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Higher Education for All

Production and Operations Management

COURSE CODE: M25BS08DC

Master of Business Administration

Discipline Core Course

Self Learning Material



SREENARAYANAGURU OPEN UNIVERSITY

SREENARAYANAGURU OPEN UNIVERSITY

The State University for Education, Training and Research in Blended Format, Kerala

SREENARAYANAGURU OPEN UNIVERSITY

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Vision

To increase access of potential learners of all categories to higher education, research and training, and ensure equity through delivery of high quality processes and outcomes fostering inclusive educational empowerment for social advancement.

Mission

To be benchmarked as a model for conservation and dissemination of knowledge and skill on blended and virtual mode in education, training and research for normal, continuing, and adult learners.

Pathway

Access and Quality define Equity.

Production and Operations Management

Course Code: M25BS08DC

Semester- II

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Discipline Core Course
Master of Business Administration
2025-26 Admission
Self Learning Material
(With Model Question Paper Sets)

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MESSAGE FROM VICE CHANCELLOR

Dear learner,

It gives me immense pride and heartfelt satisfaction to welcome you to Sreenarayanaguru Open University—a transformative space where aspirations are nurtured, potential is unlocked, and futures are shaped with purpose.

Established in September 2020 as a pioneering state initiative, the University stands as a symbol of inclusive, accessible, and high-quality higher education. Anchored in our guiding philosophy—"access and quality define equity" —we are committed not merely to expanding educational opportunities, but to ensuring that every learner receives an education that is meaningful, relevant, and transformative.

Our journey is deeply inspired by the timeless vision of Sreenarayana Guru, whose ideals of knowledge, equality, and social empowerment continue to illuminate our path. His philosophy reminds us that education is not just a means to an end, but a powerful instrument for personal growth, societal progress, and human dignity.

In a rapidly evolving and digitally driven world, we recognize that learning must be flexible, dynamic, and future-ready. Our thoughtfully designed blended learning ecosystem—integrating Self-Learning Materials, Classroom Counselling, and Virtual Learning Platforms—ensures that you experience the best of both independence and guided academic engagement. This model empowers you to learn at your own pace while staying meaningfully connected to academic support systems.

The MBA programme at Sreenarayanaguru Open University is not just a degree—it is a gateway to leadership, innovation, and professional excellence. The curriculum is meticulously curated to reflect the realities of the contemporary global business landscape, seamlessly blending foundational management principles with cutting-edge developments in business and technology.

You will explore and engage with:

- Strategic management and entrepreneurial thinking
- Digital transformation, FinTech, and emerging technologies
- Logistics, supply chain, and global business ecosystems
- Consumer behaviour and evolving market intelligence
- Human resource management in the age of Artificial Intelligence
- Ethical leadership and sustainable decision-making

Designed with a multidisciplinary and future-oriented perspective, the programme offers diverse specializations, skill enhancement pathways, and exposure to innovative domains that align with industry expectations. It is structured to strengthen your employability, entrepreneurial mindset, and leadership capabilities—equipping you to excel in competitive and complex professional environments.

Our Self-Learning Materials are crafted with exceptional care, combining conceptual clarity with real-world relevance through case studies, contemporary examples, and practical insights. They are designed not only to inform but to inspire critical thinking, problem-solving, and adaptability—skills that are essential in today's disruptive and ever-changing business world.

At the heart of our mission lies an unwavering commitment to learner success. Our comprehensive learner support system is always within your reach, ensuring that your academic journey remains smooth, enriching, and fulfilling. We encourage you to actively engage, explore, question,and grow—because your success is the true measure of our purpose.

As you begin this important journey, I invite you to dream boldly, learn continuously, and lead responsibly. Let this programme be a stepping stone towards achieving your ambitions and mak-

ing a meaningful impact in the world.

May your journey here be one of discovery, empowerment, and excellence.

With my best wishes for your success and lifelong learning.



Regards,
Dr. Jagathy Raj V. P.

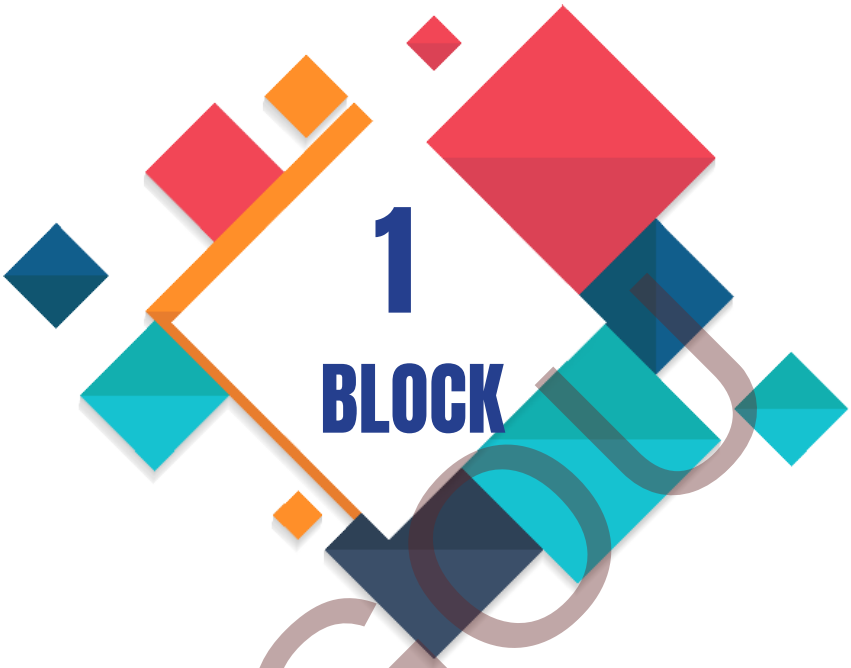
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Contents

BLOCK 1	**Introduction to Operations Management**	**1**
	Unit 1 Production Function	2
	Unit 2 Product Design	24
BLOCK 2	**Facilities Planning**	**56**
	Unit 1 Facilities Location	57
	Unit 2 Facilities Layout and Material Handling	88
BLOCK 3	**Inventory Management and Production Control**	**129**
	Unit 1 Inventory Management	130
	Unit 2 Production Planning and Control	160
BLOCK 4	**Quality and Project Management**	**190**
	Unit 1 Quality Management	191
	Unit 2 Project and Maintenance Management	228
	Model Question Paper Sets	262

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Introduction to Operations Management

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Unit 1

Production Function

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ define the fundamental concepts of production and operations management, including the 5 Ps framework
- ◊ explain the importance of production as an organizational function and describe how it contributes to efficiency, quality, and competitiveness
- ◊ apply production and operations management principles to real-world scenarios, such as facility location decisions, process improvement, and inventory control
- ◊ analyse the scope of production and operations management by breaking down its functions (planning, scheduling, quality control, etc.) and evaluating their interrelationships
- ◊ evaluate existing production systems and design improved processes that add value through quality, speed, and flexibility

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Background

The origins of production management can be traced back to the Industrial Revolution, when small-scale craft production was replaced by the factory system. This era introduced mechanisation, division of labour, and standardised parts, laying the foundation for systematic production practices. As industries grew, the need for structured management of resources, processes, and labour became evident, leading pioneers such as Frederick W. Taylor, Henry Gantt, and Frank & Lillian Gilbreth to develop scientific management principles. Their contributions emphasised efficiency, time studies, and workflow optimisation, which shaped the early framework of production as an organisational function.

Over time, production management expanded into operations management, reflecting the inclusion of both goods and services. The evolution of quality movements, globalisation, and technological revolutions further broadened its role, making it central to organisational success. The introduction of the 5 Ps of Operations- People, Plants, Parts, Process, and Planning & Control, provided a structured lens to understand how operations contribute to efficiency, innovation, and value creation. Thus, the historical growth of this discipline highlights its transformation from factory-focused production to a comprehensive system integrating manufacturing and services. This unit traces the historical evolution of production and operations management from the factory system and scientific management to modern frameworks like the 5 P's, highlighting its growing importance as a core organisational function that integrates efficiency, innovation, and value creation.



Keywords

Production Function, Operations Management, Productivity, Production Planning, 5 P's Framework



Discussion

Production as an organizational function is central to transforming resources into goods and services that meet customer needs efficiently. The importance of production and operations management lies in its ability to enhance productivity, ensure quality, optimize costs, and sustain competitiveness in dynamic markets. Its scope extends across planning, designing, controlling, and improving processes that integrate technology, people, and systems. A key framework for understanding operations is the "5 Ps"- people, plants, processes, parts, and planning, which collectively shape organizational performance. Together, these elements provide learners with a holistic foundation for analysing and managing production systems in both manufacturing and service contexts.

1.1.1 Production

Production refers to the act of creating goods and services that meet human needs. It is essentially the process of turning inputs such as raw materials and resources into outputs like finished products. In the past, the word *manufacturing* was used to mean the same thing, but today it is applied only to making physical goods, while

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production (or *operations*) covers both goods and services. Any activity that changes raw materials or components into products ready for sale is considered production, and this transformation adds value to the product. This added value comes from processes such as changing the form of materials, moving them to where they are needed, storing or preserving them, and ensuring their quality.

1.1.1.1 Production Management

Definition: - According to A.W.Field, "Production management is the process of planning and regulating the operations of that part of an enterprise which is responsible for actual transformation of materials into finished products."

Production Management refers to applying management principles, such as planning, organizing, directing, and controlling, to the production function within a factory. In simple terms, it is the systematic management of the production process to ensure efficiency and effectiveness.

The rise of production management can be traced to three major developments:

1. **The Factory System of Production:** Before the emergence of organized manufacturing, businesses were mostly small and owner-driven, with no clear distinction between ownership and management. The factory system introduced structured production, creating the need for specialized management practices. Example: The Industrial Revolution brought large textile mills, where owners could no longer manage every detail themselves, leading to the birth of production managers.

2. **Growth of Large Corporations:** As businesses expanded into large corporations with multiple owners (shareholders), it became necessary to hire professional managers to run operations. This separation of ownership and management created a formal role for production management. Example: Companies like General Motors required professional managers to oversee complex production lines and coordinate thousands of employees.

3. **Scientific Management Movement: -** Pioneers such as Frederick Taylor and Henry Gantt demonstrated that systematic techniques, like time studies, standardization, and workflow optimization, could significantly improve efficiency and profitability. Their contributions established production management as a discipline grounded in science and measurable results. Example: Taylor's time-and-motion studies in steel plants showed how reorganizing tasks could double worker productivity, proving the value of structured management.

1.1.1.2 Benefits of Production Management

Effective production management delivers advantages to multiple stakeholders within the economic system of a nation. Its impact is broad and ensures that different groups benefit from efficient production practices:

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- ◊ **Consumers**: They gain access to better-quality goods and services at reasonable prices, ensuring satisfaction and improved living standards.
- ◊ **Investors**: Sound production management increases profitability and reduces risks, giving investors confidence in the stability and growth of their ventures.
- ◊ **Community**: Local communities benefit through employment opportunities, infrastructure development, and social welfare initiatives supported by thriving industries.
- ◊ **Suppliers**: Efficient production systems create steady demand for raw materials and components, strengthening supplier relationships and ensuring business continuity.
- ◊ **Employees**: Workers enjoy improved working conditions, fair wages, and opportunities for skill development, leading to higher motivation and productivity.
- ◊ **Nation**: At the macro level, production management contributes to economic growth, industrial development, and global competitiveness, enhancing the nation's prosperity.

1.1.1.3 Functions of Production Management

The production subsystem performs several key functions that ensure efficiency, quality, and smooth workflow in manufacturing and service operations. These include:

- ◊ **Design and Development**: Creating new products or improving existing ones to meet customer needs and market trends. It ensures that products are practical, innovative, and cost-effective to produce.
- ◊ **Facility Location**: Selecting the most suitable site for production facilities by considering factors such as raw material availability, transportation, labour, and proximity to markets.
- ◊ **Facilities Layout and Handling System**: Organizing machines, equipment, and workspaces to promote smooth workflow and efficient material handling, reducing waste and delays.
- ◊ **Method Study and Work Measurement**: Analysing how tasks are performed and measuring the time required to complete them, helping to set standards and improve efficiency.
- ◊ **Production Forecasting**: Predicting future demand for products to plan resources, avoid shortages, and prevent overproduction.
- ◊ **Production Planning and Scheduling**: Determining what to produce, when to produce, and how to allocate resources, ensuring timely completion of tasks.
- ◊ **Materials and Inventory Management**: Managing raw materials, components, and finished goods to balance cost efficiency with production continuity.

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◊ **Quality Control**: Ensuring that products meet customer expectations and regulatory standards through inspections, testing, and continuous monitoring.

1.1.2 Operations

Operations refers to the organised activity of turning inputs into outputs that hold greater value. In simple terms, it is the process of using resources such as materials, machines, labour, and capital to produce goods and services. When the output is purely physical goods, the system is called a *production system,* and the process is known as *production*. In modern practice, service systems, where the output is mainly services or even entirely services, are also recognised as productive systems. These are often described as *operating systems*, highlighting that both goods and services are part of the broader field of operations.

1.1.2.1 Operations Management

Operations Management is often discussed alongside production management, as both deal with the efficient use of resources to achieve organizational goals. Operations can be understood as purposeful, methodical activities carried out according to a structured plan, with the aim of meeting predetermined objectives.

In essence, operations management involves practical tactics such as scheduling tasks, allocating resources like people and equipment, managing inventories, setting and maintaining quality standards, deciding on process types, and determining the sequence of activities for a given product mix. Put simply, it is the discipline of transforming inputs, such as raw materials, labour, and technology, into outputs that are more valuable and useful.

1.1.2.2 Objectives of Production and Operations Management

◊ Deliver maximum customer satisfaction by ensuring quality, reliability, cost-effectiveness, and timely delivery.

◊ Reduce scrap and rework to improve product quality.

◊ Maintain optimal inventory levels to avoid excess stock.

◊ Achieve efficient utilization of all resources including manpower, machinery, and materials.

◊ Minimize cash outflow to strengthen financial stability.

◊ Enhance employee satisfaction through better working conditions and motivation.

◊ Strive for maximum output in terms of production volume.

◊ Improve operational efficiency across processes.

◊ Shorten the production cycle time for faster delivery.

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◊ Secure higher profitability and return on investment.

◊ Show commitment to environmental protection in operations.

◊ Boost overall productivity to sustain competitiveness.

1.1.2.3 Difference Between Production Management and Operations Management

Table No: 1.1.1 Difference between Production Management and Operations Management

Aspect	Production Management (PM)	Operations Management (OM)
Scope	Focuses on manufacturing and tangible goods	Covers both manufacturing and services (tangible + intangible outputs)
Output Type	Produces physical, tangible products	Produces both goods and services, often intangible
Resource Emphasis	Relies more on equipment and machinery, less on labour	Relies more on human involvement, customer interaction, and service delivery
Customer Role	Customers are not directly involved in production	Customers often participate in service delivery (e.g., banks, hospitals)
Examples	Automobile manufacturing, textile mills, electronics factories	Airlines, banks, hospitals, universities, consultancies, retail chains
Historical Evolution	Earlier term used when focus was on factory systems	Modern term reflecting broader scope including services and global operations

1.1.2.4 Historical Events in Operations Management

Table No: 1.1.2 Historical Events in Operations Management

Era	Events/Concepts	Dates	Originator
Industrial Revolution	Steam engine, Division of labour, Interchangeable parts	1769, 1776, 1790	James Watt, Adam Smith, Eli Whitney
Scientific Management	Principles of scientific management, time-and-motion studies, Activity scheduling chart, moving assembly line	1911–1913	Frederick W. Taylor, Frank & Lillian Gilbreth, Henry Gantt, Henry Ford

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Human Relations	Hawthorne studies, Motivation theories	1930–1960s	Elton Mayo, Abraham Maslow, Frederick Herzberg, Douglas McGregor
Operations Research	Linear programming, Digital computer, Simulation, waiting line theory, decision theory, PERT/CPM, MRP, EDI, EFT, CIM	1947–1970s	George Dantzig, Remington Rand, Joseph Orlicky, IBM, and others
Quality Revolution	JIT (Just-in-Time), TQM (Total Quality Management), Strategy and operations, Reengineeing, Six Sigma	1970s–1990s	Taiichi Ohno (Toyota), W. Edwards Deming, Joseph Juran, Wickham Skinner, Robert Hayes, Michael Hammer, James Champy, GE, Motorola
Internet Revolution	Internet & WWW, ERP, Supply chain management, E-commerce	1990s–2000s	ARPANET, Tim Berners-Lee, SAP, i2 Technologies, ORACLE, DELL, Amazon, Yahoo, eBay, Google
Globalization	WTO, European Union, Global supply chains, Outsourcing	1990s–2000s	China, India, Emerging economies
Green Revolution / Service Science	Global warming awareness, *An Inconvenient Truth*, Kyoto Protocol initiatives	2000s–Today	Numerous scientists, statesmen, governments

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1.1.3 Nature of Production and Operations

The nature of production and operations can be explained through four main perspectives. First, they can be seen as a system, where different parts work together to turn inputs into outputs. Second, they function as an organisational activity, linking with other departments to achieve overall goals. Third, they represent a conversion or transformation process, changing raw materials and resources into goods and services. Finally, they serve as a means of creating utility, adding value by making products more useful and desirable. These four views together provide a clear understanding of how production and operations contribute to organisational success.

1.1.3.1 Production/Operations as a System

This perspective is often called the *systems concept of production*. A system can be described as a group of connected parts that work together in a predictable way. In

this view, production is seen as a system that takes inputs and transforms them into outputs. The main components of a production system include: inputs, the conversion or transformation process, outputs, and supporting subsystems such as transportation, communication, and control or decision-making. Understanding production as a system highlights how different elements interact to deliver goods and services effectively.

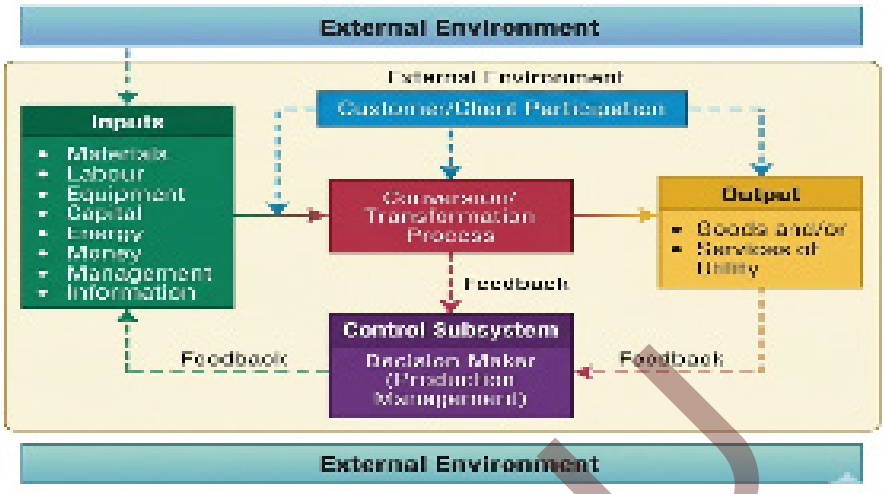


Fig 1.1.1 Production/Operations as a System

1.1.3.2 Production / Operations as an Organisational Function

Every organisation, whether it produces goods or delivers services, relies on four basic functions: marketing, production or operations, finance, and human resources. Among these, production is vital because it is the function that actually creates goods and services. Marketing focuses on generating demand and securing customer orders, finance manages the organisation's performance by handling cash inflows and outflows, and human resources ensures effective use of people within the organisation. The production function, therefore, plays a central role in helping a business achieve its objectives by turning resources into valuable outputs.

1.1.3.3 Production/Operations as a Conversion or Transformation Process

The conversion or transformation process is the central part of any production system. It involves using workers, materials, machines, and equipment to turn inputs into outputs. A simple production system can be shown in figure 1.1.2.

This process may include manufacturing activities such as cutting, drilling, machining, welding, and painting, as well as other activities like packing and selling. Each conversion process is made up of smaller steps called *operations*, which together form the sequence of activities that lead to the final product or service.

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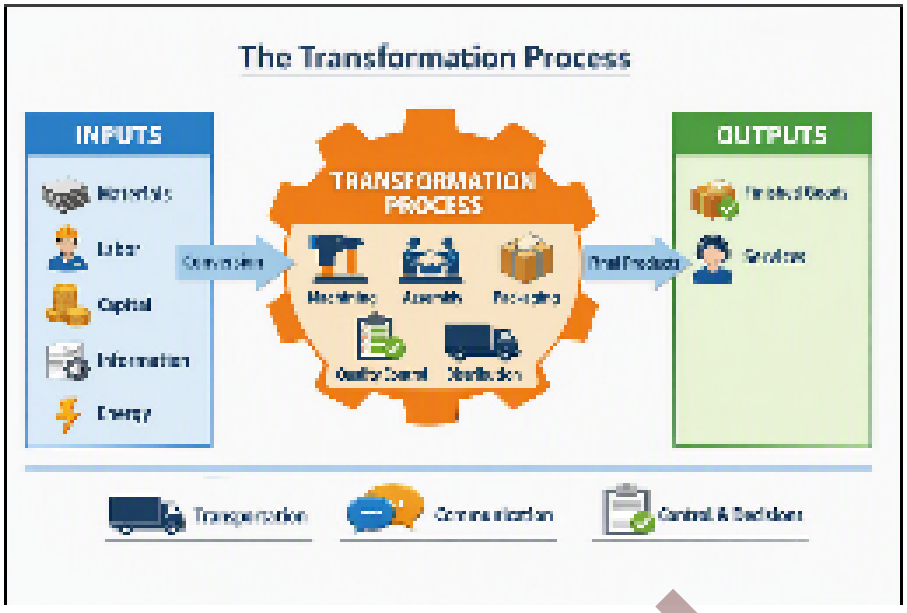


Fig 1.1.2 Production/Operations as a Conversion or Transformation Process

1.1.3.4 Production/Operations as a Means of Creating Utility

Production can be understood as the process of adding value to outputs or creating utility in them. *Utility* refers to the ability of a product or service to satisfy human needs. During the transformation of raw materials into finished goods, several types of utilities are created, each contributing to the overall value of the output.

i. **Form Utility:** This arises when the physical characteristics of inputs, such as size, shape, form, weight, colour, or smell, are changed to make them more useful to customers. For instance, iron ore is converted into steel, and wood is shaped into furniture.

ii. **Place Utility:** This is created by moving materials from their source to the place where they will be used or sold. For example, iron ore and coal are transported from mines to steel plants for processing.

iii. **Time Utility:** This results from storing or preserving materials or goods so they can be used later when demand is high and supply is limited.

iv. **Possession Utility:** This occurs when ownership of goods is transferred from one person or organisation to another. For example, when a supplier delivers materials to a firm, the possession utility increases as the firm gains ownership.

v. **Service Utility:** This is created when a professional provides a service directly to a customer, such as a doctor, lawyer, or engineer offering their expertise.

vi. **Knowledge Utility:** This arises when information or knowledge is shared with customers, such as through advertisements or sales presentations that help them understand a product better.

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Together, these utilities explain how production and operations enhance the usefulness and value of goods and services for consumers.

1.1.4 Production Function

The production function refers to the process of creating useful products for sale by using various inputs such as materials, machines, labour, land, capital, and management. It expresses the physical relationship between inputs and outputs and can be represented as:

$$Q = f(a,b,c,d,\ldots)$$

Here, Q stands for the quantity of output, while a, b, c, d, and so on represent the quantities of different inputs like materials, machine hours, labour hours, and energy. The production function shows how much output can be produced from a given amount of inputs within a specific period.

The efficient use of resources in this process is known as productivity, which measures the ratio of outputs (goods and services) to inputs (materials, energy, and other resources). It is usually expressed as:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

Productivity, also called productive efficiency, reflects how effectively a production process converts inputs into valuable outputs. High productivity indicates that resources are being used efficiently to produce goods and services that satisfy customer needs while ensuring reasonable profits for the manufacturer or seller.

1.1.5 Production/Operations as an Organisational Function

To understand how organisations create goods and services, it is important to recognise the four basic functions they perform: marketing, production or operations, finance, and human resources. Each of these functions plays a distinct role, but together they ensure that the organisation runs smoothly and achieves its objectives. The production or operations function is particularly crucial because it is directly responsible for creating the goods and services that the organisation offers to its customers.

1.1.5.1 Marketing Function

The marketing function is responsible for creating demand and connecting products or services with customers. It involves activities such as advertising, promotions, market research, and sales. For example, a company producing laptops must run campaigns to highlight features like battery life or speed to attract buyers. Without marketing, even high-quality products may fail to reach the right audience, making this function essential for business success.

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1.1.5.2 Finance Function

The finance function ensures that the organisation remains financially stable by managing cash inflows and outflows. It tracks revenue, monitors expenses, and evaluates profitability. For instance, in a retail store, finance records daily sales, pays suppliers, and ensures that enough funds are available for future investments. By keeping a close watch on financial performance, this function helps the organisation plan growth and maintain sustainability.

1.1.5.3 Human Resources Function

The human resources function is concerned with managing the people within an organisation. It ensures that employees are recruited, trained, motivated, and retained so that they can contribute effectively to organisational goals. For example, in a hospital, HR is responsible for hiring qualified doctors and nurses, arranging training programmes to keep them updated with medical advancements, and creating policies that support employee well-being. In a manufacturing company, HR ensures that workers are skilled in operating machinery safely and efficiently. By focusing on people, HR helps the organisation make the best use of its workforce, which is essential for long-term success.

1.1.5.4 Production Function

The production or operations function is at the core of any organisation because it is directly responsible for creating goods and services. It involves transforming inputs such as raw materials, labour, and technology into finished products or services that meet customer needs. For instance, in a car manufacturing company, production includes assembling parts, painting vehicles, and conducting quality checks before delivery. In a service-based organisation like a bank, operations involve processing transactions, maintaining records, and providing customer support. This function is crucial because it generates the actual outputs that customers value and that bring profits to the organisation. By ensuring efficiency and quality, the production function plays a central role in achieving business objectives.

1.1.6 Importance of the Production Function

a) Core Function of Business

Production is the central activity of any organisation because it creates the goods and services that define its existence. Without production, there would be no products to market, no revenue to manage, and no workforce to support. For example, in a car manufacturing company, production involves assembling vehicles, testing them, and preparing them for sale. If cars were not produced, marketing would have nothing to promote, finance would have no income to track, and HR would have no employees to manage. This shows that production is the foundation upon which all other functions depend.

b) Employment Opportunities

A significant portion of employees in most organisations work in production-

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related roles, often more than 50 percent. For instance, in a textile factory, workers are engaged in weaving, dyeing, stitching, and quality checking, all of which are part of the production process. Similarly, in a hospital, doctors, nurses, and technicians are directly involved in delivering healthcare services, which is the organisation's core output. This highlights that production not only creates goods and services but also provides employment opportunities, making it vital for both organisational success and societal well-being.

c) Management of Organisational Assets

The production function is also responsible for managing a large share of organisational assets, such as factories, machinery, tools, and technology. These assets represent significant investments and are essential for converting raw materials into finished goods. For example, a steel plant owns expensive furnaces, rolling mills, and transport systems, all of which are crucial for production. By creating goods and services, production supports human needs and improves living standards. In this way, the production function not only drives organisational growth but also plays a key role in the economic and social development of society.

d) Foundation for Other Business Functions

Production is the backbone of all other organisational functions. Marketing, finance, and human resources depend on production to exist. For example, if a bakery does not produce bread and cakes, marketing has nothing to advertise, finance has no revenue to manage, and HR has no employees to support. Thus, production provides the basis for the functioning of every other department.

e) Contribution to National Economy

Production plays a vital role in strengthening the economy of a country. By creating goods and services, industries contribute to GDP growth, generate employment, and improve living standards. For instance, the automobile industry in India not only produces vehicles but also supports allied industries such as steel, rubber, and electronics, thereby boosting the overall economy.

f) Innovation and Technological Advancement

Production encourages innovation and the adoption of new technologies. Organisations constantly improve their production processes to increase efficiency and reduce costs. For example, the use of robotics and automation in car manufacturing has enhanced productivity and ensured higher quality standards. This continuous improvement benefits both businesses and customers.

g) Customer Satisfaction and Value Creation

The production function ensures that goods and services meet customer needs by adding value through quality, design, and utility. For instance, a smartphone manufacturer focuses on producing devices with advanced features like better cameras and faster processors to satisfy customer expectations. By doing so, production directly contributes to customer satisfaction and loyalty.

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h) Resource Utilisation and Efficiency

Production ensures the effective use of resources such as raw materials, labour, and capital. Efficient production reduces waste and maximises output. For example, a textile company that optimises its use of fabric and energy can produce more garments at lower costs, making the business more competitive.

i) Social Development and Welfare

Beyond business success, production contributes to society by providing essential goods and services. For example, pharmaceutical companies produce medicines that improve health and save lives, while educational institutions deliver services that spread knowledge. In this way, production supports social welfare and enhances the quality of life.

1.1.7 Scope of Production and Operations Management

1.1.7.1 Scope of Production Management

i) Production Planning and Development

Production planning involves forecasting demand, designing processes, and determining the resources required to meet organizational goals. It ensures that raw materials, labor, and technology are aligned to produce goods efficiently and on time. Development also includes product design and innovation, making sure that offerings remain competitive in dynamic markets.

Example: A smartphone company plans production by forecasting demand for its new model, securing components like chips and screens, and designing assembly processes to meet launch deadlines.

ii) Production Administration

Administration covers the coordination of people, machines, and materials to ensure smooth operations. It involves setting policies, monitoring performance, and maintaining discipline across production units. Effective administration ensures that resources are used optimally and that production targets are consistently achieved.

Example: In an automobile plant, production administration ensures that assembly lines run on schedule, workers follow safety protocols, and machinery is maintained regularly to avoid breakdowns.

iii) Execution of Plans, Policies, and Decisions

Execution is the practical implementation of strategies and policies designed during planning. It requires close monitoring, problem-solving, and adjustments to ensure that production goals are met despite uncertainties. Successful execution bridges the gap between theoretical planning and real-world outcomes.

Example: A textile company executes its production plan by scheduling shifts,

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procuring raw cotton, and ensuring that dyeing and weaving processes meet quality standards.

iv) Inventory and Materials Management

Managing inventory ensures that raw materials, work-in-progress, and finished goods are available when needed without excessive holding costs. Materials management involves procurement, storage, and distribution, balancing cost efficiency with production continuity. Proper inventory control prevents delays and reduces waste.

Example: Amazon uses advanced inventory management systems to track millions of products, ensuring that warehouses are stocked efficiently and customer orders are fulfilled quickly.

v) Process Design and Improvement

Production management also focuses on designing workflows and continuously improving them for efficiency. This includes adopting lean manufacturing, automation, and process reengineering to reduce waste and enhance productivity. Continuous improvement ensures adaptability in changing market conditions.

Example: Toyota applies lean principles to eliminate unnecessary steps in production, reducing costs while maintaining high quality.

vi) Workforce Management

Human resources are central to production, and managing them involves recruitment, training, motivation, and performance evaluation. A skilled and motivated workforce ensures that production runs smoothly and innovatively. Workforce management also addresses safety and employee well-being, which directly impact productivity.

Example: Infosys invests in continuous training programs for its employees, ensuring they remain updated with new technologies and can deliver high-quality IT services.

vii) Technology and Automation Integration

Modern production management incorporates advanced technologies such as robotics, AI, and IoT. Automation reduces human error, speeds up processes, and enhances precision. Technology also enables real-time monitoring and predictive maintenance, ensuring uninterrupted production.

Example: Tesla's Gigafactories use robotics and AI-driven systems to assemble electric vehicles with high efficiency and minimal defects.

viii) Quality Assurance and Control

Quality management ensures that products meet customer expectations and regulatory standards. It involves inspections, testing, and continuous monitoring throughout the production cycle. High-quality output builds brand reputation and reduces costs associated with defects or recalls.

Example: Pharmaceutical companies implement strict quality control measures to

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ensure that medicines are safe, effective, and compliant with health regulations.

ix) Sustainability and Environmental Responsibility

Production management now includes eco-friendly practices such as waste reduction, energy conservation, and sustainable sourcing. This not only meets regulatory requirements but also appeals to environmentally conscious consumers. Sustainable operations contribute to long-term profitability and social responsibility.

Example: Unilever integrates sustainability into its production by reducing plastic packaging and sourcing raw materials from certified sustainable suppliers.

1.1.7.2 Scope of Operations Management

i) Application to Service Operations

Operations management is no longer confined to manufacturing; it now plays a vital role in service industries such as healthcare, banking, education, and hospitality. Service operations often involve intangible outputs, but they still require systematic planning, process design, and efficiency improvements. By applying operations principles, service organizations can reduce waiting times, improve customer experiences, and enhance productivity.

Example: In hospitals, operations management helps streamline patient admissions, reduce surgery delays, and optimize staff scheduling to deliver better healthcare outcomes.

ii) Growing Importance of Quality

Quality has become a central concern across industries, extending beyond product durability to include customer satisfaction, safety, and reliability. Modern operations management integrates quality assurance into every stage of production and service delivery, ensuring consistency and trust. This focus on quality also strengthens brand reputation and customer loyalty, making it a competitive advantage.

Example: Toyota's adoption of *Total Quality Management (TQM)* and *Kaizen* practices ensures continuous improvement, leading to fewer defects and higher customer satisfaction worldwide.

iii) Expansion into Allied Functions

Operations concepts such as process analysis, workflow optimization, and resource allocation are now applied in marketing, finance, and human resources. This cross-functional integration helps organizations achieve synergy, aligning operational efficiency with strategic goals. It also fosters collaboration between departments, ensuring that customer needs are met holistically. Example: In HR, operations management principles are used to design efficient recruitment processes, reducing hiring time and improving employee onboarding experiences.

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iv) Value Addition Paradigm

The modern view of operations management emphasizes creating value rather than merely cutting costs. This involves enhancing speed, flexibility, and innovation to deliver products and services that exceed customer expectations. By focusing on value, organizations can differentiate themselves in competitive markets and sustain long-term growth.

Example: Amazon adds value through fast delivery, personalized recommendations, and efficient supply chain management, making customer convenience its core operational strategy.

v) Technological Integration

Advances in automation, artificial intelligence, and data analytics have transformed operations management. Technology enables real-time monitoring, predictive decision-making, and smarter resource utilization. Digital tools also help organizations adapt quickly to market changes and improve accuracy in forecasting demand.

Example: Airlines use AI-driven systems to optimize flight schedules, reduce fuel consumption, and improve passenger experiences through dynamic pricing and efficient boarding processes.

vi) Sustainability and Green Operations

Operations management now incorporates environmental responsibility, focusing on reducing waste, conserving energy, and adopting eco-friendly practices. Sustainable operations not only meet regulatory requirements but also appeal to socially conscious consumers. This shift ensures long-term viability while protecting natural resources.

Example: IKEA integrates sustainability into its operations by sourcing renewable materials, designing recyclable products, and using energy-efficient logistics systems.

vii) Global Supply Chain Management

With globalization, operations management must handle complex supply chains that span multiple countries. This requires balancing cost efficiency with resilience, ensuring that disruptions such as pandemics or geopolitical conflicts do not halt production. Effective supply chain management enhances competitiveness and customer satisfaction.

Example: Apple manages a global supply chain by sourcing components from different countries and assembling them in China, while maintaining strict quality and delivery standards.

viii) Customer-Centric Operations

Modern operations management places customers at the heart of decision-making. Processes are designed to deliver convenience, personalization, and responsiveness. This customer-centric approach ensures that operations align with evolving consumer expectations.

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Example: Starbucks uses operations management to maintain consistency in taste and service across thousands of outlets worldwide, while also customizing offerings to local preferences.

1.1.8. Five P's Of Operations

1.1.8.1. 5 P's of Operations Management

1) People

People represent the workforce, both direct (operators, technicians) and indirect (managers, support staff), who drive the production system. Their skills, motivation, and coordination are critical for efficiency and innovation. Operations management focuses on improving workforce productivity through training, quality improvement, and performance monitoring.

Example: In a call center, managers use learning curve analysis to train employees, gradually reducing call handling time and improving customer satisfaction.

2) Plants

Plants include the physical facilities, factories, service centers, or branches, where production or service delivery takes place. Decisions about plant location, expansion, or contraction directly affect costs, accessibility, and efficiency. Modern operations also consider sustainability and smart infrastructure when managing plants.

Example: Coca-Cola strategically locates bottling plants near major markets to reduce transportation costs and ensure faster delivery.

3) Parts

Parts refer to raw materials, components, and supplies that flow through the production system. Effective management involves procurement, vendor selection, and make-or-buy decisions to balance cost, quality, and reliability. Proper handling of parts ensures smooth operations and prevents bottlenecks.

Example: Apple decides whether to manufacture its own chips (make) or outsource to suppliers like TSMC (buy), balancing innovation with cost efficiency.

4) Process

Processes are the methods, equipment, and workflows used to transform inputs into outputs. Operations management evaluates technology, redesigns workflows, and applies process reengineering to improve efficiency and reduce waste. Continuous improvement ensures adaptability in competitive markets.

Example: Amazon uses advanced robotics in warehouses to speed up order picking and packing, reducing delivery times significantly.

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5) Planning and Control

Planning and control involve forecasting demand, scheduling production, and monitoring performance. Tools like *Material Requirements Planning (MRP)*, shop floor control, and distribution systems ensure that resources are used effectively. This function balances supply and demand while minimizing costs.

Example: Walmart uses sophisticated planning systems to manage inventory across thousands of stores, ensuring products are available without overstocking.

1.1.8.2 Applications of the 5 P's of Operations Management

1. People

Operations management focuses on improving workforce efficiency and effectiveness. This includes quality improvement initiatives, revising work standards to match industry benchmarks, and applying learning curve analysis to enhance employee performance over time. By investing in people, organizations can achieve higher productivity and innovation.

Example: In a manufacturing plant, managers revise work standards to reduce assembly errors, while training programs help workers adapt quickly to new machinery, improving overall output.

2. Plants

Plants represent the physical facilities where production or service delivery occurs. Applications include adding new plants to meet growing demand, strategically locating them closer to markets, and expanding or contracting facilities based on business needs. Effective plant management ensures cost efficiency and responsiveness to customer demand.

Example: Starbucks expands by opening new outlets in high-demand urban areas, while closing underperforming stores to optimize resources.

3. Parts

Parts refer to raw materials, components, and supplies that flow through the production system. Applications include making decisions on whether to produce parts in-house or outsource them, and selecting reliable vendors to ensure quality and timely delivery. Proper management of parts reduces costs and prevents production delays.

Example: Boeing carefully selects vendors for aircraft components like engines and avionics, ensuring safety and reliability while balancing costs.

4. Process

Processes are the methods and workflows used to transform inputs into outputs. Applications include evaluating new technologies, improving existing processes, and reengineering workflows to eliminate inefficiencies. Continuous process improvement ensures adaptability and competitiveness in dynamic markets.

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Example: Amazon reengineered its warehouse processes by introducing robotics and AI-driven systems, reducing order fulfilment times and improving accuracy.

5. Planning and Control

Planning and control involve forecasting demand, scheduling production, and monitoring operations. Applications include using *Material Requirements Planning (MRP)* to manage resources, shop floor control to track production progress, and warehousing and distribution systems to ensure timely delivery. Effective planning and control balance supply and demand while minimizing costs.

Example: Walmart uses advanced planning systems to manage inventory across thousands of stores, ensuring products are available without overstocking.



Summarised Overview

Production is essentially the process of transforming inputs into outputs that meet customer needs, while production management applies the principles of planning, organising, directing, and controlling to production activities in order to achieve efficiency and effectiveness. The benefits of production management are reflected in improved product quality for consumers, profitability for investors, opportunities for employees, stability for suppliers, and economic growth for the nation. Its functions include design and development, facility location, layout, method study, forecasting, planning, inventory management, and quality control. Operations, on the other hand, are systematic activities that convert resources into useful goods and services, and operations management focuses on scheduling, resource allocation, inventory control, quality standards, and process decisions to achieve organisational objectives. The difference between production management and operations management lies in the fact that production management deals mainly with tangible goods, while operations management covers both goods and intangible services. Historical events in operations management trace milestones from the Industrial Revolution and scientific management to modern revolutions in quality, globalisation, and sustainability.

The nature of production and operations can be understood as a system, an organisational function, a transformation process, and a means of creating utility. The production function is the core organisational activity that converts resources into outputs, and its importance lies in ensuring efficiency, competitiveness, and customer satisfaction. The scope of production and operations management includes both production management, which focuses on manufacturing, and operations management, which covers goods and services. The 5 Ps of operations management are People, Plants, Parts, Process, and Planning & Control, and their applications include workforce development, facility expansion, vendor decisions, process improvement, and resource planning to enhance organisational performance.

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Self-Assessment Question

1. What is production management? State its key objectives.
2. List the benefits of production management and briefly describe each.
3. Identify the functions of production management and explain their role in organizations.
4. Explain the scope of operations management with examples from manufacturing and service industries.
5. Distinguish between production management and operations management.
6. Discuss the following views of the nature of production:

   (i) Production as a system.

   (ii) Production/operations as an organisational function.

   (iii) Production/operations as a conversion process.

   (iv) Production/operations as a means of creating utility.
7. What is a "Production function"? State its importance.
8. Discuss the statement "Production is a means of creating utility."
9. State the objectives of production/operations management.
10. Apply the concept of production/operations as a conversion process to a food processing industry.
11. Apply the 5 Ps framework to analyze and improve operations in a service organization.

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Assignments

1. A company's production manager claims that efficiency is declining due to poor coordination with other departments. Examine how production management differs from general management and why this distinction matters.
2. A consumer goods company reports rising costs but stagnant profits. Evaluate how the benefits of production management extend beyond cost savings to overall organizational performance.

3. A hospital wants to improve patient flow but faces resource constraints. Consider how operations management principles can be applied to balance service quality with efficiency.

4. A service-based start-up is facing bottlenecks in workflow. Explain how viewing operations as a system can help identify and resolve inefficiencies.

5. A technology start-up struggles to balance workforce management, facility expansion, and process improvement. Evaluate how the 5 Ps of operations management interact to enhance organizational performance.

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

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Unit 2

Product Design

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ define the fundamental concepts of product design, process design, and production design, including their factors, characteristics, and approaches
- ◊ explain the differences between process planning, process selection, and process strategy, highlighting their roles in achieving efficiency and competitiveness
- ◊ apply theoretical principles of process management by analysing case studies and suggesting improvements in production and operations
- ◊ evaluate make-or-buy decisions by assessing cost, quality, resource availability, and strategic implications for organisational success
- ◊ design integrated product and process strategies that align with organisational objectives, customer needs, and sustainability goals

Background

The historical background of product and process design can be traced back to the Industrial Revolution, when mechanisation and factory systems transformed production from small-scale craftsmanship into large-scale manufacturing. Early pioneers such as Eli Whitney introduced concepts like interchangeable parts, which laid the foundation for modern product design by emphasising standardisation and efficiency. Over time, scientific management by Frederick Taylor and the principles of Henry Ford's assembly line brought systematic approaches to process design and production design, ensuring that operations were not only efficient but also customer-oriented. As industries expanded, factors such as cost, quality, durability, and customer satisfaction became central to product design,

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while characteristics like innovation, adaptability, and sustainability began to shape the way organisations approached design and manufacturing.

In the twentieth century, process planning and process selection evolved alongside technological advancements, with lean manufacturing, Just-In-Time systems, and continuous improvement (Kaizen) becoming dominant strategies. Process strategy and process management were increasingly tied to global competition, supply chain integration, and the need for flexibility in both goods and services. The make-or-buy decision, once a simple cost-based choice, grew into a strategic consideration involving core competencies, outsourcing, and partnerships with specialised suppliers. These developments reflect a historical progression from manual production to highly sophisticated, customer-centric, and technology-driven systems. This unit focuses on the integration of product design, process design, production management, and strategic decision-making in modern operations.



Keywords

Product Design, Process Design, Production Design, Process Planning, Process Selection, Process Strategy, Make-or-Buy Decisions



Discussion

Product and process design have evolved as central pillars of industrial development, shaping the way organisations create, plan, and deliver products to meet customer needs. Rooted in the early practices of craftsmanship and later refined through the Industrial Revolution, these concepts emphasise the systematic transformation of ideas into tangible goods and services. Product design focuses on creativity, functionality, and market relevance, while process design ensures that production methods are efficient, cost-effective, and adaptable to technological advancements. Over time, production design has incorporated factors such as quality, sustainability, and innovation, alongside characteristics like reliability and flexibility. Approaches to product design, process planning, and process selection have been influenced by global competition, lean manufacturing, and strategic management, while make-or-buy decisions highlight the importance of balancing internal capabilities with external partnerships. Together, these elements provide a comprehensive framework for modern operations and industrial success.

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1.2.1 Product

A product can be understood as anything that an organisation offers to customers in order to meet their needs or wants. It is not limited to physical goods like furniture, clothing, or electronics; it also includes services such as banking, healthcare, or education, as well as experiences, events, ideas, and even places. For example, a smartphone is a tangible product, but the warranty, customer support, and software updates that come with it are intangible services. In today's competitive environment, most companies combine goods and services to create a complete customer experience; think of airlines that sell tickets (service) but also provide meals, entertainment, and comfortable seating (tangible elements).

To understand products better, marketing and design experts often describe them at three levels.

Levels of Product

1. **Core Product:** The core product is the basic benefit or solution that the customer is really buying. For example, when someone purchases a washing machine, they are not simply buying a machine; they are buying the benefit of clean clothes. This level focuses on the problem-solving aspect of the product, which is the true reason behind the purchase.

2. **Actual Product:** The actual product refers to the physical item itself, including its design, features, brand name, and packaging. In the case of the washing machine, this includes the brand (like LG or Whirlpool), the design, colour, and the packaging. It is the tangible part that customers can see, touch, and evaluate before making a decision.

3. **Augmented Product:** The augmented product consists of additional services or benefits that enhance the value of the actual product. Examples include warranties, free installation, after-sales service, or customer support. These extras help differentiate one company's product from another and often play a key role in customer satisfaction and loyalty.



Fig 1.2.1 Levels of Product

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1.2.2 Product Design

Designing new products and introducing them to the market is one of the biggest challenges faced by manufacturers across all industries, from advanced technology sectors like computer chips to everyday consumer goods like snacks. For instance, computer chip manufacturers must constantly develop more powerful integrated circuits to meet the demands of computer makers, while food producers must create new flavours and packaging styles to attract customers and maintain their market share.

The success and profitability of any organisation depend greatly on how well its products are designed and produced. A well-designed product not only meets customer expectations but also ensures efficient production and cost control. Therefore, product design is closely linked to process design and process technology, as the way a product is made influences the tools, machinery, and methods used in production.

In today's global economy, designing and developing products and production processes are essential parts of a company's operations strategy. The design of the productive system, that is, the entire setup for manufacturing, depends on the design of the product itself and the selection of suitable production processes. For example, automobile companies like Toyota or Tata Motors design their cars alongside their assembly processes to ensure efficiency and quality.

Whether a company is high-tech, low-tech, or no-tech, product design plays a vital role in its survival and profitability. The essence of any organisation lies in the products or services it offers. A strong connection exists between product design and organisational success; firms with well-designed products are more likely to achieve their goals than those with poorly designed ones. Good product design leads to customer satisfaction, brand loyalty, and long-term competitiveness.

Additional examples:

- ◊ Apple focuses on sleek design and user-friendly interfaces to maintain its premium image.
- ◊ Nike combines innovative materials and ergonomic design to enhance performance and comfort.
- ◊ Local manufacturers often adapt product designs to suit regional tastes and cultural preferences, ensuring relevance and acceptance.

1.2.2.1 Product Design, Process Design, and Production Design

1. Product Design

Product design is the process of planning and arranging the elements that make up a product or service to meet customer needs and create a competitive advantage. It focuses on both form and function.

- ◊ **Form design** deals with how the product looks, its shape, size, colour, materials, and overall appearance. It also considers what the product is made of and how it will be manufactured.

