

When you know both the supply and demand sides of the issue, you can determine whether you have the resources necessary to finish your tasks. Senior managers need the means to compare project needs with available resources. They will need to make certain judgments if the capacity to complete specific initiatives is unavailable. Are certain initiatives moved, postponed, or rejected, for instance? Alternatively, do they hire extra personnel to handle the workload?

5. Choose What to Use

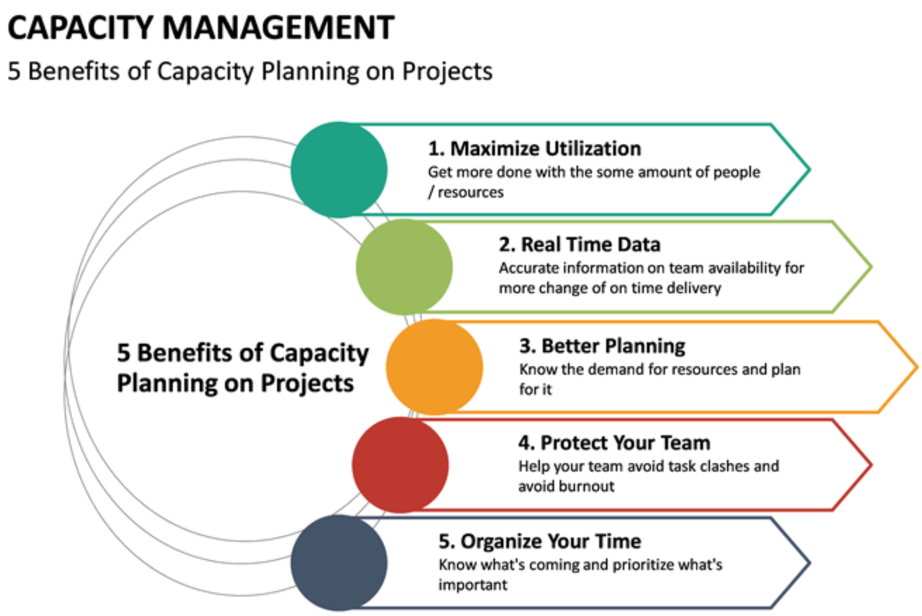
Spreadsheets, Kanban boards, and individual Gantt charts can all be used to plan capacity. Nevertheless, using specialized software is the most efficient method. The critical path can be drastically altered by a single staff member being absent due to illness or by a change in the project's scope. Additionally, since resources are frequently divided among several projects, this may have a negative impact on several different bodies of work. In such a complicated setting, manually modifying plans would be time-consuming and prone to human mistakes. However, resource planning software can automatically adjust capacity plans with just a few clicks.

6. Allocate Resources

Now, allocate those projects according to priority, ensuring they align with the company's objectives. Also, make sure to revisit allocations after constantly reviewing actuals and forecasts to ensure optimal utilization and effective execution of the plan.

7. Capture KPIs

Without measurement, management is impossible. Developing and monitoring the Key Performance Indicators is crucial to determine whether your capacity strategy is effective.



11.5 KNOW YOUR PROGRESS

- Define Capacity Planning and explain its benefits.
- Describe various types of capacity plan.
- Illustrate various factors influencing on capacity planning.
- What are the process of making a successful capacity planning for an enterprise?

UNIT-12 DECISION TREE ANALYSIS

STRUCTURE

LEARNING OBJECTIVES

After reading this unit you should be able to:

- Define the concept of Decision Tree Analysis
- Identify the core elements of Decision Tree Analysis
- Learn about the step-by-step procedure of preparing the Decision Tree Analysis.
- Identify the pros and cons of the concept.

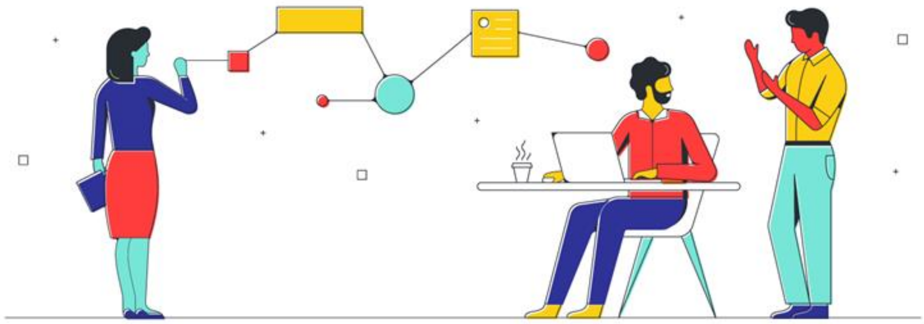
12.1 INTRODUCTION:

For an organization, analysis of decision tree is a vital part. Decision tree analysis is a powerful decision-making tool which initiates a structured nonparametric approach for problem-solving. It facilitates the evaluation and comparison of the various options and their results, as shown in a decision tree. It helps to choose the most competitive alternative.

12.2 DEFINITION:

A decision tree is a tree-like model that acts as a decision support tool, visually displaying decisions and their potential outcomes, consequences, and costs. From there, the “branches” can easily be evaluated and compared in order to select the best courses of action.

Decision tree analysis is helpful for solving problems, revealing potential opportunities, and making complex decisions regarding cost management, operations management, organization strategies, project selection, and production methods.



Types of Decisions :

There are two main types of decision trees that are based on the target variable, i.e., categorical variable decision trees and continuous variable decision trees.

1. Categorical variable decision tree

A categorical variable decision tree includes categorical target variables that are divided into categories. For example, the categories can be yes or no. The categories mean that every stage of the decision process falls into one category, and there are no in-betweens.

2. Continuous variable decision tree

A continuous variable decision tree is a decision tree with a continuous target variable. For example, the income of an individual whose income is unknown can be predicted based on available information such as their occupation, age, and other continuous variables.

12.3 ELEMENTS OF DECISION TREE

There are some core elements & terminologies associated with the concept of Decision Tree Analysis. They are as follows:

- Root Node: A root node compiles the whole sample, it is then divided into multiple sets which comprise of homogeneous variables.

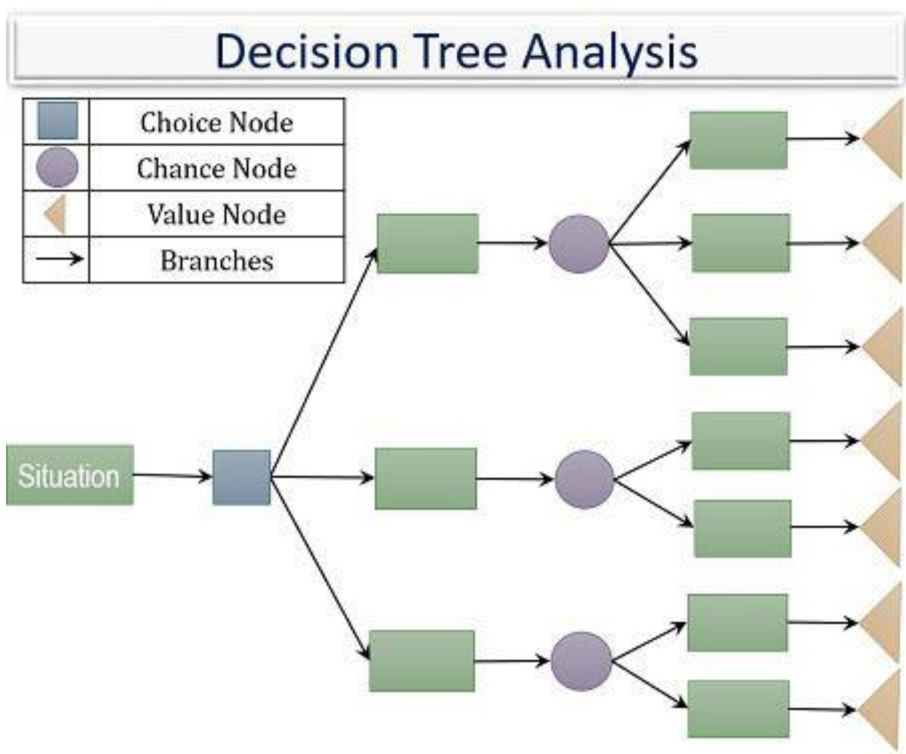
- Decision Node: That sub-node which diverges into further possibilities, can be denoted as a decision node.

- Terminal Node: The final node showing the outcome which cannot be categorized any further, is termed as a value or terminal node.

- Branch: A branch denotes the various alternatives available with the decision tree maker.

- Splitting: The division of the available option (depicted by a node or sub-node) into multiple sub-nodes is termed as splitting.

- Pruning: It is just the reverse of splitting, where the decision tree maker can eliminate one or more sub-nodes from a particular decision node.



12.4 HOW TO PREPARE A DECISION TREE ANALYSIS-THE PROCESS

The study of Decision Tree Analysis is a very important thing for an organization. To make an effective strategy formulation & regarding that taking a decision is very significant process. Decision trees are one of the best forms of learning algorithms based on various learning methods. They boost predictive models with accuracy, ease in interpretation, and stability. The tools are also effective in fitting non-linear relationships since they can solve data-fitting challenges, such as regression and classifications.

Steps in Decision Tree Analysis :

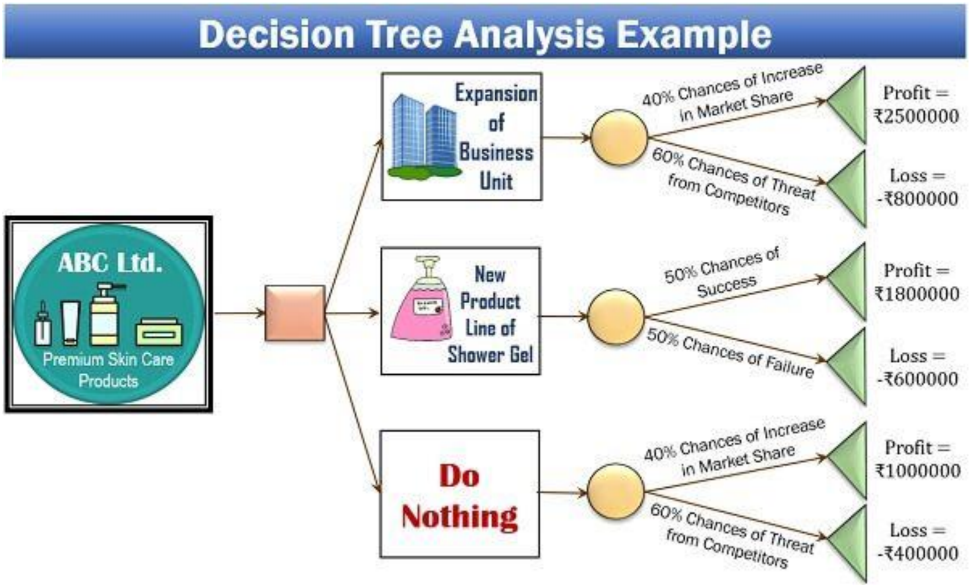
A decision tree analysis may sound like a complex management tool, but it is comparatively easier to make. Following are the steps or processes to make or perform a decision tree analysis:

- We first need to understand and specify the issue for which we need a decision tree.
- Next, we need to think of and detail all the possible answers to the issue.
- Now, we need to put the possible solutions and their probability values on a decision tree.
- Next, determine all the consequences of the possible solutions, and mark those on the decision tree.
- In the last step, we need to calculate the EMV (Expected Monetary Value) values of all the options (chance nodes). This would give us the solution where one will go with the highest expected value.

Decision Tree Analysis Example:

To know more about the decision tree analysis, let us illustrate a business situation.

ABC Ltd. is a company manufacturing skincare products. It was found that the business is at the maturity stage, demanding some change. After rigorous research, management came up with the following decision tree:



In the above decision tree, we can easily make out that the company can expand its existing unit or innovate a new product, i.e., shower gel or make no changes.

Given below is the evaluation of each of these alternatives:

Expansion of Business Unit:

If the company invests in the development of its business unit, there can be two possibilities, i.e.:

- 40% possibility that the market share will hike, increasing the overall profitability of the company by ₹2500000;
- 60% possibility that the competitors would take over the market share and the company may incur a loss of ₹800000.

To find out the viability of this option, let us compute its EMV (Expected Monetary Value):

$$\text{EMV} = \left(\frac{40}{100} \times 2500000\right) + \left(\frac{60}{100} \times -800000\right)$$
$$\text{EMV} = 1000000 - 480000$$
$$\textbf{EMV} = \textbf{₹520000}$$

New Product Line of Shower Gel:

If the organization go for new product development, there can be following two possibilities:

- 50% chances are that the project would be successful and yield ₹1800000 as profit;
- 50% possibility of failure persists, leading to a loss of ₹800000.

To determine the profitability of this idea, let us evaluate its EMV:

$$\text{EMV} = \left(\frac{50}{100} \times 1800000\right) + \left(\frac{50}{100} \times -600000\right)$$
$$\text{EMV} = 900000 - 300000$$
$$\textbf{EMV} = \textbf{₹600000}$$

Do Nothing:

If the company does not take any step, still there can be two outcomes, discussed below:

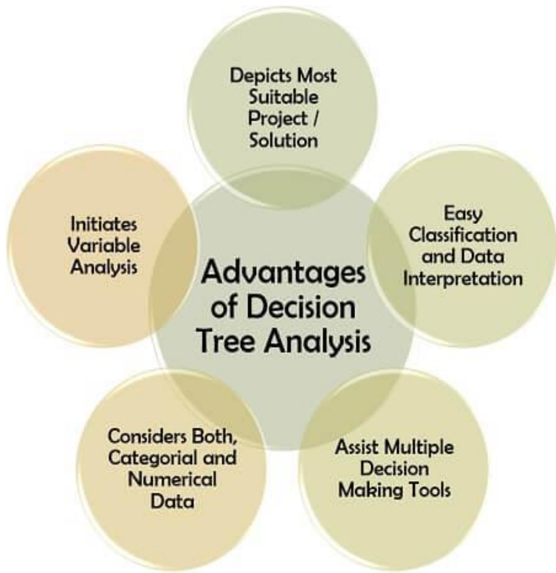
- 40% chances are there that yet, the organization can attract new customers, generating a profit of ₹1000000;
- 60% chances of failure are there due to the new competitors, incurring a loss of ₹400000.

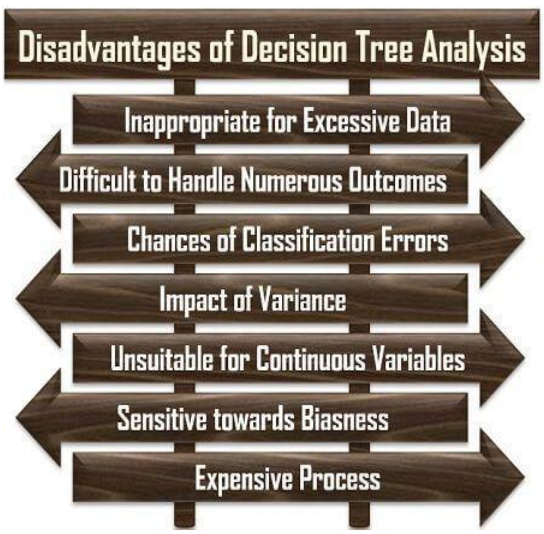
Given below is the EMV in such circumstances:

$$\text{EMV} = \left(\frac{40}{100} \times 1000000\right) + \left(\frac{60}{100} \times -400000\right)$$
$$\text{EMV} = 400000 - 240000$$
$$\textbf{EMV} = \textbf{₹160000}$$

Interpretation

From the above evaluation, we can easily make out that the option of a new product line has the highest EMV. Therefore, we can say that the company can avail this opportunity to make the highest gain by ensuring the best possible use of its resources.





Comparison Table for Advantages and Disadvantages of Decision Tree:

Advantages of Decision Tree	**Disadvantages of Decision Tree**
It is easy to create	Unstable in nature
It helps decision making and understanding easily	Get complex with new input
Reduces data cleaning	Inaccurate with new more input change
Data can be explored	Time-consuming
Can be used for the non-linear relationship	Less effective in continuous variable outcome

12.5 Model Questions

- Define Decision Tree Analysis.
- Describe the core elements of decision tree with diagram.
- Enumerate the process of making a Decision Tree Analysis.
- Explain the Pros & Cons of Decision Tree Analysis.

Block-4

Aggregate Planning

Unit No.	Unit Name
Unit 13	Aggregate Planning
Unit 14	Statistical Quality control
Unit 15	Control charts
Unit 16	Elementary Queuing Theory

UNIT 13: AGGREGATE PLANNING

STRUCTURE

LEARNING OBJECTIVES

After go through this unit you will be able to-

- Know what is Aggregate Planning
- Understand factors and techniques for Aggregate Planning
- Understand mathematical approach to Aggregate Planning
- Understand it's difference in manufacturing and services
- Understand the advantages of Aggregate Planning

13.1 INTRODUCTION

An organization can finalize its business plans on the recommendation of demand forecast. Once business plans are ready, an organization can do backward working from the final sales unit to raw materials required. Thus annual and quarterly plans are broken down into labor, raw material, working capital, etc. requirements over a medium-range period (3 months to 18 months). This process of working out production requirements for a medium range is called aggregate planning.

An aggregate plan also consists of the targeted sales forecasts, production levels, inventory levels, customer backlogs etc. In this type of planning, the word 'aggregate' is used because the planning at this level includes all the resources in the aggregate. The schedule used in the aggregate planning plays a very critical and an essential role in providing the satisfaction to the demand forecast at a minimum cost.

Aggregate planning serves as the basic structure for the future short – range type planning and this type of planning can be categorized as follows:

1. **Production plan –**
   • Also called as the manufacturing aggregate plan.
   • Is a managerial statement of the period – by – period production rates, work – force levels etc.
2. **Staffing plan –**
   • Also called as the service aggregate plan.
   • Is a managerial statement of the period – by – period staff sizes and the labor – related capacities, given customer requirements and the capacity limitations.

13.2 THE AGGREGATE PLANNING STRATEGIES

There are two pure planning strategies available to the aggregate planner: a level strategy and a chase strategy. Firms may choose to utilize one of the pure strategies in isolation, or they may opt for a strategy that combines the two.

LEVEL STRATEGY

A level strategy seeks to produce an aggregate plan that maintains a steady production rate and/or a steady employment level. In order to satisfy changes in customer demand, the firm must raise or lower inventory levels in anticipation of increased or decreased levels of forecast demand. The firm maintains a level workforce and a steady rate of output when demand is somewhat low. This allows the firm to establish higher inventory levels than are currently needed. As demand increases, the firm is able to continue a steady production rate/steady employment level, while allowing the inventory surplus to absorb the increased demand.

A second alternative would be to use a backlog or backorder. A backorder is simply a promise to deliver the product at a later date when it is more readily available, usually when capacity begins to catch up with diminishing demand. In essence, the backorder is a device for moving demand from one period to another, preferably one in which demand is lower, thereby smoothing demand requirements over time.

A level strategy allows a firm to maintain a constant level of output and still meet demand. This is desirable from an employee relations standpoint. Negative results of the level strategy would include the cost of excess inventory, subcontracting or overtime costs, and backorder costs, which typically are the cost of expediting orders and the loss of customer goodwill. The salient points are:

- Use a constant workforce & produce similar quantities each time period
- Use inventories and back-orders to absorb demand peaks & valleys
- Use inventories in better way to absorb the peak of demand and valleys

CHASE STRATEGY

A chase strategy implies matching demand and capacity period by period. This could result in a considerable amount of hiring, firing or laying off of employees; insecure and unhappy employees; increased inventory carrying costs; problems with labor unions; and erratic utilization of plant and equipment. It also implies a great deal of flexibility on the firm's part. The major advantage of a chase strategy is that it allows inventory to be held to the lowest level possible, and for some firms this is a considerable savings. Most firms embracing the just-in-time production concept utilize a chase strategy approach to aggregate planning.

Options which can be used to increase or decrease capacity to match current demand include:

1. Hire/lay off. By hiring additional workers as needed or by laying off workers not currently required to meet demand, firms can maintain a balance between capacity and demand.

2. Overtime. By asking or requiring workers to work extra hours a day or an extra day per week, firms can create a temporary increase in capacity without the added expense of hiring additional workers.

3. Part-time or casual labor. By utilizing temporary workers or casual labor (workers who are considered permanent but only work when needed, on an on-call basis, and typically without the benefits given to full-time workers).

4. Inventory. Finished-goods inventory can be built up in periods of slack demand and then used to fill demand during periods of high demand. In this way no new workers have to be hired, no temporary or casual labor is needed, and no overtime is incurred.

5. Subcontracting. Frequently firms choose to allow another manufacturer or service provider to provide the product or service to the subcontracting firm's customers. By subcontracting work to an alternative source, additional capacity is temporarily obtained.

6. Cross-training. Cross-trained employees may be able to perform tasks in several operations, creating some flexibility when scheduling capacity. 7. Other methods. While varying workforce size and utilization, inventory buildup/backlogging, and subcontracting are well-known alternatives, there are other, more novel ways that find use in industry. Among these options are sharing employees with counter-cyclical companies and attempting to find interesting and meaningful projects for employees to do during slack times.

HYBRID STRATEGY

Most firms find it advantageous to utilize a combination of the level and chase strategy. A combination strategy (sometimes called a hybrid or mixed strategy) can be found to better meet organizational goals and policies and achieve lower costs than either of the pure strategies used independently. A strategy between Level and Chase follows an intermediate path and the salient points are:

- Build-up inventory ahead of rising demand and use back-orders to level extreme peaks. Minimize finished goods inventories by trying to keep pace with demand fluctuations.
- Matched demand varying either work force level or output rate.
- Layoff or furlough workers during lulls
- Subcontract production or hire temporary workers to cover short-term peaks
- Reassign workers to preventive maintenance during lulls

13.3 FACTORS FOR AGGREGATE PLANNING

Aggregate planning is considered to be intermediate-term (as opposed to long- or short-term) in nature. Hence, most aggregate plans cover a period of three to 18 months. Aggregate plans serve as a foundation for future short-range type planning, such as production scheduling, sequencing, and loading. The master production schedule (MPS) used in material requirements planning (MRP) has been described as the aggregate plan "disaggregated."

Steps taken to produce an aggregate plan begin with the determination of demand and the determination of current capacity. Capacity is expressed as total number of units per time period that can be produced (this requires that an average number of units be computed since the total may include a product mix utilizing distinctly different production times). Demand is expressed as total number of units needed. If the two are not in balance (equal), the firm must decide whether to increase or decrease capacity to meet demand or increase or decrease demand to meet capacity. In order to accomplish this, a number of options are available.

Options for situations in which demand needs to be increased in order to match capacity include:

1. Pricing. Varying pricing to increase demand in periods when demand is less than peak. For example, matinee prices for movie theaters, off-season rates for hotels, weekend rates for telephone service, and pricing for items that experience seasonal demand.

2. Promotion. Advertising, direct marketing, and other forms of promotion are used to shift demand.

3. Back ordering. By postponing delivery on current orders demand is shifted to period when capacity is not fully utilized. This is really just a form of smoothing demand. Service industries are able to smooth demand by taking reservations or by making appointments in an attempt to avoid walk-in customers. Some refer to this as "partitioning" demand.

4. New demand creation. A new, but complementary demand is created for a product or service. When restaurant customers have to wait, they are frequently diverted into a complementary (but not complimentary) service, the bar. Other examples include the addition of video arcades within movie theaters, and the expansion of services at convenience stores.

Options which can be used to increase or decrease capacity to match current demand include:

1. Hire/lay off. By hiring additional workers as needed or by laying off workers not currently required to meet demand, firms can maintain a balance between capacity and demand.

2. Overtime. By asking or requiring workers to work extra hours a day or an extra day per week, firms can create a temporary increase in capacity without the added expense of hiring additional workers.

3. Part-time or casual labor. By utilizing temporary workers or casual labor (workers who are considered permanent but only work when needed, on an on-call basis, and typically without the benefits given to full-time workers).

4. Inventory. Finished-goods inventory can be built up in periods of slack demand and then used to fill demand during periods of high demand. In this way no new workers have to be hired, no temporary or casual labor is needed, and no overtime is incurred.

12. Subcontracting. Frequently firms choose to allow another manufacturer or service provider to provide the product or service to the subcontracting firm's customers. By subcontracting work to an alternative source, additional capacity is temporarily obtained.

13. Cross-training. Cross-trained employees may be able to perform tasks in several operations, creating some flexibility when scheduling capacity.

14. Other methods. While varying workforce size and utilization, inventory build-up/backlogging, and subcontracting are well-known alternatives, there are other, more novel ways that find use in industry. Among these options are sharing employees with counter-cyclical companies and attempting to find interesting and meaningful projects for employees to do during slack times.

13.4 FACTORS AFFECTING AGGREGATE PLANNING

Aggregate planning is an operational activity critical to the organization as it looks to balance long-term strategic planning with short term production success. Following factors are critical before an aggregate planning process can actually start;

- A complete information is required about available production facility and raw materials.
- A solid demand forecast covering the medium-range period.
- Financial planning surrounding the production cost which includes raw material, labor, inventory planning, etc.
- Organization policy around labor management, quality management, etc. For aggregate planning to be a success, following inputs are required;
- An aggregate demand forecast for the relevant period.
- Evaluation of all the available means to manage capacity planning like sub-contracting, outsourcing, etc.
- Existing operational status of workforce (number, skill set, etc.), inventory level and production efficiency.

Aggregate planning will ensure that organization can plan for workforce level, inventory level and production rate in line with its strategic goal and objective.

13.5 TECHNIQUES FOR AGGREGATE PLANNING

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

1. Determine demand for each period.
2. Determine capacity for each period. This capacity should match demand, which means it may require the inclusion of overtime or subcontracting.
3. Identify company, departmental, or union policies that are pertinent. For example, maintaining a certain safety stock level, maintaining a reasonably stable workforce, backorder policies, overtime policies, inventory level policies, and other less explicit rules such as the nature of employment with the individual industry, the possibility of a bad image, and the loss of goodwill.
4. Determine unit costs for units produced. These costs typically include the basic production costs (fixed and variable costs as well as direct and indirect labor costs). Also

included are the costs associated with making changes in capacity. Inventory holding costs must also be considered, as should storage, insurance, taxes, spoilage, and obsolescence costs. Finally, backorder costs must be computed. While difficult to measure, this generally includes expediting costs, loss of customer goodwill, and revenue loss from cancelled orders.

5. Develop alternative plans and compute the cost for each.
6. If satisfactory plans emerge, select the one that best satisfies objectives. Frequently, this is the plan with the least cost. Otherwise, return to step 5.

An example of a completed informal aggregate plan can be seen in Figure 1. This plan is an example of a plan determined utilizing a level strategy. Notice that employment levels and output levels remain constant while inventory is allowed to build up in earlier periods only to be drawn back down in later periods as demand increases. Also, note that backorders are utilized in order to avoid overtime or subcontracting. The computed costs for the individual variables of the plan are as follows:

Output costs:

Regular time = `250 per unit

Overtime = `400 per unit

Subcontracted = `600 per unit

Other costs:

Inventory carrying cost = `150 per unit per period applied to average inventory

Backorders = `500 per unit per period

Cost of aggregate plan utilizing a level strategy:

Output costs:

Regular time = `250× 1,500 = `375,000

Overtime = `400 × 0 = 0

Subcontracted = `600 × 0 = 0

Other costs:

Inventory carrying cost = `150 × 800 = `120,000

Backorders = `500 × 100 = `50,000

Total cost (Cost of aggregate plan utilizing a level strategy) = `545,000

Period		1	2	3	4	5	6
Forecast		100	150	300	300	500	150
Output							
	Regular	250	250	250	250	250	250
	Overtime						
	Sub-contract						
Output forecast		150	100	-50	-50	-250	100
Inventory							
	Beginning	0	150	250	200	150	0
	Ending	150	250	200	150	0	100
	Average	75	200	225	175	75	50
Backlog	0	0	0	0	0	100	0

13.6 MATHEMATICAL APPROACHES TO AGGREGATE PLANNING

The following are some of the better known mathematical techniques that can be used in more complex aggregate planning applications.

LINEAR PROGRAMMING

Linear programming is an optimization technique that allows the user to find a maximum profit or revenue or a minimum cost based on the availability of limited resources and certain limitations known as constraints. A special type of linear programming known as the Transportation Model can be used to obtain aggregate plans that would allow balanced capacity and demand and the minimization of costs. However, few real-world aggregate planning decisions are compatible with the linear assumptions of linear programming. Supply Chain Management: Strategy, Planning and Operation, by Sunil Chopra and Peter Meindl, provides an excellent example of the use of linear programming in aggregate planning.

MIXED-INTEGER PROGRAMMING

For aggregate plans that are prepared on a product family basis, where the plan is essentially the summation of the plans for individual product lines, mixedinteger programming may prove to be useful. Mixed-integer programming can provide a method for determining the number of units to be produced in each product family.

LINEAR DECISION RULE

Linear decision rule is another optimizing technique. It seeks to minimize total production costs (labor, overtime, hiring/lay off, inventory carrying cost) using a set of cost-approximating functions (three of which are quadratic) to obtain a single quadratic equation. Then, by using calculus, two linear equations can be derived from the quadratic equation, one to be used to plan the output for each period and the other for planning the workforce for each period.

MANAGEMENT COEFFICIENTS MODEL

The management coefficients model, formulated by E.H. Bowman, is based on the suggestion that the production rate for any period would be set by this general decisionrule:

$P_t = aW_{t-1} - bI_{t-1} + cF_{t+1} + K$, where

P_t = the production rate set for period t

W_{t-1} = the workforce in the previous period

I_{t-1} = the ending inventory for the previous period F_{t+1} = the forecast of demand for the next period a, b, c, and K are constants

It then uses regression analysis to estimate the values of a, b, c, and K. The end result is a decision rule based on past managerial behavior without any explicit cost functions, the assumption being that managers know what is important, even if they cannot readily state explicit costs. Essentially, this method supplements the application of experienced judgment.

SEARCH DECISION RULE

The search decision rule methodology overcomes some of the limitations of the linear cost assumptions of linear programming. The search decision rule allows the user to state cost data inputs in very general terms. It requires that a computer program be constructed that will unambiguously evaluate any production plan's cost. It then searches among alternative plans for the one with the minimum cost. However, unlike linear programming, there is no assurance of optimality.

SIMULATION

A number of simulation models can be used for aggregate planning. By developing an aggregate plan within the environment of a simulation model, it can be tested under a variety of conditions to find acceptable plans for consideration. These models can also be incorporated into a decision support system, which can aid in planning and evaluating alternative control policies. These models can integrate the multiple conflicting objectives inherent in manufacturing strategy by using different quantitative measures of productivity, customer service, and flexibility.

FUNCTIONAL OBJECTIVE SEARCH APPROACH

The functional objective search (FOS) system is a computerized aggregate planning system that incorporates a broad range of actual planning conditions. It is capable of realistic, low-cost operating schedules that provide options for attaining different planning goals. The system works by comparing the planning load with available capacity. After management has chosen its desired actions and associated planning objectives for specific load conditions, the system weights each planning goal to reflect the functional emphasis behind its achievement at a certain load condition. The computer then uses a computer search to output a plan that minimizes costs and meets delivery deadlines.

13.7 DIFFERENCE BETWEEN AGGREGATE PLANNING IN MANUFACTURING & AGGREGATE PLANNING IN SERVICES

Aggregate planning involves developing, analyzing and maintaining the operational schedule of an organization. It organizes areas of business that include targeted sales forecasts, production levels, inventory levels and customer backlogs. When aggregate planning is carried out effectively, the effects of shortsighted, daily scheduling are minimized. Capacity and demand are balanced in a way that minimizes costs where aggregate resources may include the total number of workers, hours of equipment and machine time, or tons of raw materials.

Techniques

The techniques for aggregate planning include informal trial-and-error that utilize simply graphs or tables as well as advanced mathematical techniques. Aggregate planning requires the demand for each period to be determined, followed by determining the capacity for each period, which should match demand. Company, departmental or union policies that are pertinent are then identified. Unit costs for the total number of units produced and the costs associated with making changes in capacity are also taken into account. Alternative plans and computational costs for each are developed as a result. The plan that best satisfies the business objectives is chose. This is normally the plan with the lowest cost.

Manufacturing

Aggregate planning in manufacturing involves allocating the correct amount of resources for every manufacturing process so that the time and costs are minimized during idle mode. Manufacturing businesses use either the Chase Strategy or the Level Strategy. The Chase Strategy involves matching demand and capacity period by period. This strategy could trigger a considerable amount of hiring or firing workers, increased inventory carrying costs, labor union problems and utilization of plant and equipment. The advantage of the Chase strategy is that inventory is held at the lowest level possible, meaning large savings for the company. With a Level Strategy, a steady production rate and a steady employment rate is maintained. The business can then raise or lower inventory levels in anticipation of forecasted demand levels.

Services

Since services do not involve stockpiles or inventory, service-focused businesses do not have the luxury of building up their inventories during periods of low demand. In aggregate planning, services are considered “perishable,” where any capacity that is unused is considered to be wasted. For example, an empty hotel room or an empty flight seat cannot be held and sold at a later time. Services have variable processing requirements that make it hard to establish a good measure of capacity.

Differentiation

Aggregate planning in manufacturing works well because of the ability to produce, hold and sell inventory at any given time. Alternatively, aggregate planning in services differs substantially because services cannot be inventoried. The demand for services is much more difficult to predict and capacity is also difficult to measure. Service capacity must be provided at the right place and the right time, while labor is generally the most constraining service resource.