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◊ **Functional design** focuses on what the product does and how well it performs its intended purpose. For example, in a television, the clarity of the picture and the quality of sound are more important than the design of the cabinet. A good product design balances both form and function. For instance, a car must look appealing (form) but also deliver safety, comfort, and fuel efficiency (function).

Examples:

◊ Smartphones combine sleek design with advanced features like high-speed processors and quality cameras.

◊ Furniture design considers both aesthetics and comfort, chairs must look good and support posture.

2. Process Design

Process design refers to planning the sequence of operations needed to produce a product according to its design specifications. It identifies the type of workstations, machines, and equipment required to carry out production efficiently. The choice of process technology, manual, mechanised, or automated, depends on the product's complexity and quality requirements. For example, precision parts for aircraft need automated, computer-controlled processes to achieve exact tolerances. Process design ensures that the manufacturing system can produce the product economically while maintaining quality. It also considers factors like workflow, layout, and resource utilisation.

Examples:

◊ Automobile manufacturing uses robotic assembly lines for consistency and speed.

◊ Food processing industries design processes for hygiene, packaging, and freshness preservation.

3. Production Design

Production design focuses on designing products in a way that makes them easy and economical to produce. It links product design with the productive system design. A product may be expensive to manufacture in one design but cheaper if redesigned with simpler components or materials. This concept is known as design for producibility, ensuring that products can be made efficiently at the lowest possible cost without compromising quality. Production design involves collaboration between product designers and process engineers to achieve cost-effective production.

Examples:

◊ Automobile parts are often redesigned to reduce assembly time and material waste.

◊ Consumer electronics companies design products with modular components to simplify manufacturing and repairs.

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Key Insights

- ◊ Product, process, and production design are interdependent, a change in one affects the others.
- ◊ Good design improves customer satisfaction, production efficiency, and profitability.
- ◊ Modern approaches like Design for Manufacturing (DFM) and Design for Assembly (DFA) help companies reduce costs and improve quality.
- ◊ Successful firms integrate design thinking into their operations strategy to stay competitive in global markets.

1.2.2.2 Importance of Product Design

Product design plays a central role in shaping a company's production and operations strategy. It is important for several reasons:

1. **Defines Product Characteristics:** When a product is designed, all its detailed features, such as size, shape, materials, and functions, are established. These characteristics directly influence how the product will be manufactured.
2. **Influences Process and Production Design:** Each product feature affects the choice of process technology (manual, mechanised, or automated) and the overall process design. The way a product is made determines the design of the production system, which is the foundation of operations strategy.
3. **Impacts Quality, Cost, and Customer Satisfaction:** A well-designed product ensures high quality, reduces production costs, and meets customer expectations. Poor design can lead to inefficiency, higher costs, and dissatisfied customers.
4. **Improves Marketability:** Good design makes products easier to use, enhances their appearance, and increases reliability. For example, ergonomic furniture improves comfort, while stylish packaging makes consumer goods more attractive.
5. **Differentiates Products in Competitive Markets:** A distinctive design may be the only factor that sets a product apart from competitors. For instance, Dyson vacuum cleaners are recognised for their unique design and usability, which differentiates them from standard models.
6. **Ensures Usability and Functionality:** Excellent design focuses on how well a product performs its intended function. Example: In smartphones, battery life and user interface are more critical than just appearance.
7. **Supports Innovation and Reliability:** Innovative designs introduce new features or technologies that attract customers. Reliable designs ensure consistent performance, building trust and loyalty.

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8. **Provides Competitive Advantage:** Strong product design helps firms achieve the right balance of quality, cost, and features. Companies like Apple and Tesla thrive because their designs combine functionality, aesthetics, and innovation.

9. **Future of Competition:** Businesses will increasingly compete not only on price and quality but also on product design. Design will become the key driver of customer preference and brand success.

1.2.2.3 Objectives of Product Design

Product design serves several important objectives that guide organisations towards efficiency, profitability, and customer satisfaction:

◊ **Long-Term Profitability:** The ultimate goal of product design is to generate profits over time by creating products that meet customer needs and remain competitive in the market.

◊ **Achieving Desired Quality:** Product design ensures that the product meets the required standards of performance, durability, and reliability.

◊ Example: Designing medical equipment with strict accuracy and safety standards.

◊ **Reducing Development Time and Cost:** A key objective is to minimise the time and expense involved in developing new products. Faster development helps companies respond quickly to market changes. Example: Using computer-aided design (CAD) tools to speed up product development.

◊ **Lowering Production Costs:** Good design reduces material and labour costs without compromising quality. Example: Redesigning packaging to use fewer resources while maintaining strength and appeal.

◊ **Ensuring Manufacturability (Design for Production):** Products must be designed so they can be manufactured easily, economically, and consistently. This includes Design for Manufacturing (DFM) and Design for Assembly (DFA) principles. Example: Electronics designed with modular components to simplify assembly and repairs.

1.2.2.4 Factors Influencing Product Design

◊ **Customer Requirements:** Designers must clearly understand what customers want so that products are convenient, reliable, and suitable for different conditions of use. For example, mobile phones are designed to work in varying climates and usage environments.

◊ **Ease of Use:** Industrial products such as machines and tools should be designed for comfort and safety. Ergonomic design ensures that operators can use them efficiently without strain.

◊ **Balancing Function and Form:** A good design combines performance with appearance. While functionality is essential, aesthetics also matter. For instance,

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a car must be safe and fuel-efficient but also visually appealing.

- ◊ **Choice of Materials:** The discovery of new materials often improves product design. Designers use advanced materials like lightweight alloys or biodegradable plastics to enhance durability, sustainability, and performance.
- ◊ **Work Methods and Equipment:** Designers must stay updated with the latest manufacturing technologies and processes. Using modern equipment and improved work methods can reduce costs and improve efficiency.
- ◊ **Cost and Price Considerations:** In competitive markets, products must be cost-effective. Designers must ensure that quality and affordability are built into the design stage itself.
- ◊ **Product Quality:** Quality depends both on design and on how well the product is manufactured. Designers set specifications and tolerances to ensure that the product meets performance standards.
- ◊ **Process Capability:** Designers must consider the capabilities of available machines and equipment. They should specify tolerances that can realistically be achieved during production.
- ◊ **Impact on Existing Products:** When new designs replace old ones, they should make use of standard parts and existing manufacturing systems to minimise costs. Blending new technology with current processes ensures smooth transition.
- ◊ **Packaging:** Packaging is an integral part of product design. It protects the product, promotes it, and enhances its appeal. Attractive packaging can significantly boost sales, especially for consumer goods like food and cosmetics.

1.2.2.5 Characteristics of Good Product Design

- ◊ **Function or Performance:** A product must perform the task customers expect it to do. For example, a motorbike should start easily, provide good pickup, reach a reasonable speed, and deliver efficient fuel consumption. Functionality is the foundation of customer satisfaction.
- ◊ **Appearance or Aesthetics:** The look and feel of a product, its style, colour, and design, add value by appealing to human senses. Attractive design often enhances marketability, especially in consumer goods like smartphones or clothing.
- ◊ **Reliability:** Reliability refers to how long a product can function without failure. A reliable product builds trust, as customers expect consistent performance over time. For instance, a refrigerator should work smoothly for years without frequent breakdowns.
- ◊ **Maintainability (Serviceability):** Products should be easy to repair and restore when they fail. High maintainability ensures that downtime is minimal, keeping customers satisfied. For example, cars designed with easily replaceable parts reduce repair time and costs.

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- ◊ **Availability:** Availability is the combination of reliability and maintainability. A product is considered available when it is operational and ready for use. High reliability and quick repairs ensure maximum availability for customers.
- ◊ **Producibility:** A good design should allow products to be manufactured economically and efficiently. This involves using suitable materials, proper tolerances, and cost-effective processes. For example, modular furniture designs simplify production and reduce costs.
- ◊ **Simplification:** Simplified designs eliminate unnecessary complexity, making products easier to produce, assemble, and use. Fewer parts mean lower costs and higher quality. For instance, smartphones with fewer buttons but touch-screen interfaces are simpler and more user-friendly.
- ◊ **Standardisation:** Standardisation reduces variety among products or parts, leading to economies of scale. For example, using standardised screws or components across multiple products lowers costs and simplifies manufacturing. However, it may limit customer choice.
- ◊ **Specifications:** Specifications provide detailed descriptions of product dimensions, weight, finish, and tolerances. They guide the production department to achieve consistency and interchangeability of parts, especially in mass production. For example, automobile parts are designed with precise specifications to fit perfectly during assembly.
- ◊ **Safety:** Products must be safe to use, store, and transport. Designers must ensure that products do not cause accidents or health hazards. For example, pharmaceutical products must cure without harmful side effects, and electrical appliances must include safety features to prevent shocks or fires.

1.2.2.6 Approaches to Product Design

1. User-Centred Design (UCD)

This approach places the customer at the heart of product development. Designers study user needs, behaviours, and expectations to ensure the product is practical and easy to use. It involves research, testing, and feedback to refine usability. Example: Smartphones are designed with touch interfaces, voice commands, and accessibility features to suit diverse users.

2. Design for Manufacturing and Assembly (DFMA)

DFMA focuses on making products simple and economical to produce. It reduces the number of parts, simplifies assembly steps, and uses standardised components. This approach ensures efficiency and cost savings in production. Example: IKEA furniture is designed with modular parts and simple fittings, making it easy to manufacture and assemble at home.

3. Sustainable Design

Sustainable design integrates eco-friendly materials and processes to reduce

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environmental impact. It considers recyclability, energy efficiency, and long-term sustainability. This approach appeals to environmentally conscious customers and meets regulatory standards. Example: Electric vehicles are designed with recyclable batteries and lightweight materials to reduce emissions.

4. Lean Product Design

Lean design emphasises speed, efficiency, and waste reduction. It uses rapid prototyping and iterative improvements to bring products to market quickly. This approach helps companies respond faster to changing customer demands. Example: Tech start-ups often launch beta versions of apps to test user feedback before finalising the product.

5. Generative/Innovative Design

Generative design uses advanced tools like AI and machine learning to explore multiple design possibilities. It creates optimised solutions that may not be achievable through traditional methods. This approach encourages creativity and innovation. Example: Aerospace companies use generative design to create lightweight yet strong aircraft components.

6. Emotional and Experience-Driven Design

This approach focuses on aesthetics, usability, and emotional connection with customers. Products are designed to evoke feelings and enhance user experience. It builds brand loyalty by making products memorable and appealing. Example: Apple products are known for their sleek design and premium feel, which create strong emotional bonds with users.

7. Process-Oriented Design

Process-oriented design aligns product features with manufacturing capabilities. It ensures smooth integration between product design and production systems. This approach reduces inefficiencies and ensures consistency in output. Example: Automobile manufacturers design cars alongside robotic assembly lines to ensure precision and efficiency.

1.2.2.7 Stages in Product Design

Product design usually progresses through several structured stages, each ensuring that the final product meets customer needs, is feasible to produce, and is cost-effective. Here's a simplified explanation of each stage:

1. Conception

At this stage, draft specifications are prepared by the marketing team in consultation with designers. These specifications outline customer expectations such as performance, appearance, safety, reliability, and cost limits. They also include details like demand forecasts and acceptable development costs. Example: Drafting specifications for a new smartphone that highlight battery life, screen size, and maximum price range.

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2. Acceptance

The draft specifications are reviewed to check technical feasibility and economic viability. If the design is not practical or too costly, it may be modified or rejected. This decision is taken jointly by the design and marketing departments. Example: A car design proposal may be rejected if the estimated production cost is too high compared to market demand.



Fig 1.2.2 Stages in Product Design

3. Execution

Here, specifications are converted into preliminary drawings and prototypes. Prototypes are tested, and if they fail to meet requirements, modifications are made until a satisfactory model is achieved. This stage proves the feasibility of the product design. Example: Building and testing multiple versions of a new washing machine model until performance standards are met.

4. Evaluation and Review

A cross-functional team evaluates the design to balance quality and cost. They review aspects such as function, appearance, materials, assembly, repair, and training requirements. The goal is to ensure the design meets all organisational and customer needs. Example: Reviewing a laptop design to ensure it is lightweight, affordable, and easy to repair.

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5. Translation

Detailed engineering drawings, parts lists, and cost estimates are prepared. These provisional design documents consider manufacturability and ensure the product can be produced economically. Example: Preparing detailed blueprints and cost breakdowns for a new automobile engine.

6. Pre-Production

A pilot production run is carried out to test the provisional design in real manufacturing conditions. Based on this experience, the design is refined and finalised for bulk production. Example: Conducting a small-scale production of a new soft drink bottle design to test packaging efficiency before mass launch.

1.2.3 Process

A process is a series of activities or steps carried out to achieve a specific result, usually to create value for customers. It transforms inputs such as materials, labour, and technology into outputs like finished goods or services. Every organisation relies on processes to perform its work efficiently; no product or service can exist without a process, and no process can exist without a product or service.

Processes are present in all departments and functions of an organisation, from manufacturing and marketing to finance and customer service. Choosing the right process is a key part of designing a production system. These decisions involve selecting suitable human resources, machinery, materials, and methods. Since process choices affect cost, quality, and flexibility, they are strategic and influence an organisation's long-term competitiveness.

1.2.3.1 Types of Processes

1. **Conversion Processes:** These involve transforming raw materials into finished products. They may include metallurgical, chemical, manufacturing, or construction processes. Example: Converting iron ore into steel through smelting and refining operations.
2. **Manufacturing Processes:** These are divided into three main types:
   - ◊ **Forming Processes**: Change the shape of materials without adding or removing any substance. Examples include forging, stamping, casting, and spinning.
   - ◊ **Machining Processes**: Involve removing material to achieve the desired shape or finish. Common operations include turning, milling, drilling, grinding, and shaping.
   - ◊ **Assembly Processes**: Join parts or components to create a complete product. Examples include welding, riveting, soldering, and fastening with bolts or adhesives.

Testing Processes: These involve inspecting and testing products to ensure

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they meet quality standards. Testing may be considered part of manufacturing and helps verify reliability and performance. Example: Checking the strength of a bridge component or testing the functionality of an electronic device before delivery.

1.2.4 Process Planning

Process planning is about deciding how raw materials will be transformed into finished products. It ensures that the right sequence of operations, machines, and resources are chosen to meet product specifications. It has two key components: process design and operations design.

1. Process Design

Process design deals with the overall sequence of operations required to produce a product. It specifies the type of workstations, machines, and equipment needed, and the order in which tasks should be performed. The sequence depends on factors such as the nature of the product, the materials used, the production volume, and the layout of the plant. Example: In automobile manufacturing, process design decides the order of stamping car body panels, welding them together, painting, and final assembly.

2. Operations Design

Operations design focuses on the details of each individual manufacturing operation. It examines how workers and machines interact in the production process and specifies the amount of labour and machine time required to produce each unit. This ensures efficiency and accuracy in production. Example: In a textile factory, operations design determines how long a worker and a loom take to weave one metre of fabric, ensuring productivity targets are met.

1.2.5 Process Selection

Process selection is about deciding how the production of goods or services will be organised. It forms the basis for important decisions such as capacity planning, plant layout, choice of equipment, and design of work systems. Firms must carefully select processes whenever they introduce new products or services to ensure efficiency and competitiveness.

Key Questions in Process Selection

1. **Variety of Products or Services:** The first question is how many different types of products or services the system must handle. A high variety requires flexible processes, while low variety allows for standardised, repetitive methods. Example: A bakery producing customised cakes needs flexible processes, whereas a factory making identical bottled water uses standardised processes.

2. **Degree of Equipment Flexibility:** The second question is how adaptable the equipment must be. Flexible equipment can handle different tasks and product variations, while specialised equipment is efficient but limited to specific

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functions. Example: A 3D printer offers flexibility to produce various prototypes, while a dedicated injection moulding machine is specialised for mass production of plastic parts.

3. **Expected Volume of Output:** The third question is about the scale of production. High output volumes favour automated, continuous processes, while low volumes may rely on manual or batch processes. Example: An automobile assembly line is designed for high-volume production, whereas a small workshop making handcrafted furniture produces in low volumes.

1.2.6 Process Strategy

A process strategy is an organisation's overall plan for producing goods and delivering services. It reflects how the firm chooses to compete in the market, supports product decisions, and helps achieve corporate goals. A strong process strategy ensures efficiency, quality, and customer satisfaction.

1. Vertical Integration

Vertical integration refers to how much of the production process a company controls, from raw materials to finished goods. A firm may choose to produce its own inputs and manage outputs at each stage, or outsource certain parts. Greater integration often means more control but also higher investment. Example: A car manufacturer that produces its own steel, engines, and assembly parts instead of buying them from suppliers.

2. Capital Intensity

This is the balance between using machines and automation (capital) versus human labour. High capital intensity means heavy reliance on equipment and technology, while low capital intensity depends more on manual work. The choice depends on product type, cost, and efficiency needs. Example: An automated bottling plant uses robotic systems for filling and packaging, while a small bakery relies mainly on skilled bakers.

3. Process Flexibility

Process flexibility is the ability to adjust resources when demand, technology, or product requirements change. Flexible processes allow companies to adapt quickly to market shifts, while rigid processes are efficient but less adaptable. Example: A 3D printing facility can easily switch from producing medical devices to customised consumer products.

4. Customer Involvement

This refers to the role of customers in the production process. In some industries, customers actively participate in design or service delivery, while in others, involvement is minimal. High customer involvement often leads to greater satisfaction but requires more adaptability. Example: In customised furniture design, customers choose materials, colours, and layouts, directly influencing the production process.

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1.2.7 Process Management

Process management ensures that a product can be manufactured efficiently using the available technology, equipment, and resources. During product design and development, designers must consider whether the firm has the capability to produce the product with its existing facilities. If the required technology and capacity are available or can be acquired easily, the company proceeds with the design; otherwise, the project may be discontinued to avoid unnecessary costs.

Once the final product design is approved, the Production Planning and Control (PPC) department takes charge of process planning and process design. This involves converting the product design into a practical production plan, selecting suitable machines, tools, and methods, and estimating the time required for each operation. The estimated processing times are then compared with available machine and labour capacities to ensure feasibility.

If the firm lacks certain facilities or if outsourcing proves more economical, parts or subassemblies may be produced externally. This decision balances cost, quality, and production efficiency. Effective process management ensures smooth coordination between design and manufacturing, leading to timely production and reduced waste.

Process management is about deciding how inputs, operations, workflows, and methods are organised to transform raw materials into finished goods or services. It begins with the make-or-buy decision, where managers decide which parts should be produced in-house and which should be purchased from suppliers. It also involves choosing the right mix of human skills and equipment, and assigning tasks to workers and machines effectively.

Process decisions are required whenever a new or modified product is introduced, when quality needs improvement, when competitive priorities change, when demand fluctuates, when material costs or availability shift, or when competitors adopt new technologies. These decisions ensure that production remains efficient, cost-effective, and competitive.

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Major Process Decisions

1. Process Choice

Managers must select the right type of process depending on product volume and variety.

- ◊ **Job Shop**: Low volume, high variety, customised products. Flexible equipment and skilled labour are used. *Example*: A tool and die shop producing one-of-a-kind tools.
- ◊ **Batch Process**: Moderate volume and variety, producing goods in batches. *Example*: Ice cream, paint, or books produced in batches.
- ◊ **Repetitive/Assembly Line**: High volume, standardised products with limited flexibility. *Example*: Automobiles or home appliances produced on assembly lines.

◊ **Continuous Process**: Very high volume, highly standardised products, capital intensive. *Example*: Petroleum, steel, cement, or paper production.

◊ **Project Process**: Large, customised, complex undertakings requiring significant resources. *Example*: Building a dam, hospital, or developing a new product.

2. Vertical Integration

Vertical integration refers to the extent to which a firm controls its supply chain, from raw materials to distribution.

◊ **Backward Integration**: Moving upstream to control raw materials. *Example*: A steel plant owning iron ore mines.

◊ **Forward Integration**: Moving downstream to control distribution. *Example*: A manufacturer owning retail outlets.

Advantages:

- Better quality
- Cost savings
- Timely delivery
- Resource utilisation

Disadvantages:

- High investment
- Less flexibility
- Slower response to market changes

3. Resource Flexibility

This is the ability of workers and equipment to handle different products, tasks, and volumes. Flexible resources help avoid bottlenecks and adapt to fluctuating workloads. *Example*: A workforce trained in multiple skills can be shifted between departments depending on demand.

4. Customer Involvement

Customer involvement refers to how much customers participate in the production process. High involvement is common in customised products, where customers influence design and specifications. *Example*: In customised furniture design, customers choose materials, colours, and layouts.

5. Capital Intensity

Capital intensity is the balance between using machines/automation and human labour. High capital intensity means heavy reliance on equipment, while low intensity depends more on manual skills. *Example*: An automated bottling plant is capital

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intensive, whereas a small bakery relies more on skilled bakers.

1.2.8 Make-or-Buy Decisions

The make-or-buy decision is regarded as the initial stage in process planning. It involves determining whether a firm should manufacture or purchase certain parts, components, or services. A manufacturing organisation may choose to procure specific items externally rather than produce them in-house. In some cases, the firm may outsource all parts and limit its role to assembly operations for the final product. Opting for the 'buy' alternative reduces or even eliminates the necessity of process selection.

Traditionally, many large organisations favoured the 'make' option, which often led to backward integration, primarily restricted to raw materials and basic components that were subsequently processed internally. Over time, however, firms expanded their ownership and integration across a wide range of manufacturing and assembly facilities. With the advent of global competition, pressures to cut costs, streamline operations, reduce workforce size, and concentrate on core competencies became more pronounced. Consequently, the modern trend has shifted towards outsourcing goods and services that were once produced internally. Thus, make-or-buy decisions are closely linked to fundamental issues of specialisation and vertical integration.

Once product design is completed, the design department prepares detailed documentation, including product structure trees, part lists, drawings of components, subassemblies, and the final assembly. At this stage, process planning engineers must take the crucial decision of whether to make or buy, after carefully evaluating several factors. The firm's production capacity to deliver the finished product is directly influenced by the choice to 'make', making this decision central to the overall planning process.

Example: Automobile Manufacturing

In the automobile industry, companies such as Toyota or Ford frequently encounter make-or-buy decisions, where they may choose to manufacture critical components like engines and transmissions internally to maintain quality control, safeguard proprietary technology, and strengthen their brand identity, while simultaneously outsourcing standardised parts such as tyres, batteries, or infotainment systems to specialised suppliers who can provide them at competitive prices; this approach allows automakers to reduce costs, avoid unnecessary investment in diverse facilities, and concentrate on their core competencies of vehicle design, assembly, and marketing, thereby striking a balance between vertical integration and specialisation that directly influences efficiency, product quality, and competitiveness in the global market.

1.2.8.1 Factors in Make-or-Buy Decisions

1. **Available Capacity:** If a firm has spare equipment, skilled labour, and time, it is sensible to produce items internally. This ensures better utilisation of resources. Example: A printing press with unused machines may decide to produce its own packaging materials instead of buying them.

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2. **Expertise:** When a company lacks technical know-how, outsourcing is often the better option. Specialised suppliers can deliver higher-quality results. Example: A shoe brand may outsource leather tanning to expert suppliers.

3. **Quality Considerations:** Suppliers often provide superior quality due to specialisation, but firms may prefer in-house production if they want strict control. Example: A medical equipment company may produce critical surgical instruments internally to maintain precision standards.

4. **Nature of Demand:** Stable, high demand favours making, while fluctuating or small orders are better outsourced. Example: A bakery may outsource seasonal cake decorations when demand spikes only during festivals.

5. **Cost:** Economic analysis compares the cost of making versus buying. Tools like break-even analysis help managers decide. Example: A furniture company may buy screws if purchasing is cheaper than producing them.

Other Non-Economic Considerations

- ◊ Availability and reliability of suppliers.
- ◊ Protecting trade secrets and design confidentiality.
- ◊ In-house research and development facilities.
- ◊ Lead times and delivery schedules.
- ◊ Employee preferences and skill utilisation.

When to Make?

Managers may decide to make items when:

- ◊ In-house production is cheaper.
- ◊ Timely availability is critical.
- ◊ Facilities and skills are already available.
- ◊ Quality control and trade secrets must be preserved.
- ◊ Transportation costs from suppliers are high. Example: A watch manufacturer makes its own precision gears to ensure accuracy and protect design secrets.

When to Buy?

Managers may decide to buy items when:

- ◊ Purchase cost is lower.
- ◊ Demand is too low to justify investment.
- ◊ Suppliers can deliver faster and with better quality.

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- ◊ Suppliers hold patents or specialised expertise.
- ◊ In-house capacity is insufficient. Example: A laptop company buys microchips from specialised semiconductor firms instead of producing them.

1.2.8.2 Make-or-Buy Analysis

Make-or-buy analysis is based on the idea that no organisation can excel in every aspect of manufacturing or service delivery, so purchasing externally allows management to focus more effectively on its core mission and competencies, often resulting in downsizing and giving the purchasing function a wider role in sourcing world-class suppliers to meet strategic needs; however, not all materials and components must be bought, since production departments can sometimes manufacture items internally at lower cost, with better quality, and faster delivery, while in other cases specialised suppliers can provide parts more economically and efficiently, which is why production and purchasing departments jointly evaluate whether to make or buy, with the process sometimes relying purely on economic considerations such as comparing in-house production costs with external purchase costs to arrive at the most viable decision.

Economic Evaluation (Break-Even Analysis) for Make-or-Buy Decision

Economic evaluation, often referred to as break-even analysis, is a method used to decide whether to manufacture internally or procure externally based solely on financial grounds, where the manager compares the purchase cost with the in-house production cost without considering other aspects such as quality, capacity, or delivery reliability; in this approach, the analyst identifies the quantity at which the total cost of buying equals the total cost of making.

Total Cost to Buy $= F_b + v_b Q$

Total Cost to Make $= F_m + v_m Q$

Where:

- ◊ F_b= Fixed cost per year of the buy option
- ◊ F_m= Fixed cost per year of the make option
- ◊ v_b= Variable cost per unit of the buy option
- ◊ v_m= Variable cost per unit of the make option
- ◊ Q= Quantity produced

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The break-even point is the quantity $Q$where both costs are equal.

Graphical Representation

Imagine a graph with Quantity (Q) on the horizontal axis and Total Cost on the vertical axis:

- ◊ The buy option line starts higher (due to fixed costs of purchasing) but rises slowly with quantity.
- ◊ The make option line starts lower (if fixed costs are smaller) but rises faster with quantity due to higher variable costs.
- ◊ The point where the two lines intersect is the break-even point.

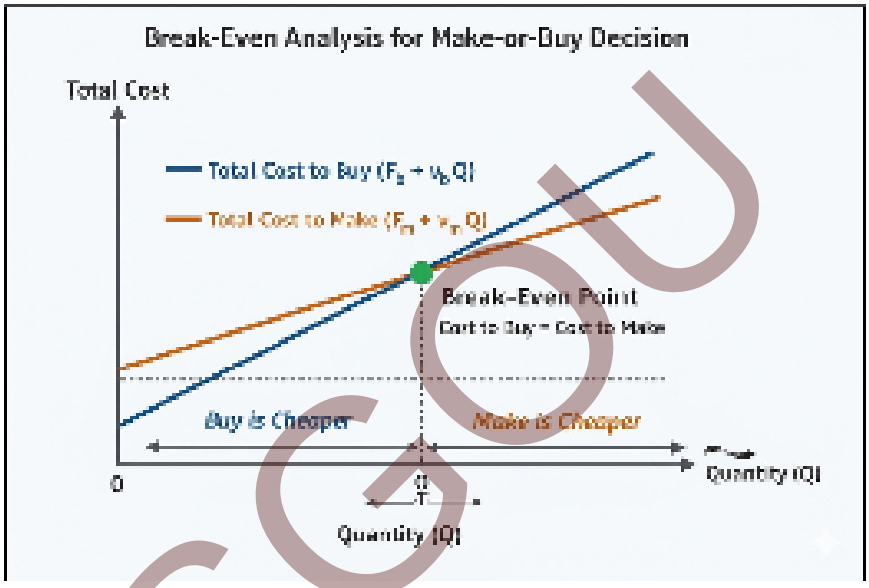


Fig 1.2.3 Break-Even Analysis for Make-or-Buy Decision

At this quantity, the total cost of making equals the total cost of buying. Mathematically, it is found by equating the two cost equations:

$$F_b + v_b Q = F_m + v_m Q$$

Solving for Qgives the break-even quantity - the point where both options cost the same.

Left of the Break-Even Point: The blue line (buy option) lies below the orange line. This means buying is cheaper for low production volumes.

Right of the Break-Even Point: The orange line (make option) lies below the blue line. This means making is cheaper for high production volumes.

Managers use this graph to decide whether to invest in production facilities or rely

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on suppliers.

- If expected demand is below the break-even quantity → Buy.
- If expected demand is above the break-even quantity → Make.

This analysis helps firms avoid unnecessary investment and ensures cost efficiency.

Problem

A company manufactures electric fans. It is considering whether to make the fan blades in-house or buy them from an outside supplier.

The following data are available:

- Fixed cost to make (F_m) = ₹60,000 per year
- Variable cost to make (v_m) = ₹150 per blade
- Fixed cost to buy (F_b) = ₹0
- Variable cost to buy (v_b) = ₹250 per blade

Find the break-even quantity and decide whether the company should make or buy the blades if the annual demand is 800 units.

Solution

Step 1: Write the cost equations

$$\text{Total Cost to Make} = F_m + v_m Q$$

$$\text{Total Cost to Buy} = F_b + v_b Q$$

Substitute the given values:

$$\text{Total Cost to Make} = 60{,}000 + 150Q$$

$$\text{Total Cost to Buy} = 0 + 250Q$$

Step 2: Find the Break-Even Point

At break-even, both costs are equal:

$$60{,}000 + 150Q = 250Q$$

$$60{,}000 = 100Q$$

$$Q = 600 \text{ units}$$

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Step 3: Interpret the Result

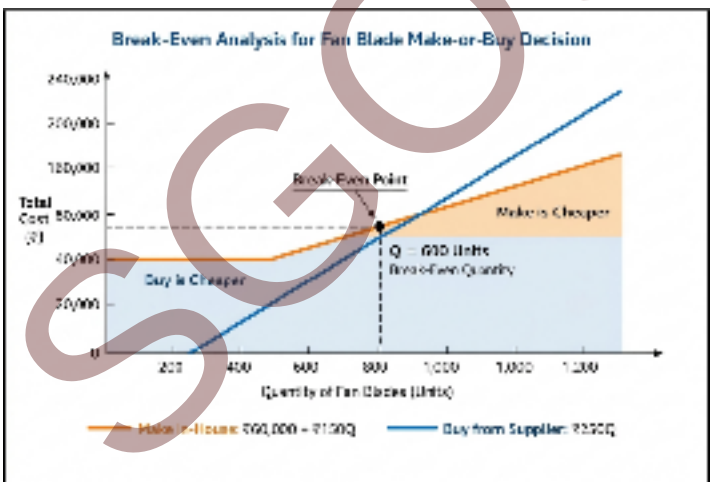
- ◊ Break-even quantity = 600 units
- ◊ If demand is less than 600 units, buying is cheaper.
- ◊ If demand is more than 600 units, making is cheaper.

Since the annual demand is 800 units, which is greater than 600, the company should make the blades in-house.

Step 4: Graphical Explanation

On the break-even graph:

- ◊ The blue line (buy option) starts at zero and rises steeply because of the higher variable cost (₹250 per unit).
- ◊ The orange line (make option) starts at ₹60,000 due to fixed cost but rises slowly (₹150 per unit).
- ◊ The two lines intersect at Q = 600 units, the break-even point.
- ◊ To the left of this point, buying is cheaper; to the right, making is cheaper.



Step 5: Managerial Decision

By producing in-house, the company saves money beyond the break-even quantity and gains better control over quality and delivery schedules. However, if demand drops below 600 units, outsourcing would be more economical.

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Summarised Overview

Product and process design constitute vital elements of operations management because they define what an organisation produces, the manner in which it is produced, and the efficiency with which resources are deployed. Product design entails the planning and development of a product that fulfils customer requirements, quality standards, functional specifications, and cost objectives, whereas process design concentrates on identifying the methods, technologies, equipment, and sequence of operations necessary to manufacture the product or deliver the service. Production design harmonises product and process requirements with production capabilities to guarantee effective manufacturing. Product design is shaped by factors such as customer expectations, product quality, cost, materials, technology, safety, environmental concerns, production capacity, and market competition. A sound product design is distinguished by attributes such as functionality, reliability, simplicity, standardisation, flexibility, maintainability, cost efficiency, and customer orientation. Organisations may employ diverse approaches to product design, including design for manufacture and assembly (DFMA), modular design, standardisation, mass customisation, value engineering, and concurrent engineering.

Process planning involves determining the sequence of operations, machinery, materials, labour, and methods required to transform inputs into finished goods. Process selection refers to choosing the most suitable production process based on considerations such as product volume, variety, technology, cost, and flexibility. Process strategies may encompass project-based production, job production, batch production, repetitive production, and continuous production, depending on the scale and nature of operations. Process management covers the planning, controlling, monitoring, and continuous improvement of production processes to secure efficiency, quality, productivity, and timely delivery. Finally, make-or-buy decisions concern evaluating whether a component, material, or service should be produced internally or procured externally by weighing factors such as cost, quality, capacity, expertise, reliability, delivery schedules, and strategic relevance. Consequently, product design, process planning, process selection, process strategy, process management, and make-or-buy decisions are interdependent and collectively enable organisations to achieve cost efficiency, superior quality, operational flexibility, customer satisfaction, and competitive advantage.

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Self-Assessment Question

1. Explain the concept of product design, process design and production design, and discuss their importance in operations management.
2. Describe the major factors that influence product design and explain how each factor affects the final product.
3. Explain the characteristics of an effective product design with suitable examples.
4. Discuss the major approaches to product design, such as standardisation, modular design, value engineering and design for manufacture and assembly.
5. Illustrate how an organisation can use product design principles to develop a new product that satisfies customer requirements while controlling costs.
6. Explain how process planning can be applied to determine the sequence of operations, resources, equipment and methods required for manufacturing a product.
7. Using suitable examples, explain how an organisation can select an appropriate production process based on product volume, variety, cost and flexibility.
8. Analyse the relationship between product design and process design and explain how changes in product design can influence production efficiency and cost.
9. Analyse the different process selection alternatives and explain their suitability for project, job, batch, repetitive and continuous production.
10. Analyse the major elements of a process strategy and explain how they contribute to achieving organisational objectives.
11. Examine the role of process management in improving productivity, quality, cost efficiency and customer satisfaction.
12. Evaluate the importance of different product design approaches in achieving quality, flexibility, innovation and competitive advantage in a modern business environment.
13. Evaluate the factors that an organisation should consider when making a Make-or-Buy Decision, with suitable examples.
14. A manufacturing company is facing rising production costs and limited production capacity. Evaluate whether it should make a component internally or purchase it from an external supplier, considering cost,

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quality, capacity, technology and strategic factors.

15. Develop a suitable product and process design strategy for a new product, explaining the product design, process planning, process selection, process strategy, process management and make-or-buy decisions involved.

16. An automobile company needs 1,200 alloy wheels per year. The fixed cost to make them in-house is ₹90,000, and the variable cost per wheel is ₹800. The supplier offers to sell them at ₹950 per wheel with no fixed cost. Should the company make or buy the wheels? Answer: Break-even quantity = 600 wheels. Since annual demand (1,200 units) > 600, the company should make the wheels in-house. (Answer: Make)

17. A bakery requires 400 customised cake boxes monthly. The fixed cost to make boxes in-house is ₹20,000, and the variable cost per box is ₹30. Buying from a supplier costs ₹50 per box with no fixed cost. Should the bakery make or buy the boxes? Answer: Break-even quantity = 1,000 boxes. Since monthly demand (400 units) < 1,000, the bakery should buy the boxes from the supplier. (Answer: Buy)

Assignments

1. A company has developed a product that receives positive customer feedback, but its production cost is very high. Analyse the product design and process design factors that may be responsible for the high cost and suggest suitable improvements.

2. A furniture manufacturer offers hundreds of product variations, resulting in high inventory and production costs. Analyse how standardisation and modular product design could improve its operational efficiency.

3. A bakery is planning to introduce a new range of packaged food products. Analyse the major product design factors, characteristics and design approaches that the company should consider before launching the products.

4. A garment manufacturer produces customised clothing in small quantities as well as standard garments in large quantities. Analyse the situation and recommend suitable process planning and process selection approaches for the two types of production.

5. A company is experiencing frequent delays because its production process contains unnecessary activities and repeated inspections. Analyse the existing process management system and suggest measures to improve process efficiency and productivity.

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6. A manufacturer can either produce a component internally at ₹120 per unit or purchase it from a reliable supplier at ₹105 per unit. However, purchasing may create dependency on the supplier. Evaluate the Make-or-Buy Decision by considering cost, quality, capacity, reliability, technology and strategic factors.

7. A small electronics company is planning to increase production to meet growing demand. Evaluate the most appropriate process strategy by considering production volume, product variety, flexibility, technology, investment and future demand.

8. A company frequently modifies its product specifications after production has already started, resulting in wastage and delays. Analyse the relationship between product design, process planning and production design, and suggest measures to coordinate these activities effectively.

9. A food-processing company is deciding whether to invest in an automated continuous production system or continue with its existing batch production system. Evaluate both alternatives based on volume, variety, cost, flexibility, quality, technology and capacity utilisation, and recommend the better option.

10. A start-up plans to introduce an environmentally friendly household product. Develop a suitable product and process design strategy covering product design factors, design characteristics, process planning, process selection, process strategy, process management and Make-or-Buy Decisions.

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PRACTICAL ACTIVITY

Select a simple product (e.g., a pen, chair, or packaged food item), describe its product design features, identify possible process design and process selection methods, make a basic Make-or-Buy decision for one of its components, and explain how the 5 Ps of Operations apply to its production

Solution:

Selected Product: Ballpoint Pen

1. Introduction

A ballpoint pen is a simple but widely used consumer product that involves several stages of product design, process design, process selection and operations management. Although the pen is a low-cost product, its successful production requires careful decisions regarding materials, component design, manufacturing methods, quality, cost and supply. This activity analyses a ballpoint pen from an operations management perspective and demonstrates how the -5 Ps of Operations Management- People, Plant, Parts, Processes and Planning and Control Systems, are applied to its production.

2. Product Design Features

The product selected is a retractable ballpoint pen designed for everyday writing. Its main components include the outer barrel, refill, ink reservoir, writing tip, ball, spring, clip and push-button mechanism.

The barrel is designed to provide a comfortable grip and protect the internal components. It may be manufactured from plastic to keep the pen lightweight and inexpensive. The refill contains the ink and is designed to provide a continuous and controlled flow of ink. The writing tip holds a small metal ball that transfers ink smoothly onto paper. The spring and push-button mechanism allow the user to extend and retract the writing tip. The clip enables the pen to be attached to a pocket, notebook or folder.

From a product-design perspective, the major considerations are functionality, ergonomics, durability, appearance, manufacturability, safety and cost. For example, the barrel should be comfortable to hold, the ink should flow consistently, and the pen should not leak during normal use. The design should also minimise the number of components and facilitate easy assembly.

3. Possible Process Design

The process design determines how the designed pen will be manufactured and assembled. A possible process flow is:

Raw materials → Plastic moulding → Component production → Refill preparation → Tip assembly → Component inspection → Final assembly → Quality testing → Packaging → Distribution

The plastic barrel and other plastic components can be manufactured through injection moulding. The metal tip can be produced through precision metal-forming or

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machining processes. The ink refill can be filled using an automated or semi-automated filling process. The individual components are then assembled, followed by testing for ink flow, writing performance, mechanism operation and leakage.

Process design should focus on reducing unnecessary movement, minimising material wastage, maintaining consistent quality and achieving efficient production flow.

4. Process Selection

Since ballpoint pens are produced in large volumes with relatively standardised designs, a repetitive or mass-production process is appropriate. Automated and semi-automated assembly lines can be used because the product has a high production volume and relatively low product variety.

The process selection may include:

- ◊ Injection moulding for plastic components.
- ◊ Metal forming or precision machining for the writing tip.
- ◊ Automated ink filling for refills.
- ◊ Assembly-line production for putting components together.
- ◊ Automated or semi-automated inspection for quality control.
- ◊ Packaging-line operations for final packing.

A mass-production approach provides economies of scale, consistent quality and lower unit costs. However, it requires relatively high initial investment in machinery, moulds and production equipment.

5. Make-or-Buy Decision

For this analysis, consider the metal writing tip as the component under consideration.

The manufacturer has two alternatives:

Make: Produce the metal writing tip internally by purchasing specialised machinery and employing skilled operators.

Buy: Purchase the writing tips from an established supplier that specialises in precision pen components.

For a medium-sized pen manufacturer, buying the writing tip may be preferable if the supplier can provide the required quality at a competitive price. Producing the tip internally may require significant investment in specialised equipment, quality-control systems and technical expertise.

The decision should not be based only on purchase price. Management should consider:

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- ◊ Direct manufacturing cost
- ◊ Supplier price
- ◊ Quality requirements
- ◊ Production capacity
- ◊ Investment in machinery
- ◊ Availability of technical expertise
- ◊ Supplier reliability
- ◊ Delivery time
- ◊ Intellectual property and technology
- ◊ Strategic importance of the component
- ◊ Long-term supply risk

Decision: In this case, the Buy option is recommended, provided that the supplier consistently meets quality, cost and delivery requirements. The company can concentrate its internal resources on core activities such as product design, assembly, quality management and branding.

6. Application of the 5 Ps of Operations

The 5 Ps of Operations Management can be applied to the production of the ballpoint pen as follows:

1. People:

People include product designers, production engineers, machine operators, quality inspectors, maintenance staff, supervisors, warehouse personnel and managers. Their skills and coordination are essential for maintaining productivity and quality.

2. Plant:

Plant refers to the physical facilities and equipment used for production. For a ballpoint pen, the plant may include injection-moulding machines, metal-processing equipment, assembly lines, ink-filling machines, testing equipment, packaging facilities and storage areas.

3. Parts:

Parts are the materials and components required to manufacture the product. In this case, they include plastic, metal, ink, springs, refill tubes, writing tips, clips and packaging materials. Proper supplier management and inventory control are necessary to ensure uninterrupted production.

4. Processes:

Processes describe the sequence of activities through which raw materials are

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transformed into the finished pen. These include moulding, machining, ink filling, component assembly, inspection, testing and packaging. Efficient process design helps reduce waste, production time and defects.

5. Planning and Control Systems:

Planning and control systems determine what to produce, how much to produce, when to produce it and how resources should be allocated. For example, demand forecasts can be used to determine production quantities, while inventory-control systems can ensure adequate availability of plastic, ink and other components. Quality-control procedures monitor production performance and identify defects.

7. Overall Operations Flow

The operations system for the ballpoint pen can be represented as:

Inputs → Transformation Process → Outputs

Inputs:

Plastic, metal, ink, springs, labour, machinery, technology and information.

Transformation:

Moulding → Component manufacturing → Ink filling → Assembly → Inspection → Testing → Packaging.

Outputs:

Finished ballpoint pens that meet specified requirements of quality, functionality, appearance and cost.

8. Conclusion

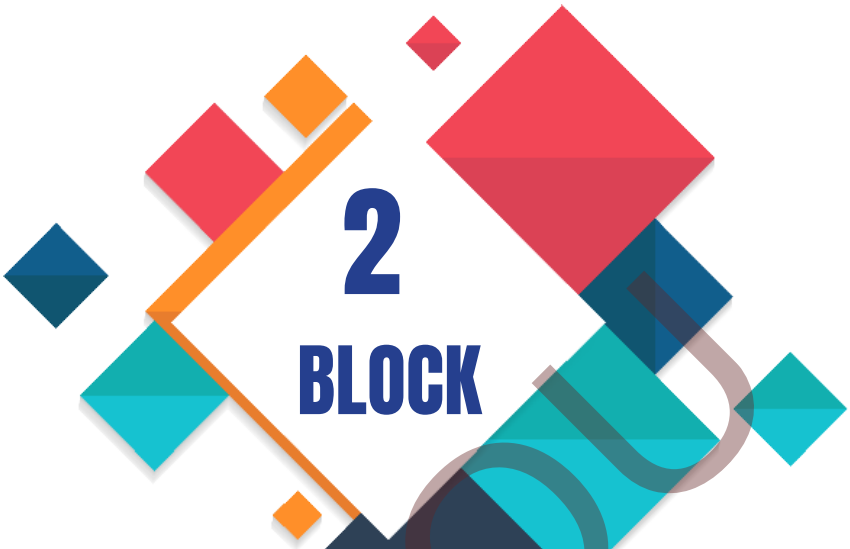
The ballpoint pen demonstrates that even a simple consumer product requires systematic product and process design decisions. Its standardised nature and high production volume make mass or repetitive production appropriate. The Make-or-Buy Decision for the metal writing tip should be based on both quantitative and qualitative factors, with outsourcing being suitable when a specialised supplier can provide reliable quality at a competitive cost. The application of the 5 Ps, People, Plant, Parts, Processes, and Planning and Control Systems, helps integrate resources and activities to achieve efficient production, consistent quality, lower costs and customer satisfaction.

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

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Facilities Planning

Unit 1

Facilities Location

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ Understand the fundamental objectives and factors influencing plant location decisions in industrial and service contexts
- ◊ Explain the sequential steps involved in selecting a suitable plant location and interpret their significance for organisational success
- ◊ Apply location models and analytical tools to evaluate alternative site options for manufacturing or service facilities
- ◊ Analyse the different plant location models, identifying their strengths, limitations, and suitability in varied business scenarios
- ◊ Formulate a comprehensive plant location strategy for a hypothetical organisation, integrating economic, social, and environmental considerations

Background

In the early stages of industrial development, decisions about where to establish production facilities were often guided by proximity to raw materials, water sources, and labour availability. As industries expanded during the late nineteenth and early twentieth centuries, the rise of railways, ports, and road networks began to reshape these choices, making accessibility to markets and distribution channels equally important. Over time, the emphasis shifted from purely resource-based considerations to a more balanced view that included infrastructure, energy supply, and socio-economic conditions. This evolution reflected the growing complexity of industrial operations and the need to integrate efficiency with sustainability in location decisions.

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With the advent of globalisation and technological advancement in the latter half of the twentieth century, facility location decisions became increasingly analytical and model-driven. Quantitative techniques such as factor rating, centre-of-gravity models, and linear programming were introduced to provide structured frameworks for evaluating alternatives. These models allowed organisations to weigh multiple variables, cost, logistics, environmental impact, and community development, before finalising a site. In contemporary practice, digital tools, simulation models, and geographic information systems further enhance decision-making, ensuring that location strategies align with competitive advantage, regulatory compliance, and long-term growth. This unit focuses on the systematic study of plant location steps and models that guide modern industrial and service organisations.



Keywords

Plant Location, Location Models, Qualitative Factor Analysis, Factor Rating, Break–Even Analysis, Point Rating Method



Discussion

Plant Location forms a vital component of operations management, as it deals with the strategic decision of selecting the most suitable geographical area for establishing a facility such as a manufacturing plant, warehouse, office, or service centre. This topic emphasises the importance of location in ensuring operational efficiency, cost reduction, and long-term competitiveness. It explores the systematic steps involved in the selection process, beginning with identifying the requirements of the facility, determining the critical factors that influence location decisions, generating alternative sites, evaluating these alternatives, and applying suitable analytical models to arrive at the most effective choice. The syllabus also introduces various location models such as the factor-rating method, locational break-even analysis, centre-of-gravity method, and transportation model, which provide structured and quantitative approaches to decision-making. By understanding these concepts, learners gain insights into how a well-planned location decision can optimise resource utilisation, improve customer service, minimise distribution costs, and contribute significantly to the profitability and sustainability of an organisation.

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2.1.1 Plant Location

Plant location refers to the process of selecting the most appropriate site for establishing a production facility. The decision is guided by the aim of achieving maximum efficiency and economy in operations. It requires careful consideration of factors such as access to raw materials, labour, transportation, markets, infrastructure, utilities, government policies, costs, and environmental conditions. A well-chosen location ensures smooth functioning of the plant, reduces expenses, and supports long-term organisational growth.