13.8 ADVANTAGES OF AGGREGATE PLANNING

Aggregate planning is a forecasting technique that businesses use in an attempt to predict the supply and demand of their products and services. Mainly, this is done in an effort to save money, streamline operations and increase productivity. To accomplish this, businesses use an aggregate planning model to develop a game plan that will assist them with determining their staffing requirements, materials needed, estimated timelines and budget costs so they can better plan ahead.

Minimize Staffing Fluctuations

By using aggregate planning to forecast production demand, businesses are better able to predict their staffing requirements. Businesses that need additional employees on a temporary basis tend to fill these positions with workers from temporary employment agencies. Through proper forecasting, a business will be able to reduce or eliminate the need to hire these extra workers. This will save the business both time and money as it won't need to pay the additional fees to the staffing agency and it won't have to pay its own workers to train the new additions.

Reduce Overhead

Excess inventory costs businesses a lot of money. Additional materials will need to be stored, and having finished products laying around increases the likelihood of damage to the products before they reach the customer. Adhering to an aggregate planning model can help businesses operate in a leaner manner. Managers will be able to better anticipate how much product they will need and when they will need it so they won't have to stockpile it in advance due to a fear that they'll run out before they can get more.

Increase Production Rates

A significant advantage to using aggregate planning is that it maximizes the utilization of production equipment. Since production equipment is being used at its full capacity, production rates significantly increase. This creates a much more streamlined process where businesses can accurately determine the time it will take to fulfill orders and can then plan their production operations accordingly. The idea is to create a good balance so orders are fulfilled before the deadlines, but they're not completed so far in advance that they are placed in storage for long periods before delivery.

Accommodate Changes

Since production orders often vary, most businesses cannot stick to one plan at all times. Aggregate planning allows for contingency measures to be put in place so businesses can better accommodate significant changes in customer orders and production. At different times, businesses can rotate between active, passive and mixed strategies. They can also fluctuate between using the chase strategy where production levels equal forecast demands, and the level production strategy where stable output rates remain constant.

13.9 LET'S SUM-UP

Aggregate planning involves planning the best quantity to produce during time periods in the intermediate-range horizon (often 3 months to 18 months) and planning the lowest cost method of providing the adjustable capacity to accommodate the production requirements. For manufacturing operations, aggregate planning involves planning workforce size, production rate (work hours per week) and inventory levels. The objectives of Aggregate Planning is A to develop plans that are:

1. **Feasible:** The plans should provide for the portion of demand that the firm intends to meet and should be within the financial and physical capacity of the firm.
2. **Optimal:** The firm should aim for plans which will ensure that resources are used as wisely as possible and costs kept as low as possible.

B to increase the range of alternatives of capacity use that can be considered by the management of the firm.

Operations Planning and Scheduling Systems

Operations planning and scheduling systems are concerned with the volume and timing of outputs, the utilization of operations capacity and balancing outputs with capacity at the desired levels of competitive effectiveness.

In doing the Aggregate Capacity Planning, we should take the following steps:

1. Prepare the sales forecast for each product that indicates the quantities to be sold in each time period (usually weeks, months or quarters) over the planning horizon (3 to18 months).
2. Sum up the individual product or service forecast into one aggregate demand for the factory.
3. Transform the aggregate demand for each time period into labor, materials, machines and other elements of production capacity required to satisfy aggregate demand.
4. Develop alternative resource schemes for supplying the necessary production capacity to support the cumulative aggregate demand.
5. Select the capacity plan from among the alternative considered that satisfy aggregate demand and best meets the objectives of the organizations.

13.10 KEY TERMS

Supply Chain Model: Supply chain model is strategic and systematic coordination model for supplying products to the end user or customer. In other words, SCM is a model that provides oversight of materials, finances, and information as they move from the supplier to the final user. It involves coordinating and integrating the aforementioned flows within and among companies. Generally, the ultimate goal of an effective supply chain model is to reduce inventory in our business (with the assumption that our products are available to our potential customers when needed).

Supply chain model is not only used to ensure business success or customer satisfaction, but can also be applied in other industries or societal settings, including disaster relief operations, medical missions, cultural evolutions, and to improve quality of life among other applications other applications.

Sales Forecast: Projection of achievable sales revenue, based on historical sales data, analysis of market surveys and trends, and salesperson’s estimates. Also called sales budget, it forms the basis of a business plan because of the level of sales revenue affects practically every aspect of a business.

Customer backlog: Customer Backlog stands for the amount of sales orders that a company has received but has not completed yet, also referred to as order backlog or BL. The perception of the impact backlog orders have on a company varies. Majority of companies measure their backlog rations in sales values. If the backlog sales value is high, this is considered very positive on the business, as it shows a high level of customer demand as well as future financial stability.

Make to order: Make to order, also referred to as build to order (BTO) or made to order (MTO), is a manufacturing process in which the production of an item begins only after a confirmed customer order is received. MTO (Make to Order) is a manufacturing process in which manufacturing starts only after a customer's order is received. Forms of MTO vary, for example, an assembly process starts when demand actually occurs or manufacturing starts with development planning.

Make to Stock: MTS (Make to Stock) literally means to manufacture products for stock based on demand forecasts, which can be regarded as push-type production. MTS has been required to prevent opportunity loss due to stockouts and minimize excess inventory using accurate forecasts. In the industrialized society of mass production and mass marketing, this forecast mass production urged standardization and efficient business management such as cost reduction.

Pull Push Manufacturing: "Push type" means make to Stock in which the production is not based on actual demand. "Pull type" means make to Order in which the production is based on actual demand. In supply chain management, it is important to carry out processes halfway between push type and pull type or by a combination of push type and pull type.

Theory of Constraints: The "TOC (Theory of Constraints)" developed by Eliyahu Goldratt is a method of increasing throughput by managing "constraints" (bottlenecks). It is a concept that serves as the theoretical base of supply chain management and a model that explains the relationship of variables in business as to how cash flow-based profitability is affected by decision-making in the supply chain concerning business processes in terms of time.

13.11 SELF-ASSESSMENT QUESTIONS

1. Planning tasks associated with job scheduling, machine loading, and dispatching typically falls under
   a. Long-range plans
   b. intermediate-range plans
   c. Short-range plans
   d. Mission-related planning
   e. Strategic planning
2. Dependence on an external source of supply is found in which of the following aggregate planning strategies?
   a. varying production rates through overtime or idle time
   b. using part-time workers
   c. back ordering during high demand periods
   d. subcontracting
   e. hiring and laying off
3. Which of the following aggregate planning strategies might direct your client to a competitor?
   a. using part-time workers
   b. subcontracting
   c. changing inventory level
   d. varying production rates through overtime or idle time
   e. varying workforce size by hiring or layoffs
4. Which of the following statements about aggregate planning is true?
   a. Advertising/promotion is a way of manipulating product or service supply.
   b. Work station loading and job assignments are examples of aggregate production planning.
   c. Overtime/idle time is a way of manipulating product or service demand.
   d. Aggregate planning uses the adjustable part of capacity to meet production requirements.
   e. All of the above are true.

5. Which of the following statements about aggregate planning is true?

   a. In aggregate planning, backorders are a means of manipulating demand while part-time workers are a way of manipulating product or service supply.
   b. A pure chase strategy allows lower inventories when compared to pure level and hybrid strategies.
   c. In spite of the research into mathematical models, aggregate production planners continue to use trial and error methods when developing their plans.
   d. All of the above are true.
   e. None of the above are true.
6. In level scheduling, what is kept uniform from month to month?
   a. product mix
   b. inventory levels
   c. demand levels
   d. production/workforce levels
   e. sub-contracting levels
7. Which of the following is consistent with a pure chase strategy?
   a. vary production levels to meet demand requirements
   b. vary work force to meet demand requirements
   c. vary production levels and work force to meet demand

13.12 MODEL QUESTIONS

1. What are the factors of Aggregate Planning? Discuss.
2. Elaborate Chase Strategy with example.
3. Justify adoption of level strategy with an example for a Bakery industry.

13.13 FURTHER READINGS

- Chopra, Sunil and Peter Meindl. Supply Chain Management: Strategy, Planning, and Operation. Upper Saddle River, NJ: Pearson Prentice Hall, 2004.
- Iyer, Ananth V., Vinayak Deshpande, and Zhengping Wu. "A Postponement
- Model for Demand Management." Management Science 49, no. 8, (2003): 983– 1002.

UNIT 14: STATISTICAL QUALITY CONTROL

STRUCTURE

LEARNING OBJECTIVES

After go through this unit you will be able to know-

- Explain the meaning of Statistical Quality Control
- Explain the tools of Statistical Quality Control
- Implementation process of Statistics and Quality Control
- Understand it’s objectives
- Benefits of understanding Statistical Quality Control (SQC)

14.1 INTRODUCTION

Statistical Quality Control (SQC) is the term used to describe the set of statistical tools used by quality professionals. SQC is used to analyze the quality problems and solve them.

Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services.

All the tools of SQC are helpful in evaluating the quality of services. SQC uses different tools to analyze quality problem.

1. Descriptive Statistics
2. Statistical Process Control (SPC)
3. Acceptance Sampling

Descriptive Statistics involves describing quality characteristics and relationships. SPC involves inspect random sample of output from process for characteristic. Acceptance Sampling involves batch sampling by inspection.

14.2 DEFINITIONS

Statistics:

Statistics means the good amount of data to obtain reliable results. The Science of statistics handles this data in order to draw certain conclusions. Its techniques find extensive applications in quality control, production planning and control, business charts, linear programming etc.

Quality:

Quality is a relative term and is generally explained with reference to the end use of the product. Quality is thus defined as fitness for purpose.

Control:

Control is a system for measuring and checking or inspecting a phenomenon. It suggests when to inspect, how often to inspect and how much to inspect. Control ascertains quality characteristics of an item, compares the same with prescribed quality characteristics of an item, compares the same with prescribed quality standards and separates defective item from non-defective ones.

Statistical Quality Control (SQC) is the term used to describe the set of statistical tools used by quality professionals. SQC is used to analyze the quality problems and solve them.

Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services.

14.3 METHODOLOGY & TOOLS OF STATISTICAL QUALITY CONTROL

Statistical Quality Control (SQC) is the term used to describe the set of statistical tools used by quality professionals. SQC is used to analyze the quality problems and solve them.

Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services.

All the tools of SQC are helpful in evaluating the quality of services. SQC uses different tools to analyze quality problem.

1) Descriptive Statistics

Descriptive Statistics involves describing quality characteristics and relationships.

2) Statistical Process Control (SPC)

SPC involves inspect random sample of output from process for characteristic.

a) Responsibilities

b) Preliminary Engineering Activities

c) Control Chart Preparation

d) Standardized the Document

e) Engineering Notification

f) Changing Control Limits.

g) Review & Approve Process.

h) Archiving of Data and Charts.

i) Computerized Control Charts.

j) Training

3) Acceptance Sampling

Acceptance Sampling involve batch sampling by inspection.

Assume that a consumer receives a shipment of parts called a lot from a producer. A sample of parts will be taken and the number of defective items counted. If the number of defective items is low, the entire lot will be accepted. If the number ofm defective items is high, the entire lot will be rejected. Correct decisions correspond to accepting a good-quality lot and rejecting a poor-quality lot.

Because sampling is being used, the probabilities of erroneous decisions need to be considered. The error of rejecting a good-quality lot creates a problem for the producer; the probability of this error is called the producer's risk. On the other hand, the error of accepting a poor-quality lot creates a problem for the purchaser or consumer; the probability of this error is called the consumer's risk.

The design of an acceptance sampling plan consists of determining a sample size n and an acceptance criterion c, where c is the maximum number of defective items that can be found in the sample and the lot still be accepted. The key to understanding both the producer's risk and the consumer's risk is to assume that a lot has some known percentage of defective items and compute the probability of accepting the lot for a given sampling plan. By varying the assumed percentage of defective items in a lot, several different sampling plans can be evaluated and a sampling plan selected such that both the producer's and consumer's risks are reasonably low.

Descriptive Statistics involves describing quality characteristics and relationships. SPC involves inspect random sample of output from process for characteristic. Acceptance Sampling involves batch sampling by inspection.

14.4 QUALITY TOOLS FOR PROBLEM SOLVING

The seven major tools used for Statistical Process Control are:

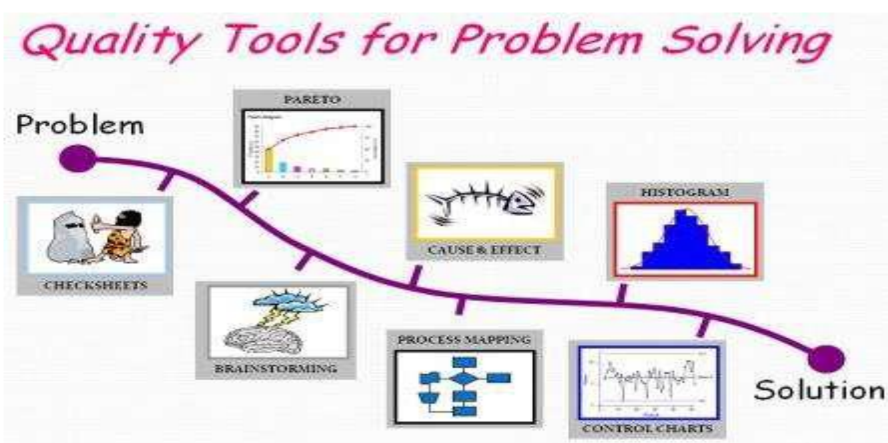


Fig 1.1

14.4.1 Histogram

A histogram is a graphical representation of how many times different, mutually exclusive events are observed in an experiment. To interpret a histogram, we find the events on the x-axis and the counts on the y-axis. Each event has a rectangle that shows what its count (or frequency) is.

Example

A power engineer required a 10 ohm, 0.1% tolerance, and high power resistor. The only resistors available were 10% tolerance. To achieve the higher tolerance, he uses a series of 100 resistors each of 0.1 ohm. The summing effect was expected to average out the low tolerance, as resistors over and under 0.1 ohm balanced each other out. When the resulting resistance started overheating, the engineer measured the value of each one and plotted a Histogram, as in Fig. 1.1.

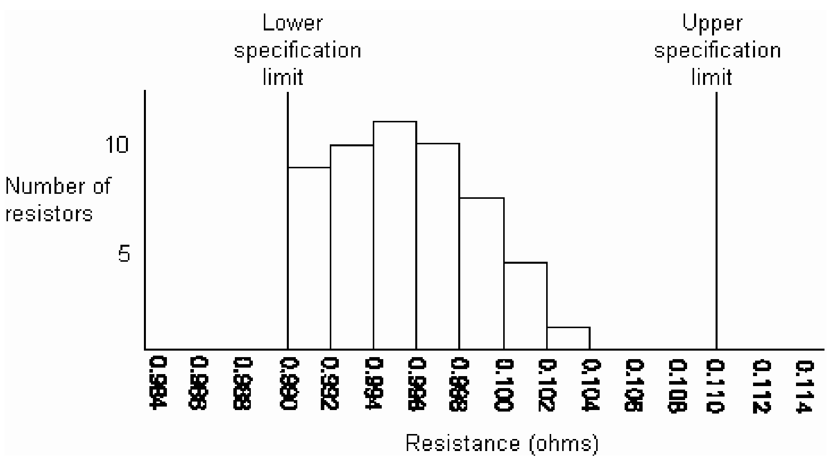


Fig 1.2

The result showed that although the resistors were within specification, their distribution was not normal and not centered on 0.1 ohm (this was probably caused by selection from an off-center production system). The solution of a specially made resistor was significantly more expensive.

14.4.2 Pareto Chart

A Pareto chart is a bar graph. The lengths of the bars represent frequency or cost (time or money), and are arranged with longest bars on the left and the shortest to the right. In this way the chart visually depicts which situations are more significant.

When to Use a Pareto Chart

- When analyzing data about the frequency of problems or causes in a process.

- When there are many problems or causes and you want to focus on the most significant.
- When analyzing broad causes by looking at their specific components.
- When communicating with others about your data.

Pareto Chart Procedure

1. Decide what categories you will use to group items.
2. Decide what measurement is appropriate. Common measurements are frequency, quantity, cost and time.
3. Decide what period of time the Pareto chart will cover: One work cycle? One full day? A week?
4. Collect the data, recording the category each time. (Or assemble data that already exist.)
5. Subtotal the measurements for each category.
6. Determine the appropriate scale for the measurements you have collected. The maximum value will be the largest subtotal from step 5.
7. (If you will do optional steps 8 and 9 below, the maximum value will be the sum of all subtotals from step 5.) Mark the scale on the left side of the chart.
8. Construct and label bars for each category. Place the tallest at the far left, then the next tallest to its right and so on. If there are many categories with small measurements, they can be grouped as "other."

   Steps 8 and 9 are optional but are useful for analysis and communication.
9. Calculate the percentage for each category: the subtotal for that category divided by the total for all categories. Draw a right vertical axis and label it with percentages. Be sure the two scales match: For example, the left measurement that corresponds to one-half should be exactly opposite 50% on the right scale.
10. Calculate and draw cumulative sums: Add the subtotals for the first and second categories, and place a dot above the second bar indicating that sum. To that sum add the subtotal for the third category, and place a dot above the third bar for that new sum. Continue the process for all the bars. Connect the dots, starting at the top of the first bar. The last dot should reach 100 percent on the right scale.

Pareto Chart Examples

Example #1 shows how many customer complaints were received in each of five categories.

Example #2 takes the largest category, "documents," from Example #1, breaks it down into six categories of document-related complaints, and shows cumulative values.

If all complaints cause equal distress to the customer, working on eliminating document-related complaints would have the most impact, and of those, working on quality certificates should be most fruitful.

Fig 1.3: **Example #1**

Fig 1.4: **Example #2**

14.4.3 Cause and Effect Diagram (also known as the "fishbone" or Ishikawa diagram)

Cause and Effect Analysis was devised by Professor Kaoru Ishikawa, a pioneer of quality management, in the 1960s. The technique was then published in his 1990 book, "Introduction to Quality Control."

The diagrams that you create with are known as Ishikawa Diagrams or Fishbone Diagrams (because a completed diagram can look like the skeleton of a fish).
Although it was originally developed as a quality control tool, you can use the technique just as well in other ways. For instance, you can use it to:

- Discover the root cause of a problem.
- Uncover bottlenecks in the process
- Identify where and why a process isn't working.

How to Use the Tool

Follow these steps to solve a problem with Cause and Effect Analysis:

Step 1: Identify the Problem

First, write down the exact problem you face. Where appropriate, identify who is involved, what the problem is, and when and where it occurs.

Then, write the problem in a box on the left-hand side of a large sheet of paper, and draw a line across the paper horizontally from the box. This arrangement, looking like the head and spine of a fish, gives you space to develop ideas.

Example:

In this simple example, a manager is having problems with an uncooperative branch office.

Fig 1.5: **Figure 1 – Cause and Effect Analysis Example Step 1**

Tip 1:

Some people prefer to write the problem on the right-hand side of the piece of paper, and develop ideas in the space to the left. Use whichever approach you feel most comfortable with.

Tip 2:

It's important to define your problem correctly.

By considering all of these, you can develop a comprehensive understanding of the problem.

Step 2: Work Out the Major Factors Involved

Next, identify the factors that may be part of the problem. These may be systems, equipment, materials, external forces, people involved with the problem, and so on. Try to draw out as many of these as possible. As a starting point, you can use models such as the McKinsey 7S Framework (which offers you Strategy, Structure, Systems, Shared values, Skills, Style and Staff as factors that you can consider) or the **4Ps of Marketing** (which offers Product, Place, Price, and Promotion as possible factors). **Brainstorm** any other factors that may affect the situation.

Then draw a line off the "spine" of the diagram for each factor, and label each line.

Example:

The manager identifies the following factors, and adds these to his diagram:

- Site.
- Task.
- People.
- Equipment.
- Control

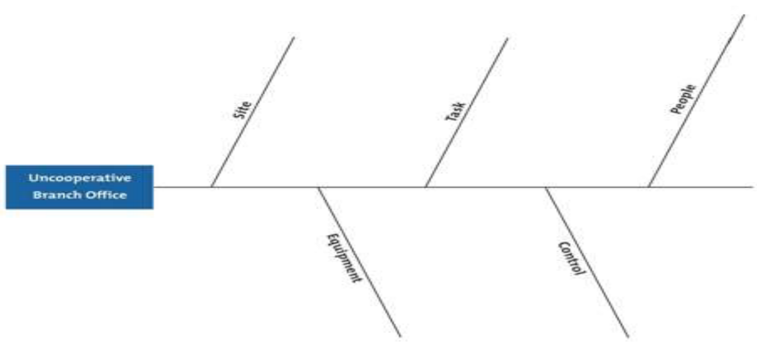


Fig 1.6: **Figure 2 – Cause and Effect Analysis Example**

Step 3: Identify Possible Causes

Now, for each of the factors you considered in step 2, brainstorm possible causes of the problem that may be related to the factor.

Show these possible causes as shorter lines coming off the "bones" of the diagram. Where a cause is large or complex, then it may be best to break it down into sub-causes. Show these as lines coming off each cause line.

Example:

For each of the factors he identified in step 2, the manager brainstorms possible causes of the problem, and adds these to his diagram, as shown in figure 3.

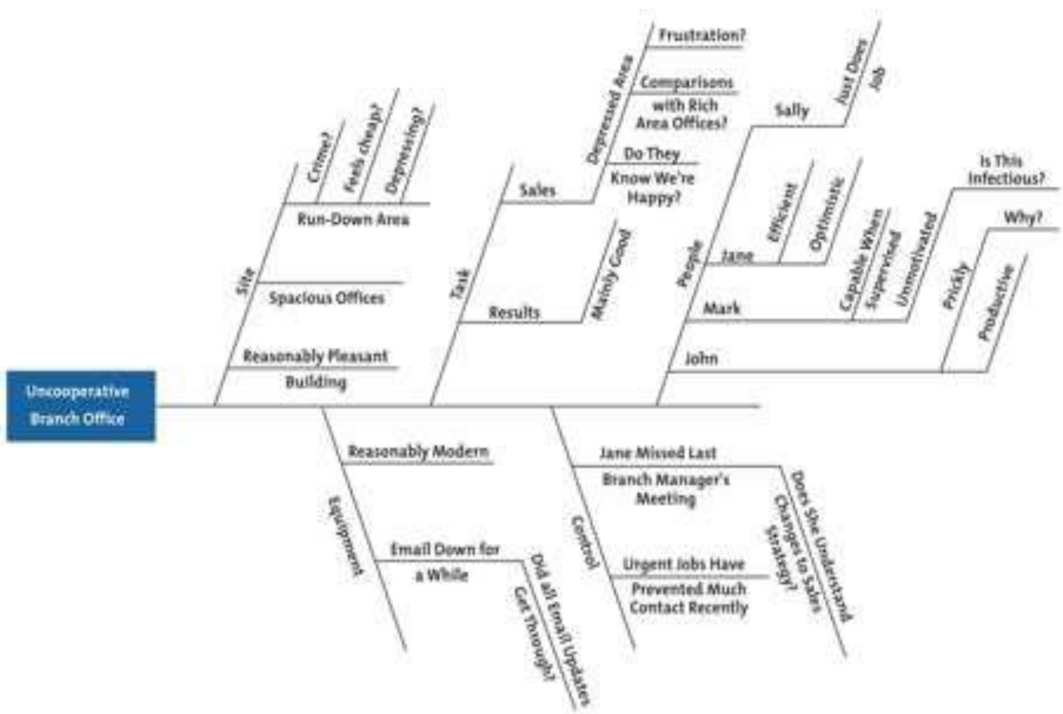


Fig 1.7: **Figure 3 – Cause and Effect Analysis Example Step 3**

Step 4: Analyze Your Diagram

By this stage you should have a diagram showing all of the possible causes of the problem that you can think of.

Depending on the complexity and importance of the problem, you can now investigate the most likely causes further. This may involve setting up investigations, carrying out surveys, and so on.

These will be designed to test which of these possible causes is actually contributing to the problem.

Example:

The manager has now finished his analysis. If he hadn't looked at the problem this way, he might have dealt with it by assuming that people in the branch office were "being difficult."

Instead he thinks that the best approach is to arrange a meeting with the Branch Manager. This would allow him to brief the manager fully on the new strategy, and talk through any problems that she may be experiencing.

There are four steps to using the tool.

1. Identify the problem.
2. Work out the major factors involved.
3. Identify possible causes.
4. Analyze your diagram.

You'll find this method is particularly useful when you're trying to solve complicated problems.

14.4.4 Defect Concentration Diagram

A check sheet, also called: defect concentration diagram is a structured, prepared form for collecting and analyzing data. This is a generic tool that can be adapted for a wide variety of purposes.

When to Use a Check Sheet

- When data can be observed and collected repeatedly by the same person or at the same location.
- When collecting data on the frequency or patterns of events, problems, defects, defect location, defect causes, etc.
- When collecting data from a production process

Check Sheet Procedure

1. Decide what event or problem will be observed. Develop operational definitions.
2. Decide when data will be collected and for how long.
3. Design the form. Set it up so that data can be recorded simply by making check marks or Xs or similar symbols and so that data do not have to be recopied for analysis.
4. Label all spaces on the form.
5. Test the check sheet for a short trial period to be sure it collects the appropriate data and is easy to use.
6. Each time the targeted event or problem occurs, record data on the check sheet.

Check Sheet Example

The figure below shows a check sheet used to collect data on telephone interruptions. The tick marks were added as data was collected over several weeks.

Telephone Interruptions

Reason	Day					
	Mon	Tues	Wed	Thurs	Fri	Total
Wrong number	~~IIII~~	II	I	~~IIII~~	~~IIII~~ II	20
Info request	II	II	II	II	II	10
Boss	~~IIII~~	II	~~IIII~~ II	I	IIII	19
Total	12	6	10	8	13	49

Fig 1.8: **Check Sheet Example**

14.4.5 Control Chart

The control chart, also called: statistical process control is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data.

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Control charts for variable data are used in pairs. The top chart monitors the average, or the centering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If your data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly.

When to Use a Control Chart

- When controlling ongoing processes by finding and correcting problems as they occur.
- When predicting the expected range of outcomes from a process.
- When determining whether a process is stable (in statistical control).
- When analyzing patterns of process variation from special causes (nonroutine events) or common causes (built into the process).
- When determining whether your quality improvement project should aim to prevent specific problems or to make fundamental changes to the process.

Control Chart Basic Procedure

1. Choose the appropriate control chart for your data.
2. Determine the appropriate time period for collecting and plotting data.
3. Collect data, construct your chart and analyze the data.
4. Look for “out-of-control signals” on the control chart. When one is identified, mark it on the chart and investigate the cause. Document how you investigated, what you learned, the cause and how it was corrected.

Out-of-control signals

- A single point outside the control limits. In Figure 1, point sixteen is above the UCL (upper control limit).
- Two out of three successive points are on the same side of the centreline and farther than 2 σ from it. In Figure 1, point 4 sends that signal.

- Four out of five successive points are on the same side of the centerline and farther than 1 σ from it. In Figure 1, point 11 sends that signal.
- A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14 or 16 out of 20. In Figure 1, point 21 is eighth in a row above the centerline.
- Obvious consistent or persistent patterns that suggest something unusual about your data and your process.

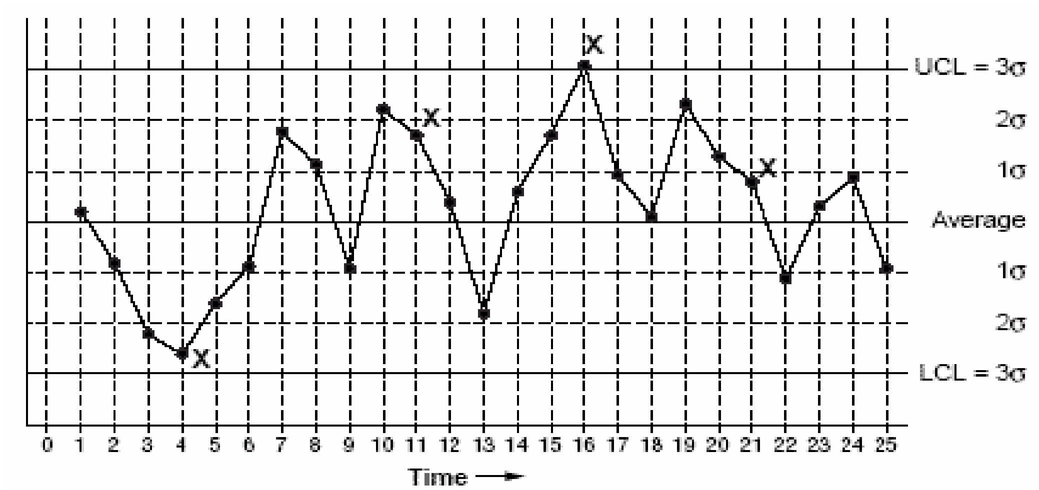


Fig 1.9: **Control Chart: Out-of-Control Signals**

1. Continue to plot data as they are generated. As each new data point is plotted, check for new out-of-control signals.

2. When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits.

14.4.6 Scatter Diagram

The scatter diagram graphs, also called: scatter plot, X–Y graph, pairs of numerical data, with one variable on each axis, to look for a relationship between them. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the tighter the points will hug the line.

When to Use a Scatter Diagram

- When you have paired numerical data.
- When your dependent variable may have multiple values for each value of your independent variable.
- When trying to determine whether the two variables are related, such as…
  - ✓ When trying to identify potential root causes of problems.
  - ✓ After brainstorming causes and effects using a fishbone diagram, to determine objectively whether a particular cause and effect are related.
  - ✓ When determining whether two effects that appear to be related both occur with the same cause.
  - ✓ When testing for autocorrelation before constructing a control chart.

Scatter Diagram Procedure

1. Collect pairs of data where a relationship is suspected.

2. Draw a graph with the independent variable on the horizontal axis and the dependent variable on the vertical axis. For each pair of data, put a dot or a symbol where the x-axis value intersects the y-axis value. (If two dots fall together, put them side by side, touching, so that you can see both.)

3. Look at the pattern of points to see if a relationship is obvious. If the data clearly form a line or a curve, you may stop. The variables are correlated. You may wish to use regression or correlation analysis now. Otherwise, complete steps 4 through 7.

4. Divide points on the graph into four quadrants. If there are X points on the graph,

- Count X/2 points from top to bottom and draw a horizontal line.
- Count X/2 points from left to right and draw a vertical line.
- If number of points is odd, draw the line through the middle point.

1. Count the points in each quadrant. Do not count points on a line.

2. Add the diagonally opposite quadrants. Find the smaller sum and the total of points in all quadrants.

A = points in upper left + points in lower right

B = points in upper right + points in lower left

Q = the smaller of A and B

N = A + B

3. Look up the limit for N on the trend test table.

- If Q is less than the limit, the two variables are related.
- If Q is greater than or equal to the limit, the pattern could have occurred from random chance.

Table 5.18 Trend test table.

N	Limit	*N*	Limit
1–8	0	51–53	18
9–11	1	54–55	19
12–14	2	56–57	20
15–16	3	58–60	21
17–19	4	61–62	22
20–22	5	63–64	23
23–24	6	65–66	24
25–27	7	67–69	25
28–29	8	70–71	26
30–32	9	72–73	27
33–34	10	74–76	28
35–36	11	77–78	29
37–39	12	79–80	30
40–41	13	81–82	31
42–43	14	83–85	32
44–46	15	86–87	33
47–48	16	88–89	34
49–50	17	90	35

Fig 1.10: **Scatter Diagram Example**

The ZZ-400 manufacturing team suspects a relationship between product purity (percent purity) and the amount of iron (measured in parts per million or ppm).

Purity and iron are plotted against each other as a scatter diagram, as shown in the figure below.

There are 24 data points. Median lines are drawn so that 12 points fall on each side for both percent purity and ppm iron.

To test for a relationship, they calculate:

A = points in upper left + points in lower right = 9 + 9 = 18

B = points in upper right + points in lower left = 3 + 3 = 6

Q = the smaller of A and B = the smaller of 18 and 6 = 6

N = A + B = 18 + 6 = 24

Then they look up the limit for N on the trend test table. For N = 24, the limit is 6.
Q is equal to the limit. Therefore, the pattern could have occurred from random chance, and no relationship is demonstrated.

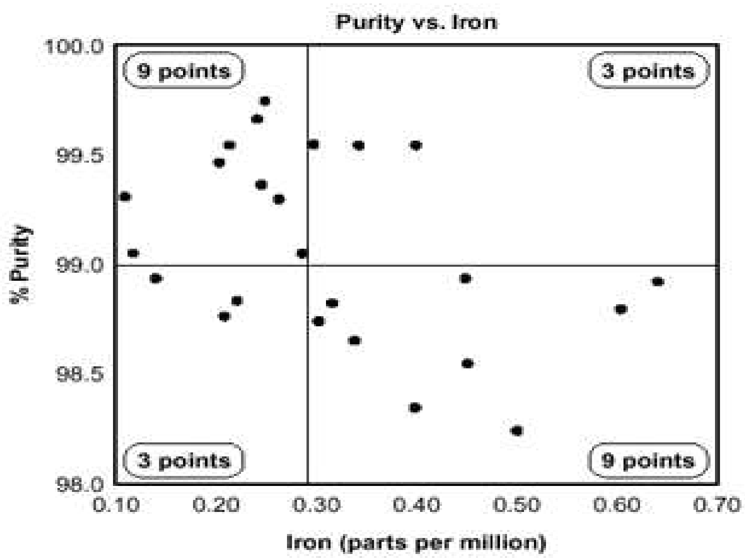


Fig 1.11: **Scatter Diagram Example**

Here are some examples of situations in which might you use a scatter diagram:

- Variable A is the temperature of a reaction after 15 minutes. Variable B measures the color of the product. You suspect higher temperature makes the product darker. Plot temperature and color on a scatter diagram.
- Variable A is the number of employees trained on new software, and variable B is the number of calls to the computer help line. You suspect that more training reduces the number of calls. Plot number of people trained versus number of calls.
- To test for autocorrelation of a measurement being monitored on a control chart, plot this pair of variables: Variable A is the measurement at a given time. Variable B is the same measurement, but at the previous time. If the scatter diagram shows correlation, do

another diagram where variable B is the measurement two times previously. Keep increasing the separation between the two times until the scatter diagram shows no correlation.