The need for selecting a location arises under specific circumstances. It becomes essential when a new business is being set up, when an existing unit has outgrown its current facilities and cannot expand further, or when new branches are planned to serve different markets. Relocation may also be required if a lease expires and the landlord refuses renewal, or due to social and economic reasons such as shortage of labour, shifting of markets, or changes in community development. In all these cases, identifying a suitable location is critical to maintaining efficiency and competitiveness.

For example, a textile manufacturer may decide to set up its plant near cotton-producing regions to ensure a steady supply of raw materials and lower transportation expenses, thereby achieving better operational efficiency and competitiveness.

2.1.2 Steps In Location Selection

2.1.2.1 Selection Within the Country or Outside

A business must decide whether to establish its plant domestically or internationally. This choice is influenced by factors such as political stability, trade regulations, currency exchange rates, and cultural or economic conditions.

- ◊ **Deciding on Domestic or International Location:** Deciding whether the plant should be established within the home country or abroad. This decision depends on factors such as political stability, trade regulations, currency exchange rates, cultural practices, and natural conditions. For instance, a company producing electronic goods may choose to set up in countries like Vietnam or China due to favourable labour costs and established supply chains, while firms focusing on pharmaceuticals may prefer countries with strong regulatory frameworks and access to global markets.

2.1.2.2 Selection of the Region

After deciding the country, the next step is to identify the most suitable region. Considerations include raw material availability, proximity to markets, transport facilities, power supply, and climate.

- ◊ **Availability of Raw Materials:** Industries that rely heavily on raw materials often locate their plants close to the source of supply. This reduces transportation costs, ensures a steady flow of inputs, and saves on storage expenses. For example, steel plants are usually located near iron ore mines, while sugar mills

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are often established in regions where sugarcane is abundantly available. Such proximity guarantees efficiency and cost savings in production.

- ◊ **Nearness to the Market:** Being close to the market provides several advantages, including reduced transportation costs for finished goods, quicker response to consumer preferences, and the ability to offer after-sales services effectively. For instance, food processing units often set up near urban centres to cater to large populations and deliver fresh products promptly. Similarly, automobile assembly plants are frequently located near major cities to ensure easy distribution and service support.

- ◊ **Availability of Power:** Power is essential for running industrial operations, and industries must ensure reliable access to energy sources such as coal, electricity, oil, or natural gas. For example, aluminium smelting plants are located in regions with abundant electricity supply, as the process is highly energy-intensive. Without consistent power, production efficiency and profitability can be severely affected.

- ◊ **Transport Facilities:** Efficient transport systems are vital for moving raw materials to the factory and distributing finished goods to markets. Industries often prefer locations with access to railways, highways, ports, or airports. For instance, automobile plants in India are commonly located near major highways and ports, such as Chennai, to facilitate both domestic distribution and export. Good transport connectivity ensures smooth operations and reduces logistical costs.

- ◊ **Suitability of Climate:** Certain industries require specific climatic conditions to function effectively. For example, cotton textile mills and jute industries thrive in humid climates, as moisture prevents fibres from breaking during processing. Similarly, industries dealing with perishable goods may prefer cooler climates to reduce spoilage. Climate suitability directly influences the quality and efficiency of production.

- ◊ **Government Policy:** Government incentives and policies play a significant role in location decisions. To promote balanced regional development, governments often encourage industries to set up in backward or underdeveloped areas by offering subsidies, tax benefits, or infrastructure support. For example, many industrial estates in India have been developed in less industrialised regions to boost employment and strengthen the local economy. Such policies can make certain regions more attractive for investment despite logistical challenges.

2.1.2.3 Selection of the Locality or Community

The selection of a suitable locality is an important stage in plant location because even after choosing a particular region, the organisation must identify the most appropriate town, industrial area, or specific locality within that region. A good locality should support smooth production, provide access to resources, minimise operating costs, and offer favourable conditions for employees and the surrounding community. The decision should consider both present requirements and the future expansion plans of

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the organisation. The following factors are important in selecting a locality.

i. Availability of Labour

The availability of an adequate and suitable workforce is one of the most important considerations in selecting a locality. An organisation should be able to obtain the required number of workers with appropriate skills, qualifications, and experience at reasonable wage rates. The availability of skilled, semi-skilled, and unskilled labour helps an organisation maintain continuous production and reduces recruitment and training costs. The locality should also have a stable labour market with relatively low employee turnover and good industrial relations. For example, automobile and engineering industries generally prefer locations where technically skilled workers are readily available.

ii. Civic Amenities for Workers

The quality of civic amenities available to employees can significantly influence the choice of locality. Workers need access to housing, schools, hospitals, transport, markets, banking facilities, recreation, and other essential services in addition to a safe and comfortable workplace. Facilities such as parks, sports centres, libraries, community centres, and entertainment facilities can improve employee satisfaction and quality of life. Good civic amenities also help organisations attract and retain skilled employees, particularly when workers are required to relocate. Therefore, a locality with adequate social infrastructure is generally more attractive for establishing a large industrial unit.

iii. Existence of Complementary and Competing Industries

The presence of complementary industries can make a locality attractive because organisations can benefit from shared suppliers, specialised labour, repair and maintenance services, transport facilities, and other supporting services. Industrial clusters can encourage cooperation, knowledge sharing, innovation, and the development of specialised business services. However, excessive concentration of competing industries may create challenges such as higher wages, competition for skilled labour, increased demand for raw materials, and pressure on infrastructure. At the same time, the presence of competitors can encourage firms to improve product quality, technology, and customer service. Therefore, an organisation should carefully evaluate both the advantages and disadvantages of industrial clustering before selecting a locality.

iv. Finance and Research Facilities

Easy access to financial institutions is an important consideration when selecting a locality for a new industrial establishment. The presence of commercial banks, financial institutions, venture capital providers, cooperative banks, and other sources of finance can make it easier for businesses to obtain working capital and long-term investment. Research and development facilities are also important, particularly for technology-intensive industries that require continuous innovation and product improvement. Proximity to universities, research institutions, testing laboratories, incubation centres, and technical institutions can provide access to knowledge and specialised expertise.

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For example, technology-based businesses often prefer locations close to universities and research parks because these locations facilitate innovation and access to skilled professionals.

v. Availability of Water and Fire-Fighting Facilities

Adequate and reliable water supply is essential for industries that use large quantities of water in production, processing, cleaning, cooling, or other operations. Industries such as textiles, paper, chemicals, food processing, leather, pharmaceuticals, and beverages may require substantial quantities of water. The organisation must assess not only the quantity of water available but also its quality, reliability, cost, and future availability. Fire-fighting infrastructure is equally important because industrial operations may involve machinery, electrical equipment, chemicals, fuels, and other fire hazards. The availability of fire stations, hydrants, emergency services, water reservoirs, and appropriate safety infrastructure can reduce operational risks and improve industrial safety.

vi. Local Taxes and Government Restrictions

Local taxes, fees, regulations, and government restrictions can significantly affect the cost of operating a facility. An organisation should examine property taxes, local levies, utility charges, licence fees, waste-management charges, and other applicable costs before selecting a locality. Government regulations relating to land use, zoning, pollution control, building permissions, labour welfare, environmental protection, and industrial safety must also be considered. Excessive restrictions or complicated approval procedures may increase the time and cost required to establish a facility. On the other hand, tax concessions, subsidies, infrastructure support, and other incentives offered by governments can make certain localities more attractive to investors.

vii. Momentum of an Early Start

A locality where industries have already been successfully established may have a natural advantage because the necessary industrial ecosystem is likely to be available. Such areas may already have transport networks, electricity supply, banking services, warehouses, suppliers, maintenance facilities, communication systems, and skilled workers. The existence of an established industrial cluster can therefore reduce the time and investment required to start operations. Organisations can also benefit from established supplier networks and business relationships in the area. For example, a new engineering unit may prefer an established industrial estate where machinery suppliers, component manufacturers, logistics providers, and skilled technicians are already available.

viii. Personal Factors

Personal considerations may sometimes influence the location decisions of entrepreneurs, particularly in small and family-owned businesses. An entrepreneur may prefer a locality because it is close to their home, family, community, or existing business interests. Familiarity with the local market, availability of family support, and personal knowledge of local suppliers and customers may also influence the decision.

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However, personal preferences should not completely override important economic and operational factors such as cost, accessibility, labour availability, and market potential. A balanced decision should consider personal convenience along with the long-term interests of the organisation.

ix. Proximity to Market

The distance between the facility and its target market is an important factor in locality selection. Locating close to major customers can reduce transportation costs, delivery time, and inventory requirements. This is particularly important for perishable products, bulky goods, and products requiring frequent or rapid delivery. Proximity to customers can also improve responsiveness and customer service. For example, a food-processing unit may prefer to locate near major consumption centres to ensure faster distribution and maintain product freshness.

x. Transportation and Connectivity

Efficient transportation facilities are essential for the movement of raw materials, employees, finished products, and equipment. A locality with good road, rail, port, and airport connectivity can reduce logistics costs and improve supply-chain efficiency. Organisations should consider both the availability and reliability of transportation infrastructure rather than merely the physical distance to transport facilities. Public transport is also important for employees who travel to and from the workplace. Therefore, localities with well-developed multimodal transport networks are generally more suitable for large-scale industrial and commercial activities.

xi. Availability and Cost of Land

The availability of suitable land is another major consideration in selecting a locality. The organisation should examine the cost, size, shape, ownership, accessibility, and development potential of the land. The land should be suitable for the proposed facility and should provide sufficient space for production, storage, parking, utilities, waste management, and future expansion. Soil conditions, drainage, flood risk, and environmental characteristics should also be examined before purchasing or leasing land. A slightly more expensive location may be preferable if it provides better infrastructure and greater opportunities for future expansion.

xii. Power and Energy Availability

Reliable and affordable energy supply is essential for most manufacturing and service operations. Industries should consider the availability, quality, reliability, and cost of electricity and other energy sources in the locality. Frequent power interruptions can cause production delays, equipment damage, wastage, and increased operating costs. Industries with high energy requirements should particularly examine the capacity and reliability of the local power network. The availability of renewable energy sources, such as solar power, can also be an additional advantage for organisations seeking to reduce energy costs and improve environmental sustainability.

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xiii. Environmental and Climatic Conditions

Environmental and climatic conditions can influence both production activities and employee welfare. Factors such as temperature, rainfall, humidity, flooding, water availability, air quality, and the risk of natural disasters should be considered before selecting a locality. Certain industries may be particularly sensitive to climatic conditions and may require specialised infrastructure to maintain stable operating conditions. The organisation should also evaluate environmental regulations and the ecological impact of its operations. A location that supports environmentally responsible operations can reduce regulatory risks and contribute to long-term sustainability.

xiv. Scope for Future Expansion

The selected locality should provide sufficient scope for the organisation to expand its operations in the future. If the business grows, additional space may be required for new production lines, warehouses, offices, parking areas, or employee facilities. A locality with limited land availability may create difficulties and force the organisation to relocate at a later stage. Relocation can involve substantial financial costs and disruption to production. Therefore, the availability of additional land and infrastructure for future expansion should be considered as part of the initial location decision.

xv. Safety, Security and Political Stability

A safe and secure locality is important for protecting employees, assets, equipment, inventory, and business operations. Organisations should consider crime levels, industrial safety conditions, emergency response services, and the general security environment of the area. Political and social stability is also important because prolonged disturbances, strikes, conflicts, or regulatory uncertainty can disrupt operations. A stable locality provides greater confidence for long-term investment. Businesses should therefore assess both physical security and the broader stability of the locality before making a location decision.

xvi. Waste Disposal and Environmental Infrastructure

Industries generate different types of solid, liquid, and hazardous waste, and appropriate disposal facilities are essential for safe and legal operations. A locality should have adequate drainage, sewage treatment, waste collection, recycling facilities, and, where necessary, authorised hazardous-waste management systems. Poor waste-disposal arrangements can lead to pollution, health risks, penalties, and damage to the organisation's reputation. Industries should therefore examine the capacity and reliability of local environmental infrastructure. This factor is particularly important for chemical, pharmaceutical, food-processing, textile, and manufacturing industries.

2.1.2.4 Selection of the Site

After selecting a suitable region and locality, the next step is to identify the exact site on which the plant or facility will be established. Site selection involves evaluating the physical characteristics of the land, availability of infrastructure, environmental conditions, accessibility, safety, and the possibility of future expansion. A carefully

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selected site can reduce construction and operating costs and support efficient production over the long term. The major considerations in the selection of a specific site are as follows.

i. Soil, Size and Topography

The quality and strength of the soil are important because the plant buildings, machinery, storage facilities, and other structures must be safely constructed on the land. Soil conditions should be examined to determine whether the site requires special foundations, soil treatment, or additional construction expenditure. For agro-based industries, the quality and fertility of soil may also be relevant, particularly where agricultural activities are directly connected with production.

The size of the site should be sufficient to accommodate the present requirements of the organisation as well as future expansion. Adequate space should be provided for production buildings, warehouses, offices, parking, utilities, internal roads, waste-treatment facilities, and employee amenities. A site that is too small may create operational difficulties and make future expansion expensive.

The topography or physical shape of the land also influences site selection. Flat or gently sloping land is generally preferred because it requires less expenditure on excavation, levelling, drainage, and construction. Hilly, rocky, marshy, or uneven land may involve higher development costs and construction difficulties. Therefore, the organisation should carefully assess the soil-bearing capacity, slope, drainage, elevation, and general physical condition of the site before making the final decision.

ii. Disposal of Waste

Proper waste disposal facilities are essential for industries that generate solid, liquid, gaseous, or hazardous waste during their operations. Industries such as chemicals, sugar, steel, leather, pharmaceuticals, food processing, paper, and breweries may produce substantial quantities of industrial waste and effluents. The selected site should therefore have adequate arrangements for safe treatment, storage, recycling, and disposal of different forms of waste.

The organisation should ensure that waste-management systems comply with applicable environmental standards and local regulations. Sufficient space may be required for waste-treatment plants, recycling units, storage areas, and authorised disposal facilities. Improper waste disposal can cause environmental pollution, health problems, legal penalties, and opposition from the local community. Hence, waste-management requirements should be evaluated before finalising the site.

iii. Accessibility and Approach Roads

The selected site should have convenient access to public roads and internal transportation networks. Good accessibility allows raw materials to reach the plant and finished products to be transported efficiently to markets, warehouses, ports, railway stations, or distribution centres. The condition, width, carrying capacity, and reliability of approach roads should be considered, especially for industries using heavy vehicles.

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The site should also provide convenient access for employees, suppliers, customers, emergency services, and maintenance personnel. Poor road connectivity can increase transportation costs and cause delays in receiving materials or delivering finished goods. Therefore, a site with good road connectivity and easy access to major transportation routes is generally preferred.

iv. Availability of Utilities

A suitable site should have reliable access to essential utilities such as electricity, water, drainage, telecommunications, and fuel or gas, depending on the nature of the business. The capacity and reliability of these utilities are more important than their mere availability. Frequent interruptions in electricity or water supply can adversely affect production and increase operating costs.

The organisation should also consider the cost of connecting the site to utility networks. If major investments are required to extend electricity lines, water pipelines, or communication networks, the overall cost of the site may become significantly higher. Hence, sites with established and dependable utility infrastructure are generally advantageous.

v. Proximity to Raw Materials and Suppliers

The distance between the plant and its major raw-material sources and suppliers can influence transportation costs and production continuity. Industries that use bulky, heavy, perishable, or difficult-to-transport raw materials may benefit significantly from locating close to suppliers. Shorter distances can reduce freight costs, transit time, material damage, and inventory requirements.

The organisation should also consider the reliability of suppliers and the availability of alternative sources. Excessive dependence on a single supplier or geographical area can create risks during shortages, strikes, natural disasters, or transportation disruptions. Therefore, the selected site should provide convenient access to a reliable and diversified supplier network.

vi. Proximity to Market

The site should be reasonably close to the organisation's target customers and major markets, particularly when transportation costs form a significant part of the total product cost. Proximity to markets can reduce delivery time, distribution expenses, and the need to maintain large inventories at distant locations. It is particularly important for perishable products and products requiring frequent deliveries.

For example, a dairy-processing plant may prefer a site close to its major consumer markets to ensure quick distribution and maintain product quality. Similarly, a distribution centre may be located near major urban markets to support faster order fulfilment. Therefore, market accessibility should be considered along with production-related factors.

vii. Transportation Facilities

The availability of different modes of transportation can strongly influence site

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selection. Depending on the nature of the industry, access to roads, railways, ports, airports, and inland waterways may be important for transporting materials and finished products. Multimodal transportation can provide greater flexibility and may help organisations reduce logistics costs.

The site should also be evaluated in terms of loading and unloading facilities, parking space, traffic conditions, and access for heavy vehicles. A location that appears inexpensive may become costly if transportation infrastructure is inadequate. Therefore, total logistics cost rather than merely the distance to a transport facility should be considered.

viii. Land Cost and Development Cost

The purchase or lease cost of land is a major component of the initial investment in establishing a plant. However, the cheapest site is not necessarily the most economical site because additional expenses may arise from land development, levelling, drainage, road construction, utility connections, and foundation work.

The organisation should calculate the total site development cost before making a decision. A slightly more expensive site may prove more economical if it already has good infrastructure and requires minimal development. Thus, both land price and associated development expenses should be considered.

ix. Drainage and Flood Risk

Adequate natural and artificial drainage is essential to protect the plant from waterlogging and flooding. Sites located in low-lying areas or flood-prone zones may cause disruption to production, damage machinery and inventory, and create safety hazards for employees. The organisation should examine historical flood patterns, rainfall levels, drainage systems, and the elevation of the site.

Good drainage is particularly important for industries that store raw materials or finished products in large quantities. Proper storm-water management can also prevent damage to roads, buildings, and utility systems. Therefore, sites with effective drainage and low flood risk are generally preferable.

x. Environmental and Ecological Conditions

The environmental characteristics of the site should be examined before establishing a plant. Factors such as air quality, water quality, noise levels, ecological sensitivity, nearby residential areas, forests, wetlands, and protected zones may influence the suitability of the site. Certain industrial activities may require specific environmental clearances before construction and operation.

The organisation should also consider the potential environmental impact of its activities on the surrounding community. Selecting an environmentally appropriate site can reduce regulatory problems, community opposition, and future operating risks. It also supports the organisation's commitment to sustainable development.

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xi. Safety and Security

The selected site should provide a safe environment for employees, machinery, materials, and business operations. The organisation should consider risks such as fire, flooding, industrial accidents, theft, natural disasters, and other emergencies. The availability of fire stations, hospitals, police services, and emergency-response facilities can be an important advantage.

The site should also allow sufficient space for emergency exits, fire-fighting systems, assembly points, internal roads, and other safety arrangements. Safety considerations are particularly important for chemical, pharmaceutical, manufacturing, and other high-risk industries. A secure and safe site helps reduce operational disruptions and protect organisational assets.

xii. Scope for Future Expansion

The selected site should provide adequate scope for future expansion because the organisation's production capacity may increase over time. Additional land may be required for new production lines, warehouses, offices, parking facilities, utilities, or research and development activities. If sufficient land is not available nearby, expansion may require relocation to another area.

Relocation can involve considerable financial expenditure and disruption to production. Therefore, management should estimate its long-term space requirements before finalising the site. A site that offers reasonable opportunities for expansion can provide greater flexibility and support long-term business growth.

2.1.3 Location Models

2.1.3.1 Qualitative Factor Analysis

Qualitative Factor Analysis is a technique used to identify and assign importance to the key factors that influence location decisions. In the factor rating system, the relevant factors are first listed and then each factor is given a weight ranging from 0 to 1.00, which reflects its relative importance in the overall decision-making process. After assigning weights, a subjective score, usually between 0 and 100, is given to each factor based on how attractive a particular location is compared to other alternatives. These scores are then multiplied by the respective weights to calculate weighted ratings, and the results are added together to obtain a total score for each location. The final decision is made by selecting the location alternative that achieves the highest total weighted score, as it represents the most favourable option among the choices considered.

Problem

Q) The Dynaco Manufacturing Company is going to build a new plant to manufacture ring bearings (used in automobiles and trucks). The site selection team is evaluating three sites, and they have scored the important factors for each as follows. They want to use these ratings to compare the locations.

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LOCATION FACTOR		SCORES (0 to100)		
	WEIGHT	SITE 1	SITE 2	SITE 3
Labor pool and climate	0.30	80	65	90
Proximity to suppliers	0.20	100	91	75
Wage rates	0.15	60	95	72
Community environment	0.15	75	80	80
Proximity to customers	0.10	65	90	95
Shipping modes	0.05	85	92	65
Air service	0.05	50	65	90

Solution

LOCATION FACTOR	Weighted scores		
	SITE 1	SITE 2	SITE 3
Labor pool and climate	24	19.50	27
Proximity to suppliers	20	18.20	15
Wage rates	9	14.25	10.80
Community environment	11.25	12	12
Proximity to customers	6.50	9	9.50
Shipping modes	4.25	4.60	3.25
Air service	2.50	3.25	4.50
Total score	**77.50**	**80.80**	**82.05**

Hint:- (Weighted scores = 0.3 x80 = 24, 0.2 x100 = 20, 0.15 x60 = 9….)

Note: - Site 3 has the highest factor rating compared with the other locations. Therefore, Site 3 must be selected for plant construction.

2.1.3.2 Break-Even Analysis

Break-Even Analysis is a widely used cost–volume–profit technique that helps managers evaluate plant location alternatives by comparing costs and expected production volumes. In its narrow sense, it identifies the point at which total revenue equals total cost, meaning there is no profit and no loss. In its broader sense, it examines how costs, output levels, and profits interact across different scales of activity.

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When applied to plant location decisions, break-even analysis involves calculating the total cost for each possible site using the formula:

$$\text{Total Cost (TC)} = \text{Fixed Cost} + (\text{Variable Cost} \times \text{Quantity Produced})$$

By plotting these costs against production volume, managers can identify the break-even point for each location. The most suitable site is the one that shows the lowest total annual cost at the expected production level. For example, if Location A has higher fixed costs but lower variable costs compared to Location B, then at higher production volumes Location A may become more economical. Thus, break-even analysis provides a systematic way to select the location that ensures maximum operating efficiency and cost savings.

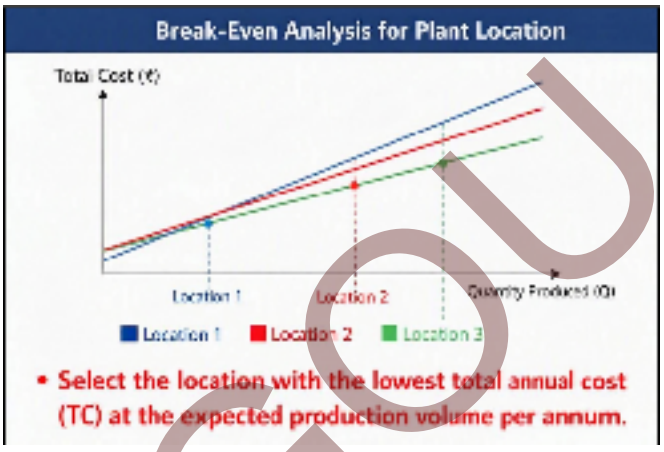


Fig 2.1.1 Break-Even Analysis for Plant location

◊ Each line represents a location's total cost equation

$$TC = \text{Fixed Cost} + (\text{Variable Cost} \times Q)$$

◊ The point where lines intersect the expected production volume (Q) indicates the annual cost for that location.

◊ The most suitable site is the one with the lowest total annual cost at the expected production level.

Problem

Potential locations A, B and C have the cost structures shown for producing a product expected to sell at Rs.100 per unit. Find the most economical location for an expected volume of 2,000 units per year.

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Location	Fixed costs/ year (Rs)	Variable Costs per unit (Rs)
A	25,000	50
B	50,000	25
C	80,000	15

Solution

To determine the most economical location for an expected annual volume of production of 2,000 units, calculate the total cost of production at each of the locations for the annual production volume, Q = 2,000 no.s.

$$TC = FC + (VC \times Q)$$

Total cost at location A, $TC_A = FC_A + (VC_A \times Q)$

$$TC_A = 25,000 + (50 \times 2,000)$$

$$= 25,000 + 1,00,000$$

$$TC_A = \text{Rs. } 1,25,000$$

Total cost at location B, $TC_B = FC_B + (VC_B \times Q)$

$$TC_B = 50,000 + (25 \times 2,000)$$

$$= 50,000 + 50,000$$

$$TC_B = \text{Rs. } 1,00,000$$

Total cost at location C, $TC_C = FC_C + (VC_C \times Q)$

$$TC_C = 80,000 + (15 \times 2,000)$$

$$= 80,000 + 30,000$$

$$TC_C = \text{Rs. } 1,10,000$$

Note: Location B is the most economical location for a volume of production of 2,000 no.s per year.

2.1.3.3 Point Rating Method

In the Point Rating Method, a company assigns relative weights to each objective or location factor by representing them as the number of points that an ideal site would receive in every category. Each potential site is then assessed based on how well it meets these factors, and points are awarded accordingly. The evaluation covers all aspects that the organisation considers important for its operations, such as accessibility, cost, infrastructure, and labour availability. After scoring each site, the total points are calculated to reflect the overall suitability of the location. The site that achieves the

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highest total score is regarded as the most favourable option among all alternatives, indicating its superiority in meeting the company's requirements.

Problem

Q) Evaluate the intangible factors of two potential sites A and B by the point rating method.

Points assigned to alternative locations			
Factors Rated	Maximum possible points	Points assigned to Locations	
		Location A	Location B
Future availability of fuel	300	200	250
Transportation flexibility and growth	200	150	150
Adequacy of water supply	100	100	100
Labor availability	250	220	200
Pollution regulations	30	20	20
Site topography	50	40	30
Living conditions	150	100	125
Total	**1080**	**830**	**875**

Note:- Location B has slightly advantage over location A.

2.1.3.4 Factor Rating Method

In this method, factor ratings are applied to assess and compare different location alternatives systematically. The process begins by listing all the relevant factors that influence the location decision. Each factor is then rated, typically on a scale from 1 (very low) to 5 (very high), based on its relative importance, meaning that higher ratings indicate greater significance. Next, each potential location is evaluated for its performance on every factor, using another scale, often from 1 (very low) to 10 (very high) - to reflect its merits. The product of the factor rating and the location rating is calculated for each factor to determine its weighted contribution.

Finally, the sum of these products is computed for each location, and the site with the highest total score is selected as the most suitable choice, as it represents the best overall balance of all evaluated factors.

Problem

The table gives the various factors considered for location decision and the factor

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ratings assigned to each factor based on its importance for location decision and the location rating for the location alternatives based on the merit of each location in each of the factors considered.

Factor Ratings and Location Ratings for Location Alternatives			
Factor	Factor Rating	Location Rating	
		Location A	Location B
Tax advantage	4	8	6
Suitability of labor skill	3	2	3
Proximity to customers	3	6	5
Proximity to suppliers	5	2	4
Adequacy of water	1	3	3
Receptivity of community	5	4	3
Quality of educational system	4	1	2
Access to rail and air transportation	3	10	8
Suitability of climate	2	7	9
Availability of power	2	6	4

Solution

Factor Ratings and Location Ratings for Location Alternatives		
Factor	Product of Rating	
	Location A	Location B
Tax advantage	4 x 8 = 32	4 x6 = 24
Suitability of labor skill	3 x2 = 6	3 x 3 = 9
Proximity to customers	3 x 6= 18	3 x 5 = 15
Proximity to suppliers	5 x 2 = 10	5 x 4 =20
Adequacy of water	1 x 3 = 3	1 x 3 = 3
Receptivity of community	5 x 4 = 20	5 x 3 = 15
Quality of educational system	4 x 1 = 4	4 x 2 = 8
Access to rail and air transportation	3 x 10 = 30	3 x 8 = 24
Suitability of climate	2 x 7 = 14	2 x 9 = 18
Availability of power	2 x 6 = 12	2 x 4 = 8
Total Score	149	144

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Note: Since the total score for location A is higher than that of location B, Location A is the choice.

2.1.3.5 Centre of Gravity Model

The Centre of Gravity model is a widely used quantitative technique in plant location analysis that helps organisations identify the most cost-effective site for a facility by balancing transportation costs and demand volumes. The principle is to determine a central point that minimises the weighted distance between the facility and its markets or suppliers, thereby reducing overall distribution expenses and improving efficiency. This method uses coordinates of demand centres along with their respective weights (such as demand or volume of goods) to calculate the average location. The formula applied is:

$$X = \frac{\sum(x_i \cdot w_i)}{\sum w_i}, \; Y = \frac{\sum(y_i \cdot w_i)}{\sum w_i}$$

where x_i, y_i are the coordinates of each demand point and w_i represents the demand weight.

Problem

A company wants to set up a distribution centre to serve three retail outlets. The details are:

- Outlet A: Coordinates (5, 10), demand = 50 units
- Outlet B: Coordinates (15, 20), demand = 100 units
- Outlet C: Coordinates (25, 15), demand = 150 units

The goal is to find the optimal location using the Centre of Gravity method.

Solution

Identify the coordinates and demand weights for each outlet.

- Outlet A: (5, 10), demand = 50 units
- Outlet B: (15, 20), demand = 100 units
- Outlet C: (25, 15), demand = 150 units

Apply Centre of Gravity Formula

Use weighted averages to calculate the X and Y coordinates.

$X = \Sigma(x_i \cdot w_i)/\Sigma w_i$, $Y = \Sigma(y_i \cdot w_i)/\Sigma w_i$

- Total demand = 50 + 100 + 150 = 300 units

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◊ X = (5×50 + 15×100 + 25×150)/300 = (250 + 1500 + 3750)/300

= 5500/300 ≈ 18.33

◊ Y = (10×50 + 20×100 + 15×150)/300 = (500 + 2000 + 2250)/300

= 4750/300 ≈ 15.83

Interpretation

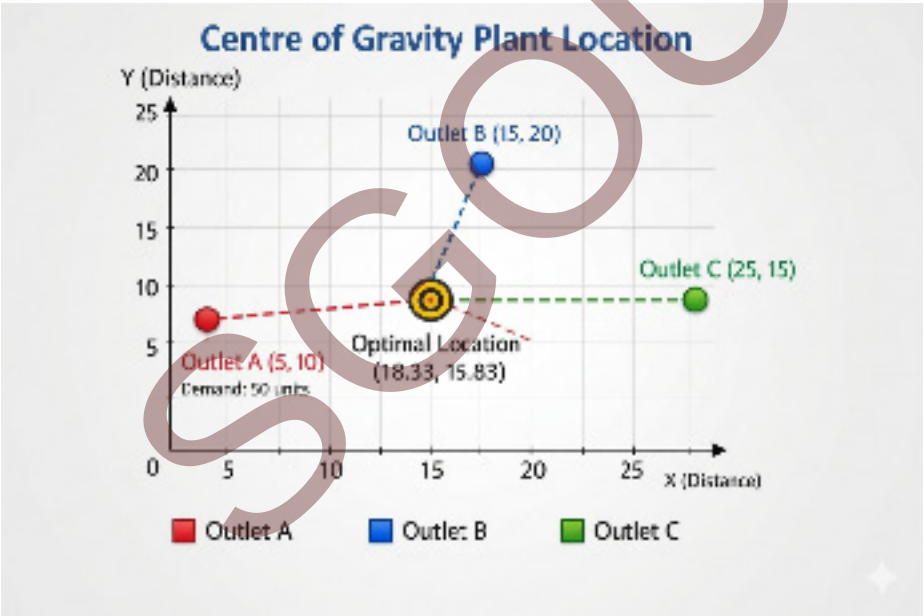
The optimal distribution centre location is at the calculated coordinates.

◊ Centre of Gravity ≈ (18.33, 15.83)

◊ This point balances demand and distance across all outlets

◊ It minimises transportation costs and improves efficiency

Note:- The best location for the distribution centre is approximately at **(18.33, 15.83)**, which balances the demand and distance among the three outlets, ensuring cost-effective operations.



2.1.3.6 Transportation Model

The Transportation Model is a mathematical approach used in plant location analysis to determine the most economical distribution of goods from multiple sources (factories or warehouses) to multiple destinations (markets or customers). Its goal is to minimise total transportation cost while satisfying supply and demand constraints. Each route between a source and destination has an associated cost per unit, and the model allocates shipments optimally using linear programming or tabular methods. This helps organisations decide whether to locate a new plant near suppliers, customers, or at an intermediate point to reduce logistics expenses.

Problem

A company has two factories (F1 and F2) and three warehouses (W1, W2, and W3). The supply and demand details are as follows:

Factory	Supply (units)	W1 (₹/unit)	W2 (₹/unit)	W3 (₹/unit)
F1	100	4	6	8
F2	150	5	3	7

Warehouse	Demand (units)
W1	80
W2	120
W3	50

The goal is to determine the optimal transportation plan that minimises total cost.

Solution

Step 1: Check balance Total supply = 100 + 150 = 250

Total demand = 80 + 120 + 50 = 250

Balanced — no dummy source or destination needed.

Step 2: Apply the Least-Cost Method

Start allocating units to the lowest cost routes first.

- ◊ Lowest cost = ₹3 (F2 → W2). Allocate 120 units (W2's full demand). Remaining supply at F2 = 150 − 120 = 30.
- ◊ Next lowest cost = ₹4 (F1 → W1). Allocate 80 units (W1's full demand). Remaining supply at F1 = 100 − 80 = 20.
- ◊ Next lowest cost = ₹5 (F2 → W1). W1's demand is already met, so skip.
- ◊ Next lowest cost = ₹6 (F1 → W2). W2's demand is met, skip.
- ◊ Next lowest cost = ₹7 (F2 → W3). Allocate remaining 30 units from F2. Remaining demand at W3 = 50 − 30 = 20.
- ◊ Next lowest cost = ₹8 (F1 → W3). Allocate remaining 20 units from F1. All supply and demand satisfied.

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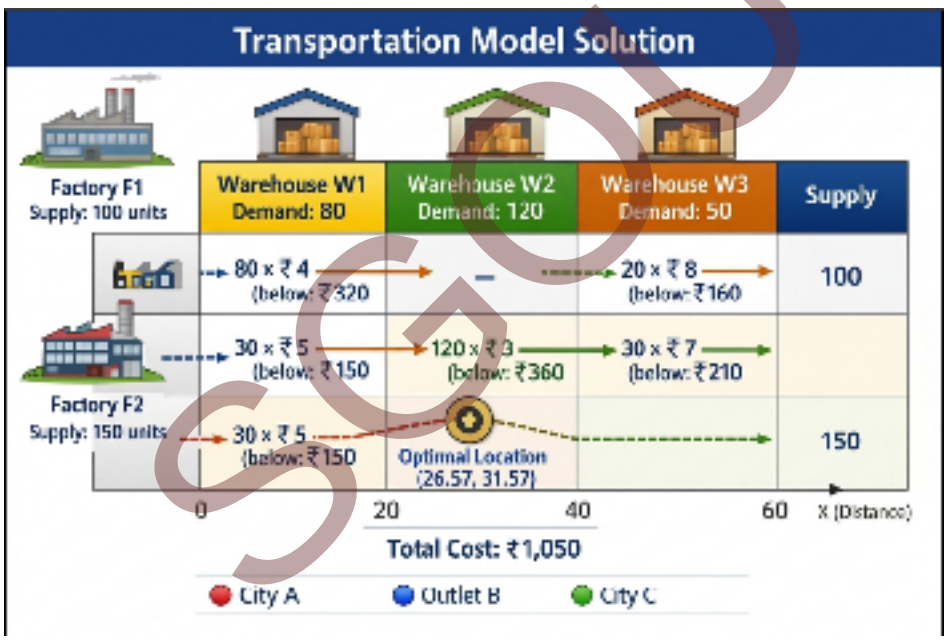
Step 3: Compute Total Cost

Route	Units	Cost (₹/unit)	Total Cost (₹)
F1 → W1	80	4	320
F1 → W3	20	8	160
F2 → W2	120	3	360
F2 → W3	30	7	210

Total Transportation Cost = 320 + 160 + 360 + 210 = ₹1,050

Decision

The optimal transportation plan results in a minimum total cost of ₹1,050. This allocation ensures that supply and demand are balanced while minimising logistics expenses.



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Summarised Overview

Facility location is a crucial decision in operations management that involves choosing the most appropriate geographical area for establishing a facility such as a manufacturing unit, warehouse, office, or service centre. Plant location specifically focuses on identifying the ideal site for setting up a production unit by assessing factors like the availability of raw materials, labour, transportation, market proximity, infrastructure, utilities, government policies, cost considerations, and environmental aspects. The process of selecting a location typically includes recognising the requirements of the facility, determining key influencing factors, developing possible alternatives, evaluating these options, applying suitable analytical models, comparing outcomes, and finalising the most advantageous site.

Location models offer structured and quantitative approaches to assess alternatives, including methods such as factor rating, locational break-even analysis, centre of gravity, and transportation models. A carefully planned decision regarding location can significantly lower operational and distribution costs, enhance customer satisfaction, ensure optimal use of resources, and strengthen the long-term competitiveness and profitability of the organisation.

Self-Assessment Question

1. Explain the concept of facilities location and discuss the major factors that influence the location of a plant.
2. Describe the various steps involved in the selection of a suitable plant location and explain the importance of each step.
3. Explain the major objectives of plant location decisions and discuss how an appropriate location can contribute to operational efficiency.
4. Analyse the factors related to raw materials, labour, transportation, markets, infrastructure, and government policies that influence plant location decisions.
5. Analyse the different stages involved in selecting a plant location and explain how organisations can evaluate alternative locations systematically.
6. Apply suitable location selection techniques to determine the most appropriate location for a manufacturing plant when several alternative locations are available.

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7. Compare and analyse the major location models used in facilities location decisions, highlighting their assumptions, advantages, and limitations.

8. Evaluate the suitability of different location models for selecting a location for a service organisation and justify your choice with suitable examples.

9. Evaluate the importance of quantitative location models in modern plant location decisions and discuss their effectiveness in reducing location-related costs.

10. Develop a suitable location selection approach for a new manufacturing enterprise by integrating the steps of plant location selection with an appropriate location model.

11. An automobile components manufacturer wants to establish a new factory to produce spare parts for cars and commercial vehicles. Three possible locations have been identified.

Location factors	**Weight**	**Site 1**	**Site 2**	**Site 3**
Skilled labour availability	0.20	85	90	75
Proximity to suppliers	0.25	95	80	85
Electricity and water supply	0.15	80	90	85
Land and building cost	0.15	70	85	90
Road and transport facilities	0.15	90	85	80
Environmental suitability	0.10	75	80	95
Total weight	1.00			

Apply the Qualitative Factor Analysis method to determine the most suitable factory location.

(Answer:- Site 1 = 84.25, Site 2 = 85.00, Site 3 = 84.00. Site 2 is the best location because it achieves the highest weighted score of 85.00.)

12. A garment manufacturing company plans to establish a new unit to produce ready-made garments. The management has shortlisted three locations.

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Location factors	Weight	Location A	Location B	Location C
Availability of skilled workers	0.25	90	80	85
Wage rates	0.15	70	90	80
Availability of raw materials	0.20	85	80	95
Market accessibility	0.15	80	90	85
Infrastructure facilities	0.15	90	85	75
Community environment	0.10	80	85	90
Total weight	1.00			

Calculate the weighted scores and identify the most appropriate location.

(Answer:- Location A = 83.50, Location B = 84.25, Location C = 85.25, Location C should be selected because it has the highest total weighted score of 85.25.)

13. A furniture manufacturer plans to produce tables and chairs. The selling price is ₹800 per unit, and the expected annual sales volume is 1,500 units.

Location	Fixed cost per year (₹)	Variable cost per unit (₹)
A	2,00,000	450
B	3,00,000	350
C	4,20,000	250

Required: Calculate the total cost and break-even quantity for each location. Recommend the best location.

(Answer: Location C is the most economical because its total cost is the lowest at ₹7,95,000. Its break-even quantity is approximately 764 units.)

14. A company intends to manufacture packaging materials. The selling price is ₹40 per unit, and the expected annual sales volume is 10,000 units.

Location	Fixed cost per year (₹)	Variable cost per unit (₹)
A	1,00,000	25
B	1,80,000	18
C	2,50,000	12

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Required:

1. Calculate the total cost for each location.
2. Identify the most economical location at 10,000 units.
3. Calculate the break-even quantity for each location.

(Answer: Location A is the most economical at 10,000 units because its total cost is the lowest at ₹3,50,000. Its break-even quantity is approximately 6,667 units.)

15. A small manufacturing enterprise is planning to expand its operations and is considering locations M and N. The following intangible factors have been rated by the management. Apply the point rating method to identify the preferred location.

Factors rated	**Maximum points**	**Location M**	**Location N**
Availability of technical expertise	250	210	200
Access to public transport	150	120	130
Availability of electricity services	200	180	170
Scope for future development	200	150	180
Local government support	100	80	90
Environmental conditions	100	90	80
Employee welfare facilities	150	110	130
Total	1,150	940	980

(Answer: Location N is recommended because it scores 980 points, which is higher than the 940 points obtained by Location M.)

16. A logistics company wants to establish a warehouse and is evaluating two sites, R and S. Using the point rating method, calculate the total points and recommend the most suitable

Factors rated	**Maximum points**	**Location R**	**Location S**
Accessibility to highways	250	220	200
Availability of warehouse workers	200	160	180

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Scope for future expansion	200	170	150
Neighbourhood safety	150	130	140
Availability of communication facilities	100	80	90
Environmental suitability	100	70	80
Employee accommodation facilities	100	80	70
Total	1,100	910	910

(Answer: Both locations obtain an equal score of 910 points. Therefore, neither location is superior under the point rating method alone. The company should consider additional factors, such as land cost, operating expenses and expected business growth, before making the final decision.)

17. A software company is considering two alternative locations, C and D, for establishing a software development centre. The management has assigned factor ratings based on importance and location ratings based on the merits of each site. Calculate the total weighted score and recommend the best location.

Factors	**Factor rating**	**Location C**	**Location D**
Availability of IT professionals	5	9	8
Internet and communication facilities	4	8	9
Tax incentives	3	7	8
Proximity to educational institutions	3	8	7
Availability of office space	4	7	9
Quality of living conditions	2	8	8
Government support	4	6	8

(Answer: Location D is preferred because its total weighted score of 205 is higher than Location C's score of 190.)

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18. A healthcare organisation plans to establish a private hospital and is evaluating locations E and F. Apply the factor rating method to determine the most suitable location.

Factors	Factor rating	Location E	Location F
Accessibility for patients	5	8	9
Availability of qualified doctors	5	9	8
Availability of nursing staff	4	8	9
Proximity to residential areas	4	9	7
Availability of emergency transport	3	7	9
Water and sanitation facilities	3	8	8
Scope for future expansion	4	7	9

(Answer: Location F is preferred because it obtains a higher weighted score of 236 compared with 226 for Location E.)

19. An e-commerce company wants to establish a delivery hub to serve three customer zones. The coordinates and daily parcel demands are given below. Find the suitable location using the Centre of Gravity method.

Customer zone	X-coordinate	Y-coordinate	Daily demand (parcels)
Zone A	10	20	80
Zone B	20	30	120
Zone C	30	10	100

(Answer: The proposed delivery hub should be located approximately at coordinates (20.67, 20.67))

20. A dairy cooperative wants to establish a collection centre to collect milk from three villages. The daily milk supply and village coordinates are given below. Find the suitable location using the Centre of Gravity method.

Village	X-coordinate	Y-coordinate	Daily milk supply (litres)
Village X	10	5	400
Village Y	20	25	600
Village Z	30	15	1,000

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(Answer: The proposed dairy collection centre should be located at coordinates (23, 16)).

21. A publishing company has two printing centres, P1 and P2, which supply books to three college bookshops, B1, B2 and B3. The transportation costs per unit, supply and demand are given below. Find the optimal transportation plan that minimises the total transportation cost.

Printing centre	Supply (books)	B1 (₹/book)	B2 (₹/book)	B3 (₹/book)
P1	120	4	6	8
P2	180	5	3	7
Demand	300	100	120	80

(Answer: The minimum total transportation cost is ₹1,340.)

22. An IT equipment supplier has two regional depots, D1 and D2, supplying equipment to three educational campuses, C1, C2 and C3. The supply, demand and transportation costs are shown below. Determine the optimal transportation plan.

Regional depot	Supply (units)	C1 (₹/unit)	C2 (₹/unit)	C3 (₹/unit)
D1	90	6	4	8
D2	160	5	7	3
Demand	250	70	80	100

(Answer: The optimal transportation plan has a total transportation cost of ₹980.)

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Assignments

1. Analyse a manufacturing company that is planning to establish a new plant in one of three different regions. The regions differ in terms of raw material availability, labour cost, transportation facilities, market proximity, and infrastructure. Identify the key location factors and analyse how each factor would influence the final location decision.

2. Analyse the following situation: A food-processing company wants to locate a new plant closer to its raw material suppliers, but most of its customers are located in major cities. Evaluate the advantages and disadvantages of locating the plant near raw materials versus near the market, and recommend the more suitable alternative with justification.

3. A company has shortlisted four possible locations for a new manufacturing unit. Each location has different scores for labour availability, transportation, power supply, land cost, and market accessibility. Apply the Factor Rating Method to analyse the alternatives and determine the most suitable plant location.

4. A furniture manufacturer is experiencing increasing transportation costs because its existing plant is far from both suppliers and customers. Analyse the location-related problems faced by the company and recommend the factors that should be considered when selecting a new facility location.

5. A pharmaceutical company is planning to establish a production facility in a new state. The management is considering availability of skilled labour, environmental regulations, utilities, transportation, government incentives, and proximity to markets. Analyse these factors and develop a systematic sequence of steps that the company should follow to select the best location.

6. A retail chain plans to open a distribution centre to serve five major markets. The management wants to minimise the total transportation distance between the distribution centre and these markets. Analyse the situation and explain how the Centre of Gravity Method could be applied to identify a suitable location.

7. Two locations are being considered for a new plant. Location A has lower fixed costs but higher transportation costs, while Location B has higher fixed costs but lower transportation costs. Analyse the cost structure of both locations and determine which location would be more suitable at different levels of production volume.

8. A company has selected a particular town for establishing its plant, but several sites within that town are available. The sites differ in terms of soil condition, land size, drainage, accessibility, expansion possibilities, and availability of utilities. Analyse the factors involved in site selection and recommend the most appropriate site for the plant.

9. A service organisation wants to establish a new hospital in a growing urban area. Possible locations differ in population density, accessibility, competition, land cost, parking facilities, and proximity to residential areas. Evaluate the suitability of the alternative locations and recommend an appropriate location model or decision-making approach.

10. A multinational company plans to establish a new production facility and has shortlisted locations in different states based on cost, infrastructure, labour availability, government policies, market access, and future expansion potential. Develop a comprehensive location selection strategy by integrating the major steps of plant location selection with an appropriate location model, and justify the final decision.

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

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Unit 2

Facilities Layout and Material Handling

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ explain the objectives, principles, and importance of plant layout and material handling in manufacturing and service organisations
- ◊ analyse the factors affecting plant layout and distinguish between different types of plant layouts based on operational requirements
- ◊ apply appropriate layout planning tools and techniques to develop an efficient plant layout for a given business situation
- ◊ evaluate different material handling systems and equipment based on factors such as cost, safety, efficiency, flexibility, and suitability
- ◊ design an integrated plant layout and material handling system that improves workflow, minimises material movement, reduces operational costs, and enhances productivity

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Background

The concept of plant layout and material handling evolved with the growth of industrial production. In the early period of craft production, goods were produced by skilled workers in small workshops, and the arrangement of machines and work areas was based mainly on convenience. The Industrial Revolution brought the factory system, mechanised production, and larger manufacturing facilities, creating the need for systematic arrangement of machines, workers, and materials. Later, the principles of Scientific Management, particularly the work of Frederick W. Taylor, emphasised efficiency, standardisation, time study, and the reduction of unnecessary movements. The development of mass production and assembly-line systems further highlighted the importance of arranging equipment according to the sequence of production operations.