14.4.7 Flow Chart

A flowchart, also called: process flowchart, process flow diagram.is a picture of the separate steps of a process in sequential order.

Elements that may be included are: sequence of actions, materials or services entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements.

The process described can be anything: a manufacturing process, an administrative or service process, a project plan. This is a generic tool that can be adapted for a wide variety of purposes.

When to Use a Flowchart

- To develop understanding of how a process is done.
- To study a process for improvement.
- To communicate to others how a process is done.
- When better communication is needed between people involved with the same process.
- To document a process.
- When planning a project.

Flowchart Basic Procedure

Materials needed: sticky notes or cards, a large piece of flipchart paper or newsprint, marking pens.

1. Define the process to be diagrammed. Write its title at the top of the work surface.
2. Discuss and decide on the boundaries of your process: Where or when does the process start? Where or when does it end? Discuss and decide on the level of detail to be included in the diagram.
3. Brainstorm the activities that take place. Write each on a card or sticky note.

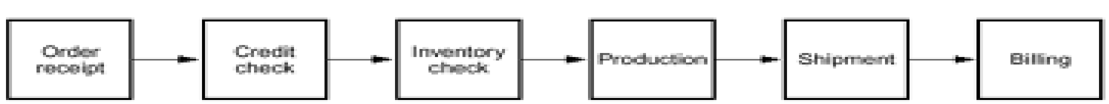
4. Sequence is not important at this point, although thinking in sequence may help people remember all the steps.
5. Arrange the activities in proper sequence.
6. When all activities are included and everyone agrees that the sequence is correct, draw arrows to show the flow of the process.
7. Review the flowchart with others involved in the process (workers, supervisors, and suppliers, customers) to see if they agree that the process is drawn accurately.

Flowchart Considerations

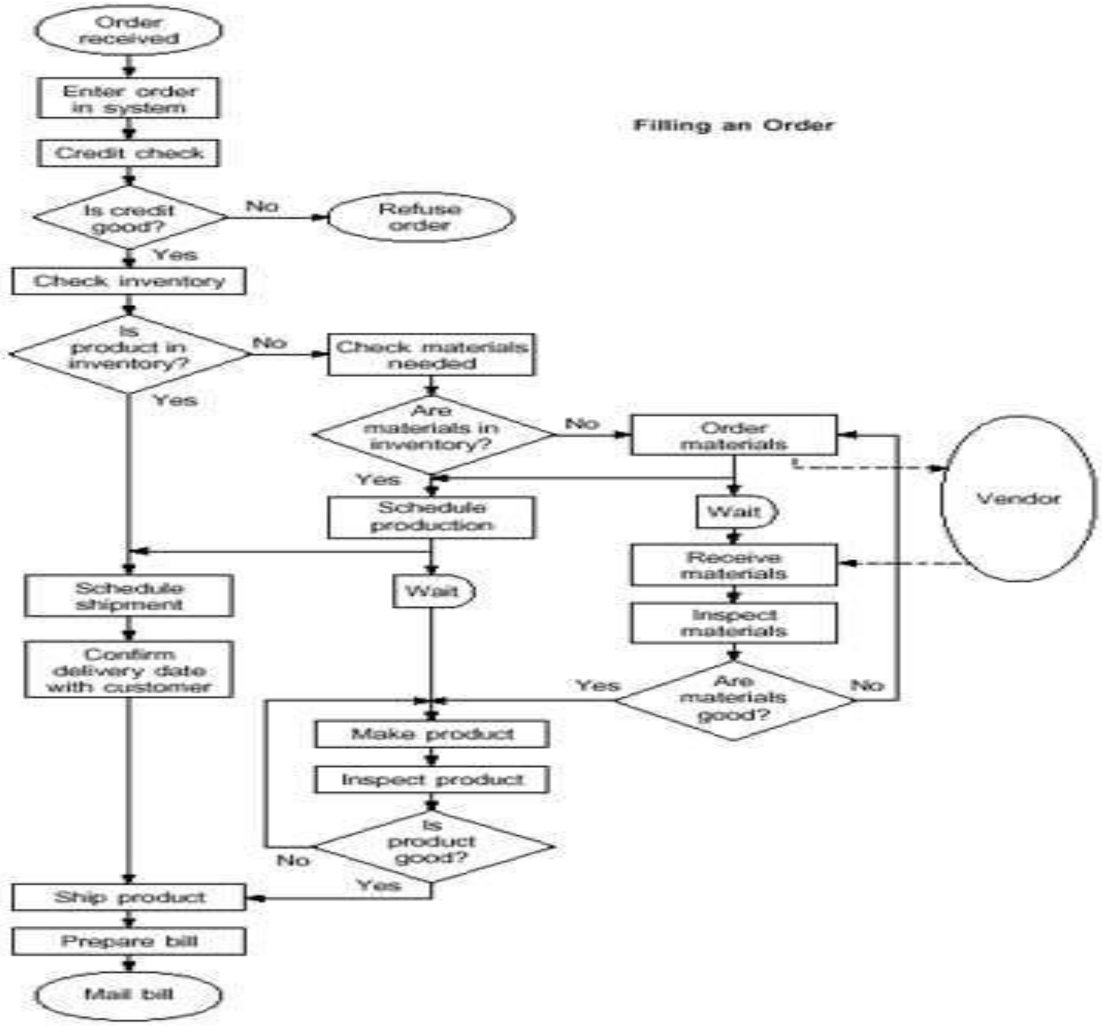
- Don't worry too much about drawing the flowchart the "right way." The right way is the way that helps those involved understands the process.
- Identify and involve in the flowcharting process all key people involved with the process. This includes those who do the work in the process: suppliers, customers and supervisors. Involve them in the actual flowcharting sessions by interviewing them before the sessions and/or by showing them the developing flowchart between work sessions and obtaining their feedback.
- Do not assign a "technical expert" to draw the flowchart. People who actually perform the process should do it.
- Computer software is available for drawing flowcharts. Software is useful for drawing a neat final diagram, but the method given here works better for the messy initial stages of creating the flowchart.

Flowchart Examples

High–Level Flowchart for an Order-Filling Process



Detailed Flowchart

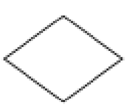


Commonly Used Symbols in Detailed Flowcharts

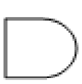
 One step in the process; the step is written inside the box.

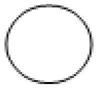
Usually, only one arrow goes out of the box.

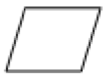
→ Direction of flow from one step or decision to another.

 Decision based on a question. The question is written in the diamond.

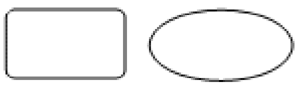
More than one arrow goes out of the diamond, each one showing the direction the process takes for a given answer to the question. (Often the answers are “yes” and “no.”)

 Delay or wait

 Link to another page or another flowchart. The same symbol on the other page indicates that the flow continues there.

 Input or output

 Document

 Alternate symbols for start and end points

14.5 STATISTICAL QUALITY CONTROL IMPLEMENTATION

Statistical Quality Control (SQC) is the term used to describe the set of statistical tools used by quality professionals. SQC is used to analyze the quality problems and solve them.

Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services.

All the tools of SQC are helpful in evaluating the quality of services. SQC uses different tools to analyze quality problem.

1) Descriptive Statistics

Descriptive Statistics involves describing quality characteristics and relationships.

2) Statistical Process Control (SPC)

SPC involves inspect random sample of output from process for characteristic.

a) Responsibilities

b) Preliminary Engineering Activities

c) Control Chart Preparation

d) Standardized the Document

e) Engineering Notification

f) Changing Control Limits.

g) Review & Approve Process.

h) Archiving of Data and Charts.

i) Computerized Control Charts.

j) Training

3) Acceptance Sampling

Acceptance Sampling involve batch sampling by inspection

14.6 OBJECTIVES OF STATISTICAL QUALITY CONTROL

Quality Control is very important for every company. Quality control includes service quality given to customer, company management leadership, commitment of management, continuous improvement, and fast response, actions based on facts, employee participation and a quality driven culture.

The main objectives of the quality control module are to control of material reception, internal rejections, clients, claims, providers and evaluations of the same corrective actions are related to their follow-up. These systems and methods guide all quality activities. The development and use of performance indicators is linked, directly or indirectly, to customer requirements and satisfaction, and to management.

14.7 BENEFITS OF STATISTICAL QUALITY CONTROL

1. It provides a means of detecting error at inspection.
2. It leads to more uniform quality of production.
3. It improves the relationship with the customer.
4. It reduces inspection costs.
5. It reduces the number of rejects and saves the cost of material.
6. It provides a basis for attainable specifications.
7. It points out the bottlenecks and trouble spots.
8. It provides a means of determining the capability of the manufacturing process.
9. It promotes the understanding and appreciation of quality control.

14.8 LET'S SUM-UP

The tension between after-the-fact inspection and defect prevention has been at the heart of manufacture since the introduction of statistical methods to industry in the 1940s. Today, to clearly divide responsibilities within an organization, and tie these very different activities to existing roles, consider a division by impact to the patient. Activities which monitor a process in real-time to prevent defects while a lot is being manufactured are known as Statistical Process Controls (SPC).

In contrast, activities which occur after manufacture to keep defects from reaching a patient by additional inspection are Statistical Quality Control (SQC). The difference is one of strategy. From the patient's perspective, SPC's feedback during manufacture prevents risk while SQC's feed-forward guards against catastrophic failure. Both are necessary in an industry of low volume, high cost, and high risk goods.

Statistical quality control (SQC) is the term used to describe the set of statistical tools deployed for evaluating the organizational quality by the quality professionals. Statistical quality control can be divided into following three broad categories.

- **Descriptive statistics –** These are the statistics used to describe certain quality characteristics such as the central tendency and variability of the observed data. It also describes the relationship. Descriptive statistics include statistics such as the mean, standard deviation, the range, and a measure of the distribution of data.
- **Statistical process control (SPC) –** It consists of statistical tools that involve inspecting a random sample of the output from a process and deciding whether the process is producing products with characteristics that fall within a predetermined range. SPC answers the question whether the process is functioning properly or not. These tools are very important for a process since they help in identifying and catching a quality problem during the production process.
- **Acceptance sampling –** It helps in evaluating whether there is problem with quality and whether desirable quality is being achieved for a batch of product. Accepting sampling consists of the process of randomly inspecting a sample of goods and deciding whether to accept the entire lot based on the results. This sampling decides whether a batch of goods is to be accepted or rejected.

There are seven basic tools employed for SQC. The seven basic tools of quality is a designation given to a fixed set of graphical techniques identified as being most helpful in trouble shooting issues related to quality. They are called basic because they are suitable for people with little formal training in statistics and because they can be used to solve the vast majority of quality related issues. These seven basic tools are described below.

14.9 KEY TERMS

- **Mean –** It is an important statistic tool that measures the central tendency of a set of data. The mean is computed by simply summing up of all the observations and dividing by the total number of observations.
- **Range and standard deviation –** This information providers with the variability of the data. It tells how the data is spread out around the mean. Range is the difference between the largest and the smallest observations in a set of data while standard deviation is a statistics that measures the amount of data dispersion around the mean. Small values of the range and standard deviation mean that the observations are closely clustered around the mean while large values of the range and standard deviation mean that the observations are spread around the mean.
- **Distribution of data –** It is a measure to determine the quality characteristics. When the distribution of data is symmetric then there are same numbers of observations below and above the mean. This is what is commonly found when only normal variation is present in the data. When a disproportionate number of observations are either above or below the mean, then the data has a skewed distribution.
- **SQC-** Activities which occur after manufacture to keep defects from reaching a patient by additional inspection are Statistical Quality Control (SQC).
- **SPC-** Activities which monitor a process in real-time to prevent defects while a lot is being manufactured are known as Statistical Process Controls (SPC).
- **Flowchart**, also called: process flowchart, process flow diagram is a picture of the separate steps of a process in sequential order.

  Elements that may be included are: sequence of actions, materials or services entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements.

The process described can be anything: a manufacturing process, an administrative or service process, a project plan. This is a generic tool that can be adapted for a wide variety of purposes.

- Cause and effect analysis diagram- When one is able to relate different causes to the effect, namely the quality characteristics, then he can use this logical thinking of cause and effect for further investigations to improve and control quality. This type of linking is done through cause and effect diagrams.

14.10 SELF-ASSESSMENT QUESTIONS

Identify the correct answer.

Q.1 Statistical quality control is also called

A. statistical process control
B. statistical failure control
C. statistical control of prevention cost
D. statistical control of sunk cost

Ans: A

Q.2 Fishbone diagram is an example of

A. Relevant costing diagram
B. Cause and effect diagram
C. Control chart
D. Pareto diagram

Ans: B

Q.3 Factors are identified by cause and effect diagrams include

A. component and material factors
B. machine-related factors
C. human factors
D. all of above

Ans: D

Q.4 Formal way of differentiate between non-random and random variations in manufacturing process is classified as

A. statistical process control

B. statistical failure control
C. statistical control of prevention cost
D. statistical control of sunk cost

Ans: A

Q.5 The assignable cause, if the size of a product is beyond the upper or lower control limit, is

A. Machine
B. Process
C. Measurement
D. All of the above

Ans: D

Q.6 The task of exercising control over the incoming raw materials and the outgoing finished products is usually known as

A. Acceptance sampling
B. Process control
C. Quality control
D. All of the above

Ans: A

Q.7 Process control is carried out

A. Before production
B. During production
C. After production control
D. All of the above

Ans: B

Q.8 High cost, low volume items requires

A. A, No inspection
B. Little inspection
C. Intensive inspection
D. 100% inspection

Ans: C

14.11 MODEL QUESTIONS

1. Explain the differences between SQC and SPC.

2. Define Fish bone diagram with an example from your working experience.
3. Enumerate benefits of Statistical Quality Control.

14.12 FURTHER READINGS

- Introduction to Statistical Quality Control by Douglas c Montgomery
- Integrating SPC and SQC by Mark SchaefferS
- Process Capability and Statistical Quality Control- Technical note

UNIT 15 CONTROL CHARTS

Structure

LEARNING OBJECTIVES

This chapter will assist students in understanding the following:

- The notion of an attribute control chart
- Control chart types
- Real-time application of P, np, and C charts.

15.1 INTRODUCTION

The control chart is a visual depiction that displays whether or not a sampling of data falls within the typical or typical range of variation. This can be done by comparing the sample to a standard deviation. Control charts may be separated into two categories: those that focus on variables and those that concentrate on characteristics. Control charts of variables like these have particular restrictions associated with them, and they can only be used in situations when the quality feature of a product can be assessed quantitatively and stated in numbers. This is the only circumstance in which they may be utilized. Because of this, control charts covering attributes are utilized in situations in which the quality features of a commodity cannot be measured. Attributes are those qualities that can only be recognized by their absence or presence from the product. For example, air bubbles, scratches, faulty print on linen, etc., are all examples of attributes that can only be recognized by their appearance or absence. Because variations in the production process are inevitable, the control chart shows when it is appropriate to stop making modifications to a process to prevent the wasteful occurrence of repeated adjustments. According to the statistical sampling theory, a suitable-sized random sample is taken from each lot, which is the foundation of control charts and visual representations. Control charts promptly inform of undesirable fluctuations and aid in identifying their origin and elimination. They also warn of any deviation from the specified tolerance limits.

When certain products deviate from the tolerances set in control charts for a quality feature's upper and lower values, the situation is examined, and urgent corrective action is taken. Suppose the monitored process appears to be under control (i.e., stable with only minimal changes). In such a scenario, doing an assessment of the control chart may assist in isolating the factors that led to the observed variation. As a result, the observed variation can be reduced, and the process can be brought back under control. Differentiating between major change and the inherent variability of a function is made possible by a special sort of run chart known as a control chart. One way to think of the control chart is as a component of a methodical, disciplined approach that makes it possible to make wise choices regarding process control, including the decision to make adjustments to the parameters of the process control. Changing the process parameters of a stable process might lead to a drop in performance; hence doing so is never recommended.

To put it another way, the control chart becomes:

- The tool for determining the statistical control state,
- The technique for attaining statistical control,
- A method for testing whether or not random variability has been eliminated.

15.2 INTENT AND BENEFITS

1. A control chart indicates whether or if a procedure is operating within acceptable limits.
2. It detects process variability and abnormalities.
3. It guarantees the level of product quality.
4. The amount of scrap produced or the percentage of rejects can be reduced if the technique is adjusted at the time of the alert.