As industries diversified, different types of plant layouts emerged to suit varying production requirements. Product layout developed for high-volume and standardised production, while process layout became suitable for organisations producing a variety of products. Fixed-position and combination layouts were later adopted for specialised and complex production activities. Plant layout planning also became more scientific through the use of tools and techniques such as flow charts, flow diagrams, travel charts, relationship charts, and systematic layout planning. Similarly, material handling evolved from simple manual methods such as carrying and pushing materials to the use of mechanical equipment such as conveyors, cranes, hoists, forklifts, trucks, and pallets, with increasing emphasis on reducing handling costs, improving safety, and ensuring smooth material flow.

In the modern period, computerisation, automation, and digital technologies have significantly transformed plant layout and material handling. Computer-aided design, simulation, optimisation techniques, robotics, automated guided vehicles, automated storage and retrieval systems, and warehouse management systems are now widely used. With the emergence of Industry 4.0, organisations increasingly focus on smart, flexible, safe, and sustainable production systems supported by technologies such as artificial intelligence, the Internet of Things, and real-time data analysis. Thus, plant layout and material handling have evolved from simple physical arrangements and manual movement of materials into integrated systems designed to achieve efficient workflow, optimum resource utilisation, minimum movement, reduced cost, improved safety, and higher productivity.

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Keywords

Plant Layout, Product Layout, Process Layout, Fixed-position layout, Cellular layouts, Flexible Manufacturing Systems, Mixed-Model Assembly Lines, Layout Planning, Material Handling

Discussion

Plant layout and material handling are essential aspects of operations management that determine how effectively an organisation uses its facilities, equipment, labour, space, and materials. Plant layout involves the systematic arrangement of machines, workstations, departments, storage areas, and service facilities to ensure smooth workflow, efficient utilisation of space, minimum material movement, reduced costs, and improved safety. The choice of layout is influenced by factors such as the nature

of the product, production volume, process requirements, machinery, labour, material flow, available space, and future expansion. Different types of layouts, along with appropriate layout planning tools and techniques, help organisations develop efficient production systems. Material handling complements plant layout by ensuring the safe and economical movement, storage, and control of materials through suitable systems and equipment such as conveyors, cranes, hoists, forklifts, pallets, and automated guided vehicles.

2.2.1 Plant Layout

Plant layout refers to the systematic physical arrangement of machines, equipment, workstations, departments, storage areas, material-handling facilities, and other supporting services within a factory or workplace. The purpose is to ensure the smooth and logical flow of materials, workers, information, and finished products while making the best use of available space and resources. A well-designed plant layout helps minimise material handling, production delays, unnecessary movement, and operating costs while improving productivity, safety, quality, and flexibility.

According to James M. Apple, *"Plant layout is a plan of the path by which the product or parts of the product travel from one operation to another."*

In simple words: Plant layout means deciding where machines, workers, materials, storage areas, and other facilities should be placed inside a plant so that production can take place efficiently, safely, and economically.

Example: In a bakery, arranging the raw-material storage → mixing → shaping → baking → cooling → packaging → finished-goods storage areas in the proper sequence creates a smooth flow of production and reduces unnecessary movement.

2.2.2 Objectives of a Good Plant Layout

The overall objective of a good plant layout is to improve productivity by ensuring that materials, workers, machines, and information move efficiently through the production system. A good layout also aims to achieve the following objectives:

1. Minimise Material Handling Costs

A good layout reduces the unnecessary movement of raw materials, components, work-in-progress, and finished products. When departments are arranged according to the sequence of operations, materials can move shorter distances and require fewer handling activities.

Example: In a bakery, placing the mixing area close to the baking section and the baking section close to packaging reduces the time and cost involved in moving dough and baked products.

2. Utilise Space Efficiently

Plant layout should make optimum use of the available floor space and vertical space

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without creating congestion. Proper placement of machines, storage facilities, aisles, and workstations prevents wastage of valuable space.

Example: A warehouse can use properly designed racks and vertical storage systems to store more products within the same floor area.

3. Utilise Labour Efficiently

An effective layout enables employees to work with minimum unnecessary movement. Workstations should be positioned so that workers can easily access the required machines, tools, materials, and information.

Example: In an automobile assembly unit, tools and components can be positioned close to workers so that they do not have to repeatedly walk long distances to collect them.

4. Reduce Hazards to Personnel

A good layout should provide adequate space for movement, proper ventilation, emergency exits, safe storage, and clear separation of hazardous activities. This reduces the possibility of injuries and exposure to dangerous conditions.

Example: In a chemical factory, hazardous material storage areas should be separated from ordinary work areas, with clearly marked pathways and emergency access.

5. Increase Employee Morale

A well-planned workplace can improve employee satisfaction and morale by providing a safe, comfortable, organised, and convenient working environment. Proper lighting, ventilation, workspace, cleanliness, and easy access to facilities contribute to employee well-being.

Example: An office furniture manufacturing unit that provides workers with sufficient workspace, comfortable working positions, and organised tools can create a more positive working environment.

6. Reduce Accidents

An effective layout separates pedestrian movement from vehicle movement, provides adequate aisles, avoids unnecessary obstructions, and ensures that machines and materials are positioned safely. This helps to reduce workplace accidents to a considerable extent.

Example: In a warehouse, clearly marked pedestrian paths and separate forklift routes can reduce the risk of collisions between workers and material-handling vehicles.

7. Promote Product and Service Quality

A suitable layout supports proper workflow, inspection, supervision, and quality control. When production stages are arranged logically, defects can be identified earlier, and contamination or damage can be reduced.

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Example: In a food-processing plant, arranging processing, quality inspection, packaging, and storage areas in a controlled sequence can help maintain hygiene and product quality.

8. Facilitate Entry, Exit and Placement of Materials, Products and People

A good layout should provide convenient entry and exit points, aisles, loading and unloading areas, storage locations, and pathways. This ensures smooth movement of raw materials, finished products, employees, visitors, and vehicles.

Example: A retail distribution centre should have separate and clearly organised areas for receiving incoming goods, storing products, picking orders, and dispatching finished orders.

9. Encourage Proper Maintenance Activities

Machines and equipment should be positioned with sufficient space around them for inspection, cleaning, repair, servicing, and replacement of parts. A layout that ignores maintenance requirements may increase machine downtime.

Example: In a manufacturing plant, leaving adequate space around a large production machine allows maintenance staff to inspect and repair it without disturbing nearby operations.

10. Increase Production Capacity

An efficient layout can increase the organisation's production capacity without necessarily requiring a major increase in floor space, labour, or equipment. By reducing bottlenecks, improving workflow, and utilising resources efficiently, more output can be achieved.

Example: A packaging company may increase daily output by rearranging workstations to eliminate unnecessary movement and reduce waiting time between filling, labelling, inspection, and packing.

2.2.3 Factors Influencing Facility Layout

Facility layout is influenced by several factors that determine how machines, workers, materials, storage areas, and other facilities should be arranged. A suitable layout must consider the nature of production, the movement of materials and people, available technology, and the organisation's future requirements. The major factors influencing facility layout are materials, product, workers, machinery, type of industry, location, and managerial policies.

1. Materials

The nature, size, shape, weight, quantity, and characteristics of materials have a significant influence on facility layout. Materials should be stored and moved in a manner that minimises handling, transportation distance, damage, and storage costs. The layout should provide convenient access to raw materials and ensure a smooth flow

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of materials from one production stage to another.

Example: In a steel manufacturing plant, heavy raw materials require strong storage facilities and suitable material-handling equipment such as cranes. In a food-processing unit, materials may require hygienic storage and temperature-controlled areas.

2. Product

The nature and characteristics of the product influence the type and arrangement of facilities. Important considerations include product size, weight, design, variety, production volume, and the sequence of manufacturing operations. Standardised products produced in large quantities generally require a product or line layout, whereas customised products with different processing requirements may require a process or functional layout.

Example: An automobile assembly plant producing large quantities of standardised vehicles can arrange workstations according to the sequence of assembly. In contrast, a custom furniture manufacturer may use a process layout because different furniture items require different operations.

3. Worker

Workers are an important consideration in designing a facility layout. The layout should provide safe, comfortable, and convenient working conditions and minimise unnecessary movement. Adequate space should be provided around workstations, along with proper lighting, ventilation, sanitation, emergency exits, and safe movement paths. Ergonomic considerations should also be incorporated to reduce worker fatigue.

Example: In a garment factory, sewing machines should be arranged so that workers can easily access fabric, tools, and accessories without excessive stretching or walking. Similarly, separate pedestrian pathways in a warehouse can protect workers from moving forklifts.

4. Machinery

The type, size, capacity, number, and arrangement of machines strongly influence facility layout. Machines should be positioned according to the sequence of operations and should have sufficient space for operation, inspection, cleaning, maintenance, and repair. The layout should also consider machine safety, power requirements, vibration, noise, and the possibility of future technological changes.

Example: In a printing press, printing, cutting, folding, binding, and packaging machines should be arranged in a logical sequence. Adequate space must also be provided around each machine for maintenance and movement of materials.

5. Type of Industry

The type and nature of the industry determine the appropriate layout because different industries have different production processes, product characteristics, volumes, and handling requirements. Manufacturing industries, process industries, service

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organisations, warehouses, hospitals, and retail establishments may require different layout approaches.

Example: A chemical-processing plant may require a process-oriented layout with specialised safety arrangements, while an automobile factory may use a product or assembly-line layout. A hospital, on the other hand, needs a layout that facilitates the movement of patients, medical staff, equipment, and visitors.

6. Location

The location of the facility can influence the layout because the availability and characteristics of land, transportation facilities, utilities, labour, and surrounding infrastructure affect the internal arrangement of the plant. The site should provide sufficient space not only for present operations but also for future expansion. Access roads, loading and unloading areas, parking, waste disposal, and external transportation should also be considered.

Example: A manufacturing plant located near a major highway may design its layout with convenient loading and dispatch areas facing the main access road. A factory located near a port may provide larger receiving and dispatch facilities to handle imported raw materials and exported finished goods.

7. Managerial Policies

Management policies and strategic decisions also influence facility layout. Policies relating to production volume, quality standards, inventory levels, automation, employee safety, environmental protection, expansion, centralisation or decentralisation, and future growth must be reflected in the layout. Management should also consider whether the facility needs flexibility to accommodate changes in products, technology, and market demand.

Example: If management plans to automate production in the future, sufficient space and appropriate infrastructure should be incorporated into the current layout for installing robots, automated guided vehicles, or conveyors. Similarly, a company following a Just-in-Time (JIT) approach may design its layout to reduce inventory and ensure a smooth and continuous flow of materials.

8. Production Process

The nature and sequence of the production process have a major influence on layout. The arrangement should support the logical movement of materials from one operation to the next and avoid backtracking, bottlenecks, and unnecessary movement.

Example: In a garment factory, the layout may follow the sequence fabric inspection → cutting → stitching → ironing → quality inspection → packing.

9. Production Volume and Variety

The volume of production and variety of products determine the most suitable layout. High-volume and low-variety production generally favours a product layout,

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while low-volume and high-variety production may require a process layout.

Example: A bottled-water factory producing millions of identical bottles may use a product layout, whereas a customised engineering workshop may use a process layout.

10. Space Requirements

The layout must consider the amount of floor and vertical space required for machines, workers, materials, storage, aisles, offices, and supporting services. Space should be utilised efficiently without creating congestion.

Example: A warehouse can use vertical racks to increase storage capacity without significantly increasing its floor area.

11. Material Flow

The direction, frequency, distance, and volume of material movement should be carefully considered. A good layout creates a smooth flow and minimises unnecessary transportation and backtracking.

Example: In a food-processing plant, raw materials should move progressively from receiving to processing, packaging, and finished-goods storage.

12. Material Handling System

The availability and type of material handling equipment influence the layout. Conveyors, forklifts, cranes, hoists, automated guided vehicles, and other systems require suitable space and movement paths.

Example: If a factory uses overhead cranes to move heavy components, sufficient clearance must be provided above the production area.

13. Storage Requirements

The layout should provide appropriate areas for raw materials, work-in-progress, finished goods, tools, spare parts, and packaging materials. Storage locations should be easily accessible and properly organised.

Example: A supermarket distribution centre requires separate areas for receiving, storage, order picking, packing, and dispatch.

14. Safety and Security

Safety is an essential consideration in facility layout. The design should provide emergency exits, fire-fighting equipment, safe walkways, adequate ventilation, proper lighting, and separation of hazardous activities.

Example: In a chemical plant, hazardous substances should be stored away from offices and common work areas, with appropriate emergency access.

15. Quality Control

The layout should facilitate inspection, testing, quality checking, and corrective

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action. Quality control points should be positioned at appropriate stages of production.

Example: In an electronics factory, inspection stations may be placed after assembly and before final packaging to identify defective products.

16. Maintenance Requirements

Machines and equipment need adequate space for inspection, cleaning, servicing, repair, and replacement of components. Poorly planned layouts can make maintenance difficult and increase machine downtime.

Example: A large industrial machine should have sufficient clearance around it so that technicians can safely access its components.

17. Flexibility

A good layout should be flexible enough to accommodate changes in product design, production volume, technology, machinery, and market demand.

Example: A factory may use modular workstations so that machines can be rearranged when a new product is introduced.

18. Future Expansion

The layout should provide opportunities for future expansion of production facilities, storage areas, machinery, and supporting services.

Example: A growing manufacturing company may reserve an unused section of land next to the production area for installing additional machines in the future.

19. Utilities and Services

The availability and distribution of electricity, water, gas, steam, compressed air, drainage, internet, ventilation, and waste-disposal facilities influence the layout.

Example: A food-processing plant needs reliable water supply, drainage, refrigeration, electricity, and waste-disposal facilities positioned conveniently near the relevant operations.

20. Environmental Considerations

Modern layouts should consider waste management, pollution control, energy efficiency, noise reduction, emissions, recycling, and sustainability.

Example: A manufacturing facility may position waste-treatment and recycling areas so that industrial waste can be collected without interfering with normal production activities.

21. Communication and Supervision

The layout should enable effective communication, monitoring, coordination, and supervision among employees and departments. Managers should be able to monitor important operations without unnecessary movement.

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Example: In a production unit, supervisors may have a clear view of several workstations so that production problems can be identified quickly.

22. Employee Convenience and Ergonomics

The layout should consider worker comfort, posture, accessibility, fatigue, lighting, ventilation, temperature, and noise. Ergonomically designed workstations can improve employee performance and reduce physical strain.

Example: Frequently used tools can be placed within easy reach of workers to reduce unnecessary bending, stretching, and walking.

23. Technology and Automation

The level of automation and technology affects the arrangement of machines and workstations. Automated systems require space for robots, sensors, control systems, conveyors, AGVs, and related infrastructure.

Example: A smart factory using robots and automated guided vehicles requires clearly defined routes and sufficient space for automated movement.

24. Cost Considerations

The layout should be economically feasible. Management must consider the cost of land, construction, machinery installation, material handling, storage, utilities, maintenance, and future modifications.

Example: A company may choose a slightly more expensive layout initially if it significantly reduces material handling and operating costs over the long term.

25. Government Regulations and Legal Requirements

Facility layout must comply with applicable building regulations, fire-safety requirements, occupational safety standards, environmental regulations, and industry-specific rules.

Example: A factory must provide legally required emergency exits, fire protection systems, safe working distances, and appropriate waste-disposal arrangements.

26. Security Requirements

The layout should protect people, materials, equipment, information, and finished products from theft, unauthorised access, and other security risks.

Example: A pharmaceutical manufacturing facility may restrict access to production and storage areas and use controlled entry points.

27. Product Handling Characteristics

The fragility, perishability, weight, size, shape, and hazardous nature of products can influence the layout.

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Example: A cold-storage facility handling perishable food products must position refrigerated storage and dispatch areas appropriately to minimise exposure to unsuitable temperatures.

28. Supply Chain and Transportation

The layout should consider the movement of materials between the facility and suppliers, warehouses, distribution centres, customers, ports, railway stations, and roads.

Example: A distribution centre may position its receiving docks close to storage areas and dispatch docks close to order-picking and packing sections.

2.2.4 Types of Layouts

There are **two types of layouts**:

1. Basic Types of Layouts

1. Process Layout
2. Product Layout
3. Fixed-Position Layout

2. Hybrid Layouts

1. Cellular Layout
2. Flexible Manufacturing Systems (FMS)
3. Mixed-Model Assembly Lines

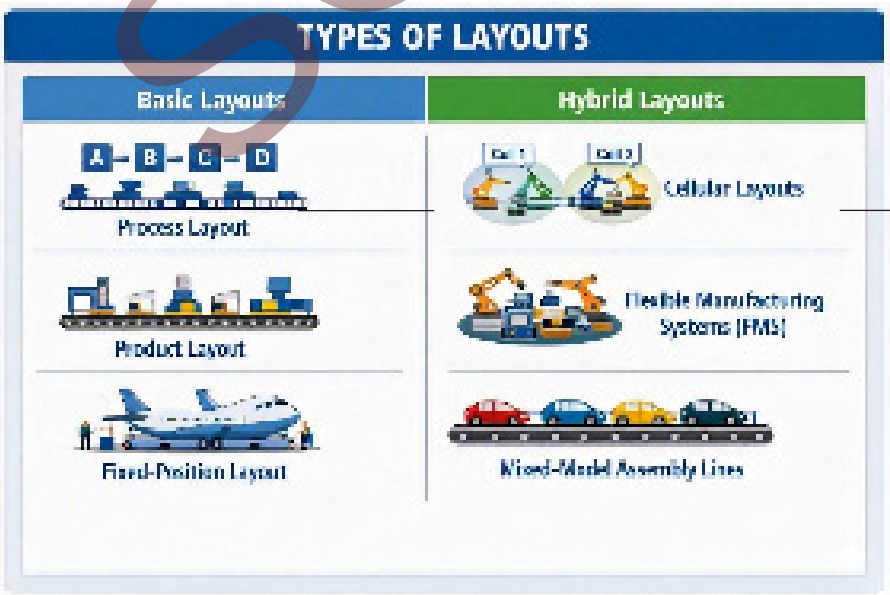


Fig 2.2.1 Types of Layouts

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2.2.4.1 Basic Types of Layouts

1. Process Layout

A process layout, also called a functional layout, is a type of facility arrangement in which similar machines, equipment, or activities are grouped together according to the type of process or function they perform. Under this arrangement, each department specialises in a particular operation, and the product or customer moves from one department to another depending on the operations required.

Example 1 – Machine Shop: In a machine shop, all drilling machines are placed in one work centre, lathes in another, and milling machines in a separate work centre. A particular component moves between these departments according to its specific processing requirements.

Example 2 – Department Store: In a department store, products are grouped according to their functions or categories. Women's clothing, men's clothing, children's clothing, cosmetics, and footwear are placed in separate departments, allowing customers to visit the section relevant to their requirements.

Process layout is generally suitable for intermittent production, job shops, service shops, and organisations handling a wide variety of products or services. Since different customers may have different requirements, each job can follow a different route through the facility.

Main Advantage – Flexibility: The major advantage of process layout is its high flexibility. Different products can be processed using different routes and operations, making the layout suitable for customised and varied production.

Main Disadvantage – Inefficiency: Its major disadvantage is lower efficiency compared with product layouts. Materials or customers may need to travel longer distances between departments, resulting in increased material handling, longer processing times, work-in-progress, and higher operating costs.

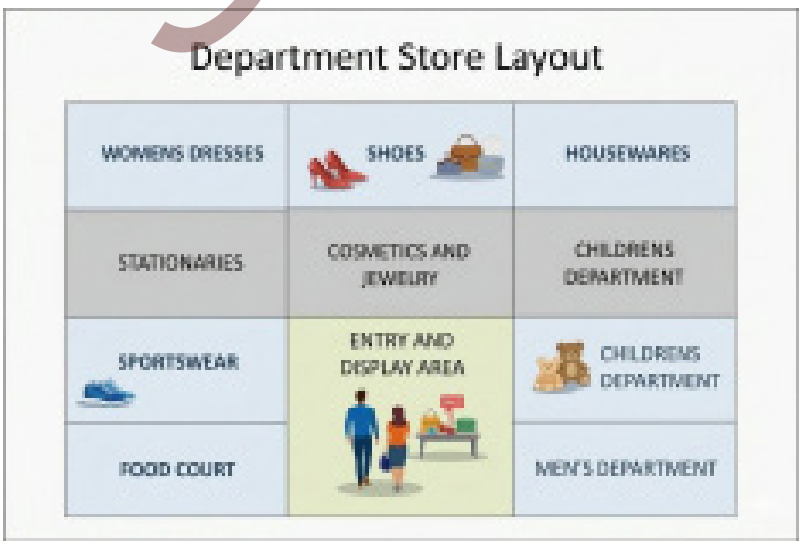


Fig 2.2.2 Department store layout

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Process Layout Analysis: Pittsburgh International Airport



Fig 2.2.3 Pittsburgh International Airport

2. Product Layout

A product layout, commonly known as an assembly-line layout, is a type of facility arrangement in which machines, equipment, and workstations are organised in a sequential order according to the operations required to produce a particular product or provide a specific service.

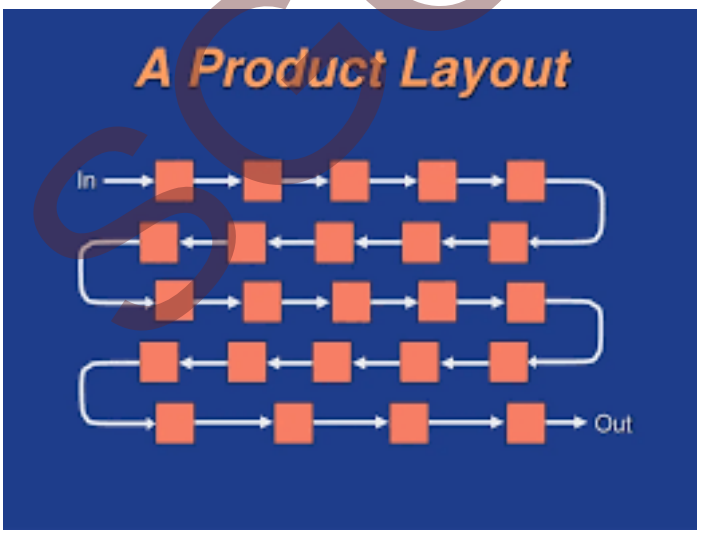


Fig 2.2.4 Product Layout

In this layout, each product follows a predetermined production route, with each workstation performing a specific task. The work moves systematically from one workstation to the next until the final product is completed. This creates a smooth, continuous, and orderly flow of work.

Example: In an automobile manufacturing plant, the production line may be arranged as body assembly → painting → engine installation → interior fitting → quality inspection → final assembly. Each stage is positioned according to the sequence of production.

Product layout is mainly suitable for high-volume production of standardised products, where the same or similar operations are repeated continuously.

Main Advantage – Efficiency: The major advantage is high efficiency and ease of operation. It reduces unnecessary movement, simplifies supervision, minimises material handling, and supports faster production.

Main Disadvantage – Inflexibility: Its major disadvantage is lack of flexibility. Since the workstations are arranged for a specific product and sequence of operations, changes in product design, production volume, or process requirements can be difficult and costly to accommodate.

3. Fixed-Position Layout

A fixed-position layout is a type of facility layout in which the product remains in a fixed location throughout the entire production process. This layout is generally used when the product is too large, heavy, bulky, fragile, or difficult to move from one place to another.

Examples: Shipbuilding, aircraft manufacturing, construction of houses, bridges, large machinery, and power plants.

In this layout, the product does not move between different workstations. Instead, workers, machinery, tools, materials, equipment, and other necessary resources are brought to the location of the product to carry out the required operations.

For example, during the construction of a ship, the ship remains at the construction site while engineers, welders, electricians, materials, cranes, and other equipment are brought to it at different stages of construction.

Fixed position layout Example: -Ship manufacturing



Fig 2.2.5 Ship manufacturing

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Fixed position layout Example: Aircraft manufacturing



Fig 2.2.6 Aircraft manufacturing

2.2.4.2 Hybrid Layouts

There are three major types of hybrid layouts:

1. Cellular Layouts
2. Flexible Manufacturing Systems (FMS)
3. Mixed-Model Assembly Lines

1. Cellular Layout

A cellular layout combines features of process and product layouts. In this arrangement, different types of machines are grouped together into work centres called cells. Each cell is designed to manufacture a family of parts or products that have similar shapes, characteristics, or processing requirements. Instead of moving parts through several separate departments, most of the required operations can be completed within the same cell.



Fig 2.2.7 Cellular Layout

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Example: In an automobile component manufacturing unit, machines such as turning, drilling, milling, and grinding equipment may be grouped into one cell to produce a particular family of similar components.

Advantages of Cellular Layout

- ◊ Reduces material handling and movement time by keeping related machines close together.
- ◊ Reduces machine setup time because similar parts are processed within the same cell.
- ◊ Reduces work-in-progress inventory by allowing faster movement of parts between operations.
- ◊ Improves utilisation of human resources by enabling workers to perform multiple related activities.
- ◊ Makes production control easier because each cell operates as a relatively independent production unit.
- ◊ Facilitates automation because machines and processes within a cell can be integrated more easily.

Disadvantages of Cellular Layout

- ◊ Difficulty in forming suitable part families: It may be difficult to identify products or components with sufficiently similar processing requirements.
- ◊ Poorly balanced cells: Some cells may become overloaded while others remain underutilised, reducing overall efficiency.
- ◊ Additional worker training and scheduling requirements: Employees may need training to operate different machines and perform multiple tasks.
- ◊ Higher capital investment: Establishing cells may require additional machines, equipment, material-handling facilities, or modifications to the existing plant layout.

2. Flexible Manufacturing System (FMS)

A Flexible Manufacturing System (FMS) is an advanced manufacturing arrangement in which programmable machines and equipment are connected through an automated material-handling system and controlled by a central computer system. It is designed to manufacture different types of products or components with minimal changes in equipment and production arrangements.

Once Group Technology (GT) is used to classify parts and products into families with similar processing requirements, computers can be used to determine and control various production activities, such as production scheduling, machine operations, routing, monitoring, and process control. The use of programmable machine tools provides a high degree of flexibility, allowing the system to respond quickly to changes

SGOU

in product type, design, or production requirements. When the movement of materials between machines is also automated and controlled by computers, the system functions as a fully integrated Flexible Manufacturing System.

Components of FMS

An FMS generally consists of **three major components**:

1. **Computer Numerical Control (CNC):** CNC machines are programmable machine tools that perform manufacturing operations automatically according to computer instructions.
2. **Computer-Controlled Material Handling System:** This system automatically transports raw materials, components, and work-in-progress between different machines and workstations. Examples include automated guided vehicles (AGVs), robots, and automated conveyors.
3. **Supervisory Computer Control Network:** This central computer-based system coordinates and monitors the overall manufacturing process, including production scheduling, machine control, material movement, and system performance.

Example: An automobile component manufacturer may use several CNC machines connected by automated material-handling equipment and controlled by a central computer. Different components can be produced on the same system by changing the computer programmes rather than completely rearranging the production facility.



Fig 2.2.8 - Flexible Manufacturing System

Types of FMS Layout

a. Progressive Layout

A progressive layout is designed for processing a family of similar parts through a predetermined sequence of operations. The machines are arranged in a progressive flow, making this layout closely resemble an automated Group Technology (GT) cell. It

is suitable when parts generally follow the same processing route.

Example: A group of similar automobile components may pass through turning, milling, drilling, and inspection operations in a fixed sequence.

b. Closed-Loop Layout

In a closed-loop layout, machines and workstations are arranged around a continuous loop through which materials and parts are transported. A major advantage is that parts do not have to visit every workstation in sequence. They can bypass certain stations or move around the loop to reach machines in a different order according to their processing requirements.

Example: A component requiring only drilling and inspection can skip milling and other unnecessary workstations.

c. Ladder Layout

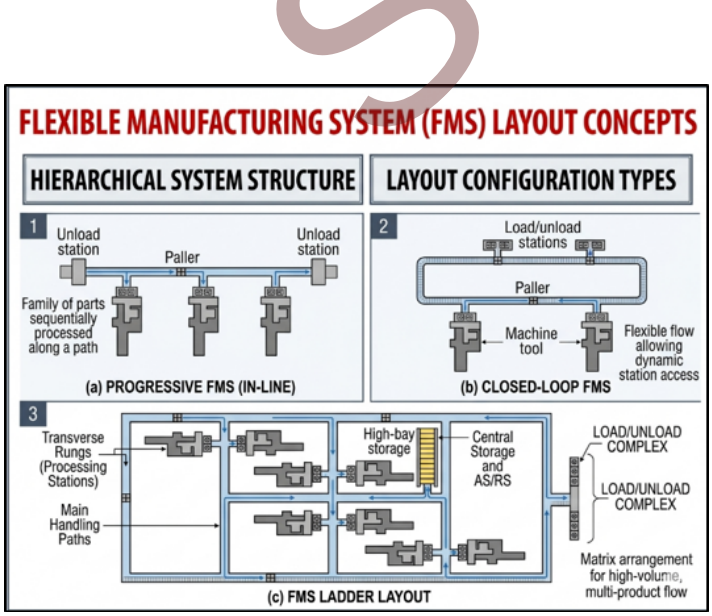
A ladder layout consists of machine tools arranged along the sides of parallel paths connected by cross paths, giving the system an appearance similar to a ladder. This arrangement provides alternative routes for material movement and allows two machines to work on the same item at the same time, where appropriate.

Example: A component can move along one side of the layout for one operation and then cross to another machine on the opposite side for a subsequent operation.

d. Open-Field Layout

An open-field layout is the most complex and flexible type of FMS layout. It allows materials and components to move between machine centres in different sequences and directions, depending on the production requirements. It can accommodate several supporting facilities in addition to machine tools.

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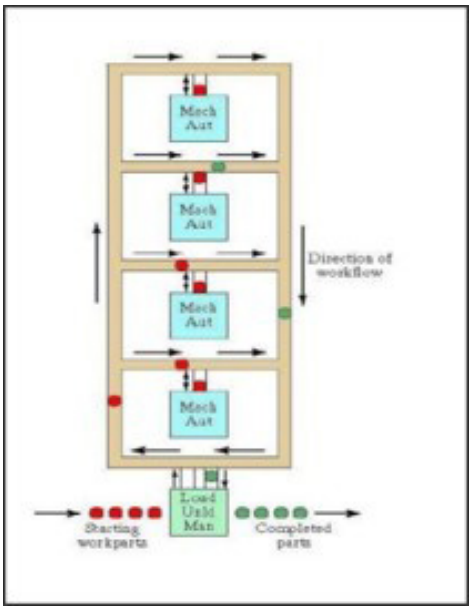


Fig 2.2.9 - Types of FMS Layout

These support facilities may include:

- ◊ Tool interchange stations
- ◊ Pallet and fixture preparation stations
- ◊ Inspection stations
- ◊ Chip collection systems
- ◊ Coolant collection and management systems

Example: A highly automated engineering plant producing a wide variety of components can use an open-field FMS to route different parts to different machines and support stations according to their individual processing requirements.

3. Mixed-Model Assembly Lines

A mixed-model assembly line is an assembly system designed to produce more than one model or variation of a product on the same production line. It provides greater flexibility than a traditional single-model assembly line and enables manufacturers to respond to different customer requirements without creating a completely separate production line for each model.

The development of mixed-model assembly lines generally involves three important changes. First, manufacturers reduce the changeover time required when switching from one model to another. Second, workers are trained to perform multiple tasks and may operate at more than one workstation when necessary. Third, the arrangement and scheduling of the assembly line are modified to accommodate the different processing requirements of various models.

Important Factors in Mixed-Model Assembly Lines

1. Line Balancing

Line balancing is an important consideration because the time required to complete the same task may differ between product models. Therefore, the line cannot be balanced based on the processing time of only one model. Instead, the expected or average processing time of different models is generally considered when assigning tasks to workstations. Apart from this difference, the basic principles of line balancing remain similar to those used for single-model assembly lines.

Example: In an automobile assembly line, installing an advanced entertainment system may take longer in a premium model than in a basic model. The average task time across the different models can be considered when balancing the workstations.

2. U-Shaped Assembly Lines

A U-shaped layout can improve flexibility because workers can move between nearby workstations and assist one another when required. This arrangement is particularly useful when different models have different work requirements. Workers can more

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easily support overloaded stations and maintain a smooth production flow.

Example: If one workstation becomes temporarily overloaded while assembling a particular car model, a worker from a nearby workstation can assist without travelling a long distance.

3. Flexible Workforce

A flexible workforce is essential for operating a mixed-model assembly line effectively. Since different models may require different amounts of time for individual tasks, actual work requirements can vary from the average. Workers trained to perform multiple operations can move between workstations and assist colleagues when necessary, helping the line maintain its required production rate.

Example: A worker trained in both dashboard installation and interior fitting can move between these stations depending on the workload generated by different vehicle models.

4. Model Sequencing

Model sequencing refers to deciding the order in which different product models should be assembled on the same line. Proper sequencing helps maintain a balanced workload and prevents excessive variation in work requirements between consecutive models. It is generally preferable to avoid producing two models requiring unusually long processing times one after another. Instead, a high-work-content model can be followed by a lower-work-content model, allowing workers to recover from the additional workload.

Example: If a premium car requires 12 minutes of work at a particular station and a basic model requires only 8 minutes, scheduling a basic model after the premium model can help workers manage the workload more effectively.

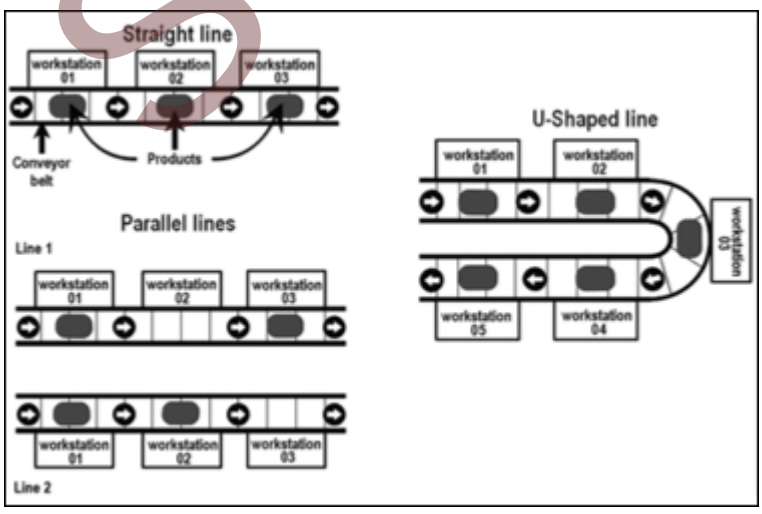


Fig 2.2.10 Model Sequencing

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2.2.5 Layout Planning

Layout planning is the systematic process of deciding the most suitable arrangement and location of machines, equipment, workstations, departments, storage areas, material-handling facilities, and service areas within a plant or facility. Its main purpose is to ensure a smooth flow of materials, workers, information, and finished products while making optimum use of available space and resources.

The layout planning process generally involves studying production requirements, analysing material and work flow, determining space requirements, identifying relationships between different departments, developing alternative layouts, evaluating the alternatives, and selecting the most suitable layout.

Example: In a garment factory, layout planning involves deciding the locations of the fabric storage, cutting, stitching, ironing, inspection, packing, and finished-goods storage areas so that garments move through the production process with minimum unnecessary movement and delay.

2.2.6 Layout Tools and Techniques

Various tools and techniques are used to plan and develop an effective plant layout. The selection of a particular technique depends mainly on the type of layout being designed and the nature of the production process. One of the most commonly used tools is the two-dimensional template, which helps planners visualise the position and arrangement of machines, equipment, departments, and other facilities before the actual layout is implemented.

Different layout methods require different planning techniques. For example, sequence analysis is commonly used when designing a process layout, as it helps study the sequence in which different operations are performed and the movement of materials between work centres. In contrast, line balancing is mainly used in designing a product or assembly-line layout. It helps distribute tasks among workstations so that the workload is balanced and production flows smoothly.

2.2.6.1 Templates

A template is a pattern or model used as a guide for representing the size and shape of an object. Traditionally, templates may be made from thin sheets of wood, metal, plastic, or other materials and are used as guides or gauges in various types of work.

In plant layout planning, a template represents a physical object such as a machine, workstation, storage area, or other facility at a predetermined scale. These templates can be moved around on a layout drawing to examine different possible arrangements before selecting the most suitable one.

Example: A factory planner can prepare scaled templates representing machines such as lathes, drilling machines, and milling machines. By moving these templates on a layout plan, the planner can identify an arrangement that provides smooth material flow, sufficient working space, and easy access for maintenance.

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Fig 2.2.11 Templates

2.2.6.2 Operations Sequence Analysis

Operations Sequence Analysis is a layout planning technique used to study the sequence of operations and the movement of materials between different departments or work centres. It helps planners represent the relationships between operations graphically and determine a suitable arrangement of departments to achieve a smooth flow of work and minimise unnecessary movement.

Example: In a manufacturing plant, if a product moves from cutting → drilling → milling → assembly → inspection, sequence analysis can be used to study these movements and determine the appropriate positioning of the departments.

2.2.6.3 Line Balancing

Line balancing is the process of distributing production tasks as evenly as possible among different workstations so that each workstation has a balanced workload and idle time is minimised. The objective is to achieve a smooth production flow while using the minimum number of workers or workstations required to meet the desired production rate.

Various analytical and optimisation techniques can be used to solve line-balancing problems, including linear programming, dynamic programming, and other optimisation methods.

Example: In an automobile assembly line, if assembling a vehicle involves several tasks, line balancing ensures that these tasks are distributed appropriately among workers so that no workstation is overloaded while another remains idle.

2.2.6.4 Analysing Layout with Computers

Computers are widely used in plant layout planning to analyse different layout alternatives and identify an efficient arrangement of departments, machines, and work

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areas. Computer-based techniques are particularly useful for designing process layouts, where there are many departments and possible material-flow patterns. Some commonly used computerised layout techniques are:

1. **ALDEP – Automated Layout Design Program:** ALDEP is a computer-based technique used to develop and evaluate alternative facility layouts by considering the relationships between different departments and their space requirements.

2. **CORELAP – Computerised Relationship Layout Planning:** CORELAP is a computerised layout planning technique that develops a suitable arrangement of departments by analysing their closeness and functional relationships.

3. **CRAFT – Computerised Relative Allocation of Facilities Technique:** CRAFT is a computer-based improvement technique that evaluates and modifies an existing layout by considering material movement, handling costs, and the relative locations of facilities to obtain a more efficient arrangement.

2.2.6.5 Criteria for Selection and Design of Layouts

The selection and design of an appropriate plant layout should be based on several performance considerations. Two important criteria are material handling cost and worker effectiveness. A good layout should minimise the distance and cost involved in moving materials while enabling workers to perform their tasks efficiently, safely, and with minimum unnecessary movement.

Methods Used for Selecting the Best Layout

1. **Travel Chart Method:** This method analyses the frequency and movement of materials or people between different departments. It helps identify departments that have frequent movement between them so that they can be positioned closer together.

2. **Load-Distance Analysis Method:** This method evaluates a layout by considering both the amount of material or load moved and the distance travelled. A layout with a lower overall load-distance value is generally preferred because it indicates less material movement.

3. **Systematic Layout Planning (SLP):** SLP is a structured approach to facility layout planning that considers activity relationships, material flow, space requirements, and other operational factors. It helps develop and compare alternative layouts before selecting the most suitable arrangement.

2.2.7 Material Handling

Material handling refers to the systematic process of moving, transporting, handling, storing, and protecting materials and products in different forms within an organisation. It involves the use of appropriate methods, equipment, and systems to ensure that materials are moved and stored safely, efficiently, economically, and with minimum unnecessary effort.

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In simple words, material handling is the efficient movement, storage, and protection of raw materials, components, work-in-progress, and finished products from one location to another during production, storage, and distribution.

Example: In a manufacturing plant, moving raw materials from the receiving area to the production section, transferring work-in-progress between machines, and moving finished products to the warehouse are all activities of material handling.



Fig 2.2.12 Material Handling

2.2.8 Material Handling Principles

Material handling principles provide guidelines for ensuring the safe, efficient, economical, and smooth movement of materials within a facility. They help organisations reduce unnecessary movement, handling costs, labour effort, and delays while improving productivity.

1. Ensure Direct Material Flow

Materials should move through the facility in the shortest and most direct route possible. Unnecessary zig-zag movement, backtracking, and repeated movement should be avoided.

Example: If the production sequence is cutting → drilling → assembly → packing, these workstations should ideally be arranged in that order.

2. Arrange Related Processes for Smooth Flow

Production processes that are closely related should be located near each other so that materials can move directly from one operation to the next without unnecessary transportation.

Example: In a bakery, the mixing, baking, cooling, and packaging areas should be arranged in a logical sequence.

3. Minimise Human Effort Through Mechanisation

Material-handling equipment should be properly selected, positioned, and designed

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to reduce manual effort. Mechanised equipment such as conveyors, forklifts, cranes, and automated guided vehicles can be used wherever appropriate.

Example: A forklift can be used to transport heavy pallets instead of requiring workers to move them manually.

4. Move Heavy and Bulky Materials the Shortest Distance

Heavy, large, or bulky materials should travel the minimum possible distance during production. This reduces transportation costs, handling effort, time, and the risk of damage.

Example: In a steel plant, heavy metal components should be processed in workstations located close to the storage and receiving areas.



Fig 2.2.13 Material Handling Solutions

5. Minimise the Number of Handling Operations

Materials should be handled as few times as possible. Every additional handling operation increases labour requirements, time, cost, and the possibility of damage.

Example: Instead of transferring raw materials between several temporary storage locations, materials can be moved directly from the receiving area to the appropriate production or storage location.

6. Provide Flexibility in the Handling System

A material-handling system should be flexible enough to deal with unexpected situations, such as equipment breakdowns, changes in production methods, changes in product design, or variations in production volume.

Example: If one conveyor becomes unavailable, an alternative route or handling equipment should be available to continue material movement without bringing production to a complete stop.

7. Utilise Mobile Equipment Efficiently

Mobile material-handling equipment such as forklifts, trucks, and automated guided vehicles should preferably operate with full or economically viable loads rather than making unnecessary trips with little or no material.

Example: A forklift should transport a properly loaded pallet whenever possible rather than repeatedly travelling between the warehouse and production area with partial loads.

2.2.9 Types of Material Handling Systems and Equipment

2.2.9.1 Types of Material Handling Systems

Material handling systems can be classified according to the basis or approach used for handling and moving materials. The major types are:

1. Equipment-Oriented Systems
2. Material-Oriented Systems
3. Method-Oriented Systems
4. Function-Oriented Systems

1. Equipment-Oriented Systems

In an equipment-oriented system, materials are moved and handled using specific types of material-handling equipment. The selection of equipment depends on factors such as the nature, size, weight, distance, volume, and frequency of material movement. The major equipment-oriented systems include:

a) Overhead Systems



Fig 2.2.14 Overhead crane hoists

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These systems transport materials above the floor level using equipment such as overhead cranes, hoists, and monorails. They are useful when floor space is limited or when heavy materials need to be moved.

Example: An automobile factory may use overhead cranes to move heavy engines or vehicle components.

b) Conveyor Systems

Conveyor systems use belts, rollers, chains, or other mechanisms to move materials continuously from one location to another. They are particularly suitable for repetitive and high-volume material movement.

Example: A packaging plant may use belt conveyors to transfer packed products from the production line to the dispatch area.



Fig No 2.2.15 Conveyors

c) Tractor-Transfer Systems

These systems use industrial tractors or powered vehicles to pull trailers or carts carrying materials from one location to another. They are suitable for transporting materials over relatively long distances within a facility.

Example: An automobile manufacturing plant may use tractors to pull several material carts between the warehouse and different production areas.



Fig 2.2.16 Tractor- Trailer Truck

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d) Forklift Truck and Pallet Truck Systems

Forklift trucks are used to lift, transport, and stack materials, while pallet trucks are mainly used to move palletised loads over short distances. These systems are widely used in warehouses and manufacturing facilities.

Example: A warehouse may use forklifts to move pallets of packaged goods from storage racks to the loading area.



Fig 2.2.17 Fork Lift Trucks



Fig 2.2.18 Pedestrian Pallet Truck

e) Industrial Truck Systems

Industrial trucks are powered or manually operated vehicles used to transport materials within a plant or warehouse. They are useful for flexible movement where fixed equipment such as conveyors may not be suitable.

Example: Hand trucks, platform trucks, and powered industrial trucks can be used to move cartons and components between different departments.



Fig 2.2.19 Industrial trucks



Fig 2.2.20 Hand trucks



Fig 2.2.21 Platform Trucks

f) Underground Systems

Underground material handling systems transport materials through below-ground routes or tunnels, helping to keep floor-level areas free for production and movement.

Example: In some large industrial facilities, underground conveyors or transport systems may be used to move materials between processing and storage areas without interfering with surface activities.

2. Material-Oriented Systems

A material-oriented material handling system classifies handling methods according to the physical nature and form of the material being moved. The major types are:

a) Unit Handling Systems

Unit handling involves moving materials as individual units or groups of units, such as boxes, cartons, packages, pallets, or containers.

Example: Moving cartons of finished products using pallets and forklifts in a warehouse.

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b) Bulk Handling Systems

Bulk handling is used for transporting large quantities of loose materials without individual packaging or containers.

Example: Coal, cement, grains, sand, and minerals can be transported using conveyors, hoppers, or specialised bulk-handling equipment.

c) Liquid Handling Systems

Liquid handling systems are designed for the transportation, storage, and transfer of liquids through suitable equipment and pipelines.

Example: Petroleum, milk, chemicals, and water can be transferred using pumps and pipelines.

3. Method-Oriented Systems

A method-oriented material handling system classifies material handling according to the method or level of technology used to move materials.

a) Manual Systems

In manual handling systems, materials are moved mainly through human effort, using simple tools or equipment.

Example: Workers using hand trolleys to move cartons within a small warehouse.

b) Mechanised or Automated Systems

These systems use mechanical equipment or automated technology to move and handle materials, reducing dependence on manual labour.

Example: Forklifts, conveyors, robots, and Automated Guided Vehicles (AGVs) used in modern manufacturing facilities.

c) Job-Shop Handling Systems

Job-shop handling systems are designed for low-volume and high-variety production, where different products may require different processing routes and material movement patterns.

Example: In a customised engineering workshop, different components may move between turning, drilling, milling, welding, and inspection sections according to their individual requirements.

d) Mass-Production Handling Systems

These systems are designed for high-volume and repetitive production, where materials move continuously or systematically through a predetermined sequence of operations.

Example: In an automobile assembly plant, conveyors and automated handling

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equipment can continuously move components from one workstation to another.

4. Function-Oriented Systems

A function-oriented material handling system classifies handling activities according to the specific function performed during the movement of materials.

a) Transportation Systems

Transportation systems are used to move materials from one location to another, either within a facility or between different areas.

Example: Forklifts and industrial trucks transporting raw materials from a warehouse to the production area.

b) Conveying Systems

Conveying systems continuously or intermittently move materials along a predetermined path using equipment such as belt, roller, chain, or screw conveyors.

Example: A belt conveyor transporting packaged products from production to the dispatch section.

c) Transferring Systems

Transferring systems are used to shift materials from one position, workstation, or handling system to another.

Example: A transfer mechanism moving an automobile component from one production station to another.

d) Elevating Systems

Elevating systems are used to move materials vertically between different levels of a facility.

Example: Goods lifts, hoists, elevators, and vertical conveyors used to move materials between different floors of a warehouse

2.2.9.2 Types of Material Handling Equipment

Material handling equipment refers to the various machines, devices, and tools used for the movement, transportation, lifting, positioning, loading, unloading, and storage of materials within a facility. The appropriate equipment is selected based on factors such as the type, size, weight, quantity, distance, and frequency of material movement.

Material handling equipment can be broadly classified into four basic categories:

1. **Conveyors** – Equipment used to move materials continuously or intermittently along a fixed path.
2. **Cranes and Hoists** – Equipment used primarily for lifting and moving heavy materials, often vertically and horizontally within a defined area.