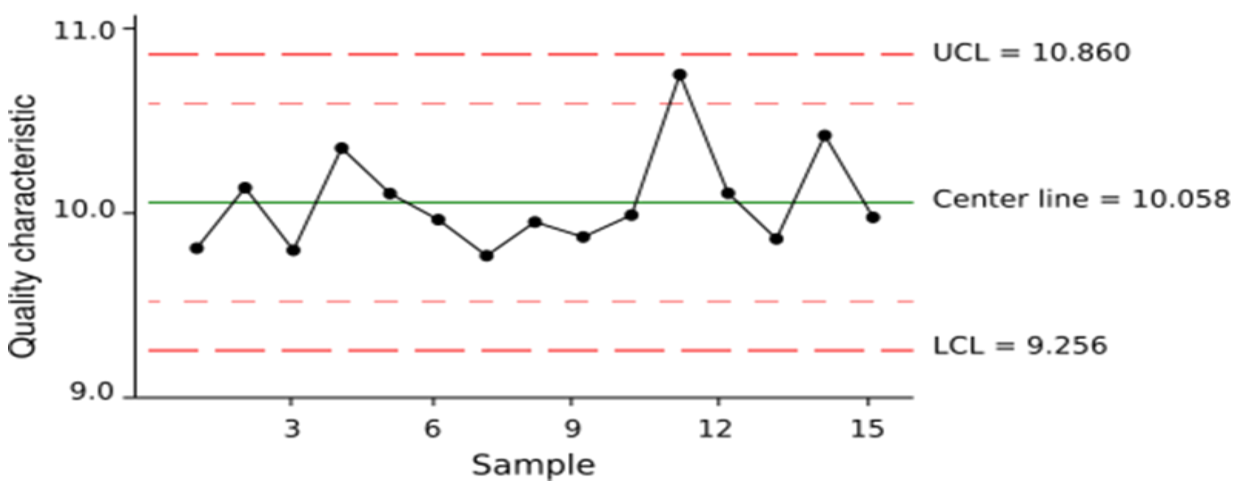
5. It includes guidance on how to pick the right procedure and how far you may push the limits of acceptance.
6. Through client satisfaction, control charts enhance the organization's reputation.

The elements that make up a control chart are:

a) Times (the data) that indicate a metric (such as a range, mean, or proportion) for assessments using a quality attribute through samples acquired by various points andprocesses.
b) The average statistics is found by taking all of the samples into account (for example, the mean of choices, the average of means, and the average of the proportions);
c) At the value representing the statistic's mean, one draws a line through the middle.
d) All of the samples are used to determine the average error of the statistic; for the mean, this means dividing the standard deviation by the square root of n.
e) Upper and lower control limits often referred to as "natural process limits," are typically drawn three standard errors from the center line. This distance represents the point at which a process output is regarded statistically "unlikely."

Other potential options for the chart include:

- Separate lines denoting lower and upper warning thresholds are shown, and often there are two standard errors above and below the middle rope.
- The area is divided into zones, and some regulations limithow many spots in each zone need to be observed.
- The quality engineer in charge of maintaining the high quality of the process will annotate occurrences that are of interest.



15.3 VARIOUS FORMS OF CONTROL CHARTS

Any feature of an item may be evaluated with the use of performance indicators, such as the number of chocolates contained in a box, the weight of a box of cereal, or the volume of a bottle of water. Control charts make it possible to measure a variety of qualities, including variables and attributes, which may be broken down into two distinct categories.

- ***Control chart for variables;***is employed to keep an eye on aspects like height, mass, or volume that can be observed and have a range of possible values. Because the amount of liquid that is contained in the bottles is tallied during the bottling process, this activity serves as a representative example of the variable measure. There is a possibility that the outcomes will take on a range of meanings. The weight of a package of sugar, the temperature inside an oven, or the diameter of a plastic tube are a few examples of units of measurement.
- ***Control chart for attributes;***theproperties that have distinct values and can be counted are monitored using a control chart. Frequently, they may be judged with a straightforward yes or no answer. Examples include hue, flavor, and odor. Because a variable must be measured, monitoring attributes typically takes less time than monitoring variables (e.g., the soft-drink bottlehas a volume of 15.9 fluid ounces). The decision for a point can be "yes" and/or "no," "good" and/or "bad," "acceptable" and/or "unacceptable" (e.g., "the apple is good or rotten," "the meat is good or stale," "the shoes have a defect or do not have a defect," "the light bulb works, or it does not," and/or "counting the number of defects," "the number of broken cookies in the box," quantity of dings in the automobile.

15.4 VARIABLE CONTROL CHARTS VS. ATTRIBUTE-BASED CHARTS

Listed below are the comparative charts:

- Variable charts, as opposed to attribute charts, which merely differentiate between faulty and non-defective products, are more in-depth and incorporate more information. They also entail measuring the dimensions of the task, with the acceptance or rejection of an item based on whether or not its measurements fall either inside or beyond the predetermined range of allowable variation.

- Because chartproperties are constructed using data that is either a "go" or a "no-go," which is of less practical utility than values obtained, they require a significantly greater sample size.
- Variable charts are considerably more expensive than standard charts due to the cost of data collection increases.
- Only attribute charts may be used for effective quality managementwhen it is either impossible to measure quality features or remarkably costly and difficult. For example, when trying to verify a product's color or finish or determining whether or not a casting has cracks, attribute charts are the sole method that can be used. Both yes and no are acceptable responses under these conditions.

15.5 BENEFITS OF CONTROL ATTRIBUTE CHART

Using characteristic control charts, engineering may rapidly summaries the different aspects of a product's quality by classifying it as suitable or unacceptable based on various quality criteria. This allows the engineer to manage the product's quality. Consequently, attribute charts may do away with the requirement for expensive, accurate equipment and measuring procedures that take much time. This chart design is also typically easier to grasp for newly promoted managers who have experience working with quality control systems. As a result, it may provide management with more convincing evidence of quality difficulties.

15.6 BENEFITS OF CONTROL VARIABLE CHARTS:

Variable control charts have a higher degree of sensitivity than control chart attributes. As a result of this, varying control charts have the potential to identify quality concerns before the point at which they are deemed "unacceptable" in the actual world. Although according to Montgomery, the control variable charts represent point ersto potential problems, alarming the manufacturing process experiences a rise in the number of rejected items (junk).

15.7 TRADITIONAL CHART FORMATS

1. Process control using (X-Bar), and R charts.
2. Utilizing a P chart, we can examine the distribution of fractional defects.

3. Defect Rate Control C-Chart.

- **Mean ($\bar{x}$)Charts**

The term "mean control chart" sometimes goes by the name "x-bar chart." It is employed to maintain track of modifications in the methods utilized in a process. Before making a chart showing the mean, we must first draw the graph's center line. We calculate the means of many samples to achieve this goal. These samples are often rather tiny, consisting of only four or five observations on average. All selection has a unique mean. When all the sample means are averaged together, the number is what's utilized to draw the vertical axis through the middle of the graph, where n is the number of samples taken into account:

a) It reflects changes in the process's average and is impacted by variations in the process variability.
b) This is a chart for determining the central tendency of the data.
c) There are significant cyclic adjustments.
d) Changes in constant progress, such as tool wear, are detected.
e) This is the table of most-used variables.
f) The use of an R chart possesses the following properties: (a). signals when the procedure should be abandoned and when it is appropriate to continue to explore and study the sources of variance; (b). ensures information safetywhile developing or modifying procedures, standards, or inspection protocols; and (c). controls the quality of the materials received.
g) A powerful instrument for pinpointing problems with product quality is produced when X-Bars and Rcharts are used in tandem.

- **The Charts Range (R)**

These charts are similar to those used for variable control. In a process, the dispersion or variability of the process may be tracked using range charts, while changes in the process's central tendency can be tracked using x-bar charts. The steps required to generate R-charts and put them to use are the same as those needed to use x-bar charts. The lower and upper limits are derived from the control chart's center line, which is generated using the average range. R charts are utilized to monitor a process's variability or to simplify process operators' computations when the sample sizes are relatively modest (n10 or less). This chart is referred to as a R-chart since the statistic presented is the sample range.

1. It maintains control over the process flow variability and is influenced by changes to the process's overall variability.
2. It is a spread measurement chart.
3. Typically, it is employed in conjunction with the X-bar charts.

- **Graph of $\bar{X}$ and R-charts:**

Over time, the process's output samples are collected. Every piece needs to be chosen randomly, and although the normal sample size is five units, sensitive control charts might use between ten to fifteen samples instead. Calculations are performed to ascertain the typical value of all measures and the range R for each example. The overall average $\bar{\bar{x}}$ (equal to the sum of all average values $\bar{X}$) and (similar to the standard of all the ranges R) is found from the sea. The R charts' control limitations can be determined. Then,

$$\bar{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \cdots + \bar{x}_m}{m}$$

Variables Data ($\bar{x}$ and R Control Charts)

$\bar{x}$ Control Chart

$$UCL = \bar{\bar{x}} + A_2\bar{R}$$
$$LCL = \bar{\bar{x}} - A_2\bar{R}$$
$$CL = \bar{\bar{x}}$$

R Control Chart

$$UCL = \bar{R}\,D_4$$
$$LCL = \bar{R}\,D_3$$
$$CL = \bar{R}$$

Considerations A2, D4, and D3 are proportional to the sample size. The larger the number, the more constrained the range. It is possible to use S.Q.C. tables to determine the values of components A2, D4, and D3. However, a tabular representation of them is provided below for convenience:

n	A_2	D_3	D_4	d_2
2	1.880	0.000	3.267	1.128
3	1.023	0.000	2.574	1.693
4	0.729	0.000	2.282	2.059
5	0.577	0.000	2.114	2.326
6	0.483	0.000	2.004	2.534
7	0.419	0.076	1.924	2.704
8	0.373	0.136	1.864	2.847
9	0.337	0.184	1.816	2.970
10	0.308	0.223	1.777	3.078

Representation:

m or n = sample size

Example

A forging technique makes automotive pistons. Using x and R charts, we aim to achieve statistically controlled inner ring diameters in this method. Assuming the procedure is stable, we have obtained twenty-five samples, each size five. The table displays the results of an interior diameter measurement taken from each piece.

Sample Number	Observations					$\bar{x}_i$	R_i
1	74.030	74.002	74.019	73.992	74.008	74.010	0.038
2	73.995	73.992	74.001	74.011	74.004	74.001	0.019
3	73.988	74.024	74.021	74.005	74.002	74.008	0.036
4	74.002	73.996	73.993	74.015	74.009	74.003	0.022
5	73.992	74.007	74.015	73.989	74.014	74.003	0.026
6	74.009	73.994	73.997	73.985	73.993	73.996	0.024
7	73.995	74.006	73.994	74.000	74.005	74.000	0.012
8	73.985	74.003	73.993	74.015	73.988	73.997	0.030

9	74.008	73.995	74.009	74.005	74.004	74.004	0.014
10	73.998	74.000	73.990	74.007	73.995	73.998	0.017
11	73.994	73.998	73.994	73.995	73.990	73.994	0.008
12	74.004	74.000	74.007	74.000	73.996	74.001	0.011
13	73.983	74.002	73.998	73.997	74.012	73.998	0.029
14	74.006	73.967	73.994	74.000	73.984	73.990	0.039
15	74.012	74.014	73.998	73.999	74.007	74.006	0.016
16	74.000	73.984	74.005	73.998	73.996	73.997	0.021
17	73.994	74.012	73.986	74.005	74.007	74.001	0.026
18	74.006	74.010	74.018	74.003	74.000	74.007	0.018
19	73.984	74.002	74.003	74.005	73.997	73.998	0.021
20	74.000	74.010	74.013	74.020	74.003	74.009	0.020
21	73.982	74.001	74.015	74.005	73.996	74.000	0.033
22	74.004	73.999	73.990	74.006	74.009	74.002	0.019
23	74.010	73.989	73.990	74.009	74.014	74.002	0.025
24	74.015	74.008	73.993	74.000	74.010	74.005	0.022
25	73.982	73.984	73.995	74.017	74.013	73.998	0.035
						$\Sigma = 1850.028$	0.581
						$\bar{\bar{x}} = 74.001$	$\bar{R} = 0.023$

So, $\bar{\bar{X}} = 74.001$

$\bar{R} = 0.023$

From S. Q. C tables (Fig.3) for sample size 5

$A_2=0.58, D_4=2.11$ and $D_3=0$

$UCL\bar{X} = \bar{\bar{X}} + A_2\bar{R}$

$=74.001+ 0.58(0.023)$

$= 74.01434$

$LCL\bar{X} = \bar{\bar{X}} - A_2\bar{R}$

$=74.001-0.58(0.023)$

$= 73.98766$

UCL (R chart) = $D_4\bar{R}$

$= 2.11*0.023$

$= 0.04853$

LCL (R chart) $D_3\ \overline{R}$

= 0*0.023

=0

Now both the chart and the R chart are plotted on the plot, as can be seen in Figures 1 and 2

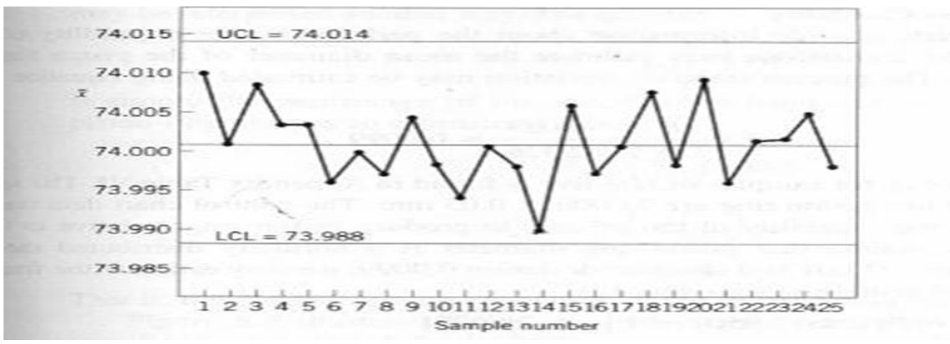


Fig.1: Chart

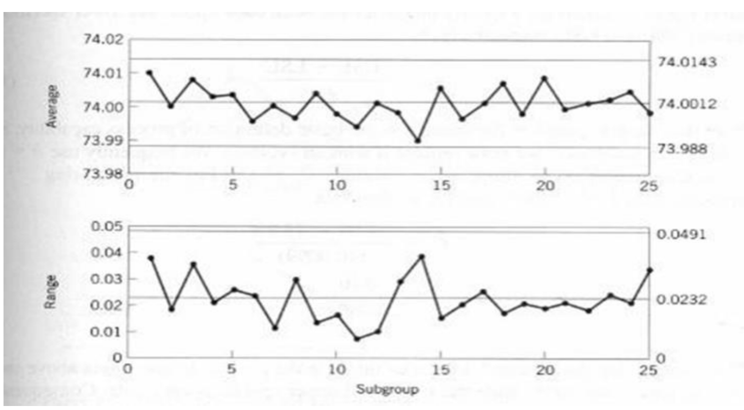


Fig.2: R Chart

<u>Inference:</u>

the chart in the plotted dots that reflect the average is consistent with the control limits throughout the study. However, suppose any of the samples are found to be outside of the control limits. In that case, this indicates that the process has either already gone wrong or is on the verge of going wrong, and a check has to be performed to prevent the appearance of defective goods.