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Fig 2.2.22 Cranes



Fig 2.2.23 Electric Hoist

3. **Trucks** – Mobile equipment used to transport materials from one location to another. Examples include forklifts, platform trucks, hand trucks, and pallet trucks.

4. **Auxiliary Equipment** – Supporting equipment used to facilitate the handling, storage, positioning, and protection of materials. Examples include pallets, containers, racks, bins, and storage devices.



Fig 2.2.24 Expendable Pallet



Fig 2.2.25 Skid boxes



Fig 2.2.26 Double Deck Wood Pallet

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Summarised Overview

Plant layout refers to the systematic arrangement of machines, equipment, workstations, departments, storage areas, and other facilities within a plant to ensure smooth and efficient production. The major objectives of plant layout are to achieve effective utilisation of space and resources, minimise material movement and production delays, improve workflow, reduce operational costs, ensure employee safety, and provide flexibility for future expansion. Layout decisions are influenced by factors such as the nature of the product, production volume and variety, type of manufacturing process, availability of space, material flow, machinery, labour, storage requirements, safety, and future expansion. The major types of plant layout include product or line layout, process or functional layout, fixed-position layout, and combination or cellular layout. Layout planning involves analysing production requirements, determining space requirements, studying material and work flow, developing alternative arrangements, and selecting the most suitable layout using appropriate tools and techniques.

Material handling involves the movement, storage, protection, and control of raw materials, components, work-in-progress, and finished goods within an organisation. An effective material handling system aims to ensure safe, economical, efficient, and continuous movement of materials while minimising unnecessary handling and damage. Important principles include planning, standardisation, work minimisation, ergonomics, safety, system integration, space utilisation, and flexibility. Material handling systems may be manual, mechanised, semi-automated, or fully automated. Common material handling equipment includes conveyors, cranes, hoists, forklifts, industrial trucks, elevators, pallets, containers, and automated guided vehicles (AGVs). Proper integration of plant layout and material handling helps organisations improve productivity, reduce costs, minimise delays, enhance safety, and achieve efficient utilisation of facilities.

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Self-Assessment Question

1. Explain the concept of plant layout and discuss its major objectives and importance in achieving efficient production operations.
2. Describe the various factors affecting plant layout and explain how each factor influences the selection of an appropriate layout.
3. Explain and compare the different types of plant layouts, namely product layout, process layout, fixed-position layout, and combination layout, with suitable examples.

4. Apply the principles of layout planning to develop a suitable plant layout for a manufacturing organisation producing a standardised product in large quantities.

5. Analyse the role of layout planning tools and techniques such as flow charts, flow diagrams, travel charts, relationship charts, and systematic layout planning in improving plant efficiency.

6. Analyse the relationship between plant layout and material flow and explain how an effective layout can reduce material movement, delays, and production costs.

7. Explain the concept and objectives of material handling and discuss the major principles that should be followed while designing an effective material handling system.

8. Classify the different types of material handling systems and equipment and explain their applications in manufacturing and warehouse operations.

9. Evaluate the suitability of different material handling equipment, such as conveyors, cranes, hoists, forklifts, and automated guided vehicles, for different operational requirements.

10. Analyse the factors that should be considered while selecting material handling equipment for an organisation, including cost, safety, flexibility, capacity, and space requirements.

11. Evaluate the importance of integrating plant layout and material handling systems for improving productivity, safety, space utilisation, and operational efficiency.

12. Design a suitable plant layout and material handling system for a manufacturing organisation and justify the selection of the layout type, planning technique, handling system, and equipment.

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Assignments

1. A furniture manufacturing company is experiencing excessive movement of raw materials between departments, long production delays, and congestion in the work area. Analyse the existing situation and recommend a suitable plant layout with justification.

2. A food-processing company is planning to establish a new production facility. The company expects high production volume, limited product variety, and continuous production throughout the year. Evaluate the

factors affecting its plant layout and recommend the most appropriate type of layout.

3. An automobile component manufacturer has grouped similar machines together, but materials are travelling long distances between departments. Management wants to reduce material movement and production time. Analyse the limitations of the existing layout and suggest suitable layout planning tools and techniques.

4. A warehouse currently uses manual labour to move heavy materials. The organisation is facing high handling costs, frequent material damage, and workplace safety concerns. Evaluate the existing material handling system and recommend suitable equipment to improve efficiency and safety.

5. A company produces customised industrial machinery in small quantities. Each product remains at the production site for several months while workers, tools, machines, and materials are brought to it. Analyse the production characteristics and justify the most suitable type of plant layout.

6. A manufacturing unit is expanding its production capacity but has limited floor space. Management must decide how to rearrange departments, storage areas, machines, and material movement paths. Apply appropriate layout planning principles and tools to propose an improved arrangement.

7. An e-commerce warehouse handles thousands of orders every day and wants to introduce conveyors, forklifts, automated storage systems, and automated guided vehicles. Evaluate the suitability of these material handling systems and recommend an integrated system based on efficiency, cost, flexibility, and safety.

8. A manufacturing company has frequent accidents, damaged materials, unnecessary handling, and delays in transferring work-in-progress between departments. Analyse the causes of these problems and design an improved plant layout and material handling system that follows the principles of efficient material handling.

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PRACTICAL ACTIVITY

Create a basic layout plan for a small manufacturing unit (like a T-shirt printing unit or a snack factory), choose an appropriate location using any one location selection method, and explain the reasons for the choice. They will also suggest suitable material handling equipment based on the layout and product type.

Solution:

Case: Small T-Shirt Printing Unit

Business Selected: T-Shirt Printing Unit

Products: Printed cotton T-shirts

Scale: Small manufacturing unit

Production System: Small-batch and customised production

1. Basic Layout Plan

For a small T-shirt printing unit, a process-oriented layout with a simple linear flow is suitable because different orders may require different printing designs and quantities.

Suggested Layout Flow:

Raw Material Receiving

↓

Raw Material & T-Shirt Storage

↓

Design & Screen Preparation

↓

Printing Section

↓

Drying/Heat Pressing

↓

Quality Inspection

↓

Folding & Packing

↓

Finished Goods Storage

↓

Dispatch

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The office, staff area, washroom, and maintenance/storage area can be positioned along the sides of the production area without disturbing the main material flow.

2. Location Selection Method – Factor Rating Method

The Factor Rating Method can be used to select the most appropriate location. In this method, important location factors are identified, weights are assigned according to their importance, and each alternative location is rated. The weighted scores are then calculated and compared.

Suppose the three possible locations are:

- ◊ Location A – Industrial Estate
- ◊ Location B – Town Area
- ◊ Location C – Rural Area

The following factors can be considered:

Location Factor	Weight	A: Industrial Estate	B: Town Area	C: Rural Area
Availability of labour	20	9	8	6
Rent/land cost	20	8	5	9
Accessibility and transport	20	9	8	5
Availability of electricity and water	15	9	8	6
Proximity to suppliers	10	8	7	6
Market accessibility	10	8	9	5
Scope for expansion	5	9	4	8
Total weighted score	**100**	**855**	**695**	**635**

Calculation:

For each factor:

Weighted Score = Weight × Rating

The Industrial Estate receives the highest weighted score of 855 and is therefore selected as the most suitable location.

3. Reasons for Selecting the Industrial Estate

The Industrial Estate is selected because it provides:

1. Good transportation facilities for receiving blank T-shirts, printing materials, and packaging materials.

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2. Better availability of labour with manufacturing and printing-related skills.
3. Reliable electricity and water supply required for production.
4. Reasonable rental and operating costs compared with a busy town area.
5. Better access to suppliers, reducing transportation time and cost.
6. Suitable infrastructure for a small manufacturing unit.
7. Scope for future expansion if production increases.
8. Better waste-management and safety facilities than an unsuitable residential location.

4. Suitable Material Handling Equipment

The material handling equipment should be selected according to the size, weight, quantity, and movement requirements of the T-shirt printing unit.

a) Hand Trolley:

Used to move cartons of T-shirts, printing materials, and packaging materials between storage and production areas.

b) Pallets:

Used to store and move cartons of raw materials and finished products in an organised manner.

c) Pallet Truck:

Useful for moving loaded pallets over short distances between storage and production areas.

d) Storage Racks:

Used to store blank T-shirts, printing materials, inks, packaging materials, and finished products systematically.

e) Plastic Bins/Containers:

Suitable for storing small items such as labels, tags, printing accessories, and other consumables.

5. Reasons for Selecting the Equipment

The selected equipment is appropriate because the T-shirt printing unit handles relatively light and medium-weight materials, and the movement distances within the facility are short. Therefore, expensive automated handling systems are unnecessary at the initial stage. Hand trolleys, pallets, pallet trucks, racks, and containers provide flexibility, low investment cost, easy operation, and efficient material movement.

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6. Overall Proposed System

The proposed facility can be represented as:

Receiving → Raw Material Storage → Design/Screen Preparation → Printing → Drying/Heat Pressing → Quality Inspection → Folding & Packing → Finished Goods Storage → Dispatch

This arrangement ensures that materials move forward with minimum backtracking and unnecessary handling. Raw materials enter through the receiving area and progressively move through production until the finished T-shirts reach the dispatch section.

7. Expected Benefits

The proposed layout and material handling system will help the T-shirt printing unit to:

- ◊ Reduce unnecessary material movement.
- ◊ Minimise material handling costs.
- ◊ Utilise floor space effectively.
- ◊ Reduce production delays.
- ◊ Improve worker productivity.
- ◊ Maintain better workplace safety.
- ◊ Facilitate easy supervision.
- ◊ Reduce damage to materials and finished products.
- ◊ Support future expansion.
- ◊ Improve the overall efficiency of the manufacturing process.

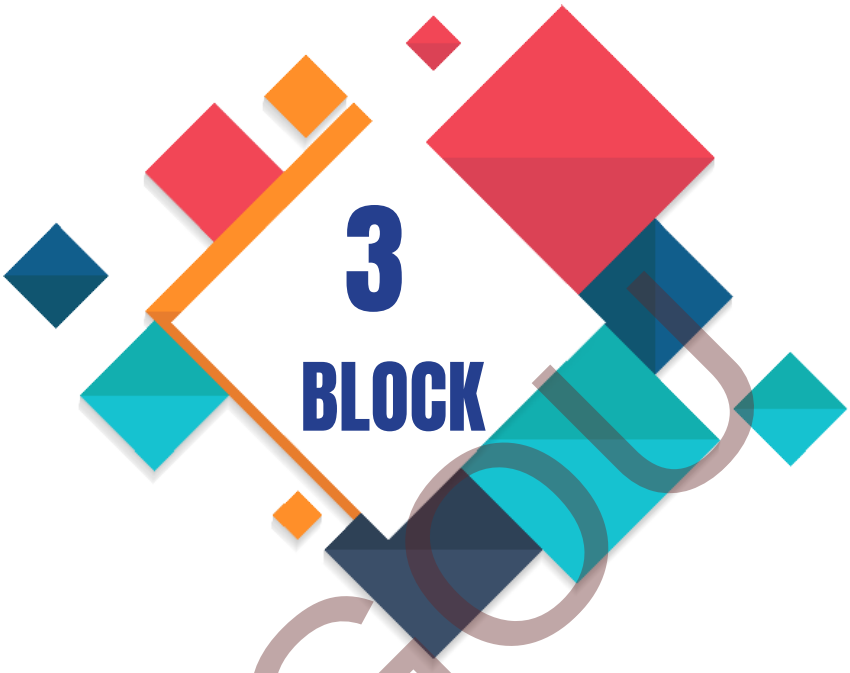
Conclusion: The Factor Rating Method identifies the Industrial Estate as the most suitable location, while a process-oriented layout with a forward material flow is appropriate for the small T-shirt printing unit. Simple equipment such as hand trolleys, pallets, pallet trucks, storage racks, and containers can provide economical and effective material handling without requiring substantial investment in automation.

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

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Inventory Management and Production Control

Unit 1

Inventory Management

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ explain the meaning, components, and objectives of inventory
- ◊ describe the different types of inventory costs
- ◊ examine the factors that influence inventory management and control
- ◊ compare continuous inventory system and periodic inventory system
- ◊ evaluate various inventory control techniques in detail

Background

Inventory management is a fundamental aspect of operations that ensures the right quantity of materials is available at the right time. It involves planning, organizing, and controlling the flow of goods from procurement to final consumption. The concept encompasses different types of inventories - such as raw materials, work-in-progress, and finished goods, each serving a specific role in maintaining production continuity and meeting customer demand. Effective inventory management balances availability with cost efficiency, preventing both shortages and excess stock.

Managing inventory requires understanding the costs associated with holding, ordering, and stockouts. These costs influence decisions on how much to order and when to replenish. Organizations adopt systems like continuous inventory (perpetual tracking) and periodic inventory (scheduled reviews) to monitor stock

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levels. Classification methods such as the ABC system help prioritize items based on value and usage, ensuring that critical items receive closer attention. Models like Economic Order Quantity (EOQ) and quantity discount approaches provide mathematical frameworks to minimize total inventory costs while meeting demand.

Beyond systems and models, inventory control techniques such as setting reorder levels and maintaining buffer stock act as safeguards against uncertainty. The reorder level triggers replenishment before stock runs out, while buffer stock provides a cushion against unexpected demand or supply delays. Together, these practices create a structured process that enhances efficiency, reduces waste, and supports smooth operations. By integrating classification, cost analysis, and control techniques, inventory management becomes a strategic tool for sustaining competitiveness and customer satisfaction.



Keywords

Inventory, Inventory Costs, Continuous Inventory System, Periodic Inventory System, ABC Classification, Economic Order Quantity (EOQ), Buffer Stock



Discussion

The management and control of inventory is a universal challenge faced by organizations in every sector of the economy. These issues are not limited to profit-oriented businesses; social and non-profit institutions encounter similar difficulties. Inventories are essential not only in industries and agriculture but also in diverse settings such as retail outlets, hospitals, religious institutions, prisons, zoos, universities, and government bodies at all levels.

Although societies have always grappled with inventory problems, systematic analytical approaches to study them emerged only in the 20th century. The manufacturing sector provided the initial drive for such analysis, recognizing the need for efficiency and cost control. After World War II, greater emphasis was placed on understanding risk and uncertainty in inventory management, leading to more structured methods of evaluation and control.

In theory, inventory management has become a well-developed area of organizational operations, supported by models and techniques. However, in practice, many organizations still lag in applying these methods effectively. This gap is expected to

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narrow as educational institutions increasingly incorporate materials management into their curricula, equipping future professionals with the knowledge and skills to address inventory challenges more systematically.

3.1.1 Concept of Inventory Management

Inventory refers to the stock of materials and goods maintained by an organization to ensure smooth operations and meet future demand. It includes raw materials, work-in-progress items, finished products, packaging materials, spare parts, and other supplies. The word "inventory" originates from the French *Inventaire* and the Latin *Inventariom*, both meaning a list of items found. Scholars have defined inventory as the tangible assets – such as raw materials, semi-finished goods, finished products, or merchandise - held at a given time, which can be seen, measured, and counted. In accounting, inventory also represents the value assigned to goods owned by a firm at a particular point in time.

Inventory management is the systematic process of ordering, storing, tracking, and selling a company's inventory, covering raw materials, components, and finished goods. It ensures the right products are available at the right time, prevents stockouts and overstocking, and balances costs with customer demand.

3.1.1.1 Importance of Inventory Management

The concept is crucial because inventory represents a significant investment for most businesses. Poor management can lead to stockouts, missed sales opportunities, dissatisfied customers, or conversely, overstocking that results in wastage, obsolescence, and high carrying costs. Effective inventory management helps businesses maintain smooth operations, reduce costs, and improve customer satisfaction.

3.1.1.2 Methods of Inventory Management

Several methods are used to manage inventory efficiently. Techniques such as Just-in-Time (JIT) ensure materials arrive only when needed, reducing storage costs. Economic Order Quantity (EOQ) helps determine the optimal order size to minimize total inventory costs. ABC analysis classifies items based on their importance and value, allowing managers to focus on critical stock. Modern businesses also rely on ERP systems and AI-driven forecasting to predict demand and automate replenishment.

3.1.1.3 Challenges in Inventory Management

Challenges in inventory management include demand fluctuations, perishability of goods, and the need for accurate forecasting. Industries such as retail, manufacturing, and food services face unique pressures in managing stock effectively. For example, retailers must balance seasonal demand, while manufacturers must coordinate raw materials and production schedules.

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3.1.2 Types of Inventories

1. **Production Inventories:** Production inventories consist of raw materials, components, and parts that enter into the manufacturing process. These may include items specifically designed and manufactured to company specifications, as well as standard industrial products purchased directly from suppliers. They form the foundation of production, ensuring that the firm has the necessary inputs to create its goods.

   Example: Steel sheets used in automobile manufacturing.

2. **MRO Inventories:** Maintenance, Repair, and Operating (MRO) inventories are supplies consumed during production but do not become part of the final product. Examples include lubricating oils, cleaning agents, and spare machine parts. Although they are not incorporated into the finished goods, they are vital for keeping machinery and operations running smoothly.

   Example: Lubricating oil used in textile machinery.

3. **In-Process Inventories**: In-process inventories, often referred to as work in progress, are semi-finished goods found at different stages of the production cycle. These items represent products that are partially completed and awaiting further processing. They are essential for maintaining a continuous flow in manufacturing and preventing bottlenecks.

   Example: Half-assembled smartphones on the production line.

4. **Finished Goods Inventories:** Finished goods inventories are completed products that are ready for sale or distribution. These stocks ensure that customer demand can be met promptly and that the organization can maintain a steady supply of goods in the market. They also provide flexibility in scheduling and delivery.

   Example: Packaged biscuits stored in a warehouse, ready for distribution.

5. **Operating Supplies:** Operating supplies include general consumables required to support production and organizational activities. These may range from packaging materials to office supplies and other items necessary for day-to-day functioning. While not directly part of the production process, they contribute to the overall efficiency of operations.

   Example: Cardboard boxes used for packaging finished products.

3.1.3 Inventory Costs

Managing inventory involves financial trade-offs, making cost analysis a crucial factor in inventory decisions. Total inventory expenses generally encompass four main categories: ordering costs, carrying costs, shortage (out-of-stock) costs, and capacity costs.

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3.1.3.1 Ordering Costs

Ordering costs are incurred whenever goods are requested, whether from external suppliers or internal manufacturing facilities.

◊ **External Purchases (Vendor Orders):** Expenses related to administrative processing, such as drafting purchase orders, completing payment transactions, and handling material inspection upon delivery.

Example: Cost of processing a purchase order for raw cotton from a supplier.

◊ **Internal Production (Plant Orders):** Costs associated with preparing manufacturing machinery for a new run, including machine setup times and initial material scrap generated during startup.

Example: Expense of recalibrating machines before producing a new batch of shoes.

3.1.3.2 Carrying Costs

Carrying costs represent the expenses associated with holding and storing inventory over time.

◊ **Material-Direct Expenses:** Financial losses resulting from items becoming outdated (obsolescence), spoiling or degrading in quality (deterioration), or being stolen (pilferage).

Example: Expired medicines in a pharmacy warehouse.

◊ **Financial & Administrative Overhead:** Recurring expenditures including property taxes, insurance premiums, facility storage costs, and the interest accrued on capital tied up in inventory.

Example: Monthly warehouse rent and insurance for storing electronic goods.

i. **Capital Costs (Subcategory of Carrying Costs):** Capital costs reflect the opportunity cost or interest paid on funds committed to holding stock:

◊ **Inventory Capital:** Interest paid or lost on the capital invested directly in acquiring stock.

Example: Interest lost on ₹10 lakh tied up in raw cotton inventory.

◊ **Facility Capital:** Interest on investments in the land and physical buildings designated for storage.

Example: Interest on funds invested in building a dedicated warehouse for finished goods.

◊ **Equipment Capital:** Interest tied up in machinery and systems purchased to handle, hold, and manage inventory operations.

Example: Interest on capital invested in forklifts and automated conveyor systems.

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ii. **Storage Space & Facility Costs**

Expenses required to secure and maintain physical warehouse spaces include:

- ◊ Facility rent, property taxes, building insurance, and structural depreciation.

  Example: Monthly rent and insurance for a rented warehouse storing electronics.

- ◊ Depreciation of warehouse installations and ongoing facility maintenance/ repairs.

  Example: Depreciation of installed shelving racks and repair of loading docks.

- ◊ Utility bills (heating, lighting, water) and compensation for facility security and maintenance staff.

  Example: Electricity bills for cold storage facilities and salaries for security guards.

iii. **Inventory Service Costs**

Expenses tied directly to managing stock operations and record-keeping:

- ◊ Inventory-specific taxes and labour costs for stock handling and maintenance.

  Example: Labour wages for workers handling pharmaceutical stock.

- ◊ Clerical costs associated with inventory tracking and record management.

  Example: Salaries of staff maintaining digital inventory records.

- ◊ Employee benefit packages for warehouse staff and administrative personnel.

  Example: Health insurance provided to warehouse employees.

iv. **Material Handling-Equipment Costs**

Costs associated with operating warehouse machinery and tools:

- ◊ Equipment depreciation, taxes, and specialised insurance policies.

  Example: Depreciation of forklifts used in a logistics hub.

- ◊ Operational fuel expenses alongside routine maintenance and repairs.

  Example: Diesel costs and maintenance for trucks used inside the warehouse.

v. **Inventory Risk Costs**

Financial hazards inherent to holding physical stock over time:

- ◊ Inventory obsolescence and physical deterioration.

  Example: Outdated mobile phones losing market value in storage.

- ◊ Losses resulting from pilferage/theft and the insurance coverage purchased to mitigate these risks.

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Example: Theft of spare parts from a warehouse and insurance claims filed.

3.1.3.3 Out-of-Stock Costs & Capacity-Related Expenses

i. **Shortage (Out-of-Stock) Costs:** Financial impacts incurred when stock is unavailable, resulting in back-ordering overhead or outright lost sales. Example: Lost sales when a clothing retailer runs out of popular sizes during peak season.

ii. **Capacity Costs:** Financial strains resulting from operational misalignment:

Under-Capacity: Overtime wages paid when facilities are too small for demand.

Example: Paying overtime to workers during festive season when demand exceeds production capacity.

Over-Capacity: Severance/lay-off costs and idle time expenses when facilities are excessively large.

Example: Idle machinery and lay-offs in a factory after demand drops post-holiday season.

3.1.4 Continuous Inventory Systems or Fixed Order Quantity System or 'Q' System

The Fixed Order Quantity System, also known as the Q System or Continuous Review System, is an inventory control system in which a fixed quantity of material is ordered whenever the inventory level reaches the predetermined Re-order Level.

The quantity ordered is generally based on the Economic Order Quantity (EOQ), while the time between orders is not fixed and depends on the rate of consumption.

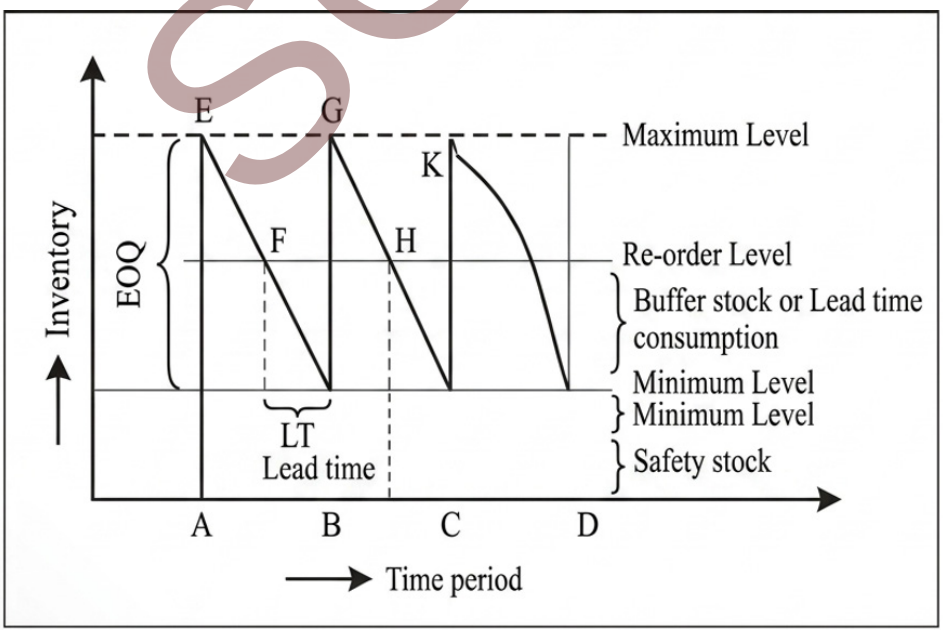


Fig 3.1.1 Continuous Inventory System

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1. Inventory Level

- ◊ The vertical axis represents the inventory level, while the horizontal axis represents the time period.

2. Maximum Level

- ◊ The Maximum Level represents the highest inventory level reached immediately after a new order is received.
- ◊ In the diagram, points E, G and K represent inventory levels after replenishment.

3. EOQ

- ◊ EOQ (Economic Order Quantity) represents the fixed quantity ordered each time the inventory reaches the Re-order Level.
- ◊ In the diagram, the vertical distance between the minimum level and the maximum level represents the EOQ.

4. Inventory Consumption

- ◊ After receiving the order, inventory gradually decreases as materials are consumed in production or issued to users.
- ◊ The downward lines from E to B and G to C show the reduction in inventory due to consumption.

5. Re-order Level

- ◊ The Re-order Level is the predetermined inventory level at which a new order is placed.
- ◊ In the diagram, points F and H represent the inventory reaching the Re-order Level.

6. Placing the Order

- ◊ When the inventory reaches the Re-order Level, a new order for the fixed EOQ quantity is immediately placed.
- ◊ The order is not received immediately because the supplier requires a certain amount of lead time.

7. Lead Time

- ◊ Lead time (LT) is the period between placing an order and receiving the ordered materials.
- ◊ In the diagram, when the inventory reaches point F, an order is placed, and the material is received at point B after the lead-time period.

8. Buffer Stock or Lead-Time Consumption

- ◊ During lead time, materials continue to be consumed even though the

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replenishment order has already been placed.

- ◊ The inventory maintained to cover this consumption is represented by the buffer stock or lead-time consumption.

9. Minimum Level

- ◊ The Minimum Level represents the lowest planned inventory level reached after the ordered materials arrive.
- ◊ In the diagram, points B and C indicate the minimum inventory level before the next replenishment raises the stock again.

10. Safety Stock

- ◊ Safety stock is the additional inventory maintained to protect the organisation against unexpected increases in demand or delays in supply.
- ◊ It acts as a protection against uncertainty during the replenishment period.

11. Replenishment at B

- ◊ At point B, the previously ordered EOQ is received, causing the inventory level to rise sharply from the minimum level to the maximum level at G.
- ◊ The same inventory cycle is then repeated.

12. Replenishment at C

- ◊ At point H, the inventory reaches the Re-order Level again, so another fixed-quantity order is placed.
- ◊ After the lead time, the order is received at C, and the inventory is replenished.

13. Variable Time Between Orders

- ◊ Unlike the P System, the time interval between two orders in the Q System is not necessarily fixed.
- ◊ If demand increases, inventory reaches the Re-order Level faster and a new order is placed sooner.
- ◊ If demand decreases, the inventory takes longer to reach the Re-order Level and the next order is placed later.

Key Characteristics of the Q System

- ◊ The order quantity is fixed, usually at the EOQ.
- ◊ Inventory is continuously monitored.
- ◊ An order is placed whenever inventory reaches the Re-order Level.
- ◊ The time between orders varies according to the rate of consumption.
- ◊ Lead time must be considered when determining the Re-order Level.

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- ◊ Safety stock is maintained to protect against demand and supply uncertainties.
- ◊ The system aims to maintain sufficient inventory while minimising ordering and holding costs.

The Q System follows the principle: "Continuously monitor inventory and order a fixed quantity whenever stock reaches the Re-order Level."

Q System = Continuous Review + Fixed Order Quantity + Re-order Level + Variable Order Interval.

Advantages of 'Q' System

The fixed order quantity system offers several operational benefits. The main advantages claimed are:

1. Each material can be procured in the most economical quantity.
2. Procurement and inventory management staff focus their attention automatically on items only when replenishment is required.
3. Total inventory investment can be controlled directly and kept at a target level simply by adjusting the predetermined maximum and minimum thresholds.

Disadvantages of 'Q' System

The disadvantages are that:

1. Orders are initiated at variable time intervals, which can create scheduling inconvenience for suppliers.
2. When procurement lead times are lengthy, such as three months, and ordering cycles occur monthly, multiple open orders accumulate with the vendor, creating a high likelihood that the supplier dispatches several orders simultaneously.
3. Items cannot be grouped together into consolidated purchase orders because individual reorder triggers occur at different, unpredictable times.
4. The calculated Economic Order Quantity (EOQ) may yield purchase volumes below the supplier's threshold for price discounts, while stock levels for a given item might reach the reorder threshold without immediate detection, increasing the risk of a stockout.
5. Additionally, the system relies on the premise of constant consumption rates and predictable lead times; when either fluctuates significantly, calculating a revised order volume and establishing a new reorder point becomes laborious.

3.1.5 Periodic Inventory Systems or Fixed-Order Periodic System or 'P' System

The Fixed-Order Periodic System, also known as the P System, is an inventory control system in which the inventory level is reviewed at fixed and predetermined

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time intervals. After each review, an order is placed for the quantity required to bring the inventory up to a desired or target level.

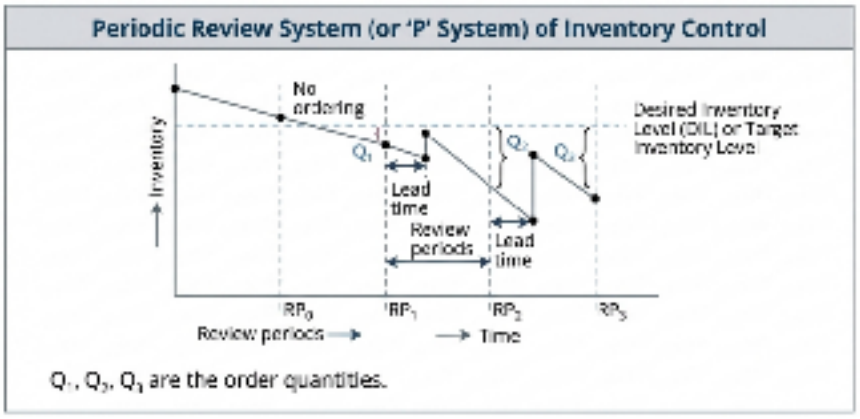


Fig 3.1.2 Periodic Inventory System

The diagram illustrates the Periodic Review System (P-System) of Inventory Control, where inventory levels are checked at fixed review periods (RP_0, RP_1, RP_2, RP_3) rather than continuously. At each review point, the current stock is compared with the desired inventory level (DIL), and an order quantity (Q_1, Q_2, Q_3) is placed to replenish stock up to that target. Since orders take time to arrive, a lead time is shown between placing and receiving them. Inventory gradually decreases over time due to usage or sales, and if it remains above the reorder point, no ordering is done until the next review. This system helps maintain stock at a planned level while balancing ordering costs and holding costs, though it risks shortages if demand spikes between review periods.

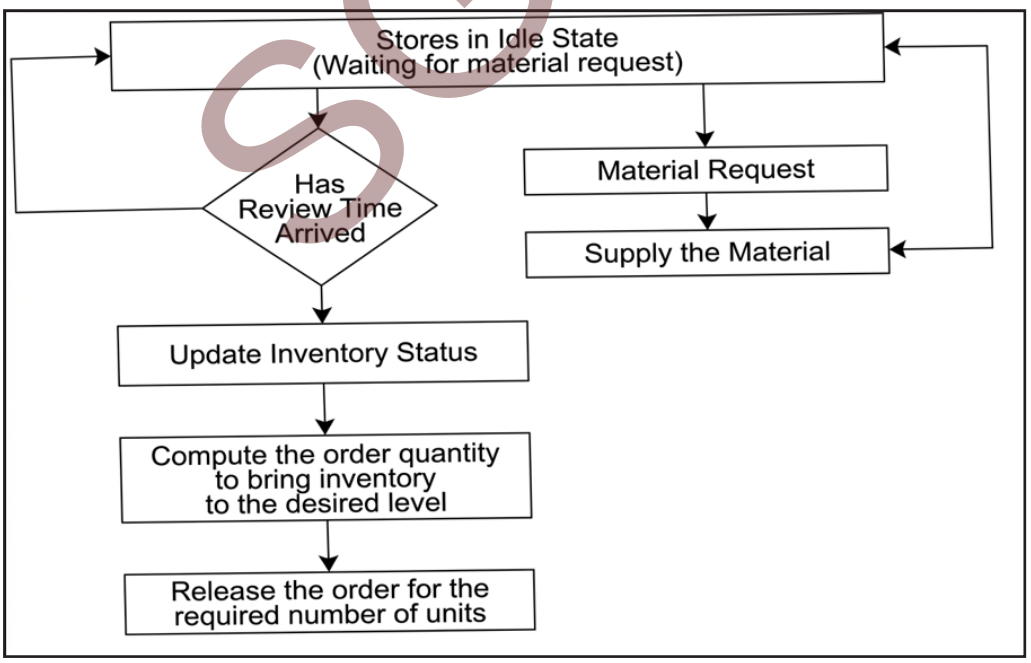


Fig 3.1.3 Fixed-Order Periodic System

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1. Stores in Idle State

The stores remain in an idle state while waiting for a material request or for the predetermined inventory review time to arrive.

2. Material Request

When a department requires materials, it sends a material request to the stores.

3. Supply the Material

The stores issue the required materials to the concerned department and the inventory level is consequently reduced.

4. Waiting for Review Time

After supplying materials, the stores continue to operate normally until the fixed review time arrives.

5. Has Review Time Arrived?

At the predetermined review date, the inventory position is checked to determine the quantity of stock currently available.

6. Update Inventory Status

The organisation updates the inventory records by considering the available stock, materials already ordered, materials received, and materials issued.

7. Compute the Order Quantity

The required order quantity is calculated to bring the inventory up to the desired inventory level.

The basic idea can be expressed as:

Order Quantity = Desired Inventory Level − Current Inventory Position

8. Release the Order

The calculated quantity is ordered from the supplier, and the order is released for the required number of units.

9. Repeat the Cycle

After placing the order, the system returns to the waiting stage, and the inventory is reviewed again at the next fixed interval.

Important Features of the P System

- ◊ Inventory is reviewed at fixed time intervals, such as weekly, fortnightly, or monthly.

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- ◊ The order quantity is not fixed and changes according to the inventory position at each review.
- ◊ Orders are generally placed only when the scheduled review takes place.
- ◊ The system aims to raise inventory to a predetermined target or desired level.
- ◊ The time between two inventory reviews remains constant.
- ◊ The system is useful when several items can be reviewed and ordered together at regular intervals.

The P System follows the principle: "Check the inventory at fixed intervals and order enough to restore it to the desired level." Thus, unlike a fixed-order-quantity system, the review period is fixed, but the order quantity varies according to the inventory position.

Advantages of 'P' System

The periodic review system provides several primary benefits:

1. It minimizes administrative and ordering expenses. Although individual shipments may require minor follow-ups, overall purchasing overhead is reduced.
2. Vendors are more inclined to grant bulk discounts because purchase volumes and recurring sales are guaranteed.
3. It is ideal for managing items with seasonal or unpredictable demand patterns, allowing procurement to be scheduled ahead using demand forecasts.

Disadvantages of 'P' System

The periodic system also has notable drawbacks:

1. Mandatory fixed-schedule evaluations across all items can create operational inefficiencies. Low-consumption items might not require reordering until a subsequent cycle, while high-consumption items could run out before the scheduled review date. To mitigate stockouts caused by sudden demand surges, a safety threshold must be established to trigger emergency reorders.
2. To keep administration manageable, order sizes are often standardized rather than optimized. While an ideal Economic Order Quantity (EOQ) exists for every item based on holding costs and unit price, forcing products into set evaluation schedules causes real order sizes to deviate significantly from their optimal economic batch sizes.
3. Administrative workload becomes concentrated in spikes surrounding the review dates rather than being spread evenly over time.

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Difference between 'Q' System and 'P' System

Table No:- 3.1.1 - Difference between 'Q' System and 'P' System

Sl.No	Q-System	P-System
1.	Fixed order quantity system	Fixed time period system
2.	Event triggered	Time triggered
3.	Fixed order quantity	Order quantity varies
4.	Continuous inventory updation	Updation only before the review
5.	Comparatively less inventory	More inventory
6.	Suitable for freely available materials	Suitable for scarce materials.

3.1.6 The ABC Classification System

The ABC system is a technique used to categorize inventory items based on criteria such as their monetary value to the organization. In manufacturing and retail, companies often manage thousands of independent demand items, but only a small fraction contributes significantly to the overall inventory value. Typically, about 5–15% of items account for 70–80% of the total inventory value; these are designated as Class A items and require strict monitoring. Class B items usually represent around 30% of inventory units but only 15% of the value, while Class C items make up 50–60% of the units yet contribute just 5–10% of the value. For instance, a discount retailer like Walmart may stock relatively few televisions (Class A), a moderate number of bicycles or bed sheets (Class B), and hundreds of low-cost products such as soap, shampoo, or batteries (Class C).

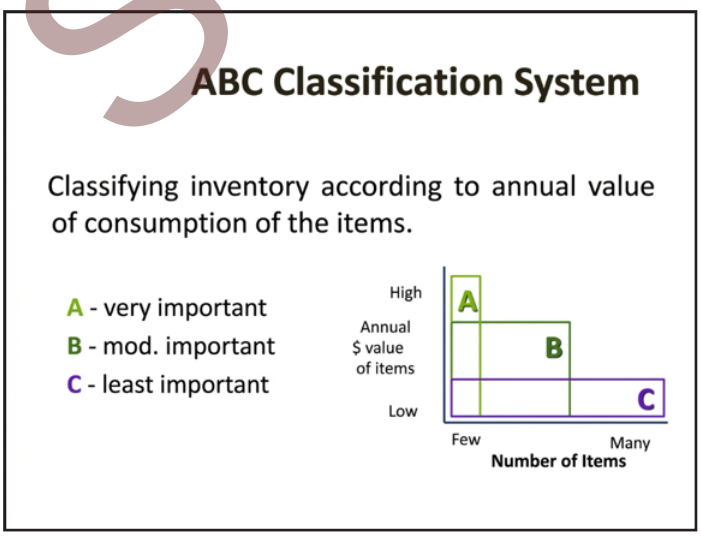


Fig 3.1.4 ABC Classification System

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In practice, each class demands different levels of control. Class A items need close supervision, accurate forecasting, and minimal safety stock because of their high value. Class B and C items, on the other hand, can be managed with less stringent methods, sometimes relying on periodic reviews or simple observation. Historically, continuous monitoring was considered too costly for all items, but the widespread use of bar code scanning has made it feasible even for large inventories.

The process of ABC analysis begins by calculating the annual dollar value of each item (unit cost × annual demand). Items are then ranked and divided into categories, top 10% as A, next 30% as B, and the remaining 60% as C. While these proportions are approximate, they are consistently observed across industries. Beyond cost, other factors such as supply scarcity or long lead times may also justify assigning higher priority to certain items. For example, a company in Australia sourcing parts from Europe might classify those items as higher priority due to extended delivery times.

3.1.7 Economic Order Quantity Models

In a continuous or fixed-order-quantity system, inventory is replenished whenever it falls to a predetermined level known as the reorder point. At this stage, a fixed quantity is ordered. The most common and traditional approach for deciding how much to order is the Economic Order Quantity (EOQ) model, also called the economic lot-size model. The concept was first formally derived in 1915 by Ford Harris of Westinghouse.

The EOQ model's main purpose is to identify the optimal order quantity that minimizes the total cost of inventory management. These costs include ordering costs (expenses incurred each time an order is placed) and carrying costs (expenses related to holding inventory). Several versions of the EOQ model exist, depending on the assumptions made about the inventory system, two major ones being the basic EOQ model and the production quantity model.

Basic EOQ Model

The **basic EOQ model** determines the ideal order size that minimizes the combined total of ordering and carrying costs. It is based on several simplifying assumptions:

- ◊ Demand is known and constant over time.
- ◊ No shortages are permitted.
- ◊ Lead time (the time between placing and receiving an order) is constant.
- ◊ The entire order quantity is received at once.

Under these conditions, inventory is replenished in fixed quantities (Q). As stock is consumed steadily, a new order is placed when inventory reaches the reorder point (R). The delivery arrives exactly when the inventory level reaches zero, ensuring no stockouts. This cycle repeats continuously with the same order quantity, reorder point, and lead time.

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Cost Relationship

The EOQ model balances two opposing costs:

◊ Ordering cost decreases as order size increases (fewer orders needed).

◊ Carrying cost increases with larger order sizes (more inventory held).

The optimal order quantity (EOQ) is the point where these two costs are equal, minimizing total inventory cost.

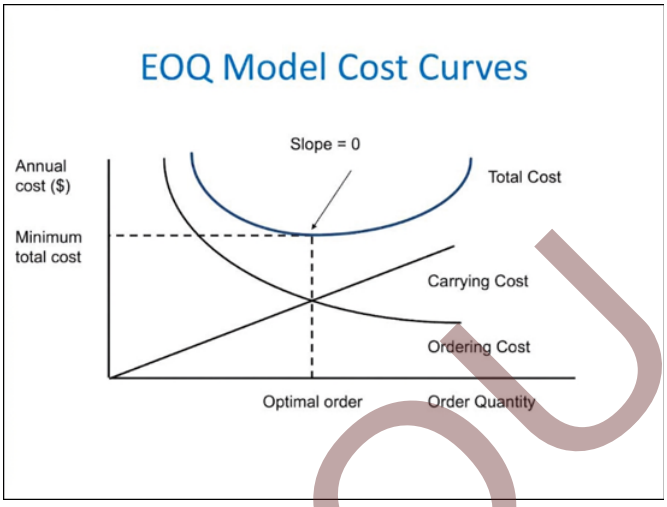


Fig 3.1.5 **EOQ model**

The correct formula for Economic Order Quantity (EOQ) is:

$$EOQ = Q^* = \sqrt{\frac{2DC_0}{C_h}}$$

Where:

◊ D= Annual demand (units per year)

◊ C_0= Ordering cost per order (₹ or $ per order)

◊ C_h= Holding (or carrying) cost per unit per year (₹ or $ per unit per year)

Problem

Q) The annual demand for an item is 3200 units. The unit cost is Rs. 6/- and inventory carrying charges 25% per annum. If the cost at one procurement is Rs. 150/- determine:

i. EOQ

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ii. Number of orders per year

iii. Time between two consecutive orders

iv. TIC*

v. Total optimal cost including purchase cost

Solution

Given

◊ Annual demand (D) = 3200 units

◊ Unit cost = ₹6

◊ Inventory carrying charges = 25% per annum

◊ Ordering cost (C_0) = ₹150 per order

Step 1: Holding Cost per Unit per Year (C_h)

C_h = Carrying charge × Unit cost

$C_h = 0.25 \times 6 = ₹1.50$ per unit per year

Step 2: EOQ Formula

$$EOQ = \sqrt{\frac{2DC_0}{C_h}}$$

$$EOQ = \sqrt{\frac{2 \times 3200 \times 150}{1.5}}$$

$$EOQ = \sqrt{\frac{960{,}000}{1.5}} = \sqrt{640{,}000}$$

$EOQ = 800$ units

Step 3: Number of Orders per Year

$$\text{Number of Orders} = \frac{D}{EOQ}$$

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$$\text{Number of Orders} = \frac{3200}{800} = 4 \text{ orders per year}$$

Step 4: Time Between Two Consecutive Orders

$$\text{Time between orders} = \frac{12 \text{ months}}{\text{Number of Orders}}$$

$$\text{Time between orders} = \frac{12}{4} = 3 \text{ months}$$

Step 5: Total Inventory Cost (TIC\)*

$TIC^* = \text{Ordering Cost per year} + \text{Holding Cost per year}$

◊ Ordering cost per year: $\frac{D}{EOQ} \times C_0 = 4 \times 150 = ₹600$

◊ Holding cost per year: $\frac{EOQ}{2} \times C_h = \frac{800}{2} \times 1.5 = 400 \times 1.5 = ₹600$

$TIC^* = 600 + 600 = ₹1200$

Step 6: Total Optimal Cost Including Purchase Cost

Total Cost = Purchase Cost + TIC^*

Purchase Cost = $D \times$ Unit cost = $3200 \times 6 = ₹19,200$

Total Cost = $19,200 + 1,200 = ₹20,400$

Final Results:

◊ EOQ = 800 units

◊ Number of orders per year = 4

◊ Time between orders = 3 months

◊ TIC* = ₹1200

◊ Total optimal cost including purchase cost = ₹20,400

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3.1.8 Quantity Discounts in Inventory Management

Quantity discounts refer to price reductions offered by suppliers when buyers purchase larger quantities of goods. The main purpose of these discounts is to encourage bulk buying, which benefits both the seller and the buyer. For the seller, it ensures higher sales volume and reduces handling or shipping costs per unit. For the buyer, it lowers the per-unit cost and can lead to significant savings in procurement. However, purchasing in bulk also increases inventory holding costs, so firms must carefully analyse whether the discount justifies the additional storage expense.

There are generally two types of quantity discounts: all-unit discounts and incremental discounts. In an all-unit discount, the reduced price applies to all units purchased once the quantity threshold is met. For example, if a supplier offers ₹100 per unit for orders below 500 units and ₹90 per unit for orders above 500, buying 600 units means paying ₹90 for each unit. In incremental discounts, the reduced price applies only to the units beyond the threshold. For instance, if the first 500 units cost ₹100 each and any additional units cost ₹90, buying 600 units means paying ₹100 for the first 500 and ₹90 for the remaining 100.

Quantity Discount EOQ model:

Case 1: When Discount is Allowed (Order Quantity = Q)

$$TC(Q) = \frac{D}{Q} \cdot C_0 + \frac{Q}{2} \cdot C_h' + C' \cdot D$$

- ◊ D= Annual demand
- ◊ C_0= Ordering cost per order
- ◊ C_h'= Holding cost per unit per year (based on discounted price)
- ◊ C'= Unit price after discount
- ◊ Q= Order quantity (must meet discount condition)

Case 2: When EOQ is Followed (No Discount)

$$TC(Q^*) = \sqrt{2DC_0C_h} + C \cdot D$$

- ◊ Q^*= EOQ without discount
- ◊ C_h= Holding cost per unit per year (based on original price)

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◊ C= Original unit price

Decision Rule

◊ Accept discount if:

$$TC(Q) < TC(Q^*)$$

◊ Otherwise, order the EOQ quantity Q^*.

Problem

A factory requires 1500 units of an item per month, each costing Rs.27. The cost per order is Rs. 150 and the inventory carrying charges work out to 20% of the average inventory. Find out the EOQ and the number of orders per year. Would you accept a 2% price discount on a minimum supply quantity of 1200 no: s ? Compare the total costs in both the cases.

Solution

Given

◊ Monthly demand = 1500 units

◊ Annual demand (D) = $1500 \times 12 = 18{,}000$units

◊ Unit cost (C) = ₹27

◊ Ordering cost (C_0) = ₹150 per order

◊ Carrying charges = 20% of unit cost

$$C_h = 0.20 \times 27 = ₹5.40 \text{ per unit per year}$$

Discount offered: 2% if order quantity ≥ 1200 units. Discounted price (C') =

$$27 \times 0.98 = ₹26.46$$

Step 1: EOQ (without discount)

$$EOQ = \sqrt{\frac{2DC_0}{C_h}}$$

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$$EOQ = \sqrt{\frac{2 \times 18{,}000 \times 150}{5.4}}$$

$$EOQ = \sqrt{\frac{5{,}400{,}000}{5.4}} = \sqrt{1{,}000{,}000}$$

$$EOQ = 1000 \text{ units}$$

Step 2: Number of Orders per Year

$$\text{Orders per year} = \frac{D}{EOQ} = \frac{18{,}000}{1000} = 18 \text{ orders}$$

Step 3: Total Cost at EOQ (No Discount)

$$TC(Q^*) = \frac{D}{Q^*} \cdot C_0 + \frac{Q^*}{2} \cdot C_h + C \cdot D$$

◊ Ordering cost $= \frac{18{,}000}{1000} \times 150 = 18 \times 150 = ₹2700$

◊ Holding cost $= \frac{1000}{2} \times 5.4 = 500 \times 5.4 = ₹2700$

◊ Purchase cost $= 27 \times 18{,}000 = ₹486{,}000$

$$TC(Q^*) = 2700 + 2700 + 486{,}000 = ₹491{,}400$$

Step 4: Total Cost with Discount (Q = 1200)

$$TC(Q) = \frac{D}{Q} \cdot C_0 + \frac{Q}{2} \cdot C_h' + C' \cdot D$$

◊ Ordering cost $= \frac{18{,}000}{1200} \times 150 = 15 \times 150 = ₹2250$

◊ Holding cost $= \frac{1200}{2} \times (0.20 \times 26.46)$

$$= 600 \times 5.292 = ₹3175.20$$

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◊ Purchase cost = $26.46 \times 18{,}000 = ₹476{,}280$

$$TC(Q) = 2250 + 3175.20 + 476{,}280 = ₹481{,}705.20$$

Step 5: Comparison

◊ Without discount (EOQ = 1000 units): ₹491,400

◊ With discount (Q = 1200 units): ₹481,705.20

Final Answer

◊ EOQ = 1000 units

◊ Number of orders per year = 18

◊ Accept the discount, because total cost with discount (₹481,705.20) is lower than total cost at EOQ (₹491,400).

3.1.9 Reorder Level

The **reorder level** is the point at which new stock must be ordered to avoid running out of inventory. It acts as a trigger mechanism in a continuous inventory system, ensuring that replenishment happens before stockouts occur. The reorder level is calculated based on the average consumption rate of an item and the lead time required for suppliers to deliver. In simple terms, it ensures that by the time new stock arrives, the existing inventory has not yet been fully depleted.

For example, suppose a company sells 50 units of a product per day, and the supplier takes 10 days to deliver an order. The reorder level would be 50 × 10 = 500 units. This means that when inventory falls to 500 units, a new order should be placed. By the time the order arrives after 10 days, the company would have used up those 500 units, and the new stock would arrive just in time to continue operations without interruption.

Re-order Level

◊ The reorder point is the level of inventory at which a new order should be placed.

◊ This is the point fixed between maximum and minimum stock levels.

◊ ROL = Average usage of inventory x Lead time

◊ ROL= Safety Stock + Normal Lead time consumption

◊ Normal lead time Consumption = (Monthly /Daily Consumption x Lead Time)

◊ Lead Time: When an order is placed, it may be received immediately or it may take some time for the receipt. The time between the placement of an order and its actual arrival in the inventory is known as the lead time.

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3.1.10 Buffer Stock

Buffer stock, also known as safety stock, is the extra quantity of inventory maintained to protect against uncertainties in demand and supply. It acts as a cushion that ensures operations continue smoothly even when unexpected events occur, such as sudden spikes in customer demand or delays in supplier deliveries. The main purpose of buffer stock is to prevent stockouts, which can disrupt production schedules or lead to lost sales.

For example, imagine a pharmaceutical company that sells 1,000 units of a medicine every week. If the supplier usually takes two weeks to deliver but sometimes delays by three weeks, the company may keep an additional 1,000 units as buffer stock. This ensures that even if the supplier is late, the company can still meet customer demand without interruption. Similarly, a supermarket might maintain extra stock of essential items like rice or cooking oil during festive seasons when demand is unpredictable.

Buffer Stock (Safety Stock)

- ◊ This is the additional stock needed to allow for delay in delivery or for any higher-than-expected demand that may arise during the lead time.
- ◊ Buffer stock (BS) = (Maximum lead time – Normal lead time) x r
- ◊ Where 'r' is the consumption rate during the lead time or normal lead time.
- ◊ Maximum inventory = BS + Q*
- ◊ Minimum Inventory = BS
- ◊ Average inventory = BS + 1/2 Q*

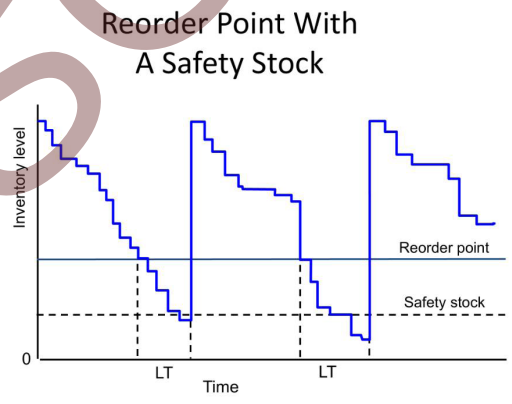


Fig 3.1.6 Reorder Point with Safety Stock

Problem

Calculate the various parameters for putting an item with following data on EOQ system. Annual consumption is 12,000 units at the cost of Rs.7.50 per unit. Set up cost

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is Rs.6.00 and the average inventory holding cost is 12% p.a. Normal lead time is 15 days and maximum lead time is 20 days.

Solution

Given Data

- ◊ Annual demand (D) = 12,000 units
- ◊ Unit cost (C) = ₹7.50
- ◊ Ordering cost (C_0) = ₹6.00 per order
- ◊ Carrying charges = 12% of unit cost

$$C_h = 0.12 \times 7.50 = ₹0.90 \text{ per unit per year}$$

- ◊ Normal lead time = 15 days
- ◊ Maximum lead time = 20 days

Step 1: EOQ

$$EOQ = \sqrt{\frac{2DC_0}{C_h}}$$

$$EOQ = \sqrt{\frac{2 \times 12{,}000 \times 6}{0.90}}$$

$$EOQ = \sqrt{\frac{144{,}000}{0.90}} = \sqrt{160{,}000}$$

$$EOQ = 400 \text{ units}$$

Step 2: Number of Orders per Year

$$\text{Orders per year} = \frac{D}{EOQ} = \frac{12{,}000}{400} = 30 \text{ orders}$$

Step 3: Cycle Time (Time Between Orders)

$$\text{Cycle time} = \frac{12 \text{ months}}{30} = 0.4 \text{ months} \approx 12 \text{ days}$$

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Step 4: Reorder Level (ROL)

Reorder level is based on maximum lead time:

Daily demand = $\frac{12{,}000}{365} \approx 32.88$ units/day

ROL = Daily demand × Maximum lead time

$$ROL = 32.88 \times 20 \approx 658 \text{ units}$$

Step 5: Safety Stock

Safety stock = (Maximum lead time – Normal lead time) × Daily demand

$$= (20 - 15) \times 32.88 \approx 164 \text{ units}$$

Step 6: Average Inventory

$$\text{Average inventory} = \frac{EOQ}{2} + \text{Safety stock}$$

$$= \frac{400}{2} + 164 = 200 + 164 = 364 \text{ units}$$

Final Results

- ◊ EOQ = 400 units
- ◊ Number of orders per year = 30
- ◊ Cycle time = 12 days
- ◊ Reorder level = 658 units
- ◊ Safety stock = 164 units
- ◊ Average inventory = 364 units

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Summarised Overview

Inventory management is the practice of balancing stock availability with cost efficiency, using tools and models to guide decision-making. It covers different types of inventories, raw materials, work-in-progress, and finished goods, while accounting for costs like ordering, carrying, and stockouts. Systems such as continuous (fixed-order-quantity) and periodic reviews help track and replenish stock, while methods like the ABC classification system prioritize items based on their value contribution. Models like the Economic Order Quantity (EOQ) determine the most economical order size, and strategies such as quantity discounts, reorder levels, and buffer stock ensure smooth operations by minimizing costs, preventing shortages, and safeguarding against demand or supply uncertainties. Together, these concepts form a structured framework that enhances efficiency, reduces waste, and maintains customer satisfaction.

Self-Assessment Question

1. Explain the concept, objectives and importance of inventory management in an organisation.
2. Describe the different types of inventories with suitable examples.
3. Explain the various costs associated with inventory management.
4. Describe the continuous inventory system and periodic inventory system, highlighting their main features.
5. Explain the ABC classification system and its role in effective inventory control.
6. Explain the concept of Economic Order Quantity (EOQ) and its importance in inventory management.
7. Describe the reorder level and its significance in inventory management.
8. What is buffer stock? Explain its importance.
9. Explain the concept of quantity discounts and their influence on purchasing decisions.
10. The annual demand for a component is 5,000 units. Each unit costs ₹8, and the annual inventory carrying charge is 25% of the unit cost. The ordering cost is ₹100 per order. Calculate EOQ, the number of orders per year, the time between orders, TIC and total optimal cost, including purchase

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cost. (**Answer:** H = Rs.2, EOQ = 707.11 units, N = 7.07 orders, T = 51.62 days, TIC = Rs. 1,414.21, Total optimal cost including purchase cost = Rs. 41,414.21)

11. A business requires 2,400 units of a material annually. The purchase price is ₹15 per unit. The inventory carrying charge is 20% per annum, and the ordering cost is ₹120 per order. Determine:

    a. Economic Order Quantity

    b. Number of orders per year

    c. Time between orders

    d. Total Inventory Cost

    e. Total optimal cost including purchase cost

    (**Answer:** H = Rs. 3, EOQ = 438.18 units, N = 5.48 orders, T = 66.64 days approximately, TIC = ₹1,314.53, Total optimal cost including purchase cost = ₹ 37,314.53)

12. A manufacturing company requires 800 units of a component per month. Each unit costs ₹30, the ordering cost is ₹120 per order, and the annual carrying charge is 20% of the average inventory value. The supplier offers a 2% discount for orders of 1,500 units or more.

    Find the EOQ, the number of orders per year, the total annual cost without the discount and the total annual cost with the discount. Advise the company whether to accept the offer.

    (**Answer:** H = Rs. 6, EOQ = 619.68 units, N = 15.49 orders, TC (without discount) = Rs. 2,91,718.06, TC (with discount) = Rs. 2,87,418, Decision = Accept discount)

13. A company requires 2,000 units of a material per month. The purchase price is ₹12 per unit, the ordering cost is ₹80 per order, and the annual carrying charge is 25% of the average inventory value. The supplier offers a 1.5% discount for a minimum order quantity of 2,000 units.

    Calculate the EOQ, the number of orders per year and the total annual costs under both alternatives. Decide whether the company should accept the discount.

    (**Answer:-** H = Rs.3. EOQ = 1,131.37 units, N = 21.21 orders, TC (without discount) = Rs. 2,91,394.12, TC (with discount) = Rs. 2,87,595, Decision = Accept discount)

14. A manufacturing firm consumes 18,000 units of a component annually. Each unit costs ₹5, and the ordering cost is ₹40 per order. The annual holding charge is 15% of the unit cost. Normal lead time is 8 days and

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maximum lead time is 12 days.

Calculate EOQ, the number of orders per year, the time between orders, annual ordering cost, annual holding cost, reorder level and safety stock.

(**Answer:-** H = Rs. 0.75, EOQ = 1,385.64 units, N = 12.99 orders, T = 28.10 days approximately, Annual ordering cost = Rs. 519.98 approximately, Annual holding cost = Rs. 519.62 approximately, Reorder level = 592 units approximately, Safety stock = 197 units approximately)

15. A business consumes 6,000 units of a raw material annually at ₹18 per unit. The ordering cost is ₹75 per order, and the annual holding charge is 20% of the unit cost. Normal lead time is 6 days and maximum lead time is 10 days.

    Determine EOQ, the number of orders per year, the time between orders, annual ordering cost, annual holding cost, reorder level and safety stock.

    (**Answer:-** H = Rs. 3.60, EOQ = 500 units, N = 12 orders, T = 30.42 days approximately, Annual ordering cost = Rs. 900, Annual holding cost = Rs. 900, Reorder level = 165 units approximately, Safety stock = 66 units approximately)



Assignments

1. Evaluate the effectiveness of the ABC classification system as a tool for inventory control.
2. Assess the suitability of continuous and periodic inventory systems for small and large business organisations.
3. Evaluate the importance of the EOQ model in minimising total inventory costs.
4. Critically evaluate the advantages and limitations of accepting quantity discounts when purchasing inventory.
5. Assess the importance of maintaining buffer stock in balancing inventory costs and uninterrupted production.
6. Evaluate the role of effective inventory management in improving organisational profitability and operational efficiency.
7. A manufacturing company frequently experiences delays in production because raw materials are unavailable, while large quantities of finished goods remain unsold. Explain how effective inventory management can help overcome these problems.

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8. A business maintains raw materials, semi-finished goods, finished products and spare parts. Explain the significance of maintaining these different categories of stock.

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

SGOU

Unit 2

Production Planning and Control

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ explain the meaning, functions, factors and objectives of production planning and production control
- ◊ identify the functions and organisational structure of the Production Planning and Control (PPC) department
- ◊ apply production planning principles to develop suitable aggregate production plans based on organisational requirements
- ◊ evaluate capacity requirements to determine the adequacy of production resources for meeting planned production targets
- ◊ develop appropriate Materials Requirement Planning (MRP) approaches by integrating production schedules, material requirements and available resources

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Background

The concept of Production Planning and Control (PPC) emerged during the Industrial Revolution of the eighteenth and nineteenth centuries when industries shifted from small-scale craft production to large-scale factory systems. Early manufacturers faced challenges in coordinating labour, machines, and materials efficiently. Pioneers such as Adam Smith highlighted the benefits of division of labour, while the rapid expansion of factories created a need for systematic planning of production activities. During this period, production management primarily focused on increasing output and reducing manufacturing costs through better organization of work.

A significant advancement occurred in the early twentieth century with the

development of Scientific Management by Frederick W. Taylor. Taylor emphasized standardization, work measurement, and systematic production scheduling to improve efficiency. Later, Henry Gantt introduced the Gantt Chart, which became an important tool for planning and tracking production activities. The growth of mass production systems, particularly in automobile manufacturing led by Henry Ford, further strengthened the importance of planning production processes, controlling workflow, managing inventory, and ensuring optimal utilization of resources. These developments laid the foundation for modern Production Planning and Control systems.

After World War II, increasing industrial complexity, globalization, and technological advancements transformed PPC into a more sophisticated managerial function. The introduction of computers enabled techniques such as Aggregate Planning, Capacity Planning, and Materials Requirement Planning (MRP), which helped organizations forecast demand, allocate resources, and manage inventories more effectively. With the advent of Enterprise Resource Planning (ERP), Just-in-Time (JIT), Lean Manufacturing, and Industry 4.0 technologies, PPC evolved into an integrated decision-making system that coordinates production activities across the entire supply chain. Today, PPC plays a crucial role in achieving productivity, quality, cost efficiency, and customer satisfaction in modern manufacturing and service organizations.

Keywords

Production Planning, Production Control, Aggregate Planning, Capacity Planning, Materials Requirement Planning (MRP), Scheduling

Discussion

Production Planning and Control (PPC) is an important function of operations management that ensures the efficient and systematic conversion of inputs such as materials, labour, machines and capital into finished goods and services. Production planning involves deciding what to produce, how much to produce, when to produce and what resources are required, while production control ensures that the planned activities are carried out according to schedule, quality and cost requirements. Effective PPC helps an organisation make the best use of its resources, minimise production delays and wastage, maintain optimum inventory levels and meet customer demand on time. This topic covers the meaning, functions, factors and objectives of production planning, the functions and organisation of the PPC department, and important planning techniques such as aggregate planning, capacity planning and Materials Requirement Planning (MRP).

SGOU

3.2.1 Production and Operations Planning and Control (PPC)

Production and Operations Planning and Control (PPC) is a vital function in management that ensures resources are utilised efficiently to meet organisational goals. It involves forecasting demand, designing production schedules, and coordinating materials, machines, and manpower to achieve timely delivery of goods and services. The essence of PPC lies in balancing supply with demand, reducing waste, and maintaining quality standards while keeping costs under control.

There are three main stages in Production Planning and Control (PPC). They are:

1. **Planning:** Planning involves selecting the most suitable option from various alternatives for using the available resources efficiently and economically to achieve the desired objectives.

2. **Operations:** Operations refer to carrying out production activities according to the specifications, schedules and procedures established in the production plan.

3. **Control:** Control involves monitoring actual performance through feedback and comparing the results achieved with the planned targets. Any deviations are identified and appropriate corrective measures are taken to improve performance and achieve the desired results.

The planning phase focuses on anticipating future requirements and preparing strategies to meet them. This includes demand forecasting, capacity planning, and scheduling. For example, a car manufacturer must plan how many vehicles to produce in a quarter, considering customer demand, available raw materials, and workforce capacity. Effective planning ensures smooth workflow and prevents bottlenecks in production.

The control phase ensures that actual performance aligns with planned targets. It involves monitoring production activities, comparing them with schedules, and taking corrective actions when deviations occur. For instance, if a textile factory faces machine breakdowns that delay output, control measures such as rescheduling or reallocating resources are applied to maintain delivery commitments. Control thus acts as a feedback mechanism that keeps operations on track.

3.2.2 Production Planning and Control Functions

The functions of Production Planning and Control (PPC) cover all activities required to plan, organise, coordinate and monitor production. The major functions of PPC are explained below with suitable examples.

a) Materials

PPC ensures the procurement, storage, inventory control and issue of materials required for production. The right quantity of materials must be available at the right time without maintaining excessive inventory.

Example: A furniture manufacturer ensures that sufficient wood, nails, screws and

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varnish are available before production begins.

b) Methods

This function involves deciding the processes, operations and sequence of activities required to manufacture a product efficiently. PPC determines the most suitable method of production.

Example: In making a wooden chair, the sequence may be cutting the wood, shaping the parts, drilling, assembling, polishing and packing.

c) Machines and Equipment

PPC is responsible for the selection, allocation and effective utilisation of machines and equipment. Jobs are assigned to suitable machines according to their capacity and availability.

Example: In a garment factory, cutting machines are allocated for fabric cutting, while sewing machines are assigned for stitching.

d) Routing

Routing determines the path or sequence through which materials and work should move during production. It specifies the order in which different operations are performed.

Example: In a bakery, the production route for bread may be mixing → kneading → fermentation → shaping → baking → cooling → packing.

e) Estimating

Estimating involves determining the time required to complete each production operation, along with the resources needed. Accurate estimates help in preparing realistic production schedules.

Example: A company may estimate that assembling one table requires 30 minutes and polishing it requires another 20 minutes.

f) Loading and Scheduling

Loading and scheduling involve preparing the production timetable, assigning work priorities and allocating jobs to machines or workers. This ensures that production is completed within the required time.

Example: A printing company may schedule 500 brochures to be printed on Monday morning and 1,000 product labels on Monday afternoon.

g) Dispatching

Dispatching means authorising the commencement of production activities according to the approved plan and schedule. It releases work orders, materials and instructions to the relevant departments.

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Example: A factory supervisor issues a work order authorising workers to begin producing 1,000 units of a particular product.

h) Expediting or Progressing

Expediting involves following up production activities, identifying delays and maintaining records of work progress. It helps ensure that production remains on schedule.

Example: If a machine breaks down and delays production, the PPC department follows up with the maintenance team and takes corrective action to minimise the delay.

i) Inspection

Inspection involves checking the quality of materials, components and finished products during the production process. It ensures that products meet the required standards and specifications.

Example: In a bottled-water plant, bottles are inspected for cleanliness, correct filling levels and proper sealing before dispatch.

j) Evaluating or Controlling

This function involves assessing actual production performance against planned targets and taking corrective action when deviations occur. It helps improve productivity, quality, cost efficiency and delivery performance.

Example: If the planned production is 1,000 units per day but only 850 units are produced, the PPC department investigates the reasons and takes suitable corrective measures.

3.2.3 Production Planning

Production planning is the systematic organisation of the overall manufacturing or operating system to produce a product in the required quantity, quality and time, using available resources such as materials, labour, machines and money efficiently. It involves deciding what to produce, how much to produce, when to produce and what resources and methods are required.

3.2.3.1 Factors Determining Production Planning Procedures

The production planning procedure varies from one organisation to another. It mainly depends on the following three factors:

1. Volume of Production

The volume of production refers to the quantity of products that an organisation plans to manufacture. The production planning method differs depending on whether the production volume is low, medium or high.

- ◊ **Low-volume production:** Usually requires flexible planning because products may be customised.

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- ◊ **Medium-volume production:** Requires systematic scheduling and efficient allocation of resources.
- ◊ **High-volume production:** Requires detailed planning, standardisation and continuous monitoring because even a small interruption can affect a large number of products.

Example:

A furniture workshop producing 20 customised tables per month will require flexible production planning. In contrast, a company producing 10,000 identical plastic bottles per day needs highly structured planning, automated processes and continuous material supply.

2. Nature of Production Processes

The nature of the production process refers to the type of manufacturing system used to convert raw materials into finished products. Different processes require different planning procedures.

Production may involve job production, batch production, mass production or continuous production.

- ◊ In job production, each product may be different, so planning focuses on individual customer requirements.
- ◊ In batch production, products are manufactured in groups or batches, requiring careful scheduling between batches.
- ◊ In mass production, standardised products are produced in large quantities, requiring detailed scheduling and machine coordination.
- ◊ In continuous production, production operates continuously for long periods, requiring uninterrupted supply of materials and close process control.

Example:

A customised wedding dress follows job production, so the plan is prepared according to the individual customer's measurements and design. A bakery producing 500 cakes in batches needs batch-wise planning. A car manufacturing plant requires highly coordinated mass-production planning.

3. Nature of Operations

The nature of operations refers to the type, complexity and sequence of activities involved in producing a product. Production planning must consider the number of operations, their sequence, processing time, machines required and skills of workers.

When operations are simple and repetitive, planning is relatively straightforward. When operations are complex and interdependent, detailed planning and coordination are required.

SGOU

Example:

In a bottling plant, operations such as filling, capping, labelling and packing are repetitive and follow a fixed sequence. Therefore, planning can be standardised. In contrast, manufacturing an aircraft involves thousands of complex operations performed by different teams, requiring detailed production planning and coordination.

3.2.4 Objectives of Production Planning

The main objective of production planning is to ensure that production activities are carried out systematically, efficiently and economically so that the required products are produced in the right quantity, at the right time and with the desired quality. The important objectives are:

1. **To meet production targets:** To ensure that the required quantity of products is manufactured according to the production schedule.
2. **To ensure timely production:** To complete production within the planned time and ensure timely delivery to customers.
3. **To make optimum use of resources:** To utilise materials, labour, machines, equipment and other resources efficiently and avoid unnecessary idle time.
4. **To minimise production costs:** To reduce unnecessary expenditure, wastage, overtime and other avoidable production costs.
5. **To maintain optimum inventory:** To ensure adequate availability of raw materials, work-in-progress and finished goods without excessive stock.
6. **To ensure smooth flow of production:** To coordinate different production activities and prevent bottlenecks, interruptions and delays.
7. **To maintain quality standards:** To plan production in such a way that products are manufactured according to the required specifications and quality standards.
8. **To achieve balanced utilisation of machines and labour:** To distribute work properly among available machines and workers and reduce idle capacity.
9. **To reduce wastage:** To minimise the wastage of raw materials, labour time, machine capacity and other resources.
10. **To improve productivity:** To increase the quantity and quality of output obtained from the available resources.
11. **To coordinate different departments:** To establish effective coordination among purchasing, stores, production, quality control, maintenance and other departments.
12. **To provide flexibility:** To enable the organisation to adjust production plans

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when there are changes in customer demand, material availability, machine capacity or market conditions.

3.2.5 Production Control

Production control is the process of monitoring and regulating production activities to ensure that the actual production performance follows the planned schedule. It involves coordinating activities, identifying deviations, providing feedback and taking corrective action so that products are manufactured in the required quantity, quality and time, while making the best use of available resources.

1. Production of the Required Quality and Quantity at the Required Time

Production control ensures that the right quantity of products is produced, according to the required quality standards and within the specified time. It prevents overproduction, underproduction and delays in delivery.

Example: A mobile phone manufacturer receives an order for 5,000 phones to be delivered by the end of the month. Production control monitors the manufacturing process to ensure that all 5,000 phones are produced on time and meet the required quality standards.

2. Coordination, Monitoring and Feedback

Production control coordinates different production activities, monitors progress and provides feedback to management. If actual production differs from the plan, corrective action can be taken.

Example: If a garment factory plans to produce 1,000 shirts per day but produces only 800 because of a machine breakdown, the production control department reports the problem to management and coordinates with the maintenance department to restore production.

3. Optimum Utilisation of Resources

Production control aims to ensure the effective utilisation of materials, labour, machines, equipment and production facilities. It reduces idle time, wastage and unnecessary use of resources.

Example: In an automobile factory, production control allocates different jobs to available machines so that machines do not remain idle while other machines are overloaded.

4. Low-Cost Production and Reliable Customer Service

Production control helps to reduce production costs by minimising wastage, delays, idle time, rework and unnecessary inventory. At the same time, it ensures reliable customer service by supporting on-time delivery of quality products.

Example: A bakery carefully controls the quantity of ingredients, production

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schedules and inventory levels to avoid wastage. This helps reduce costs while ensuring that customers receive fresh products when required.

3.2.6 Functions of PPC Department

The major functions of the PPC Department are:

1. Routing
2. Scheduling
3. Dispatching
4. Progressing

1. Routing

Routing defines the path that raw materials, parts, or assemblies must follow through the production process. It specifies what work has to be done, where it will be carried out, and how it will be executed. This ensures that operations flow logically from one stage to another, minimizing confusion and delays. Routing also determines the sequence of operations, the machines to be used, and the departments involved, creating a structured roadmap for production. By establishing a clear route, the PPC department can identify potential bottlenecks and streamline processes. Proper routing reduces waste, ensures consistency, and improves efficiency. In industries with complex workflows, routing is essential for maintaining order and achieving uniform quality across products. It essentially acts as the blueprint for the entire production system.

Example: In automobile manufacturing, routing specifies that raw steel is first sent to the stamping department, then to welding, painting, and finally assembly.

2. Scheduling

Scheduling involves assigning specific time frames for each stage of production. It determines when a job should start and when it should be completed, ensuring that tasks are carried out in the right order and within deadlines. Scheduling balances workloads across machines and workers, preventing idle time and overburdening.

Example: In a textile mill, scheduling ensures that weaving begins immediately after spinning is completed, avoiding machine downtime.

Facility loading, or machine loading, is a critical part of scheduling. It refers to deciding which jobs should be assigned to which machines or work centers. This ensures that resources are used optimally and that no machine is left underutilized or overloaded. Effective scheduling and loading help maintain a steady rhythm of operations, align production with delivery schedules, and meet customer demand on time.

Example: In a furniture factory, machine loading assigns cutting tasks to one set of machines and polishing tasks to another to balance workloads.

SGOU

3. Dispatching

Dispatching is the process of issuing production orders to the shop floor. It involves giving instructions, authorizations, and materials to start specific tasks. Dispatching bridges the gap between planning and execution, ensuring that workers and machines begin operations at the right time. There are two kinds of dispatching: centralized dispatching, where instructions are issued from a central authority, and decentralized dispatching, where decisions are made at individual work centers. Centralized dispatching provides uniformity and control, while decentralized dispatching offers flexibility and quicker responses to local conditions.

Example: In an electronics plant, dispatching issues work orders to start circuit board assembly once raw materials are ready.

This function provides clarity and direction to the workforce, reducing downtime and confusion. Without dispatching, even the best schedules cannot be implemented effectively. It ensures that production flows smoothly from one stage to the next, keeping operations aligned with the overall plan and enabling timely completion of tasks.

Example: In a printing press, dispatching ensures that paper rolls and ink are supplied to machines exactly when needed to avoid stoppages.

4. Progressing

Progressing, also known as follow-up, refers to monitoring and evaluating the progress of production activities. It involves checking whether operations are being carried out as planned and identifying deviations or delays. Progressing ensures accountability and allows managers to take corrective action when necessary. The objective of progressing is to minimize variations from the plan and ensure smooth execution.

Example: In a shipyard, progressing tracks whether hull construction is on schedule and identifies delays in welding operations.

This function is vital for maintaining quality and efficiency. By tracking progress, companies can detect problems early, adjust schedules, and improve future planning. Progressing also generates valuable data for continuous improvement, making production systems more resilient and adaptable to changing demands.

Example: In a pharmaceutical company, progressing monitors batch production timelines and adjusts schedules if quality testing takes longer than expected.

3.2.6.1 Elements of Scheduling

a) Demand Forecast

Demand forecasting is the starting point of scheduling. It involves predicting future customer demand based on historical data, market trends, and seasonal variations. Accurate forecasts help organizations plan production levels, allocate resources, and avoid shortages or excess inventory. By anticipating demand, companies can align their production schedules with market needs. This reduces uncertainty, ensures timely

SGOU

delivery, and supports better decision-making in procurement, workforce planning, and capacity utilization.

Example: A toy manufacturer forecasts higher demand during the holiday season and increases production accordingly.

b) Aggregate Scheduling

Aggregate scheduling focuses on medium-term planning, typically spanning 3–18 months. It balances overall demand with available production capacity by determining workforce size, inventory levels, and production rates. This element ensures that resources are allocated efficiently across product lines. Aggregate scheduling provides a framework for detailed plans, helping organizations maintain stability while adapting to fluctuations in demand.

Example: A cement factory plans production for the next year by balancing workforce shifts and raw material supply to meet construction industry demand.

c) Production Plan

The production plan translates aggregate schedules into specific operational targets. It outlines what products will be manufactured, in what quantities, and within which timeframes. This plan serves as a roadmap for departments, ensuring coordination between procurement, manufacturing, and distribution. A well-prepared production plan minimizes bottlenecks and ensures smooth workflow across the organization.

Example: A bakery prepares a weekly plan to produce 10,000 loaves of bread and 5,000 cakes, coordinating procurement of flour and sugar.

d) Master Production Schedule (MPS)

The MPS is a detailed timetable that specifies when each product will be produced. It breaks down the production plan into weekly or daily schedules, aligning closely with customer orders and delivery commitments. By providing precise timelines, the MPS ensures that production activities are synchronized with demand. It also helps in monitoring progress, adjusting schedules, and maintaining customer satisfaction through timely delivery.

Example: An electronics company uses MPS to schedule daily assembly of 500 smartphones to meet online customer orders.

e) Priority Planning

Priority planning determines which jobs or orders should be executed first. It ensures that urgent or high-value tasks are given precedence, preventing delays in critical deliveries. This element helps balance competing demands, especially when resources are limited. By setting clear priorities, organizations can meet deadlines, maintain customer trust, and optimize resource usage.

Example: A printing press prioritizes urgent government election ballot orders over routine commercial printing jobs.

SGOU

f) Capacity Planning

Capacity planning evaluates whether available resources, machines, labour, and facilities, can meet production requirements. It identifies gaps between demand and capacity, enabling adjustments such as overtime, outsourcing, or investment in new equipment. Effective capacity planning prevents overloading and underutilization. It ensures that production schedules are realistic and achievable, reducing stress on resources and avoiding costly disruptions.

Example: An automobile plant adds overtime shifts when demand for cars exceeds normal production capacity.

g) Facility Loading

Facility loading, or machine loading, involves assigning specific jobs to machines or work centers. It ensures that workloads are distributed evenly and that no machine is left idle or overburdened. By optimizing machine usage, facility loading enhances efficiency and reduces downtime. It also supports smooth workflow, ensuring that production targets are met without bottlenecks.

Example: In a textile factory, facility loading assigns weaving tasks to one set of machines and dyeing tasks to another to balance workloads.

h) Evaluation of Workload

This element involves assessing the workload assigned to each resource, machines, workers, and departments. It ensures that tasks are manageable and aligned with capacity.

i) Evaluation

Evaluation helps identify imbalances, such as overworked machines or underutilized labour. By addressing these issues, organizations can improve efficiency, reduce fatigue, and maintain consistent productivity.

Example: In a textile mill, evaluation reveals that weaving machines are overworked while dyeing machines remain idle, prompting workload redistribution.

j) Sequencing

Sequencing determines the order in which jobs should be performed. It ensures that tasks are arranged logically to minimize setup time, reduce delays, and optimize workflow. Proper sequencing improves efficiency by reducing idle time and ensuring smooth transitions between operations. It also enhances customer satisfaction by prioritizing urgent orders and maintaining timely deliveries.

Example: In a printing press, sequencing ensures that urgent election ballot printing is completed before routine magazine jobs.

SGOU

3.2.6.2 Types of Scheduling

There are mainly three types of scheduling; they are mentioned below:

a) Master Production Schedule (MPS)

The Master Production Schedule is a detailed plan that specifies what products need to be produced, in what quantities, and when. It translates customer demand and forecasts into a production timetable, ensuring that manufacturing activities are aligned with delivery commitments. MPS provides a structured framework for daily and weekly operations, helping managers allocate resources effectively. By breaking down aggregate plans into specific tasks, MPS ensures that production runs smoothly and meets deadlines. It also serves as a communication tool across departments, linking marketing, procurement, and manufacturing. A well-prepared MPS minimizes uncertainty, balances workloads, and ensures customer satisfaction through timely delivery.

Example: An automobile company uses MPS to schedule weekly production of 2,000 cars aligned with dealer orders.

b) Detailed Scheduling

Detailed scheduling focuses on assigning specific jobs to machines, workers, and work centers with precise start and finish times. Unlike MPS, which provides a broader overview, detailed scheduling deals with the finer aspects of production, ensuring that every task is executed in the correct sequence. This type of scheduling helps reduce idle time, avoid bottlenecks, and maintain a steady workflow. It ensures that resources are used optimally and that production targets are met efficiently. Detailed scheduling is particularly important in industries with complex processes, where precision and coordination are critical.

Example: In a pharmaceutical plant, detailed scheduling assigns exact times for mixing, testing, and packaging of medicines.

c) Machine Loading

Machine loading, also known as facility loading, involves assigning jobs to specific machines or work centers. It ensures that workloads are distributed evenly and that no machine is left underutilized or overloaded. Proper loading balances capacity with demand, preventing delays and maximizing efficiency. By carefully allocating tasks, machine loading reduces downtime and enhances productivity. It also supports smooth workflow across departments, ensuring that production schedules are realistic and achievable. This function is crucial for maintaining consistency and avoiding disruptions in manufacturing operations.

Example: In a shoe factory, machine loading assigns cutting tasks to one set of machines and stitching tasks to another to balance workloads.

SGOU

3.2.7 Organisation of PPC Department

The size and structure of a Production Planning and Control (PPC) department largely depend on the responsibilities assigned by top management, the clarity of corporate objectives, and the scale and complexity of the manufacturing operations. Typically, the PPC manager reports directly to senior leadership such as the production manager, factory manager, or general manager of the production unit.

The core functions of the PPC department include routing, scheduling, dispatching, and progressing, each of which plays a vital role in ensuring that production activities are well-organised, resources are efficiently utilised, and output is delivered on time. These functions will be explained in detail in the following section.

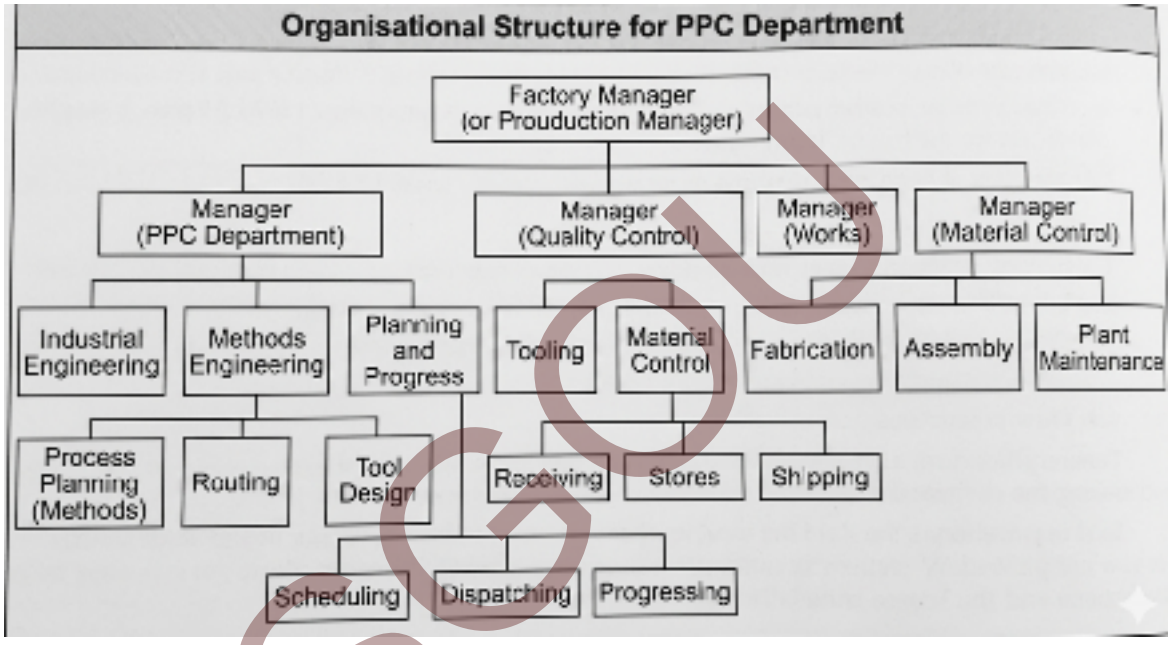


Fig 3.2.1 Organisational structure for the PPC department

The diagram illustrates the organisational structure of a Production Planning and Control (PPC) Department in a manufacturing organisation. At the top of the hierarchy is the Factory Manager (or Production Manager), who holds overall responsibility for production operations. The Factory Manager coordinates and supervises various functional departments to ensure smooth production, quality standards, efficient resource utilization, and timely delivery of products. Reporting directly to the Factory Manager are four major managerial positions: Manager (PPC Department), Manager (Quality Control), Manager (Works), and Manager (Material Control).

The Manager of the PPC Department plays a central role in planning, coordinating, and controlling production activities. This department consists of Industrial Engineering, Methods Engineering, and Planning and Progress sections. Industrial Engineering is responsible for Process Planning (Methods), which involves determining the best production processes and techniques. Methods Engineering focuses on work simplifi-

SGOU

cation and develops efficient manufacturing procedures through activities such as Routing and Tool Design. Routing determines the sequence of operations through which a product passes, while Tool Design involves creating and selecting tools, jigs, fixtures, and equipment necessary for manufacturing. The Planning and Progress section monitors production activities and ensures that planned schedules are achieved.

A key function under PPC is Scheduling, Dispatching, and Progressing. Scheduling determines when production activities should occur and allocates time for each operation. Dispatching involves issuing production orders and authorizing the commencement of work at various stages. Progressing, also known as follow-up, monitors actual production against planned schedules and identifies delays or bottlenecks. Together, these activities ensure effective coordination and timely completion of production processes.

The Quality Control Department, headed by the Manager (Quality Control), ensures that products meet the required quality standards. This department includes Tooling and Material Control functions. Tooling is responsible for maintaining and managing production tools and equipment required for manufacturing operations. Material Control oversees the flow of materials from procurement to final dispatch. Under Material Control are the functions of Receiving, Stores, and Shipping. Receiving handles incoming raw materials and components, Stores manages inventory and material storage, and Shipping is responsible for dispatching finished goods to customers.

The Manager (Works) is responsible for the actual manufacturing operations and supervises the Fabrication and Assembly departments. Fabrication involves transforming raw materials into components through machining, cutting, welding, or other manufacturing processes. Assembly combines manufactured parts into finished products. The Works Department ensures efficient production execution and maintains production continuity.

The Manager (Material Control) oversees the availability and movement of materials within the organisation. This department is closely associated with inventory management and production support activities. It also supervises Plant Maintenance, which ensures that machines, equipment, and facilities remain in proper working condition. Effective plant maintenance minimizes breakdowns, reduces downtime, and enhances overall productivity.

Overall, the structure demonstrates how various departments such as Production Planning and Control, Quality Control, Works, and Material Control work together under the leadership of the Factory Manager. The integration of planning, scheduling, quality assurance, material management, manufacturing operations, and maintenance ensures efficient production, optimum resource utilization, cost control, and timely delivery of quality products to customers.

3.2.8 Aggregate Production Planning (APP)

Aggregate Production Planning (APP) is concerned with determining the resource capacity a firm will need to meet demand over an intermediate time horizon, typically

SGOU

6 to 12 months. Within this period, the focus is on balancing demand forecasts with available resources to ensure smooth operations. APP provides a framework that bridges long-term strategic planning and short-term scheduling, ensuring that production goals are realistic and achievable.

Because the horizon is intermediate, APP does not involve major expansions like building new facilities or purchasing large equipment. Instead, it emphasizes adjustments that can be made within existing capacity to meet demand effectively.

Example: A car manufacturer may forecast higher demand during the festive season. Instead of building a new plant, they plan overtime shifts and subcontract certain parts to suppliers to meet the surge.

a. Feasible Adjustments

During this time frame, firms can make practical adjustments to manage demand and capacity. These include hiring or laying off workers, increasing or reducing the work week, adding extra shifts, subcontracting work, or using overtime. Inventory levels can also be built up during low-demand periods and depleted during peak demand to balance fluctuations.

Such measures provide flexibility without requiring heavy capital investment. They allow firms to respond quickly to changes in demand while maintaining efficiency and minimizing disruptions in production.

Example: A textile company may hire temporary workers before wedding season to handle increased orders, while reducing staff during off-season months.

b. Strategic Importance

APP plays a strategic role in ensuring that resources are used optimally while meeting customer requirements. By carefully planning workforce levels, inventory policies, and production rates, firms can reduce costs, avoid bottlenecks, and maintain customer satisfaction. It also helps management evaluate trade-offs between different options, such as overtime versus subcontracting, or inventory buildup versus flexible workforce adjustments.

Ultimately, APP ensures that organizations remain competitive by aligning production capacity with market demand. It provides stability in operations while allowing flexibility to adapt to changing business conditions, making it a cornerstone of effective production planning and control.

Example: An electronics company may decide between subcontracting circuit board assembly or using overtime in-house, depending on which option is cheaper and faster to meet holiday demand.

c. Aggregate Planning: -Determine overall levels of

- ◊ Production
- ◊ Work force

SGOU

◊ Inventory

To meet future demand at minimum cost.

1. Production

In aggregate planning, determining the overall level of production is crucial because it sets the foundation for meeting future demand. Managers must forecast demand accurately and decide how much output is required within a given time horizon, usually 6 to 12 months. This ensures that production capacity is neither underutilized nor overstretched.

Production planning involves balancing available resources such as machinery, raw materials, and technology with forecasted demand. Adjustments may include increasing production rates during peak seasons or reducing them during low-demand periods. These decisions help maintain a steady flow of goods without creating bottlenecks or shortages.

By carefully planning production levels, firms can achieve stability in operations, reduce waste, and ensure customer satisfaction. It also allows organizations to evaluate trade-offs, such as whether to rely on overtime, subcontracting, or inventory buildup, to meet demand efficiently.

Example: A bakery may increase bread production during Christmas by running machines longer hours, while reducing production after the season to avoid wastage.

2. Workforce

The workforce is a critical factor in aggregate planning because labour availability directly influences production capacity. Managers must determine the optimal number of workers required to meet forecasted demand while avoiding excessive labour costs. This involves decisions about hiring, layoffs, overtime, and flexible work arrangements.

Adjusting workforce levels provides flexibility in responding to demand fluctuations. For instance, during peak demand, firms may hire temporary workers or schedule additional shifts, while in low-demand periods, they may reduce working hours or rely on a smaller workforce. These adjustments help balance labour costs with productivity.

Effective workforce planning ensures that employees are utilized efficiently without compromising morale or stability. It also minimizes disruptions by aligning labour supply with production needs, thereby supporting both efficiency and effectiveness in aggregate planning.

Example: An ice cream factory may hire seasonal workers during summer months when demand is high, but reduce staff during winter when sales drop.

3. Inventory

Inventory plays a strategic role in aggregate planning by acting as a buffer between fluctuating demand and stable production capacity. Managers must decide how much inventory to build up during low-demand periods and how much to deplete during high-

SGOU

demand periods. This helps maintain a smooth supply chain and prevents stockouts or excess storage costs.

Inventory management involves trade-offs between holding costs, ordering costs, and shortage costs. Firms must balance these factors to minimize expenses while ensuring product availability. For example, building inventory in advance may reduce overtime costs later, but it increases storage expenses. Conversely, keeping inventory low reduces holding costs but risks unmet demand.

By optimizing inventory levels, organizations can achieve cost efficiency and customer satisfaction simultaneously. Proper inventory planning ensures that products are available when needed, supports continuous production, and strengthens the overall effectiveness of aggregate planning.

Example: A toy company may build up inventory before December to meet Christmas demand, even though storage costs rise, because shortages would hurt sales and customer trust.

3.2.8.1 Objectives and Central Concepts of Aggregate Production Planning (APP)

1. Match Supply and Demand (Effectiveness)

The foremost objective of APP is to ensure that supply aligns with demand over the planning horizon. This means that production levels, workforce size, and inventory must be coordinated to meet customer requirements without significant shortages or surpluses. When supply and demand are balanced, firms can deliver products on time, maintain customer satisfaction, and avoid disruptions in the market.

Achieving this balance requires accurate demand forecasting and flexible production strategies. APP allows managers to adjust workforce levels, production rates, and inventory policies to respond to fluctuations in demand. For example, during peak seasons, firms may rely on overtime or subcontracting, while in low-demand periods, they may reduce production or build inventory for future use.

Effectiveness in APP is not just about meeting demand but doing so consistently and reliably. By matching supply with demand, firms strengthen their reputation, build customer trust, and maintain competitiveness in dynamic markets. This objective emphasizes responsiveness and stability in operations.

Example: A smartphone company may subcontract assembly to external vendors during new product launches to meet high demand, while reducing production after the launch period to avoid excess inventory.

2. Minimize Costs (Efficiency)

The second major objective of APP is efficiency, which focuses on minimizing costs while meeting demand. Production planning involves significant expenses related to labour, materials, inventory storage, and machine utilization. APP helps managers

SGOU

evaluate trade-offs between different options to ensure that resources are used optimally and costs are kept under control.

For instance, firms must decide whether it is more economical to hire temporary workers, pay overtime, or subcontract work during peak demand. Similarly, inventory decisions involve balancing holding costs against shortage costs. By carefully analysing these alternatives, APP enables organizations to choose the most cost-effective strategies without compromising quality or customer satisfaction.

Efficiency in APP directly contributes to profitability. By reducing waste, avoiding unnecessary expenses, and optimizing resource utilization, firms can deliver products at competitive prices. This objective ensures that organizations remain financially sustainable while maintaining operational flexibility, making efficiency a cornerstone of successful aggregate planning.

Example: A furniture manufacturer may choose to build inventory during off-season months when labour costs are lower, instead of paying overtime during peak demand, thereby saving overall production expenses.

3. Central Concept – Aggregate Production Planning

Aggregate Production Planning serves as the operational bridge between strategic long-term goals and short-term execution. It focuses on balancing overall supply and demand over an intermediate horizon, typically 3 to 18 months, by managing high-level resource categories rather than individual product items. By harmonizing production capabilities with market requirements, this process allows organizations to optimize capacity, lower operating costs, and maintain steady workflow.

It sets the baseline framework from which detailed master scheduling and inventory control activities are subsequently derived.

Example: An automobile company may use APP to plan overall production of different car models for the next year, ensuring that resources like labour, raw materials, and assembly lines are allocated efficiently before moving into detailed scheduling of specific variants.

3.2.8.2 Inputs and Outputs to Aggregate Planning

A) Inputs to Aggregate Planning

a. Demand Forecasts

Demand forecasts provide the foundational estimate of future customer needs over the planning period. These projections are compiled using quantitative statistical models, historical sales patterns, market trends, and qualitative insights from sales teams. Accurate demand estimates prevent companies from under-preparing or overbuilding capacity.

Within aggregate planning, these numbers serve as the primary driver determining how much workforce, machinery, and material resources will be necessary to satisfy expected sales volume.

Example: A clothing retailer may forecast higher demand for winter jackets in November–January based on past sales data, guiding production and inventory buildup in advance.