Observations in Sample, n	Chart for Averages			Chart for Standard Deviations						Chart for Ranges						
	Factors for Control Limits			Factors for Center Line		Factors for Control Limits				Factors for Center Line		Factors for Control Limits				
	A	A_2	A_3	c_4	$1/c_4$	B_3	B_4	B_5	B_6	d_2	$1/d_2$	d_3	D_1	D_2	D_3	D_4
2	2.121	1.880	2.659	0.7979	1.2533	0	3.267	0	2.606	1.128	0.8865	0.853	0	3.686	0	3.267
3	1.732	1.023	1.954	0.8862	1.1284	0	2.568	0	2.276	1.693	0.5907	0.888	0	4.358	0	2.574
4	1.500	0.729	1.628	0.9213	1.0854	0	2.266	0	2.088	2.059	0.4857	0.880	0	4.698	0	2.282
5	1.342	0.577	1.427	0.9400	1.0638	0	2.089	0	1.964	2.326	0.4299	0.864	0	4.918	0	2.114
6	1.225	0.483	1.287	0.9515	1.0510	0.030	1.970	0.029	1.874	2.534	0.3946	0.848	0	5.078	0	2.004
7	1.134	0.419	1.182	0.9594	1.0423	0.118	1.882	0.113	1.806	2.704	0.3698	0.833	0.204	5.204	0.076	1.924
8	1.061	0.373	1.099	0.9650	1.0363	0.185	1.815	0.179	1.751	2.847	0.3512	0.820	0.388	5.306	0.136	1.864
9	1.000	0.337	1.032	0.9693	1.0317	0.239	1.761	0.232	1.707	2.970	0.3367	0.808	0.547	5.393	0.184	1.816
10	0.949	0.308	0.975	0.9727	1.0281	0.284	1.716	0.276	1.669	3.078	0.3249	0.797	0.687	5.469	0.223	1.777
11	0.905	0.285	0.927	0.9754	1.0252	0.321	1.679	0.313	1.637	3.173	0.3152	0.787	0.811	5.535	0.256	1.744
12	0.866	0.266	0.886	0.9776	1.0229	0.354	1.646	0.346	1.610	3.258	0.3069	0.778	0.922	5.594	0.283	1.717
13	0.832	0.249	0.850	0.9794	1.0210	0.382	1.618	0.374	1.585	3.336	0.2998	0.770	1.025	5.647	0.307	1.693
14	0.802	0.235	0.817	0.9810	1.0194	0.406	1.594	0.399	1.563	3.407	0.2935	0.763	1.118	5.696	0.328	1.672
15	0.775	0.223	0.789	0.9823	1.0180	0.428	1.572	0.421	1.544	3.472	0.2880	0.756	1.203	5.741	0.347	1.653
16	0.750	0.212	0.763	0.9835	1.0168	0.448	1.552	0.440	1.526	3.532	0.2831	0.750	1.282	5.782	0.363	1.637
17	0.728	0.203	0.739	0.9845	1.0157	0.466	1.534	0.458	1.511	3.588	0.2787	0.744	1.356	5.820	0.378	1.622
18	0.707	0.194	0.718	0.9854	1.0148	0.482	1.518	0.475	1.496	3.640	0.2747	0.739	1.424	5.856	0.391	1.608
19	0.688	0.187	0.698	0.9862	1.0140	0.497	1.503	0.490	1.483	3.689	0.2711	0.734	1.487	5.891	0.403	1.597
20	0.671	0.180	0.680	0.9869	1.0133	0.510	1.490	0.504	1.470	3.735	0.2677	0.729	1.549	5.921	0.415	1.585
21	0.655	0.173	0.663	0.9876	1.0126	0.523	1.477	0.516	1.459	3.778	0.2647	0.724	1.605	5.951	0.425	1.575
22	0.640	0.167	0.647	0.9882	1.0119	0.534	1.466	0.528	1.448	3.819	0.2618	0.720	1.659	5.979	0.434	1.566
23	0.626	0.162	0.633	0.9887	1.0114	0.545	1.455	0.539	1.438	3.858	0.2592	0.716	1.710	6.006	0.443	1.557
24	0.612	0.157	0.619	0.9892	1.0109	0.555	1.445	0.549	1.429	3.895	0.2567	0.712	1.759	6.031	0.451	1.548
25	0.600	0.153	0.606	0.9896	1.0105	0.565	1.435	0.559	1.420	3.931	0.2544	0.708	1.806	6.056	0.459	1.541

For $n > 25$.

$$A = \frac{3}{\sqrt{n}} \quad A_3 = \frac{3}{c_4\sqrt{n}} \quad c_4 \cong \frac{4(n-1)}{4n-3}$$

$$B_3 = 1 - \frac{3}{c_4\sqrt{2(n-1)}} \quad B_4 = 1 + \frac{3}{c_4\sqrt{2(n-1)}}$$

$$B_5 = c_4 - \frac{3}{\sqrt{2(n-1)}} \quad B_6 = c_4 + \frac{3}{\sqrt{2(n-1)}}$$

15.8 STATE OF PROCESS BEYOND CONTROL

Following establishing the control boundaries, it is necessary to evaluate the process to see if it demonstrates statistical control. If not, it indicates that the process is being thrown out of control by an outside factor. This reason must be identified and eliminated for the process to resume operating under stable statistical conditions. The process may be out of control for several reasons, including:

1. Defective equipment
2. A significant and unexpected shift in the properties of newly delivered materials.
3. The lubricating system must be broken.

4. Errors for speed mechanism control.

15.9 MANAGING THE PROCESS

It is possible to establish whether or not the process's capacity is in line with the necessary criteria the method is found to be statistically stable.

15.10 CONTROL-CHARTS ATTRIBUTES

When evaluating quality features that are tallied rather than measured, control charts evaluating attributes are an effective tool to utilize. Features may be either on or off, making judgments about them easy. You can matter the number of damaged light bulbs, spoiled apples, scratched tiles, and customer complaints, among other things. Attribute control charts typically come in two flavors: p-charts and c-charts.

- A P-chart can be used to arrive at a calculation for the proportion of defective items that are present in a sample. Within a batch of autos, some broken cookies or fenders aren't aligned properly. This might be the case. P-charts are helpful in situations where it is possible to count the overall size of the sample as well as the total number of mistakes. When this is done, we are presented with a piece of information known as a percentage, which may be used for assessment purposes.

- It can be a defective fraction chart.
- Each chart is evaluated and assigned a grade based on whether it contains any errors or not (defective).
- This chart regulates the overall quality of the component components. It determines whether or not the variations in product quality (level) are just the result of random occurrences.

<u>P-charts mapping</u>: first, identifying the incorrect fraction; immediately after that comes the control restrictions.

It is determined that the process seems to be under command if the fraction of inaccurate values falls within the control boundaries. In the event that the procedure becomes unpredictable, it will be required to do a root-cause analysis.

The mean proportion defective ($\overline{p}$):

$$\overline{p} = \frac{\text{Total Number of Defectives}}{\text{Total Number Inspected}}$$

The standard deviation of p:

$$\sigma_{\overline{p}} = \sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

where n = sample size.

Control Limits are:

$$UCL = \overline{p} + Z^{*}\sigma_{\overline{p}} \qquad LCL = \overline{p} - Z^{*}\sigma_{\overline{p}}$$

or

$$UCL = \overline{p} + Z^{*}\sqrt{\frac{\overline{p}(1-\overline{p})}{n}} \qquad LCL = \overline{p} - Z^{*}\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

Because variances in a data set that lie within 3 standard deviations are regarded as normal, the Z value will often equal 3 (in the X/R charts). The number of Z is established based on the application of the graph as well as the discretion of the administrative personnel.

• C-charts track defect numbers. We may count customer complaints monthly, microorganisms in a petri dish, or barnacles on a boat. However, we cannot calculate the percentage of consumers complaining about the bacteria in pet food or even the balusters on a boat's bottom.

Defective items v/s individual defects

Distinguishes nonconformity and nonconforming units, just as between defective and defective units. This distinction is also made between faulty units. Let's try to unravel the mystery around this artificial conundrum, even if it might seem like we're splitting hairs.

Imagine a wafer on which there are numerous chips placed in a row. The industry calls the wafer a "product item.". One can talk about the chip in terms of "a precise spot" if one wants to. Certain criteria need to be satisfied before the wafers may be used. "Nonconforming items" are wafers that do not meet at least one requirement. Furthermore, every single chip (for instance, the specific location) in which a standard is not satisfied evolves into a defect or a non-conformity.

As a result, a nonconforming or faulty object will always have at least one flaw or nonconformity present. It is important to note that despite several defects, a wafer might still be judged to comply with the standards. For example, the faults might be located on the wafer in areas that are not considered significant. If, on the other hand, the quantity of the purportedly "unimportant" faults climbs to alarming levels, then it is required to investigate these wafers' manufacturing process. Control charts with counts might show the average number of faults in each inspection unit or the overall number of problems in the sample of teams inspected.

Defect v/s. Defective

- ‘Defect’– a single non-conforming quality characteristic.
- ‘Defective’– items that have one or more defects.

<u>Control charts for some defects (C-chart)</u>

C-charts are utilizedwhen the management is primarily concerned with lowering the number of faults that occur per unit. Sometimes there is more than one flaw in a single product unit, such as the number of air bubbles in a glass sheet or the number of complaints lodged against a certain establishment. These charts provide the management with the information necessary to determine whether or not the number of faults falls within the tolerance level.

The following equations can be utilized to plot C charts:

$$\boxed{UCL = c + 3\sqrt{c}}$$

$$\bar{c} = \frac{\text{total number of defects}}{\text{total number of samples}}$$

$$\boxed{LCL = c - 3\sqrt{c}}$$

Example: Develop a control chart for such proportion of defectives acquired in a resampling sample with a size 50 from a process that is regarded as under control when the mean of the proportion of defectives P falls within a certain predetermined range

i.e.,$\bar{P}$isequalto0.10.Drawacontrollineandtheupperandlowercontrollimitsongraphpaper.

Solution: - $\bar{P}$ (Central Line or Mean) (Given) = 0.10

UCL =$\bar{P}$ +3 $\sqrt{\bar{P}(1-\bar{P})/n}$

$=0.10 + 3 \sqrt{0.10(1-0.10)/50}$

$\sqrt{0.10 \ X \ 0.90/50}$

$=0.10+3$

$=0.10 + 0.127 = 0.227$

$LCL = \bar{P} - 3 \sqrt{\bar{P}(1-\bar{P})/n}$

$=0.10-3 \sqrt{0.10(1-0.10)/50}$

$\sqrt{0.10 \ X \ 0.90/50}$

$=0.10-3$

$=0.10 - 0.127 \qquad = -0.027$

Since LCL is negative so it will be taken as zero.

The idea of improvement may be reduced to its simplest form: if you want to enhance a process's results, you have to improve the process and its inputs. If you want to enhance the output, which is also known as the "Y" or the "Key Measure," you must first identify, measure, and then improve the inputs and process metrics, which are also known as the "X's." To improve the results, an after-the-fact, reactive, costly, and inefficient strategy would be to concentrate on the output Y measurements rather than the Xs. The idea that Y is a function of X (Y=f (X1, X2... Xn) lies at the heart of the DMAIC phases, which define, measure, analyze, improve, and control. These steps are also abbreviated as DMAIIC.

15.11 SUMMARY

Managers should have control charts for attributes as a vital weapon in their armory when it comes to controlling qualitative characteristics that cannot be measured. P charts are utilized to control the proportion of defective process outputs. When the total number of defects is more important than the percentage of total defects, annP chart is utilized. Similar C charts are used to show the data whenever the defect rate per unit is utilized in the process of determining the product's overall quality.

It suggests that there are assignable factors subject to human control. When an absolutely single point is situated inside the control boundaries that have been established, it is not monetarily viable to determine the cause, even though we cannot state with absolute certainty that there is no assignable explanation. There is no way to do any statistical analysis. Even with the most efficient manufacturing processes, some assignable causes still can occur, such as mistakes; nonetheless, statistical action cannot be taken. Control charts for characteristics are an essential tool for regulating the quality traits that cannot be described in quantitative terms and are used by management. Control charts for attributes. P charts facilitate control over the proportion of flawed products produced by a process. nP charts are utilized when the quantity of defectives, as opposed to the balance of defectives, is the primary issue. Similarly, when evaluating the quality of a product based on the number of defects found per unit, C charts are the tool of choice.

15.12 Model Questions

1. What are the different benefits of control variable Chart and control attribute chart?
2. What do you mean by Control Chart and what are intent and benefits of control chart?

UNIT 16 QUEUING THEORY

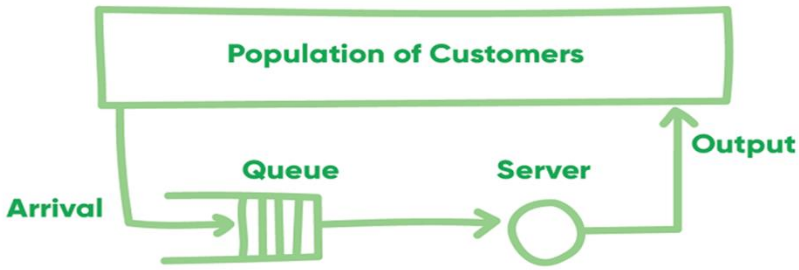
Structure

Reading this chapter should aid:

- The idea of queuing theory
- The implication of Kendal's theory
- The application of little's law
- Practical application of queuing theory.

16.1 INTRODUCTION

Queues are a common occurrence. We have all grown accustomed to waiting but still find it annoying when lines are especially long to do things like pay for groceries, mail packages, get lunch in cafeterias, or ride rides in amusement parks. When operating a queuing system that includes high operating expenses due to an excessive amount of service capacity, queuing models are highly helpful in establishing the most efficient way to do it. The models make it possible to strike the right balance between service costs and wait times.



The act of waiting in line is one that occurs frequently in everyday life. At post offices, ATMs, restaurants, train stations, and airline reservation kiosks, we stand in lines to wait for our turn. Both automobiles and aircraft must wait for their turns at traffic lights and airport taxiways before they may land. You are likely able to think of a great deal more cases. After standing in line for a considerable amount of time, there are always going to be some consumers who need some kind of service. The term "customer" can refer to a living being, an inanimate object, a parked car, or anything else that requires some kind of assistance. In reality, of course, waiting for services is an essential component of our day-to-day lives, and it usually comes at a significant financial cost as well.

We would like to develop ways of minimizing the amount of time that the client must wait while simultaneously maximizing the amount of money that can be saved by the service provider. The queuing theory, which is also sometimes referred to as the queueing theory, can be of use to us in this regard. It must have been developed in 1909 by A. K. Erlang while he was attempting to assess the congestion of telephone communication. Since it is expensive to offer more service capacity than is necessary, the goal of queuing analysis is to collect data that may be used to establish what constitutes an acceptable level of care and service capacity. Nevertheless, the provision of inadequate service capacity also incurs costs. For instance, when a hospital's emergency department continually has a lengthy line of people waiting to be seen, many of those patients may cause the injury or sickness to become worse.

16.2 OBJECTIVES

This unit should prepare you to:

- In terms of queuing theory, describe the Poisson distribution as well as the death and birth cycle;

- Describe the basic components of a queuing system;
- In your own words, please explain how a queuing system functions.
- Provide an explanation for a server-based queuing model that uses Poisson inputs and exponential time for service;
- Utilizing the M/M/1 queuing paradigm, find solutions to the difficulties.

16.3 BASIC CONCEPTS OF QUEUING THEORY

It is necessary to have a working knowledge of probability theory to comprehend queuing systems. A substantial part of the process of characterizing queuing systems is played by the idea of random variables and the probability distributions of these variables. In Probability Theory (MST-003), you have learned about probability theory, random variables, and Poisson and Exponential distributions, among other topics. Nevertheless, the Poisson process is an unfamiliar idea for you, and we will explain it to you in a nutshell. Let's review a couple of the most fundamental definitions in a hurry.

Imagine conducting an investigation in which the results cannot be precisely predicted. In a scenario like this one, the result of an experiment that was carried out is one among some conceivable results. One of the results of an operation is referred to as a sample point, while the collection of all of the attainable results of a random phenomenon is referred to as a sample space.

Events are any subset of the sample that may be examined. For each sample point, there is indeed a stochastic process that is a variable that is correlated with a real number. This association takes place using a random number generator. A group (or collection) of the stochastic process can be referred to as a stochastic function or stochastic process. For six-sided dice with 1, 2, 3,..., and 6-sided faces, the set of all possible outcomes is denoted by the equation S= {1, 2, 3, 4, 5, 6}. A sample space is denoted by the set S. A random variable is denoted by the number that is printed on the function (X) that allocates a result or a sampled point. The occurrence of an even number corresponds to the subset of S known as {2, 4, 6}, which can be found in the previous sentence.

Let us take another straightforward experiment, such as tossing a standard die.

1. Assume that the result of the nth throw, where n is greater than one, is Xn. Then the family of random variables denoted by the expression {Xn, n $\geq$ 1} is one in which one obtains a separate random variable denoted by "Xn" for each individual value of the parameter n. A random or stochastic process denoted even as the Bernoulli process is formed by the sequence {Xn, n $\geq$ 1}.
2. Let's say that Xn refers to the number of sixes that have occurred in the first n tosses. We obtain a separate Binomial random variable for each possible value of n, where n might be 1, 2, etc. The process that may be thought of as random or stochastic is denoted by {Xn, n $\geq$ 1} produces a group of unrelated factors.
3. Consider the scenario where a switchboard operator answers a phone call. Let the random variable X_t, which will reflect the total number of new calls throughout the interval, do its job (0, t). Therefore, X_t is a random variable, and the family {Xt, t □T} is a stochastic process. Here, T refers to the interval 0≤ t≤□.

In the first two examples — 1 and 2 — that were given earlier, we observed that perhaps the subscript n in Xn could only include positive numbers such as 0, 1, 2,… In these instances, we watch what happens when a random variable is subjected to different amounts of time, such as n = 0, 1, 2, etc. In this context, the concept of “time” has a more general meaning. One way to picture an infinite collection of random variables is as "{Xt, t □T}". These variables should be chosen so that the system's state can be described at every moment, whether the interval is finite or infinite. The procedure (or group) is then described over an infinitely long span of time, at which point we refer to our situation as a stochastic process. The family of discrete variable (or discrete time) stochastic processes is denoted by the notation Xn, where n can be any of the numbers 0, 1, 2,... It is common practice to refer to the value of Xn for a particular realization of the process as the state of the procedure at the nth stage. It is referred to be a discrete state process when the independent variables Xn are considered to be discrete random variables. This means that they can only take on integer values.