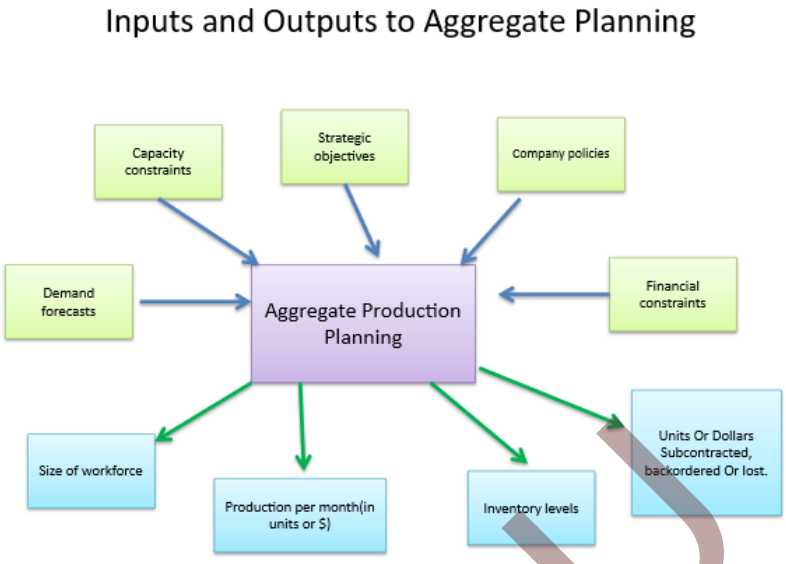


Fig 3.2.2 Inputs and Outputs to Aggregate Planning

b. Capacity Constraints

Capacity constraints represent the physical and operational upper limits of a production facility's output capabilities. These boundaries include available machine hours, facility square footage, tooling limits, and maximum throughput capacity under normal operating conditions. Understanding these limits prevents aggregate planners from creating unrealistic production schedules.

By mapping demand forecasts directly against existing capacity constraints, management can identify potential bottlenecks well in advance and plan necessary adjustments like shifts or temporary expansions.

Example: A steel plant may forecast demand for 10,000 tons of steel but realize its maximum monthly capacity is only 8,000 tons. Managers may then plan subcontracting or add extra shifts to bridge the gap.

c. Strategic Objectives

Strategic objectives define the top-level business priorities set by executive leadership, such as target market share, long-term growth targets, and customer service commitments. These overarching goals dictate whether a business prioritizes aggressive expansion, cost leadership, or premium service delivery.

In aggregate planning, strategic objectives guide high-level trade-offs when balancing supply and demand. For instance, a firm prioritizing maximum customer

SGOU

satisfaction may plan higher capacity buffers, while a cost-focused company might prioritize running operations as close to peak efficiency as possible.

Example: A luxury hotel chain may maintain excess staff and inventory of premium supplies to guarantee flawless service, while a budget airline may focus on minimizing costs by running flights at maximum occupancy with limited buffers.

d. Company Policies

Company policies establish the internal rules, ethical baselines, and operational constraints that govern how business operations must function. Examples include rules regarding maximum overtime hours allowed per employee, union agreements, safety requirements, and policies against worker layoffs.

These guidelines ensure that production plans remain compliant with organizational values and legal obligations. Aggregate planning must account for these rules so that the chosen operational strategies do not violate internal standards or employment contracts.

Example: An automobile manufacturer bound by union agreements may be restricted from laying off workers during low-demand periods, so instead they reduce weekly working hours or reassign employees to maintenance tasks.

e. Financial Constraints

Financial constraints dictate the budget limits and capital availability designated for operational activities. These include working capital restrictions, credit limits, maximum inventory holding expenditure, and strict budgets allocated for hiring or overtime.

Planners must operate within these monetary boundaries to protect the company's financial stability and cash flow. Financial constraints force decision-makers to evaluate the cost-effectiveness of different aggregate strategies, such as choosing between paying overtime rates or holding extra safety stock.

Example: A small electronics firm may avoid subcontracting production due to limited credit availability and instead rely on overtime from existing staff, ensuring expenses remain within budget.

B) Outputs of Aggregate Planning

a. Size of Workforce

The workforce size output details the exact staffing levels required to execute the aggregate production plan. This includes decisions on total headcount, hiring plans, necessary layoffs, or temporary staffing requirements needed over specific time periods.

By determining labour needs early, human resources and plant management can plan recruitment, onboarding, or labour adjustments in an organized fashion. Aligning workforce size with planned output prevents labour shortages during peak periods and minimizes excess labour costs during slowdowns.

Example: A food processing company may plan to hire 200 seasonal workers during

SGOU

harvest months to meet demand, then reduce staff once the season ends.

b. Production per Month (in units or $)

This output establishes the targeted production volume for each month of the planning horizon, expressed either in physical units or total monetary value. It outlines the master volume expected from the facility across general product lines for each interval.

Establishing steady monthly production targets enables plant managers to coordinate material orders and facility scheduling systematically. It provides a clear monthly baseline that ensures production rates stay aligned with projected demand and operational goals.

Example: A cement factory may set a monthly target of 50,000 tons based on demand forecasts, ensuring raw material procurement and machine scheduling are aligned with this output.

c. Inventory Levels

Inventory level outputs define the target quantities of finished goods and raw materials that should be maintained at the end of each planning period. These targets are designed to absorb demand fluctuations and maintain adequate safety stock without over-accumulating stock.

Managing planned inventory levels ensures a balance between carrying costs and stockout risks. Clear inventory targets allow warehouse managers to optimize storage space and help finance teams forecast working capital tied up in stored goods.

Example: A pharmaceutical company may maintain a minimum of 10,000 units of essential medicines in stock to handle sudden spikes in demand, while avoiding excess storage costs that could arise from overproduction.

d. Units or Dollars Subcontracted, Backordered, or Lost

This output quantifies the planned trade-offs when internal production cannot fully or economically match customer demand. It specifies the volume or dollar amount of work delegated to third-party subcontractors, delayed via backorders, or intentionally unfulfilled as lost sales.

Documenting these parameters gives management clear insight into the financial and customer-relationship trade-offs of their production strategy. It allows the business to control external manufacturing costs and minimize the negative impact of unfulfilled demand on customer goodwill.

Example: A shoe manufacturer may subcontract 5,000 pairs to an external supplier during peak festival demand, backorder 2,000 pairs for later delivery, and accept 500 lost sales due to capacity limits.

3.2.8.3 Techniques for Aggregate Planning (AP)

a. Informal or Trial-and-Error Techniques

Informal or trial-and-error methods are the most commonly used in practice because

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they are simple, flexible, and easy to apply. Managers often rely on experience, intuition, and basic calculations to adjust production, workforce, and inventory levels.

By testing different scenarios and observing outcomes, they can identify workable solutions without complex mathematical models. Although these techniques may not guarantee optimal results, they are practical in real-world settings where demand forecasts are uncertain and conditions change rapidly. Their strength lies in adaptability, managers can quickly revise plans when faced with unexpected demand fluctuations or resource constraints.

This makes trial-and-error approaches particularly useful for small and medium-sized enterprises.

Example: A bakery may experiment with producing 500, 700, or 900 loaves per day during festive weeks, adjusting output based on daily sales feedback without using complex forecasting models.

b. Mathematical Techniques – Linear Programming

Linear programming is a mathematical technique used to optimize aggregate planning decisions. It involves formulating equations that represent constraints (such as production capacity, labour availability, and inventory limits) and an objective function (such as minimizing cost or maximizing efficiency).

By solving these equations, managers can determine the best combination of production, workforce, and inventory levels. This method provides a systematic and quantitative approach, ensuring that decisions are not based solely on intuition.

Linear programming is especially valuable when dealing with complex situations involving multiple variables and constraints. It helps organizations achieve cost efficiency and resource optimization, making it a powerful tool for large-scale operations.

Example: An automobile company may use linear programming to decide whether to allocate more machine hours to SUVs or sedans, balancing labour costs, raw material availability, and forecasted demand.

c. Simulation Techniques

Simulation techniques involve creating models that mimic real-world production and demand scenarios. By running simulations, managers can test different strategies under varying conditions, such as demand surges, workforce shortages, or supply chain disruptions.

This provides a maximum chance of identifying effective solutions before implementing them in practice. The advantage of simulation is its ability to capture uncertainty and variability. Unlike rigid mathematical models, simulations allow managers to experiment with “what-if” situations and evaluate the impact of different decisions.

This makes simulation a valuable tool for risk management, enabling firms to

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prepare for unexpected challenges while still aiming for efficiency and effectiveness in aggregate planning.

Example: A retail chain may simulate scenarios of sudden demand spikes during holiday sales to test whether overtime, subcontracting, or inventory buildup would be the most effective solution.

3.2.9 Capacity Planning

Capacity planning refers to the process of determining the production capacity needed by an organization to meet future demand. It ensures that facilities, equipment, and workforce are sufficient to produce goods or services without delays or shortages.

In PPC, capacity planning is vital because it directly influences the efficiency of operations and the ability to satisfy customer requirements. Without proper planning, firms risk either underutilization of resources or inability to meet demand.

Example: A hospital may plan the number of beds and medical staff required for the next flu season to avoid overcrowding and ensure timely patient care.

a. Short-Term Capacity Planning

In the short term, capacity planning focuses on immediate adjustments such as scheduling overtime, reallocating workers, or using existing machinery more intensively. These measures help organizations respond quickly to fluctuations in demand without making large investments.

For example, during seasonal peaks, firms may temporarily increase working hours or hire part-time staff to maintain output levels. Short-term planning is flexible and cost-effective, but it cannot sustain long-term growth if demand continues to rise.

Example: An ice cream factory may add weekend shifts and hire temporary workers during summer months when demand is highest, but this adjustment alone cannot support long-term expansion if demand keeps growing year after year.

b. Medium-Term Capacity Planning

Medium term capacity planning looks at resource utilization over several months to a few years. It involves decisions such as purchasing additional equipment, reorganizing workflows, or improving process efficiency.

This level of planning balances stability with adaptability, ensuring that production systems can handle moderate increases in demand. It also helps firms avoid bottlenecks by aligning workforce skills, machine availability, and material supply with forecasted requirements.

Example: A garment manufacturer may invest in new sewing machines and reorganize its production floor layout to improve efficiency over the next two years, ensuring smoother handling of seasonal demand peaks.

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c. Long-Term Capacity Planning

Long term capacity planning is strategic and involves major investments such as building new plants, acquiring advanced technology, or expanding workforce capabilities. These decisions are made to support sustained growth and competitiveness in the market.

Since they require significant capital and time, long term planning must be based on reliable demand forecasts and thorough analysis of market trends. In PPC, this ensures that the organization is prepared for future challenges and opportunities, maintaining efficiency and effectiveness over the long run.

Example: An automobile company may build a new factory and adopt robotic assembly lines to meet projected demand for electric vehicles over the next decade.

3.2.10 Materials Requirement Planning (MRP)

Materials Requirement Planning (MRP) is a systematic approach used in production planning to ensure that the right materials are available at the right time for manufacturing. It is a computer-based inventory management system that calculates the materials and components needed to produce a product.

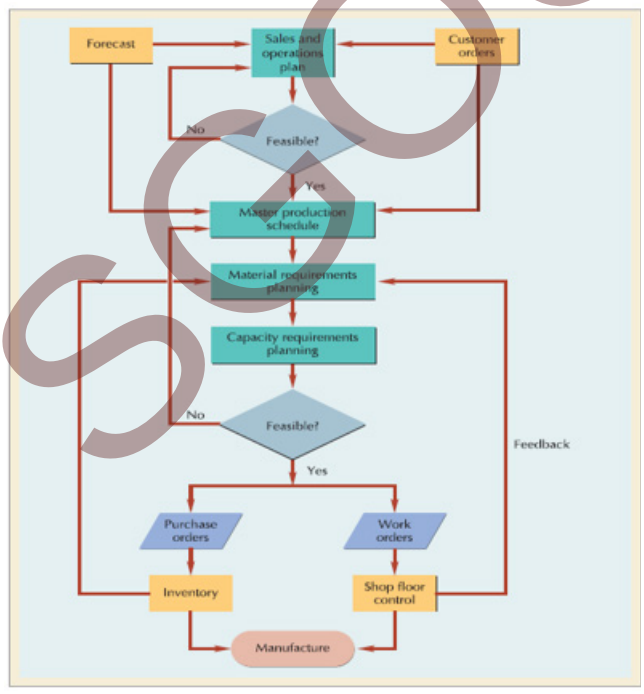


Fig 3.2.3 Materials Requirement Planning (MRP)

The purpose of MRP is to avoid both shortages and excess inventory, thereby ensuring smooth production flow and timely delivery of goods.

Example: A smartphone manufacturer uses MRP to ensure that microchips, screens, and batteries are available exactly when needed for assembly, avoiding costly delays.

The picture illustrates the Materials Requirement Planning process as a structured flowchart. It begins with forecasting and customer orders, which feed into the sales and operations plan. At this stage, feasibility is checked, if the plan is not feasible, it loops back for revision; if feasible, it moves forward to the master production schedule. From there, the process continues to material requirements planning and capacity requirements planning, ensuring that both materials and production capacity are aligned with demand. Another feasibility check occurs here, with feedback loops to earlier stages if adjustments are needed. Once confirmed feasible, the system generates purchase orders (linked to inventory management) and work orders (linked to shop floor control). These two streams converge at the final stage, manufacture, where production is executed. Overall, the diagram highlights the logical sequence, feedback loops, and integration of forecasting, scheduling, resource planning, and execution in effective production planning and control.

a. Inputs of MRP

The effectiveness of MRP depends on three key inputs: the Master Production Schedule (MPS), the Bill of Materials (BOM), and Inventory Records.

- ◊ The MPS outlines what products need to be produced and when.
- ◊ The BOM lists all raw materials and components required.
- ◊ Inventory records provide data on current stock levels.

Together, these inputs allow MRP to calculate precise material requirements and generate purchase or production orders.

Example: A bicycle company's MPS may specify 5,000 bikes for October, the BOM lists frames, wheels, and chains, and inventory records show 2,000 wheels already in stock MRP then calculates how many more wheels must be ordered.

b. Process of MRP

The MRP system processes these inputs to determine what materials are needed, how much is required, and when they should be available. It schedules orders for raw materials and components, ensuring that production can proceed without interruptions.

By considering lead times, lot sizes, and safety stock, MRP helps managers plan procurement and production activities in a coordinated manner. This reduces uncertainty and improves efficiency across the supply chain.

Example: A furniture company may use MRP to schedule timber deliveries two weeks before production starts, ensuring raw materials arrive on time without excess storage costs.

c. Benefits of MRP

The main benefits of MRP include improved inventory control, reduced carrying costs, and enhanced customer satisfaction. By ensuring timely availability of materials, MRP minimizes production delays and avoids costly stockouts.

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It also prevents overstocking, which ties up capital and increases storage expenses. Ultimately, MRP supports better decision making, aligns production with demand forecasts, and strengthens overall organizational performance.

Example: A toy manufacturer avoids overstocking plastic components by using MRP, ensuring just enough materials are available to meet Christmas demand without burdening warehouses with excess inventory afterward.

Summarised Overview

Production Planning and Control (PPC) is the systematic process of organizing and regulating production activities to ensure efficiency, cost-effectiveness, and timely delivery. Production planning focuses on deciding what, when, and how to produce, considering objectives such as smooth workflow, optimal resource utilization, and meeting customer demand. Production control complements this by monitoring actual performance against planned targets and applying corrective measures to maintain consistency and quality. The PPC department coordinates these functions through scheduling, routing, dispatching, and follow-up, while also integrating key tools like Aggregate Planning (balancing demand and supply), Capacity Planning (ensuring facilities and workforce meet demand), and Materials Requirement Planning (MRP) (computer-based scheduling of materials using MPS, BOM, and inventory records). Together, these elements reduce waste, optimize resources, and strengthen competitiveness, making PPC essential for operational excellence and customer satisfaction.

Self-Assessment Question

1. Explain the meaning, nature and importance of Production and Operations Planning and Control (PPC). Describe the three main stages of PPC.
2. Explain the major functions of Production Planning and Control and discuss how they contribute to the smooth functioning of a production system.
3. What is production planning? Explain its objectives and the factors determining production planning procedures.
4. Explain the objectives of production control and distinguish between production planning and production control.

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5. Explain the elements of scheduling and discuss the different types of scheduling used in production management.

6. Describe the organisation of the PPC department and explain the major functions performed by the department.

7. Explain the meaning, objectives and central concepts of Aggregate Production Planning (APP). Discuss its importance in matching production with demand.

8. Explain the major inputs and outputs of aggregate production planning and discuss the techniques used for aggregate planning.

9. What is capacity planning? Explain its objectives, importance and relationship with production planning.

10. Explain the meaning, objectives and working process of Materials Requirement Planning (MRP). Discuss its major components.



Assignments

1. A factory frequently experiences machine breakdowns and delays in completing orders. Explain how the functions of the PPC department can be applied to improve production control.

2. A company manufactures products with different processing times and delivery dates. Explain how suitable scheduling methods can be selected and applied to complete orders on time.

3. Analyse the inputs, outputs and central concepts of Aggregate Production Planning (APP). Explain how these elements influence production decisions.

4. Compare and analyse the major techniques of aggregate production planning, highlighting their suitability under different demand and capacity conditions.

5. Evaluate the effectiveness of Materials Requirement Planning (MRP) in controlling inventory, reducing production delays and ensuring the timely availability of materials. Discuss its limitations.

6. Develop an Aggregate Production Plan for a company facing seasonal demand fluctuations. Explain how production levels, workforce requirements, inventory and capacity should be coordinated.

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7. Prepare a capacity-planning framework for a manufacturing unit expecting an increase in customer orders. Explain how the company can estimate capacity requirements and identify possible capacity gaps.

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Suggested Reading

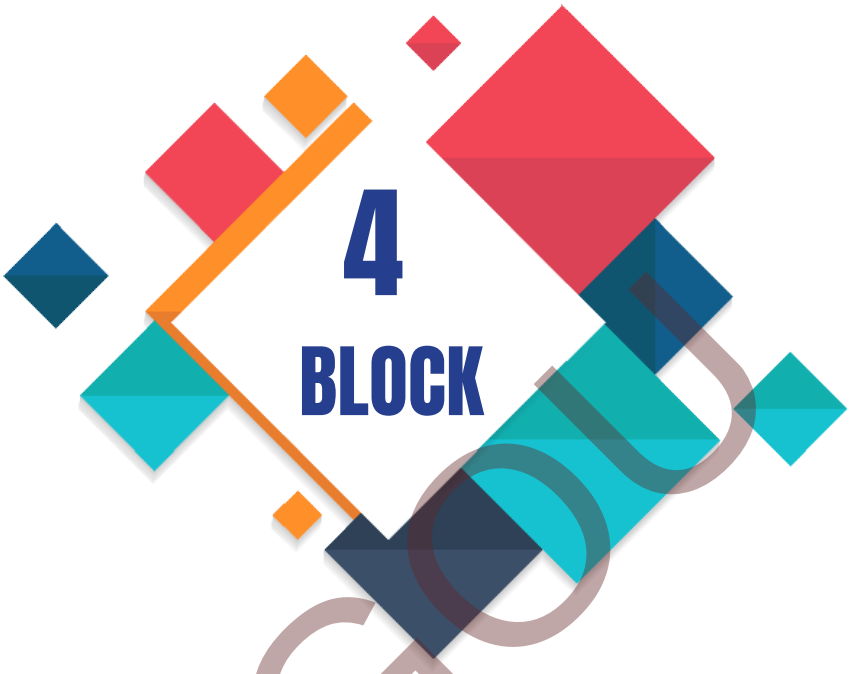
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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

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Quality and Project Management

Unit 1

Quality Management

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ explain the concepts of quality, Total Quality Management (TQM), Quality Circles, Quality Control, and Six Sigma and their significance in operations management
- ◊ apply Statistical Quality Control (SQC) techniques and quality control methods to monitor and improve production processes
- ◊ analyse quality control charts to identify variations, trends, and potential quality problems in manufacturing or service processes
- ◊ evaluate the effectiveness of TQM, Quality Circles, quality certification, and Six Sigma approaches in achieving continuous quality improvement
- ◊ develop appropriate quality improvement strategies using TQM, SQC, control charts, quality certification, and Six Sigma principles for organisational quality management
- ◊ evaluate ISO certifications and Six Sigma for defect reduction

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Background

Quality management has emerged as a central discipline in modern organizations, driven by the need to deliver products and services that consistently meet customer expectations. The concept of quality goes beyond mere compliance with specifications; it encompasses excellence, reliability, and fitness for use. As industries became more competitive, organizations recognized that quality was not just a technical measure but a strategic tool for survival and growth. This realization gave rise to systematic approaches to managing quality across all levels of production and service delivery.

The evolution of quality management can be traced from traditional inspection methods to more advanced frameworks such as Total Quality Management (TQM), Quality Circles, and Statistical Quality Control (SQC). Early practices focused on detecting defects after production, but modern approaches emphasize prevention, continuous improvement, and employee involvement. Tools like control charts and Six Sigma methodologies have further strengthened the ability of organizations to monitor processes, reduce variation, and achieve near-perfect outcomes. These developments highlight the shift from reactive to proactive quality practices. Quality management is closely linked with certification standards such as ISO, which provide credibility and assurance to customers worldwide. Organizations that adopt these standards demonstrate their commitment to excellence and process discipline. Moreover, initiatives like Six Sigma have redefined quality by integrating statistical rigor with business strategy, aiming for defect-free performance. Thus, the background of quality management reflects a journey from basic inspection to a holistic, integrated system that ensures customer satisfaction, operational efficiency, and long-term competitiveness.

Keywords

Quality, TQM, Quality Circle, Quality Control, SQC, Control Charts, Quality Certification, Six Sigma

Discussion

Quality management is an essential part of operations management that focuses on ensuring that products and services consistently meet customer expectations and organisational standards. Total Quality Management (TQM) provides an organisation-wide approach to continuous improvement, while Quality Circles encourage employees to participate in identifying and solving workplace quality problems. Quality Control involves monitoring processes and outputs to maintain required standards, supported by Statistical Quality Control (SQC) and Quality Control Charts for identifying and controlling variations in processes. Quality Certification helps organisations demonstrate compliance with recognised quality standards, while Six Sigma provides a structured, data-driven approach to reducing defects and improving process performance. Together, these concepts help organisations achieve consistent quality, reduce costs, improve efficiency, enhance customer satisfaction, and gain a competitive advantage.

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4.1.1 Quality

Quality refers to how well a product, service, or process meets a certain standard of excellence. Excellence here means achieving superior performance, reliability, and consistency compared to ordinary or average outcomes.

For example, a high-quality musical instrument produces precise tones and lasts longer, while a high-quality academic paper demonstrates clarity, depth, and originality. This definition emphasizes that quality is not just about meeting minimum requirements but striving toward the highest possible standards.

In practice, this concept of excellence becomes the benchmark against which organizations measure their performance. Companies often adopt quality certifications, such as ISO standards, to demonstrate their commitment to excellence. Customers perceive quality when they experience products or services that exceed expectations, whether through durability, precision, or customer satisfaction. Thus, quality as excellence is both a goal and a competitive advantage.

Example: A luxury car brand like Mercedes-Benz maintains ISO certifications and rigorous testing to ensure superior performance, which builds customer trust and brand loyalty.

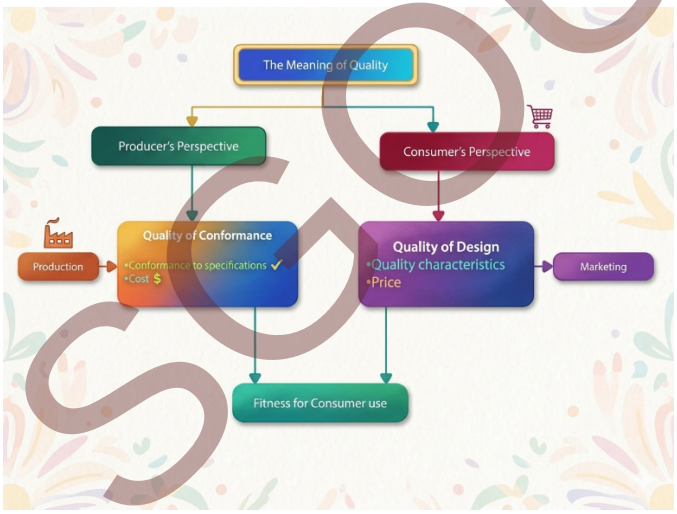


Fig 4.1.1 Meaning of Quality

1. Totality of Features and Characteristics

Quality is also defined as the complete set of attributes that determine how well a product or service fulfils its intended purpose. This includes tangible aspects like design, durability, and functionality, as well as intangible ones such as aesthetics, ease of use, and customer support.

For instance, a smartphone's quality is judged not only by its technical specifications but also by its user interface, battery life, and after-sales service.

This holistic view ensures that organizations do not focus narrowly on one aspect

of performance while neglecting others. A product may be technically advanced but fail if it lacks user-friendliness or reliability. By considering the totality of features, businesses can deliver balanced offerings that satisfy customers in multiple dimensions, thereby building trust and loyalty.

Example: Apple's iPhone is valued not just for its hardware but also for its sleek design, intuitive interface, and strong customer support, making it a benchmark for holistic quality.

2. Fitness for Use

Fitness for use means that a product or service is suitable for the purpose for which it was designed. It emphasizes practicality and customer satisfaction rather than abstract perfection.

For example, a chair is of good quality if it is comfortable, stable, and durable for everyday use, even if it is not luxurious. Similarly, a software application is considered high quality if it performs tasks efficiently and without errors, regardless of whether it has advanced features that users do not need.

This perspective highlights that quality is relative to customer needs and expectations. A product that is "fit for use" in one context may not be suitable in another. For instance, a budget car may be perfect for daily commuting but inadequate for racing. Therefore, organizations must understand their target customers and design offerings that match their specific requirements. Fitness for use ensures that quality is practical, customer-centered, and aligned with real-world applications.

Example: Google Docs is considered high quality for everyday office work because it is reliable, easy to use, and accessible online, even though it lacks advanced publishing features found in specialized software.

4.1.2 Total Quality Management (TQM)

Total Quality Management (TQM) highlights the important role of top management in guiding and supporting organisation-wide quality improvement. It requires employees at every level to actively focus on maintaining and improving quality. Under TQM, quality is considered the responsibility of all employees and is integrated into every organisational function. It also treats quality as a strategic priority, recognising it as one of the most important factors influencing the organisation's overall performance and success.

1. Leadership Commitment

Total Quality Management (TQM) emphasizes the critical role of top management in leading and sustaining a culture of quality. Leadership commitment is essential because quality initiatives require vision, resources, and organizational alignment.

When senior leaders prioritize quality, it signals to all employees that excellence is not optional but a core value. This top-down approach ensures that quality improvement

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becomes embedded in the organization's mission and strategy, rather than being treated as a separate or secondary activity.

Example: Toyota's leadership has consistently emphasized quality through its "Kaizen" philosophy, ensuring continuous improvement across all levels of the company.

2. Employee Responsibility

TQM also highlights the responsibility of every employee, at every level, to contribute to continuous quality improvement. Unlike traditional systems where quality was confined to inspection departments, TQM integrates quality into all organizational functions production, marketing, customer service, and administration.

Employees are encouraged to identify problems, suggest solutions, and take ownership of outcomes. This collective responsibility fosters teamwork, innovation, and accountability, making quality improvement a shared organizational goal rather than an isolated task.

Example: At Motorola, employees were trained to apply Six Sigma principles, empowering them to identify defects and improve processes, which significantly reduced errors and costs.

3. Quality as a Strategic Issue

Finally, TQM positions quality as a strategic issue, the most important concern for any company seeking long-term success. In competitive markets, quality directly influences customer satisfaction, brand reputation, and profitability.

By treating quality as a strategic priority, organizations can differentiate themselves, reduce waste, and achieve sustainable growth. Thus, TQM is not merely a set of tools or techniques; it is a philosophy that integrates leadership, employee involvement, and strategic focus to make quality the center piece of organizational excellence.

Example: Samsung treats quality as a strategic priority by investing heavily in R&D and quality assurance, which has helped it become a global leader in electronics and maintain competitiveness.

4.1.2.1 Principles of TQM

a. Customer Defines Quality

In TQM, the customer is the ultimate judge of quality. A product or service is considered high quality only if it meets or exceeds customer expectations. This principle shifts the focus from internal standards to external satisfaction.

Customer satisfaction becomes the top priority because it directly influences loyalty, reputation, and long-term success. Organizations must constantly gather feedback to understand evolving needs. By making the customer the center of quality efforts, companies ensure that every process, design, and improvement is aligned with delivering

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value and satisfaction.

Example: Amazon continuously collects customer reviews and feedback to improve product listings and delivery services, ensuring customer expectations are met or exceeded.

b. Leadership of Top Management

Quality improvement requires strong leadership from top management. Leaders set the vision, allocate resources, and inspire employees to embrace quality as a core value.

Without leadership commitment, quality initiatives often fail because employees lack direction and motivation. Management must demonstrate quality through actions, not just words. This principle ensures that quality becomes part of the organizational culture, driven from the top and practiced at every level.

Example: At Toyota, leadership actively promotes the "Kaizen" philosophy of continuous improvement, ensuring quality is embedded in every stage of production.

c. Quality as a Strategic Issue

TQM treats quality as a strategic priority, not just a technical or operational concern. It is integrated into long-term planning and competitive positioning.

Organizations that view quality strategically can differentiate themselves in the market, reduce costs, and build strong customer trust. Thus, quality is not an isolated activity but a central element of business strategy, influencing growth and sustainability.

Example: Apple positions product quality as a strategic differentiator, using premium design and reliability to maintain its competitive edge globally.

d. Responsibility of All Employees

Quality is not the job of a single department; it is the responsibility of every employee. Each individual contributes to maintaining and improving standards.

This principle encourages ownership and accountability, ensuring that quality is embedded in daily tasks across all functions. When employees at all levels participate, quality improvement becomes continuous and widespread, rather than limited to inspection teams.

Example: At Motorola, employees across all functions were trained in Six Sigma, empowering them to identify and eliminate defects in their daily work.

e. Continuous Improvement Across Functions

Every function, production, marketing, HR, finance must focus on continuous quality improvement. Improvement is not a one-time effort but an ongoing process.

This principle ensures that all departments work together toward strategic goals, eliminating silos and inefficiencies. Continuous improvement builds resilience, adaptability, and innovation, helping organizations stay competitive in dynamic markets.

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Example: Procter and Gamble continuously improves processes across R&D, marketing, and supply chain to maintain efficiency and innovation in consumer goods.

f. Cooperation Between Employees and Management

Quality problems are best solved through cooperation and teamwork. TQM promotes collaboration between employees and management rather than hierarchical control.

Joint problem-solving fosters trust, communication, and shared responsibility. It ensures that solutions are practical and widely accepted. This cooperative approach strengthens organizational unity and creates a culture where quality challenges are addressed collectively.

Example: At General Electric, management and employees collaborated under Six Sigma programs to reduce defects, leading to significant cost savings and improved customer satisfaction.

g. Use of Statistical Quality Control (SQC)

Problem solving in TQM relies on data and statistical methods rather than guesswork. SQC tools help identify variation, measure performance, and guide decisions.

By using charts, sampling, and probability analysis, organizations can distinguish between normal fluctuations and real problems. This scientific approach ensures accuracy, reduces errors, and supports continuous improvement with measurable results.

Example: A pharmaceutical company uses control charts to monitor drug production quality, ensuring consistency and compliance with safety standards.

h. Training and Education

Continuous quality improvement requires skilled and knowledgeable employees. Training equips staff with the tools, techniques, and mindset needed for TQM.

Education ensures that employees understand quality principles, statistical methods, and teamwork practices. By investing in training, organizations build a workforce capable of sustaining long-term quality improvement and innovation.

Example: Infosys invests heavily in employee training programs to ensure staff are equipped with quality management skills, enabling consistent service delivery in IT projects.

4.1.2.2 W. Edwardsdeming's 14 Points

1. Constancy of purpose-create
2. Prevention-adopt philosophy
3. Mass inspection-cease
4. Suppliers-select a few based on quality
5. Constantly improve-system and workers

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6. SPC (Statistical Process Control)- institute worker training
7. Instil leadership among supervisors.
8. Eliminate fear among employees
9. Eliminate barriers between departments.
10. Eliminate slogans
11. Remove numerical quotas
12. Enhance workers' pride
13. Institute vigorous education programs on quality management
14. Implement these 13 points.

4.1.2.3 The Deming Wheel or PDCA Cycle

(Plan-Do-Check-Act)

The PDCA Cycle, also known as the Deming Cycle or Deming Wheel, is a continuous improvement method used in Total Quality Management (TQM). It provides a systematic way for organisations to identify problems, test solutions, measure results, and make improvements.

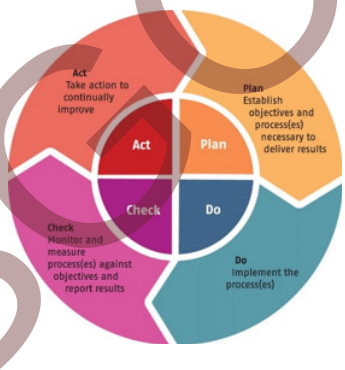


Fig 4.1.2 PDCA Cycle

The PDCA Cycle has four stages:

1. Plan

Identify the problem, determine its causes, set improvement objectives, and develop a plan to solve the problem. Example: A bakery finds that 10% of its bread loaves are underweight. It plans to check the weighing process and improve the accuracy of the weighing equipment.

2. Do

Implement the planned solution on a small scale or under controlled conditions. Example: The bakery calibrates its weighing machine and trains workers to measure the dough accurately.

3. Check

Measure and analyse the results to determine whether the solution has achieved the desired improvement. Example: After one week, the bakery checks the number of underweight loaves. If the percentage has fallen from 10% to 2%, the solution appears to be effective.

4. Act

If the solution is successful, standardise it and apply it more widely. If the desired results are not achieved, identify what went wrong and begin the cycle again with a revised plan. Example: The bakery makes the new weighing procedure a standard practice and continues monitoring the results.

4.1.2.4 Strategic Implications of TQM

a. Quality as a Strategic Component

Quality is a key component of strategic planning because it directly influences customer satisfaction, competitiveness, and long-term success. A company's ability to deliver consistent quality determines its reputation and market position.

By embedding quality into strategic planning, organizations ensure that excellence is not treated as an afterthought but as a central pillar guiding all decisions and actions. This approach makes quality a driver of growth rather than just a measure of performance.

Example: Toyota integrates quality into its strategic planning through the "Kaizen" philosophy, which has helped it maintain global competitiveness and customer trust.

b. Setting Ambitious Goals

Strategic plans should always include ambitious goals for quality. These goals act as benchmarks that push the organization to continuously improve and innovate.

Setting high standards ensures that the company does not settle for mediocrity but strives to exceed customer expectations. Such goals also provide direction for resource allocation, process design, and employee engagement, making quality improvement a shared mission across the organization.

Example: Samsung sets ambitious quality goals in its smartphone division, ensuring innovation in design and durability, which helps it compete against global rivals.

c. Operational Programs and Policies

In addition to setting goals, strategic planning involves designing operational programs and policies that translate vision into action. These programs may include quality control systems, training initiatives, and continuous improvement projects.

Policies ensure consistency and accountability, guiding employees in their daily work. By aligning operational plans with strategic quality objectives, organizations create a structured pathway to achieve excellence.

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Example: Infosys implements structured training programs and quality audits to align employee performance with its strategic quality objectives in IT services.

d. Leadership Commitment

Strong leadership is essential for the success of any strategic plan. Leaders must champion quality, communicate its importance, and provide the necessary resources to achieve it.

Their commitment inspires employees to take ownership of quality improvement and fosters a culture where excellence is valued. Without leadership, even the best plans remain ineffective. Thus, leadership and quality together form the backbone of strategic planning, ensuring that organizational goals are achieved with integrity and consistency.

Example: At General Electric, leadership drove Six Sigma initiatives, ensuring quality improvement became a company-wide culture that reduced defects and costs.

4.1.3 Quality Circle Process



Fig 4.1.3 Quality Circle

a. Organization

Overview and Structure: The cycle begins with establishing the core group, typically composed of 8 to 10 members who work within the same operational area. A supervisor or designated moderator leads the group to guide meetings, keep discussion focused, and ensure members collaborate effectively on common work-floor challenges.

Operational Focus: Because members share the same work environment, they possess direct operational experience with the day-to-day processes being evaluated.

This shared context allows the team to identify practical issues quickly and maintains focus on tangible, local operational improvements.

Example: In a car assembly plant, a quality circle of 10 workers and a supervisor may meet weekly to address recurring defects in door alignment.

b. Training

Skill Development: Once organized, team members undergo targeted training to build baseline skills in group dynamics, data collection methods, and problem-analysis techniques. This equips participants with structured problem-solving toolkits rather than relying solely on informal guesswork.

Standardizing Methods: Training ensures all 8 to 10 participants speak a common methodological language when gathering baseline operational metrics and evaluating root causes. Standardizing these analytical tools upfront increases the quality and accuracy of all subsequent project phases.

Example: A textile factory trains its quality circle members in Pareto analysis and cause-and-effect diagrams to systematically identify sources of fabric defects.

c. Problem Identification

Generating Options: In this stage, the team engages in structured brainstorming sessions to assemble a broad list of operational challenges and potential areas for improvement. Members contribute observations about inefficiencies, quality defects, or workflow bottlenecks experienced in their daily tasks.

Reaching Consensus: After listing various issues and alternatives, the team evaluates the suggestions to establish a shared consensus on which specific problem to address first. Selecting a single, well-defined target ensures the group's effort remains concentrated on high-impact areas.

Example: In a food processing plant, a quality circle may brainstorm issues like packaging errors, machine downtime, and hygiene concerns, then agree to first tackle packaging errors as the most urgent problem.

d. Problem Analysis

Root-Cause Investigation: With a target problem selected, the team conducts a deep-dive investigation using cause-and-effect tools (such as Ishikawa/fishbone diagrams) to trace symptoms back to their underlying root causes. This step prevents the team from implementing temporary fixes for surface-level symptoms.

Example: In a printing company, a fishbone diagram may reveal that frequent paper jams are not just due to poor paper quality but also improper machine maintenance and operator error.

Data-Driven Evaluation: Alongside root-cause mapping, members perform systematic data collection and analysis to validate their hypotheses with measurable facts. Gathering concrete operational metrics ensures that decisions are driven by

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evidence rather than subjective opinions.

Example: In a call center, data collection may show that 60% of customer complaints are linked to long wait times, confirming that staffing levels are the root cause rather than poor communication skills.

e. Solution

Developing Actionable Results: During the solution phase, the team translates their analytical findings into concrete, actionable recommendations designed to eliminate the identified root causes. They formulate targeted interventions and test potential fixes to determine the most effective approach.

Example: A food processing plant may recommend installing automated sensors to detect packaging errors, reducing human mistakes and improving efficiency.

Formulating the Proposal: The output of this stage is a fully developed solution package containing expected outcomes, resource requirements, and procedural steps. The team prepares these final results to demonstrate how the proposed fix will measurably improve quality, cost, or process efficiency.

Example: In a textile factory, the proposal may include retraining workers, upgrading looms, and setting measurable targets such as reducing fabric defects by 40% within six months.

f. Presentation

Management Review: In the final stage of the circular workflow, the team presents their findings, proposed solutions, and implementation plans to management for review and authorization. This formal delivery bridges front-line employee insights with executive decision-making.

Example: A hospital quality circle may present its plan to reduce patient waiting times by reorganizing appointment scheduling and reallocating staff.

Implementation & Monitoring: Once approved, the proposed measures are implemented on the shop floor while the team actively monitors performance parameters to verify success. Tracking ongoing results ensures long-term process compliance and feeds lessons learned back into the continuous improvement cycle.

Example: In an electronics plant, after implementing new testing procedures, the team monitors defect rates weekly to ensure improvements are sustained.

4.1.4 Identifying Quality Problems and Causes

Identifying the causes of quality problems often relies on a set of widely used tools known as the “seven QC tools” or the “magnificent seven.” These include Pareto charts, flow charts, check sheets, histograms, scatter diagrams, process control charts, and cause-and-effect diagrams. They are designed to help organisations pinpoint where issues originate and guide improvement efforts.

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1) Pareto Analysis

Pareto analysis is one of the most effective methods for uncovering the main sources of poor quality. Developed in the early 1950s by Joseph Juran and named after the Italian economist Vilfredo Pareto, it is based on the principle that a small number of causes are responsible for the majority of problems. For instance, Juran observed in a textile mill that nearly 75% of defective cloth came from just a few weavers. By addressing these critical causes, companies can achieve the greatest impact on cost reduction and quality improvement.

The technique involves recording the number of defects linked to different possible causes and then creating a frequency distribution. This distribution is presented in a Pareto diagram, which visually highlights the most significant issues. Such diagrams are powerful tools for focusing attention on the few major factors that drive most quality problems, enabling managers to prioritise corrective actions effectively.

Table 4.1.1 – Pareto Table

CAUSE	NO: OF DEFECTS	PERCENTAGE
Poor design	80	64
Wrong part dimensions	16	13
Defective parts	12	10
Incorrect machine calibration	7	6
Operator errors	4	3
Defective material	3	2
Surface abrasions	3	2
Total	125	100

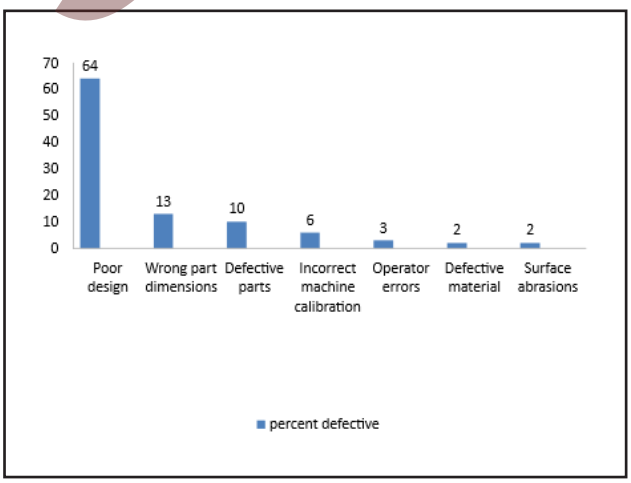


Fig 4.1.4 Pareto Chart

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2) Flow Charts:-

A flow chart or process flowchart is a diagram of the steps in a job, operation or process.

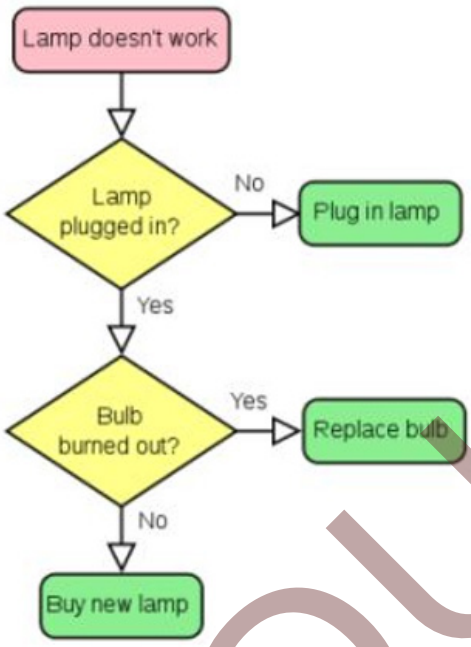


Fig 4.1.5 Flow Chart

3) Check Sheets and Histograms: -

A check sheet is a list of causes of quality problems with the number of defects resulting from each cause used to develop a bar chart called a histogram.

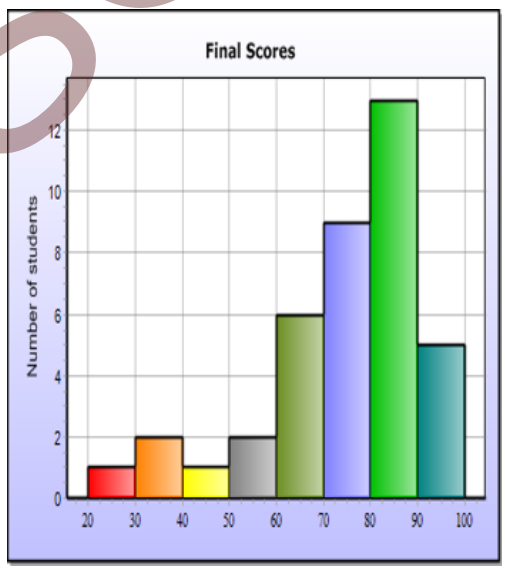
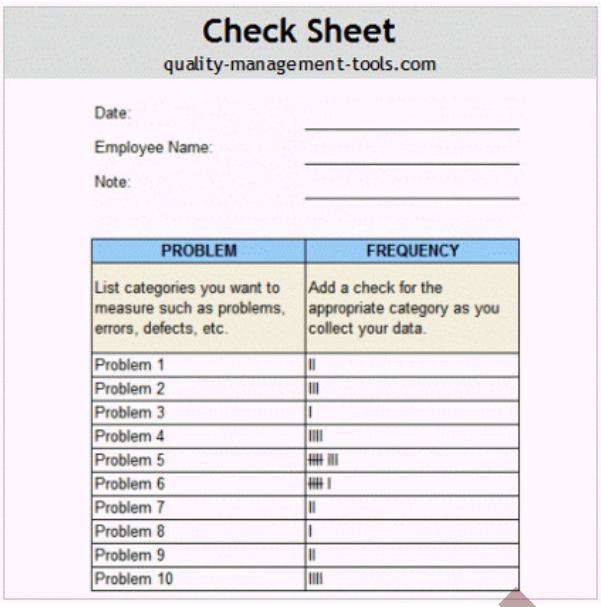


Fig 4.1.6 Histograms

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Check Sheet

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Date: _____

Employee Name: _____

Note: _____

PROBLEM	FREQUENCY
List categories you want to measure such as problems, errors, defects, etc.	Add a check for the appropriate category as you collect your data.
Problem 1	II
Problem 2	III
Problem 3	I
Problem 4	IIII
Problem 5	𝍸 III
Problem 6	𝍸 I
Problem 7	II
Problem 8	I
Problem 9	II
Problem 10	IIII

Fig 4.1.7 Check Sheet

4) Scatter Diagrams

A scatter diagrams is a graph showing how two process variables relate to each other.

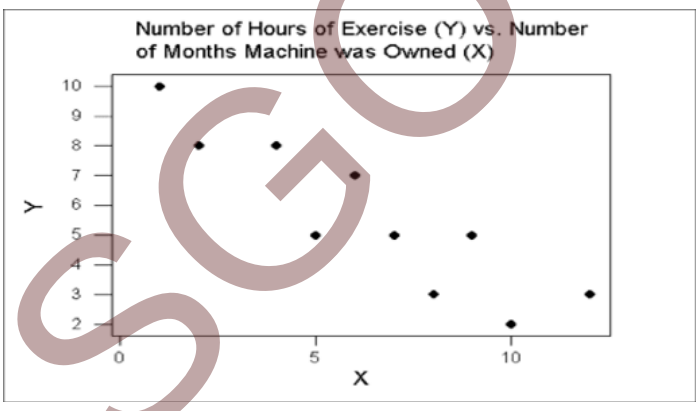


Fig 4.1.8 Scatter Diagrams

5) Process Control Charts & SQC

A chart with statistical upper and lower limits; if the process stays between these limits over time, it is in control and a problem does not exist.