16.3.1 Poisson Process

Let's say that X(t) represents the highest temperature recorded in a certain location. In this context, we are concerned with stochastic processes with discrete states but continuous times, which means that X(t) is a kind of variable that is not continuous. One of the most well-known examples of this category of a stochastic process is known as the Poisson process. The investigation of a diverse range of occurrences benefits greatly from its use. The Poisson process may be explained in the following manner: Let's name this occurrence "E," which might be anything from (a) calls going into a switchboard to (b) the influx of sick people seeking care at a hospital or (c) a measure of the frequency with which mishaps occur in a certain area.

We look at the sum total of repetitions of an entity E over some period of time t, denoted N(t). Consider the likelihood that the gaussian random N(t) takes the value n to be Pn(t), where N(t) is the outcome of the time series i.e.

$$P_n(t) = P[N(t) = n] \qquad \ldots (1)$$

for n = 0, 1, 2, 3, …. We have

$$\sum_{n=0}^{\infty} P_n(t) = 1, \text{ for each fixed } t. \qquad \ldots (2)$$

According to equation (2), the stochastic process is the family of random variables {Nt, t > 0}. Pn(t) in terms of N's probability mass function (t). If you recall from before, this family is a state-space-discontinuous stochastic process and continuous parameter (time, in this case). The Poisson process describes this phenomenon. N(t) has the mean of a Poisson Distribution λt (λ constant) under specific circumstances. For the most part, this is how the real world works.

Assumptions in Poisson Process

i) There are separate steps in the procedure. Changes in N(t) in the future will be unrelated to changes in N(t) in the past; that is, the number of customers that come to your business at different times is statistically independent.

ii) The likelihood that event E will occur more than once between the times t and t+Δt is o(Δ(t)); this indicates that two or more consumers might arrive in a short amount of time Δt is extremely low. Thus,

$$P_0(\Delta t)+P_1(\Delta t)+o(\Delta t) = 1 \qquad \ldots(3)$$

iii) Theprobabilitythatevent E occursbetween time t and Δtisequal toλΔt+o(Δ(t)). Thus,

$$P_1(\Delta t)=\lambda\Delta t+o(\Delta t),$$

i.e., $P_1(\Delta t)$ is approximately proportional to the interval length where λ is the typical rate at which consumers are expected to arrive and $\lambda>0$. Here, λ is a constant, whereas Δt is a variable that increases with time. Here λ is constant and Δt is an incremental element.

16.2.2 Birth and Death Process

The overall continuous-time Markov process may be broken down into its component parts, and the birth and death processes are one of those parts. Put another way, a birth-and-death method does not "jump" between states. It is instead described as a Markov decision process where all transformations are to go to the next state, either instantaneously above ("birth") or immediately below ("death") in the innate numeric ordering of states. A birth or death does not occur in a different state. Birth-death course may be considered a subcategory of the Poisson process. Since there is no chance of someone dying due to the procedure, it may be more accurate to refer to it as a birth process (μi). The birth rates, denoted by λi are equivalent to a fixed value denoted by λ. A process of the Poisson is frequently utilized for modelling scenarios of several things happening in a particular amount of time. This form of modelling is common in the field of statistics. It will be used, for instance, to describe the arrivals of clients to a service facility while we are discussing queuing models. The current condition, denoted by the letter't,' would equal the number of people who had arrived by the time t. Pn (t) is the likelihood that there will be n customers in the system at any particular instant t, either waiting to be served or already being served. Pn (t) can take on positive or negative values. The time-independent probability that there are n customers in the system at any given moment, either waiting for service or receiving it, is denoted by the symbol "Pn". Arrivals are comparable to births because they bring new life into the world. When an arrival takes place in a system that is already in state En, the system will transition to state En+1. Similarly, one's departure from a place might be seen as that person's death. If there is a departure that occurs while the system is in state En, then the system will transition to state En–1 as a result of the departure. A method of this sort is sometimes called a birth-death process in a common language.

Suppositions about the process of birth and death

The birth-death process is based on the following ideas:

If the system is in state En, the probability distribution of the time t until the next arrival (birth) is exponential with parameter λ_n, where n = 0, 1, 2, ….

i) If the system is in state E_n, the current probability distribution of the time t until the next arrival (birth) is exponential with parameter λ_n, where n = 0, 1, 2, ….

ii) If the system is in state E_n, the current probability distribution of the time t until the next departure or service completion (death) is exponential with parameter μ_n, where n = 0, 1, 2, … .

iii) Only one birth or death can occur quickly, i.e., Δt. After going through some of the most essential ideas and approaches for researching queuing systems, we will now describe the fundamental framework of a queuing system.

16.4 CHARACTERISTICS

(a) Input source

The size of the source is one of its characteristics of it. The size refers to the number of individual units that can, on occasion, require regular. It is possible to interpret it either as infinite or as finite. The assumption made by the consumer is that they produce at a certain average rate according to the Poisson distribution. As a consequence of this, the assumption that corresponds to it is that they generate an exponentially distributed between successive arrivals. While you work on a solution to the problem, it is helpful to make assumptions about the customer demography.

(b) Queue Discipline

The definition of a queue is determined by the maximum number of items that it can hold at once. A queue is said to be either finite or endless depending on whether or not the number of people waiting in it is finite or infinite. The assignment of service queue numbers is an aspect of the service discipline that must be considered. For instance, first-in, first-out (FIFO) ordering is usually presumed to be used unless otherwise specified. It might also be based on priority or randomness.

(c) Service mechanism

Included in this package are one or so more service facilities, each of which possesses one or more service channels that run in parallel. If there are a significant number of service facilities, the arriving unit could get the product from several different service channels.

16.5 QUEUING CLASSIFICATION MODELS USING KENDAL’S AND LEE REPRESENTATIONS

The arrival occurs within the scope of a certain facility's service area and is completely attended to by the aforementioned server. The length of time an individual unit has been in operation at a facility is quantified in terms of service time, and this measurement often follows an exponential distribution.

Any queueing model may be completely specified by using the following symbolic language. Form a/b/c: d/e

- → a classification of the intervals between arrival times
- → b the manner in which the time between services is divided.
- → c Number of servers
- → d Capacity of the system
- → e Queue system
- → M Arrival time follows the Poisson distribution

Mode lI: M/M/1: /FCFS

Where M Arrival time follows a Poisson distribution

M → There is an exponential distribution underlying the service time.

1 → Single service model

 → The capacity of the system is infinite

FCFS → Queued Is cip line is first come, first served

Mode lII: M /M /1:N/FCFS

Where N → Capacity of the system is finite

Model III: M /M/1:/ SIRO

Where, SIRO → Service in random order

Model IV: M /O /1:/FCFS

Where D $\longrightarrow$ The amount of service time is either predictable or follows a constant distribution.

Model V: M / G/1:/FCFS

Where G $\longrightarrow$ A random or universal distribution is used to determine the order of the services provided.

Model VI: M /E_k/1:/FCFS

Where E_k $\longrightarrow$ Service time follows Erlang distribution with K phases.

Model VII: M /M/K: /FCFS

Where K $\longrightarrow$ Multiple Server model

Model VIII: M/M/K: N/FCFS

The model I: M /M /1:/ FCFS

For example, think of an ATM.

It can serve one customer at a time; in a first-in-first-out order; with a randomly-distributed arrival process and service distribution time, unlimited queue capacity, and an unlimited number of possible customers.

Queuing theory would describe this system as an M/M/1 queue ("M" here stands for Markovian, a statistical process to describe randomness).

There are several online calculators for queueing theory; however, frequently, they ask you to select a system from the Kendall notation before calculating inputs.

16.6 IMPORTANCE

Keeping one's place in line is an everyday event, and this is because the activity itself serves several important reasons. When there are a limited number of resources available, a means of limiting the flow of consumers that is both fair and essential is to use queues. Negative outcomes are likely to occur if a queuing mechanism is not designed to accommodate situations of overcapacity.

For example, if a website does not have the capability to queue users or adjust the pace that it processes requests, the website will become unusable when it receives an overwhelming number of visitors since it will begin to run more slowly.

Consider instead a plane that is looking for a place to land, such as a runway. When there are an excessive number of flights, the absence of a line might have major implications for safety since all of the aircraft would attempt and land at the same time.

Queuing theory is essential because it provides tools for optimizing lines and assists in defining queue characteristics, such as the typical amount of time spent waiting in a line. From a business point of view, queueing theory offers assistance in creating good and cost-effective workflow systems.

16.7 APPLICATIONS OF QUEUING THEORY

Since waiting in lines is a common occurrence, the idea behind queues may be applied in many contexts.

A few applications of queueing theory are presented below:

- Broadcastings
- Conveyance
- Logistics
- Investment
- Backup services
- Computation
- Manufacturing engineering
- Project administration

16.8 LITTLE'S LAW OF QUEUING THEORY

Little's Formula establishes a correlation between the capacity of a queuing system, the average amount of time spent in the framework, and the standard number of arrivals in the system. This connection may be made without understanding any other aspects of the queue. The formula, which is presented in the following format and may be grasped with relative ease, is as follows:

$$L = \lambda W$$

or reworked must determine the third and fourth variables to:

$$\lambda = \frac{L}{W}$$

$$W = \frac{L}{\lambda}$$

Where:

- ***L*** is the typical number of users that are logged into the system.
- ***λ*** (lambda) refers to the typical number of new users who sign up for the system each day.
- ***W*** is the typical length of time that users spend logged into the system.

Project management processes like Lean and Kanban wouldn't exist without Little's Law. They're critical for business applications, in which Little's Law can be written in plain English as:

$$Work\ in\ Progress = Throughput * Lead\ Time$$

$$Throughput = \frac{Work\ in\ Progress}{Lead\ Time}$$

$$Lead\ Time = \frac{Work\ in\ Progress}{Throughput}$$

Little's Law Applied to Real-World Situations:

Because it allows us to solve for significant variables such as the average wait time in a queue or even the number of people in a queue merely based on two additional inputs, Little's Law is an extremely useful piece of knowledge that can provide useful insights.

For example: While you're standing in line at Starbucks, Little's Law can give you an estimate of how much longer it will be until you get your coffee.

Let's say there are 15 individuals waiting in line, each server, so each person is served at a rate of two per minute. Little's Law, in its form, would be what you'd use to make an approximation like this.:

$$\frac{L}{\lambda} = W$$

Showing that you could expect to wait 7.5 minutes for your coffee.

$$\frac{15\ \textit{people in line}}{2\ \textit{people served per minute}} = 7.5\ \textit{minutes of waiting}$$

A line in a virtual waiting room:

Using a computation that is based on Little's Law and adding in elements to account for no-shows and re-entries, Queue-it displays to visitors their estimated wait time in the online queue:

$$\frac{L}{\lambda} * \frac{1-N}{1-R} = W$$

Where:

- ***L*** how many people are ahead of you in line
- ***λ*** (lambda) is the number of redirected users to the app or website per minute
- **N** is the number of no-shows
- **R** how often people come back to the line
- ***W***, Duration you think you'll have to wait

Process optimization:

We may examine a military example of process optimization courtesy of Process St.

In this particular real-life scenario, the military sought to figure out the optimal length of time the B-2 stealth bombers would spend in the repair hangar. Only twenty B-2 aircraft out of the total fleet must be prepared to take off immediately. On the other hand, they need regular maintenance anywhere from every 18 to 45 days. By applying Little's Law, one might discover a better balance between the number of aircraft in operation and the number of aircraft undergoing repair.

After examining the B-2 bomber's flying schedule, it was determined that three of the aircraft would be undergoing repair at any one moment. In addition, the frequency at which bombers went in for repair was estimated to be around once per week.

So:

- **L**= amount of work-in-progress (maintenance) = 3
- **A**= Arrival and Departure Frequency = 1 every 7 days = 1/7 days
- **W**= mean maintenance intervals

16.9 BENEFITS OF QUEUING THEORY

To cut down on the number of times customers have to wait to be served and to increase the total number of clients who can be accommodated, a firm can employ queuing theory to create more effective queuing systems, procedures, pricing mechanisms, personnel solutions, and arrival management methods. To assess and streamline personnel needs, scheduling, and inventory, queueing theory is frequently utilized as an operations management strategy, which enhances total customer service. Six Sigma experts frequently employ it to enhance operations. The notion of queues is used to locate and eliminate bottlenecks in a process. The queue could be made up of items, people, or data. They are, in any case, made to wait for assistance. That is ineffective, detrimental to the company, and irritating (when the queue consists of people).Queuing theory is used to evaluate the current procedure and identify improvements.

16.10 QUEUING NETWORKS

Systems known as networks of queues connect many queues via a process called customer routing. A consumer can leave the network or join another node after receiving service at one node. An m-dimensional vector (x1, x2,..., Xm) may be used to describe the system's status for networks with m nodes, where xi stands for the number of clients located at each node.

The most fundamental type of network, including queues, is called a tandem queue. The first significant discoveries made in this area were Jackson networks, which have been shown to have an effective product-form stationary distribution and mean value analysis, which makes it possible to compute average metrics like throughput and sojourn times. The network is considered to be an example of a closed network. If there is no change in the total number of customers in the network, the Gordon-Newell theorem predicts that there will be a product with a stable distribution. This prediction has been demonstrated to be true. This finding was extended to the BCMP network, where it was demonstrated that a network with highly general service time, regimes, and customer routing could also display a stationary distribution of a product's shape. This was done by demonstrating that a stationary distribution of a product's shape is possible in a network with highly general service time, regimes, and customer routing to get the normalizing constant; one might use the Buzen method from 1973.

Kelly network, in which customers of different classes are given varying degrees of priority at different service nodes, was also the subject of research. G-networks are a distinct variety of networks; in contrast to the conventional Jackson Network, which operates on the assumption of exponential temporal distributions, Erol Gelenbe first presented the concept of G-networks in 1993.

16.11 SUMMARY

Queuing models can help to clarify the mathematics underlying how queues operate. However, understanding queue psychology is essential when it comes to understanding human lines. According to studies on queue psychology, how people feel while waiting determines whether they have a positive or negative experience in a line. Little's Law is helpful since it enables us to solve complex variables like the number of clients in a queue or the average wait time with just two other inputs. In a basic queuing system, "customers" arrive at a bank of "servers" and ask for a service from one of them. It's crucial to realize that a "client" need not necessarily be a human being; it could be anything that is waiting for assistance. The "customers" in a "back-office" scenario, such as interpreting radiologic images, can be the images that are waiting to be read.

1. The purpose of queueing theory is to provide knowledge that may be used to determine an appropriate level of service. It is vital to do this because it is costly to provide too much service capacity (due to people or equipment sitting idle), and it is also costly to provide too little service capacity (owing to waiting members of the queue). The term "queuing system" refers to a system that is comprised of the following three components: (1) The method by which customers join or arrive; (2) The service mechanism; and (3) The discipline of the queue.

2. The input process refers to the sequence in which new consumers sign up for the service and enter the system. The scale of an input process, the distribution of arrival times, and the consumers' disposition are the elements that define its characteristics.

3. In most cases, service time distributions take the form of exponential distributions. Depending on the configuration, a service facility may be referred to as a "single channel facility," "one queue-many station facilities," "several queues-one service station," "multi-channel facility," "multi-stage channel facility," or "multi-stage facility".

4. The term "queue discipline" refers to the sequence in which the station chooses the next client to be serviced from the line of customers who are waiting to be attended to. It might be the first in, first out, or the last in, first out system. Within the context of this section, the First-Come, First-Served queue regulation has been analyzed.

5. Solutions that rely on the passage of time are known as transitory solutions. A stable solution is a solution that is not reliant on the passage of time and that indicates the likelihood that the systems is in the stable state.

6. In most cases, a queuing system may be expressed using the following five symbols: a/b/c: d/e, or a/b/c/d/e. The first symbol, „a, ‟ describes the arrival process. The secondsymbol, „b,‟ describes the service time distribution. The third symbol, „c,‟stands for the number of servers. The symbols„ d‟and„e‟ stand for the system

16.12 MODEL QUESTIONS

1. Explain the process of Queuing Network.
2. Briefly explain the queuing theory with its benefit
3. Discuss the applications and importance of Queuing theory.

16.13 FURTHER READINGS

1. **TahaHA**,OperationResearch -An Introduction,PrenticeHallofIndia,7thedition,2003
2. **Ravindran, Phillips and Solberg**, OperationsResearch :Principlesand Practice, JohnWiely&Sons,2ndEdition
3. **D.S.Hira**,OperationResearch,S.Chand&CompanyLtd., NewDelhi,2004

ଓଡ଼ିଶା ରାଜ୍ୟ ମୁକ୍ତ ବିଶ୍ୱବିଦ୍ୟାଳୟ, ସମ୍ବଲପୁର
Odisha State Open University, Sambalpur
www.osou.ac.in
e-mail: info@osou.ac.in