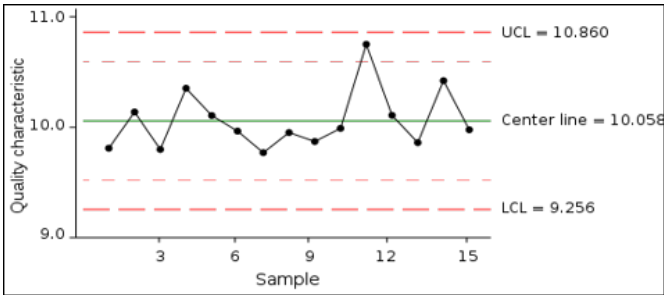


Fig 4.1.9 Process Control Charts

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6) Cause And Effect Diagrams / Fishbone Diagram

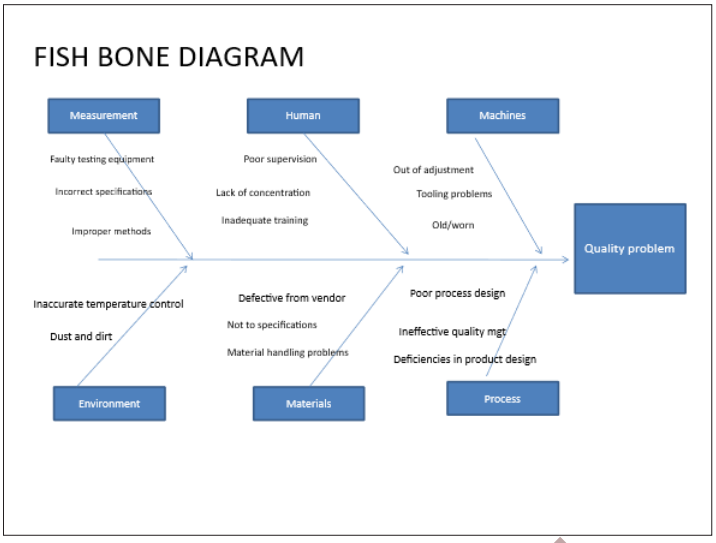


Fig 4.1.10 Fishbone Diagram

A cause-and-effect diagram, also called a fishbone diagram, is a visual tool used to categorise and display the possible reasons behind a quality problem. Its purpose is to help teams systematically identify and analyse the root causes so corrective action can be taken. Typically developed through participative problem-solving, it involves employees, supervisors, and managers working together to brainstorm potential causes.

In the diagram, the effect box at the end represents the specific quality issue that needs resolution. A central line connects this box to major categories of causes, which branch out like the bones of a fish. Each branch is labelled with a category (such as methods, materials, manpower, or machinery), and individual causes are added as smaller lines along the branches during brainstorming. This structured approach allows teams to think through problems comprehensively and record possible causes in an organised, easy-to-interpret format, making it a powerful tool for diagnosing and addressing quality issues.

4.1.5 Quality Control

Quality control is the systematic process of ensuring that products meet established standards during manufacturing. It acts as a mechanism to align production outcomes with the requirements of sales, engineering, and manufacturing departments.

By monitoring each stage of production, quality control ensures that the final product is consistent, reliable, and capable of satisfying customer expectations. This prevents defects from reaching the market and strengthens the company's reputation.

Example: In an automobile plant, every car undergoes multiple inspections during assembly to ensure safety features like brakes and airbags meet strict standards before delivery.

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a. Control of Variables

The excellence of a product depends on several variables materials, manpower, machines, and manufacturing conditions. Quality control systematically regulates these factors to minimize variation and maintain uniformity.

For example, raw materials are inspected for consistency, machines are calibrated to precise standards, and workers are trained to follow standardized procedures. By controlling these variables, organizations reduce errors and achieve predictable, high-quality outcomes.

Example: A pharmaceutical company tests raw chemical ingredients for purity, calibrates mixing machines, and trains staff to follow strict protocols to ensure medicine quality.

b. Preventive and Corrective Approach

Quality control is not limited to detecting defects after production; it emphasizes prevention through continuous monitoring. Statistical methods, sampling, and inspections are used to identify deviations early, allowing corrective action before problems escalate.

This proactive approach saves costs, reduces waste, and ensures efficiency. Corrective measures may include adjusting machine settings, retrain workers, or revise processes to eliminate root causes of defects.

Example: In a textile mill, if fabric thickness deviates from standards, machine settings are corrected immediately to prevent an entire batch from being wasted.

c. Strategic Importance

Beyond technical monitoring, quality control plays a strategic role in organizational success. It ensures customer satisfaction, compliance with industry standards, and competitiveness in the market.

Companies that implement strong quality control systems can achieve lower production costs, higher reliability, and stronger customer trust. In essence, quality control transforms manufacturing from a routine process into a disciplined system that guarantees excellence and long-term sustainability.

Example: Samsung's strict quality control in electronics ensures fewer product recalls, strengthening its global reputation and customer loyalty.

4.1.5.1 Objectives of Quality Control

The objectives of quality control may be stated as follows:

1. To take the necessary corrective steps to keep the quality of the product from dropping below the desired level during manufacture.

   Example: In a beverage company, if bottles are found leaking during production, corrective steps like adjusting sealing machines are taken immediately.

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2. To analyze the trend and extent of quality deviation in a part or product during manufacture, and to determine the cause of such deviation by statistical techniques when it cannot reasonably be attributed to chance.

   Example: In a steel plant, statistical analysis may show that cracks in sheets are linked to specific rolling machines, helping identify the root cause.

3. To establish standards of quality that are readily acceptable to the customer and economical to maintain.

   Example: A smartphone company sets durability standards for screens that balance customer expectations with cost-effective production.

4.1.6 Statistical Quality Control (SQC)

A quality control system ensures that every product is inspected, tested, and analyzed to verify compliance with established standards. When statistical techniques are applied, this process becomes more reliable and cost-effective.

Instead of checking every single item, SQC uses sampling methods to draw conclusions about the entire batch. This reduces inspection costs while maintaining accuracy, making it a practical tool for large-scale manufacturing.

Example: In a biscuit factory, inspectors check samples from each batch rather than every biscuit, ensuring quality while saving time and cost.

4.1.6.1 Objectives of SQC

The main objective of SQC is to control the quality of outgoing products so that customers receive items that meet specifications.

By applying statistical methods, organizations can detect variations early and prevent defective products from reaching the market. This proactive approach not only ensures customer satisfaction but also reduces waste, rework, and production costs.

Example: In an electronics company, SQC helps detect faulty circuit boards early, preventing defective products from being shipped to customers.

a. Probability and Variation

The foundation of SQC lies in probability theory. It recognizes that even within the same batch, components may vary slightly due to machine characteristics, material differences, or environmental conditions.

These variations are natural, but excessive deviations indicate problems. By analyzing probability distributions, SQC helps distinguish between acceptable variation and defects that require corrective action.

Example: In a car tire factory, slight variations in thickness are acceptable, but probability analysis helps identify when deviations exceed safe limits.

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b. Scientific Techniques in SQC

SQC employs several scientific techniques such as control charts, sampling plans, and process capability studies.

- ◊ Control charts monitor production processes over time to identify unusual patterns.
- ◊ Sampling plans determine how many items to inspect from a batch to ensure reliability.
- ◊ Process capability studies measure whether a process consistently produces items within specification limits.

Together, these techniques provide a systematic framework for maintaining and improving product quality.

Example: A dairy company uses control charts to monitor milk packaging consistency, sampling plans to check bottles from each batch, and capability studies to ensure filling machines meet required accuracy.

4.1.6.2 Main Methodologies of Statistical Quality Control (SQC)

a. Sampling Inspection

Sampling inspection is the process of selecting a subset of items from a batch or population to check whether they meet quality standards. Instead of inspecting every single product, which is costly and time-consuming, a random sample is drawn to represent the entire lot.

This method relies on probability theory to ensure that the sample reflects the overall quality of the batch. If the sample passes inspection, the batch is accepted; if not, corrective measures are taken. This approach balances efficiency with reliability, making it a cornerstone of SQC.

Inspection itself is the act of checking whether a component meets the required specifications. Sampling adds a statistical dimension by ensuring that the inspection is representative and unbiased. By using random sampling, organizations reduce inspection costs while still maintaining confidence in product quality.

Example: A biscuit factory inspects 50 biscuits from a batch of 10,000. If the sample meets quality standards, the entire batch is approved for packaging and sale.

b. Analysis of Data

Analysis of data involves evaluating information gathered during inspection using logical and statistical reasoning. Data from samples is collected, reviewed, and analyzed to identify patterns, variations, and potential defects.

This step transforms raw numbers into meaningful insights about the production process. Through data analysis, organizations can detect whether variations are within

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acceptable limits or whether they indicate deeper problems.

For example, consistent deviations in measurements may point to machine wear or operator error. By interpreting data correctly, managers can make informed decisions about process adjustments, resource allocation, and corrective actions.

Example: In a steel plant, data analysis may reveal that sheet thickness consistently deviates by 0.5 mm, indicating worn-out rollers that need replacement.

c. Control Charting

Control charts are graphical tools used to monitor process performance over time. They plot data points against predetermined control limits, which represent the acceptable range of variation.

If the process stays within these limits, it is considered stable and under statistical control. If data points fall outside the limits, it signals that corrective action is needed. Control charts help distinguish between normal variation (common causes) and abnormal variation (special causes).

This distinction is crucial because it prevents unnecessary interventions when variation is natural, while ensuring timely action when problems arise. By continuously monitoring processes, control charts support ongoing quality improvement and process stability.

Example: A pharmaceutical company uses control charts to monitor tablet weight. If weights remain within control limits, production continues; if they exceed limits, machine calibration is adjusted immediately.

d. Integration of Techniques

Together, sampling inspection, data analysis, and control charting form the backbone of SQC. Sampling ensures efficient inspection, data analysis provides insights into process behaviour, and control charts monitor stability over time.

These methodologies work in harmony to reduce defects, improve efficiency, and maintain consistent quality. By applying these scientific techniques, organizations can move beyond guesswork to evidence-based decision-making.

This systematic approach not only enhances product reliability but also builds customer trust and strengthens competitiveness in the market.

Example: An electronics manufacturer integrates sampling inspection, defect data analysis, and control charts to ensure circuit boards meet reliability standards, reducing customer complaints.

e. Acceptance Sampling

Acceptance sampling is the application of statistical techniques to decide whether to accept or reject a batch of products that has already been produced.

Instead of inspecting every single item, a random sample is drawn from the lot, and

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its quality is assessed. If the sample meets the required standards, the entire batch is accepted; if not, it is rejected.

This method saves time and cost while still ensuring reliability. Acceptance sampling is particularly useful when 100% inspection is impractical or too expensive.

Example: A textile mill inspects 100 rolls of fabric from a batch of 5,000. If defects are below the acceptable threshold, the batch is approved; otherwise, it is rejected.

f. Process Control

Process control, on the other hand, focuses on monitoring and controlling quality during the production process itself.

It is widely used in mass production industries where standard products are manufactured in large quantities. By applying statistical techniques, organizations can detect variations while production is ongoing and take corrective action immediately.

This prevents defects from accumulating and ensures that the process remains stable and efficient.

Example: In a car assembly line, sensors continuously monitor torque levels during bolt tightening. If deviations occur, adjustments are made instantly to prevent defective vehicles.

g. Probability Theory Basis

The foundation of SQC for process control lies in probability theory. It acknowledges that variations in product dimensions or performance are inevitable due to machine characteristics, material differences, or environmental conditions.

Probability helps distinguish between normal variation (common causes) and abnormal variation (special causes). By applying statistical methods, managers can determine whether the process is under control or whether intervention is required.

Example: In a bottling plant, probability analysis shows that minor variations in fill levels are normal, but sudden large deviations indicate machine malfunction.

h. Strategic Importance

Using SQC for process control provides organizations with a scientific and systematic way to maintain quality.

It reduces waste, improves efficiency, and ensures customer satisfaction by keeping production consistent. Moreover, it shifts quality management from a reactive approach (detecting defects after production) to a proactive one (preventing defects during production).

This makes SQC not just a technical tool but a strategic asset for achieving long-term competitiveness and excellence.

Example: Toyota's use of SQC in process control ensures consistent car quality,

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reduces recalls, and strengthens its global reputation for reliability.

4.1.6.3 Statistical Process Control (SPC)

a. Monitoring Production Processes

SPC is a statistical procedure that uses control charts to monitor whether a production process is functioning properly. By plotting data points against control limits, SPC helps identify variations that could lead to poor quality.

This allows organizations to detect problems early, before defective products are produced in large quantities. The focus is on prevention rather than correction, making SPC a proactive tool for maintaining consistency.

Example: In a bottling plant, SPC charts track the fill levels of bottles. If the data shows bottles consistently underfilled, corrective action is taken before thousands of defective bottles are produced.

b. Preventing Poor Quality

Unlike traditional inspection methods that detect defects after production, SPC emphasizes controlling the process while it is happening. By continuously monitoring variables such as machine performance, material consistency, and operator actions, SPC ensures that the process remains stable.

This reduces waste, lowers costs, and improves efficiency. In mass production industries, SPC is especially valuable because even small variations can lead to significant quality issues when scaled.

Example: In a semiconductor factory, SPC monitors wafer thickness during production. Detecting small deviations early prevents large batches of defective chips.

c. Role in TQM

Employee training in SPC is a fundamental principle of Total Quality Management (TQM). Workers must understand how to interpret control charts, recognize signals of abnormal variation, and take corrective action.

This involvement empowers employees to take responsibility for quality at the operational level. Training also fosters a culture of continuous improvement, where employees actively contribute to maintaining and enhancing process stability.

Example: At Toyota, assembly line workers are trained to read SPC charts and stop production immediately if abnormal variations are detected, ensuring defects don't accumulate.

d. Strategic Importance

SPC is not just a technical tool but a strategic asset. By ensuring that processes remain under statistical control, organizations can consistently deliver products that meet customer expectations.

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It strengthens competitiveness, builds trust, and supports long-term sustainability. When integrated into TQM, SPC becomes part of a holistic system where leadership, employee involvement, and statistical methods work together to make quality the centrepiece of organizational success.

Example: Samsung uses SPC across its electronics production lines to maintain consistent quality, which strengthens its global reputation and customer trust.

4.1.6.4 Basics of Statistical Process Control (SPC)

a. SPC and Sampling

SPC relies on sampling, where a subset of items produced is selected for inspection. This makes the process efficient because it is impractical to check every single product in mass production.

By analyzing samples, SPC can identify whether the production process is stable or if corrective action is needed. The goal is not only to detect problems but to prevent them by monitoring the process continuously.

Example: In a biscuit factory, inspectors check random samples from each batch to ensure weight and size consistency, preventing large-scale defects.

b. SPC as a Tool for Improvement

SPC is more than just inspection - it is a tool for identifying problems and driving improvements. By using control charts and statistical methods, SPC highlights variations that may lead to defects.

Once these variations are detected, managers and employees can investigate root causes and implement corrective measures. This proactive approach ensures that quality is built into the process rather than inspected at the end.

Example: In a textile mill, SPC reveals recurring defects in fabric width. Managers trace the issue to worn-out rollers and replace them, improving quality.

c. Quality Measures: Attributes

An attribute is a product characteristic that can be evaluated with a discrete response, such as “yes/no” or “good/bad.”

For example, checking whether a light bulb works or whether a surface is free from scratches are attribute measures. These are simple, binary checks that provide quick feedback but may not capture the full extent of variation in a product.

Example: In a toy factory, inspectors check whether each toy car’s wheels are properly attached (yes/no) before packaging.

d. Quality Measures: Variables

A variable measure, on the other hand, is a product characteristic that can be measured on a continuous scale, such as weight, length, or temperature.

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Variable measures provide more detailed information because they show the degree of variation rather than just a pass/fail result. For example, measuring the diameter of a pipe reveals whether it is within tolerance limits and how close it is to the ideal specification.

Variable data is more powerful for SPC because it allows for precise monitoring and control of processes.

Example: In a pharmaceutical company, the exact weight of tablets is measured to ensure they fall within tolerance limits, guaranteeing dosage accuracy.

4.1.7 Quality Control Charts

A control chart is a graphical tool used in Statistical Process Control (SPC) to monitor whether a process is stable and functioning within acceptable limits. It plots data points over time and compares them against control limits, the upper and lower boundaries that define the expected range of variation. If the process data stays within these limits, it is considered under control; if points fall outside, it signals that corrective action may be needed. Control charts thus help distinguish between normal variation (common causes) and abnormal variation (special causes).

4.1.7.1 Control Charts and their Types

A) Attribute Charts

Attribute charts are used when quality is measured in terms of discrete responses such as "yes/no" or "good/bad." They are particularly useful for counting defects or defective items.

- **p-chart**: Monitors the proportion of defective items in a sample.
- **c-chart**: Tracks the number of defects per unit (e.g., scratches, errors).

i. p-charts

Control charts for Attributes p-chart uses the proportion defective in a sample. A c-chart uses the number of defective items in a sample. Based on the normal distribution to compute the upper control limit (UCL) and lower control limit (LCL) of a p-chart.

$$UCL = \bar{p} + z \cdot \sigma_{\bar{p}}$$

$$LCL = \bar{p} - z \cdot \sigma_{\bar{p}}$$

Where:

- z = the number of standard deviations from the process average (control limit multiplier).
- $\bar{p}$ = the average sample proportion defective (process mean).

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◊ $\sigma_{\bar{p}} = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ = the standard deviation of the sample proportion, with n being the sample size.

Where n is the sample size. explain more

These charts are simple to use and provide quick insights into whether the process is producing too many defects.

ii. C-charts: -

A c-chart is used when it is not possible to compute a proportion defective and the actual number of defects must be used.

$$UCL = \bar{c} + z \cdot \sigma_{\bar{c}}$$

$$LCL = \bar{c} - z \cdot \sigma_{\bar{c}}$$

Where:

◊ z = the number of standard deviations from the process average (control limit multiplier).

◊ $\bar{c}$ = the average count of defects per sample (process mean).

◊ $\sigma_{\bar{c}} = \sqrt{\bar{c}}$ = the standard deviation of the defect count.

B) Variable Charts

Variable charts are used when quality is measured on a continuous scale, such as weight, length, or temperature. They provide more detailed information about the degree of variation.

i. Range (R)-chart

R-chart: Tracks the range (spread) of values within a sample.

In an R- chart, the range is the difference between the smallest and largest values in a sample. The formulas for determining control limits are,

$$UCL = D_4 \cdot \bar{R}$$

$$LCL = D_3 \cdot \bar{R}$$

Where:

◊ $\bar{R} = \frac{\sum R}{k}$ = the average range, calculated as the sum of ranges of all samples divided by the number of samples.

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◊ R = the range of each sample (difference between maximum and minimum observation in the sample).

◊ k = the number of samples.

◊ D_3 and D_4 = tabulated constants used to determine control limits, developed based on range values rather than standard deviation.

ii. Mean X – Chart

For an X –chart , the mean of each sample is computed and plotted on the chart; the points are the sample means.

$$\bar{\bar{X}} = \frac{X_1 + X_2 + \cdots + X_k}{k}$$

Formulas for control limits:

$$UCL = \bar{\bar{X}} + A_2 \cdot \bar{R}$$

$$LCL = \bar{\bar{X}} - A_2 \cdot \bar{R}$$

Where:

◊ $\bar{\bar{X}}$ = the grand mean, i.e., the average of the sample means.

◊ $\bar{R} = \frac{\sum R}{k}$ = the average range, calculated as the sum of ranges of all samples divided by the number of samples.

◊ R = the range of each sample (difference between maximum and minimum observation in the sample).

◊ k = the number of samples.

◊ A_2 = tabulated constant used to determine control limits for the $\bar{X}$-chart, based on sample size.

Together, X-bar and R-charts show whether the process mean and variability are stable, making them powerful tools for detecting subtle shifts in production quality.

4.1.7.2 Importance of Chart Selection

Choosing the right type of chart depends on the nature of the data being measured.

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Attribute charts are best for categorical outcomes, while variable charts are suited for measurable characteristics. Both types complement each other in providing a comprehensive view of process performance. By applying these charts, organizations can maintain statistical control, reduce defects, and ensure consistent product quality.

4.1.8 Quality Certification

Quality certification is a formal recognition granted to organizations that meet established standards of quality in their processes, products, or services. It serves as proof that the company adheres to internationally accepted practices and consistently delivers outcomes that satisfy customer requirements.

Certification is not just a technical approval, it enhances credibility, builds trust with customers, and strengthens competitiveness in the global market.

Example: A hospital earning NABH (National Accreditation Board for Hospitals) certification demonstrates adherence to patient safety and quality standards, building trust among patients.

a. Common Standards

The most widely recognized quality certifications are issued under the ISO (International Organization for Standardization) framework, such as ISO 9001 for Quality Management Systems. These certifications require organizations to demonstrate systematic control over processes, continuous improvement, and customer focus.

Other certifications include Six Sigma, which emphasizes defect reduction, and industry-specific standards like HACCP for food safety or ISO/TS 16949 for automotive quality.

Example: A food processing company with HACCP certification assures customers that its products meet strict food safety standards.

b. International Standards

International standards are standards developed by international standards organizations. ISO stands for the International Organization for Standardization, set up with the objective to promote the development of standards and related activities for facilitating international exchanges of goods and services.

Example: A textile exporter in India adopts ISO standards to ensure its products meet international requirements, enabling smooth trade with European markets.

4.1.8.1 ISO 9000

The ISO 9000 standards were first developed in 1978, evolving from quality assurance systems used in several nations. The International Organization for Standardization (ISO) consolidated these practices into a unified framework, making ISO 9000 a globally recognized benchmark for quality management.

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Over time, the standards have been revised to reflect modern business needs, technological advancements, and customer expectations.

Example: A manufacturing company updates its ISO 9000 compliance to include digital tracking systems, aligning with modern technological practices.

a. Focus on Quality Management

The ISO 9000 family specifically addresses quality management systems (QMS). It defines how organizations should structure their processes to consistently meet customer requirements and regulatory obligations.

Rather than focusing only on product inspection, ISO 9000 emphasizes building quality into every stage of operations—from planning and production to delivery and customer service.

Example: An electronics company integrates ISO 9000 standards into its design and production processes, ensuring consistent quality from prototype to final product.

b. Customer and Regulatory Requirements

A central principle of ISO 9000 is fulfilling both customer quality requirements and applicable regulatory requirements.

This dual focus ensures that organizations not only satisfy customer expectations but also comply with laws, industry standards, and safety regulations. By aligning these two aspects, ISO 9000 helps companies reduce risks, avoid penalties, and strengthen customer trust.

Example: A pharmaceutical firm ensures compliance with FDA regulations while meeting customer expectations for safe and effective medicines.

c. Continuous Improvement and Satisfaction

ISO 9000 also emphasizes enhancing customer satisfaction and achieving continual improvement. Organizations are encouraged to monitor performance, gather feedback, and implement corrective actions to refine processes.

This cycle of improvement ensures that businesses remain competitive, efficient, and responsive to changing market demands. Ultimately, ISO 9000 transforms quality management into a strategic tool for long-term success.

Example: A hotel chain uses customer feedback to refine services, ensuring continual improvement in guest satisfaction under ISO 9000 guidelines.

d. Flexibility and Global Relevance

ISO 9000 is characterized by its flexibility and global relevance. It can be implemented in organizations of any type or size, whether small businesses or large multinational corporations, making it universally applicable.

The standards are independent of product type, industry, or country, ensuring that

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they can be adopted across diverse sectors worldwide. With international acceptance and recognition, ISO 9000 provides credibility and trust, helping companies compete in global markets.

Example: A small IT startup adopts ISO 9000 to build credibility with international clients, despite being a new entrant in the market.

4.1.8.2 ISO 9000 Categories and Benefits

a. ISO 9000 Categories

The ISO 9000 series is divided into specific categories to address different aspects of quality management:

ISO 9001 focuses on suppliers and designers, ensuring that design and development processes meet customer requirements.

Example: A software company uses ISO 9001 to ensure its design process meets client specifications.

ISO 9002 applies to production, emphasizing process control and consistency in manufacturing.

Example: A car manufacturer applies ISO 9002 to maintain consistency in assembly line production.

ISO 9003 deals with inspection and testing, ensuring that finished products conform to standards before reaching customers.

Example: A toy company uses ISO 9003 to inspect toys for safety before distribution.

ISO 9004 provides guidelines for overall quality management, helping organizations improve performance and efficiency across all functions.

Example: A logistics company adopts ISO 9004 to enhance efficiency across supply chain operations.

b. Tangible Benefits

ISO 9000 certification provides clear, measurable advantages. It offers a competitive edge in the global market by demonstrating compliance with internationally recognized standards.

It ensures consistency in quality by detecting non-conformities early, allowing corrective action before defects reach customers. Documentation of quality procedures adds clarity, transparency, and accountability, making systems easier to manage and audit.

Example: A chemical company reduces defects by 30% after implementing ISO 9000 documentation and early detection systems.

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c. Intangible Benefits

Beyond measurable outcomes, ISO 9000 also delivers intangible benefits. It ensures regular training for employees, which builds competence and confidence.

Customers benefit from cost-effective purchasing because certified companies reduce the need for extensive inspection and testing, lowering quality costs and lead times. This efficiency translates into higher productivity and smoother operations.

Example: A certified electronics supplier reduces lead times for clients, improving customer satisfaction and loyalty.

d. Organizational Impact

ISO 9000 strengthens morale and involvement among workers by fostering a culture of quality and responsibility. Employees feel more engaged, leading to improved job satisfaction.

The certification signals that the organization values excellence, which motivates staff and builds pride in their work. Ultimately, ISO 9000 is not just a compliance tool- it is a framework that enhances competitiveness, productivity, and long-term sustainability.

Example: Employees in a certified textile company report higher job satisfaction due to clear quality standards and recognition of their role in maintaining excellence.

e. Process of Certification

Obtaining quality certification involves several steps: preparing documentation of processes, implementing quality management systems, conducting internal audits, and undergoing external audits by accredited certifying bodies.

Once certified, organizations must maintain compliance through periodic reviews and continuous improvement. Certification is therefore not a one-time achievement but an ongoing commitment to excellence.

Example: A construction firm undergoes annual ISO audits to maintain certification and ensure compliance with evolving safety standards.

f. Strategic Importance

Quality certification provides organizations with a competitive edge. It assures customers that the company follows disciplined processes, reduces risks of defects, and prioritizes satisfaction.

It also opens doors to new markets, as many clients and governments require certified suppliers. In essence, certification transforms quality from an internal goal into a recognized standard of excellence that drives long-term sustainability.

Example: An automotive parts supplier gains access to international contracts after achieving ISO/TS 16949 certification, boosting global competitiveness.

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4.1.9 Six Sigma

Six Sigma was introduced by Motorola in 1986 as a business management strategy to improve quality and efficiency. The term comes from statistical modeling, where "sigma" represents the standard deviation a measure of variation. Achieving "six sigma" means that a process produces only 3.4 defects per million opportunities, or a 99.99966% defect-free rate. This extremely high level of precision became the benchmark for world-class manufacturing and later expanded into service industries.

Example: General Electric adopted Six Sigma in the 1990s, reducing defects in its manufacturing processes and saving billions in operational costs.

a. Methodology and Tools

Six Sigma focuses on identifying and eliminating the causes of defects and minimizing variability in processes. It uses a structured methodology known as DMAIC (Define, Measure, Analyze, Improve, Control) for existing processes and DMADV (Define, Measure, Analyze, Design, Verify) for new processes. Statistical tools such as regression analysis, hypothesis testing, and design of experiments are employed to analyze data and drive improvements.

Example: A bank applies DMAIC to reduce errors in loan processing, improving accuracy and customer satisfaction.

b. Infrastructure and Roles

A unique feature of Six Sigma is its specialized infrastructure of trained experts within the organization. These include Green Belts, Black Belts, and Master Black Belts, who lead projects and mentor teams in applying Six Sigma techniques. This structured hierarchy ensures that improvement initiatives are systematically managed and embedded into the company's culture.

Example: At Honeywell, Black Belts lead cross-functional projects to reduce production cycle times, while Green Belts support departmental improvements.

c. Strategic Importance

Six Sigma is not just about defect reduction, it is a comprehensive management philosophy. By improving process capability and reducing variability, organizations achieve higher customer satisfaction, lower costs, and greater efficiency. It also fosters a culture of data-driven decision-making and continuous improvement. Over time, Six Sigma has become a global standard for excellence, giving companies a competitive advantage in both manufacturing and service sectors.

Example: Amazon applies Six Sigma principles to streamline warehouse operations, ensuring faster deliveries and fewer errors.

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4.1.9.1 Quality Management Tools used in Six Sigma

a. Pareto Analysis and Pareto Chart

Pareto analysis is based on the 80/20 principle, which suggests that 80% of problems often come from 20% of causes. A Pareto chart is a bar graph that helps visualize this by ranking problems or defects in descending order of frequency. This allows organizations to focus improvement efforts on the most critical issues that will yield the greatest impact.

Example: In a call center, Pareto analysis may show that 80% of complaints come from just two recurring issues, long wait times and billing errors.

b. Analysis of Variance (ANOVA)

ANOVA is a statistical method used to compare means across multiple groups to determine if differences are significant. In Six Sigma, it helps identify whether variations in process outcomes are due to random chance or specific factors such as machine settings, materials, or operator performance.

Example: In a factory, ANOVA may reveal that one machine consistently produces higher defect rates compared to others, indicating a need for maintenance.

c. Check Sheet

A check sheet is a simple data collection tool used to record the frequency of defects or events. It provides a structured way to gather information directly from the process and is often the first step in problem analysis.

Example: A bakery uses check sheets to record daily occurrences of burnt bread, helping identify patterns linked to oven temperature settings.

d. Chi-Squared Test

The chi-squared test of independence and goodness of fit is used to determine whether categorical data sets are related or whether observed frequencies match expected ones. In quality management, it helps verify whether defects are randomly distributed or linked to specific causes.

Example: A textile company uses chi-squared testing to check if fabric defects are linked to specific shifts or operators.

e. Control Chart

Control charts are central to Six Sigma. They track process performance over time, comparing data points against upper and lower control limits. This helps distinguish between normal variation and special cause variation, guiding corrective action when needed.

Example: A pharmaceutical company uses control charts to monitor tablet weight consistency, ensuring dosage accuracy.

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f. Correlation and Regression Analysis

Correlation measures the strength of the relationship between two variables, while regression analysis models how one variable influences another. These tools help identify cause-and-effect relationships in processes, enabling data-driven improvements.

Example: A car manufacturer uses regression analysis to study how tire pressure affects fuel efficiency.

g. Cost-Benefit Analysis

This tool evaluates whether the benefits of a proposed improvement outweigh the costs. It ensures that Six Sigma projects deliver measurable value and prioritize initiatives that maximize return on investment.

Example: A logistics company conducts cost-benefit analysis before investing in automated sorting machines, ensuring savings outweigh costs.

h. Scatter Diagram

A scatter diagram plots data points to show the relationship between two variables. It visually reveals patterns, trends, or correlations, helping teams understand how changes in one factor affect another.

Example: A beverage company uses scatter diagrams to analyze the relationship between storage temperature and spoilage rates.

i. Histograms

Histograms are bar charts that display the distribution of data. They help visualize variation in process outcomes, showing whether data is normally distributed or skewed. This aids in identifying patterns of defects and opportunities for improvement.

Example: An electronics company uses histograms to analyze defect rates in circuit boards, identifying whether issues are random or systematic.

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Summarised Overview

Quality management encompasses a broad set of practices designed to ensure that organizations consistently deliver products and services that meet customer expectations and regulatory requirements. Total Quality Management (TQM) emphasizes continuous improvement, customer focus, and employee involvement, while Quality Circles encourage small groups of workers to collaboratively solve problems. Quality Control (QC) ensures standards are met during production, and Statistical Quality Control (SQC) applies probability and statistical techniques to monitor and improve processes. Tools like control charts help distinguish between normal variation and defects, ensuring processes remain stable and efficient.

Building on these foundations, Quality Certification such as ISO 9000 provides international recognition of an organization's commitment to quality systems, while Six Sigma offers a data-driven strategy to minimize defects and variability, aiming for near-perfect performance. Together, these approaches provide both technical and strategic benefits: they reduce costs, improve productivity, enhance customer satisfaction, and strengthen competitiveness in global markets. In essence, quality management integrates systematic control, statistical rigor, and organizational culture to achieve excellence and sustainability.

Self-Assessment Question

1. Explain the meaning of quality and discuss its importance in production and operations management.
2. Explain the concept of Total Quality Management (TQM) and describe its major principles.
3. Describe W. Edwards Deming's 14 points and explain their importance in improving organisational quality.
4. Explain the Deming Wheel or PDCA Cycle and describe the activities involved in each stage.
5. Explain the strategic implications of TQM and discuss its contribution to organisational performance.
6. Describe the quality circle process and explain how quality circles help employees participate in quality improvement.

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7. Explain the methods used for identifying quality problems and their causes in a manufacturing organisation.
8. Explain the meaning, objectives and importance of quality control.
9. Explain Statistical Quality Control (SQC) and discuss its major objectives.
10. Describe the main methodologies of Statistical Quality Control (SQC) and explain their applications in quality management.
11. Explain the basics of Statistical Process Control (SPC) and discuss its importance in maintaining consistent product quality.
12. Explain the meaning and purpose of quality control charts and describe their major types.
13. Explain quality certification and discuss the meaning, categories and benefits of ISO 9000.
14. Explain the concept of Six Sigma and discuss its importance in reducing defects and improving quality.
15. Describe the major quality management tools used in Six Sigma and explain their applications.



Assignments

1. Analyse the relationship between quality, customer satisfaction and organisational performance. Explain how quality influences competitiveness.
2. Analyse the major principles of TQM and explain how they work together to create a culture of continuous improvement.
3. Apply the PDCA Cycle to solve a recurring quality problem in a manufacturing organisation. Explain the activities involved in each stage.
4. A company identifies frequent defects in its production process. Explain how quality problem identification and root-cause analysis can be applied to find the causes and suggest corrective actions.
5. A factory experiences variations in the dimensions of its manufactured components. Explain how Statistical Process Control (SPC) and suitable control charts can be used to monitor the process.

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6. A manufacturing organisation plans to obtain ISO 9000 certification. Explain the steps it should follow to establish an appropriate quality management system.

7. Apply the Six Sigma methodology to a company experiencing high defect rates and increasing production costs. Explain how quality management tools can support the improvement process.

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Suggested Reading

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

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Unit 2

Project and Maintenance Management

Learning Outcomes

After completing this unit, learner will be able to:

- ◊ explain the nature, characteristics and different stages of the Project Life Cycle
- ◊ apply Gantt Charts to schedule and monitor project activities effectively
- ◊ analyse project activities using CPM and PERT techniques to identify critical activities and estimate project completion time
- ◊ evaluate different types of maintenance management practices and select appropriate maintenance strategies for organisational requirements
- ◊ develop a basic Total Productive Maintenance (TPM) approach to improve equipment effectiveness, productivity and minimise breakdowns

Background

Project and Maintenance Management is a dual discipline combining the systematic execution of projects with the upkeep of organizational assets. Projects are temporary endeavours with defined objectives, requiring structured phases from initiation to closure. Techniques such as Gantt charts, Critical Path Method (CPM), and Program Evaluation and Review Technique (PERT) help in scheduling and resource allocation. Maintenance management, on the other hand, focuses on sustaining equipment reliability through corrective, preventive, predictive, and TPM strategies. This integration ensures operational efficiency, cost control, and long-term sustainability in industries ranging from manufacturing to services.

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Keywords

Project Management, Project Life Cycle, Gantt Chart, CPM, PERT, Maintenance Management, Types of Maintenance, Total Productive Maintenance (TPM)

Discussion

Project and Maintenance Management are important areas of operations management that help organisations plan, execute, control and sustain their activities efficiently. Project management involves managing a temporary set of activities to achieve specific objectives within a defined time, cost and quality framework. Understanding the nature and characteristics of projects and the Project Life Cycle helps managers effectively handle projects from initiation to completion. Various project management techniques, such as Gantt Charts, Critical Path Method (CPM) and Programme Evaluation and Review Technique (PERT), assist in scheduling, monitoring and controlling project activities. Maintenance management focuses on keeping machinery, equipment and facilities in good working condition to ensure smooth and uninterrupted operations. Different types of maintenance, including preventive, corrective and predictive maintenance, help reduce breakdowns and improve equipment reliability. Total Productive Maintenance (TPM) further promotes the involvement of employees at all levels in maintaining equipment, improving productivity, reducing losses and achieving continuous improvement.

4.2.1 Project

A project is essentially a temporary and unique endeavour undertaken to create a specific product, service, or result. Unlike routine operations, which are repetitive and ongoing, projects are defined by their uniqueness and finite duration. They have a clear beginning and end, and their purpose is to achieve a particular objective whether it's constructing a building, developing software, or launching a new product. Because of this, projects often involve uncertainty, innovation, and the need for careful coordination of resources.

4.2.2 Nature of a Project

1. Temporary in nature

A project is undertaken for a limited period and ends when its objectives are achieved or the project is terminated.

Example: Constructing a shopping mall is a project that ends after construction and handover.

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2. Objective-oriented

Every project is undertaken to achieve one or more clearly defined objectives. Example: A company may undertake a project to develop and launch a new mobile application.

3. Planned activity

Projects require systematic planning of activities, resources, time, cost and responsibilities before implementation.

4. Resource-intensive

Projects require resources such as people, money, materials, equipment, technology and information. Proper allocation of these resources is essential for successful completion.

5. Limited time and budget

Projects normally operate within predetermined time and cost constraints. Project managers must complete the work within the approved schedule and budget.

6. Involves change

Projects are often undertaken to introduce something new or bring about improvement or change in an organisation.

Example: Implementing a new ERP system changes how employees perform their daily activities.

7. Requires coordination

Different individuals, departments, contractors and suppliers may be involved in a project. Their activities must be properly coordinated.

8. Associated with uncertainty and risk

Projects may face uncertainties relating to technology, costs, resources, suppliers, regulations or customer requirements. Therefore, risk identification and management are important parts of project management.

4.2.3 Characteristics of a Project

The major characteristics of a project are:

1. Specific Objective

A project has a clearly defined purpose or goal that needs to be achieved.

Example: The objective of a road construction project may be to construct a 10-kilometre road within 18 months.

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2. Definite Start and Finish

A project has a specific starting point and a planned completion date. Once the intended objectives are achieved, the project comes to an end.

3. Uniqueness

Every project is unique because it involves a particular combination of objectives, resources, conditions and circumstances.

Example: Constructing two buildings may involve similar activities, but their locations, designs, budgets and requirements may differ.

4. Interrelated Activities

A project consists of several activities that are connected to one another. Delay in one activity may affect subsequent activities.

Example: In a construction project, foundation work must generally be completed before major structural work begins.

5. Limited Resources

Projects have limited resources in terms of time, money, labour, materials and equipment. Project managers must use these resources efficiently.

6. Time Constraint

Projects must normally be completed within a specified period. Techniques such as Gantt Charts, CPM and PERT help managers plan and control project schedules.

7. Cost Constraint

A project is usually carried out within an approved budget. Uncontrolled expenditure can lead to project failure even when the project is completed successfully.

8. Quality Requirement

The project must meet predetermined quality standards and specifications.

Example: A hospital construction project must satisfy required safety, structural and service standards.

9. Risk and Uncertainty

Projects involve various risks, such as delays, cost increases, technical problems, labour shortages and changes in customer requirements.

10. Multiple Stakeholders

A project may involve several stakeholders, including project managers, employees, customers, suppliers, contractors, government agencies and investors. Their expectations need to be managed effectively.

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11. Progressive Development

A project is developed gradually through different stages. Details become clearer as the project progresses from initiation and planning to execution and completion.

12. Team-Based Approach

Projects usually require people with different skills and expertise to work together towards a common objective.

Example: An IT project may require software developers, designers, testers, project managers and business analysts.

4.2.4 Project Life Cycle

The Project Life Cycle refers to the series of stages through which a project passes from its beginning to its completion. It provides a systematic framework for planning, executing, monitoring and closing a project. Although the names and number of stages may vary depending on the type of project, a project generally moves through four major phases: Initiation, Planning, Execution, and Closure.

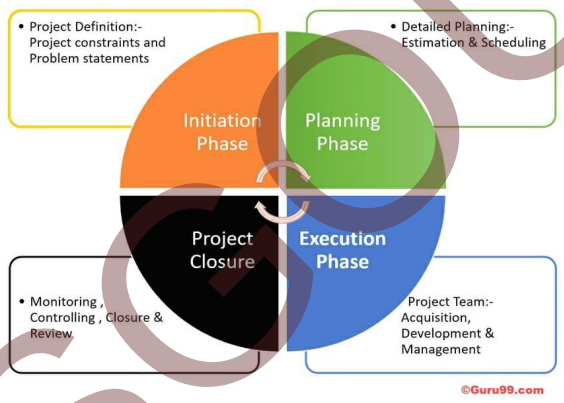


Fig 4.2.1 Project Life Cycle

1. Initiation Phase

The initiation phase is the starting point of the project. The organisation identifies a need, problem or opportunity and determines whether a project should be undertaken.

Major activities include:

- ◊ Identifying the project idea or need.
- ◊ Defining the broad objectives.
- ◊ Identifying major stakeholders.
- ◊ Conducting a preliminary feasibility study.
- ◊ Estimating the initial cost and time requirements.

- ◊ Identifying major risks.
- ◊ Preparing a Project Charter or project proposal.
- ◊ Obtaining approval to proceed.

Example: A company decides to develop a new mobile application to improve customer service. The organisation first examines the need, expected benefits, approximate cost and feasibility.

2. Planning Phase

The planning phase determines how the project will be completed. It is one of the most important phases because proper planning reduces delays, cost overruns and resource problems.

Major activities include:

- ◊ Defining project scope and objectives.
- ◊ Breaking the project into activities.
- ◊ Preparing the project schedule.
- ◊ Estimating costs and preparing the budget.
- ◊ Allocating human and other resources.
- ◊ Identifying and analysing risks.
- ◊ Preparing quality plans.
- ◊ Developing communication procedures.
- ◊ Assigning responsibilities to team members.
- ◊ Selecting appropriate project management techniques such as Gantt Chart, CPM and PERT.

Example: For the mobile application project, the team identifies activities such as requirements analysis, software design, coding, testing and implementation and determines the time and resources required for each activity.

3. Execution Phase

The execution phase is the stage where the actual project work is carried out according to the approved plan. The project team performs the planned activities and produces the required outputs.

Major activities include:

- ◊ Mobilising project resources.
- ◊ Assigning work to team members.

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- ◊ Performing project activities.
- ◊ Coordinating employees, suppliers and contractors.
- ◊ Managing communication among stakeholders.
- ◊ Monitoring quality.
- ◊ Managing changes and risks.
- ◊ Producing project deliverables.

Example: In the mobile application project, programmers develop the application, designers create the interface and testers check whether the application works correctly.

4. Monitoring and Controlling

Monitoring and controlling takes place throughout the execution of the project. It ensures that actual performance remains consistent with the project plan.

Major activities include:

- ◊ Comparing actual progress with planned progress.
- ◊ Monitoring project costs.
- ◊ Controlling the project schedule.
- ◊ Checking quality standards.
- ◊ Monitoring risks.
- ◊ Managing changes.
- ◊ Taking corrective action when deviations occur.

Example: If software development is taking longer than planned, the project manager analyses the reason for the delay and takes corrective action to bring the project back on schedule.

Note: In many project management frameworks, monitoring and controlling is treated as a separate process group that operates alongside execution rather than as a completely separate sequential phase.

5. Closure Phase

The closure phase is the final stage of the project. The project is formally completed after the required deliverables have been accepted.

Major activities include:

- ◊ Completing all remaining project activities.
- ◊ Delivering the final product or service.
- ◊ Obtaining customer or client acceptance.

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- ◊ Closing contracts.
- ◊ Releasing project resources.
- ◊ Preparing the final project report.
- ◊ Documenting lessons learned.
- ◊ Evaluating project performance.
- ◊ Formally closing the project.

Example: After the mobile application is successfully tested and accepted by the client, it is launched, project documents are completed, the project team is released and the project is formally closed.

4.2.5 Project Management

Project management, therefore, is the discipline of planning, organizing, and controlling the various activities required to achieve the project's goals. It involves defining the scope of work, scheduling tasks, allocating resources, and monitoring progress to ensure that the project stays within budget and time constraints. Effective project management also requires risk assessment, communication among stakeholders, and adaptability to changes that may arise during execution. For example, in the construction of a shopping mall, project management would oversee everything from architectural design and procurement of materials to workforce coordination and compliance with safety regulations.

In practice, project management is not limited to construction alone. It applies to diverse fields such as information technology, healthcare, education, and manufacturing. For instance, implementing a new hospital management system or introducing a new curriculum in a university are projects that demand structured management. The essence of project management lies in balancing constraints, time, cost, and quality, while ensuring that the intended innovation or change is successfully delivered. This makes project management a vital function in modern organizations, enabling them to adapt, grow, and remain competitive in dynamic environments.

a. **Project Team:** In project management, the project team plays a central role in ensuring that objectives are achieved effectively. A project team is typically composed of individuals drawn from different departments within the organization. This diversity allows the team to bring together varied expertise, perspectives, and skills, which are essential for tackling complex tasks.

   Example: A construction project might involve engineers, financial analysts, procurement specialists, and safety officers, all working collaboratively toward the same goal.

b. **Matrix Organization** A common structure used to organize such teams is the matrix organization. In this arrangement, team members are selected from different functional areas, such as marketing, finance, operations, or IT, based

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on the specific skills required for the project. Unlike traditional hierarchical structures, the matrix model emphasizes flexibility and resource sharing. Team members often report both to their functional manager and the project manager, which ensures that their specialized expertise is utilized while still aligning with the overall project objectives.

Example: In a product launch project, a marketing specialist reports to the marketing department head for branding guidance and to the project manager for campaign deadlines.

c. **Project Manager:** At the centre of this setup is the project manager, who acts as the leader and coordinator of the project team. The project manager is responsible for defining goals, assigning tasks, monitoring progress, and ensuring that the project stays on track in terms of time, cost, and quality. Beyond technical oversight, the project manager also plays a crucial role in motivating the team, resolving conflicts, and facilitating communication among members from different departments.

Example: In a software development project, the project manager ensures coders, testers, and designers work together to deliver the product within six months.

d. **Statement of Work (SOW):** In project planning, the Statement of Work (SOW) is a foundational document that outlines the goals, scope, and deliverables of a project. It provides a written description of what the project intends to achieve, the specific tasks to be performed, and the expected time frame for completion. By clearly defining objectives, the SOW ensures that all stakeholders share a common understanding of the project's purpose and boundaries.

Example: In a university curriculum reform project, the SOW specifies that new courses must be introduced within one academic year, including training for faculty.

e. **Activities:** Every project is composed of activities, which require labor, resources, and time. These activities represent the individual tasks or operations that must be carried out to achieve the overall project goals. Effective planning involves estimating the manpower, materials, and duration needed for each activity.

Example: In a software development project, activities may include coding, testing, and documentation, each requiring specific skills and resources.

f. **Precedence Relationship:** A critical aspect of project planning is the precedence relationship among activities. This refers to the sequential order in which tasks must be performed. Some activities can only begin once others are completed, while certain tasks may run concurrently.

Example: In construction, the foundation must be laid before walls can be built, but electrical wiring and plumbing might proceed simultaneously once the structure is ready.

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g. **Simplified Project Network:** A simplified project network is a visual representation of the sequence of activities in a project, showing how tasks are connected and in what order they must be completed. It helps project managers and teams understand dependencies, allocate resources, and schedule work efficiently. Instead of listing tasks in isolation, the network diagram illustrates the logical flow, making it easier to identify critical paths and potential bottlenecks.

For example, in a construction project, activities such as constructing forms and pouring concrete are closely linked. Constructing forms refers to building the temporary structures (usually wooden or steel molds) that will hold the concrete in place until it hardens. This step must be completed before concrete can be poured, as the forms provide the necessary shape and support. Once the forms are ready, the next activity, pouring concrete, can begin. This involves mixing, transporting, and placing the concrete into the prepared forms, followed by compaction and curing to ensure strength and durability.

In the project network, these two activities would be shown in sequence: *Construct forms → Pour concrete*. This precedence relationship highlights that pouring concrete cannot start until the forms are constructed. By mapping such dependencies, the simplified project network ensures clarity in planning, prevents scheduling conflicts, and helps the team focus on

h. **Define Project Objective(s):** Defining project objectives is the first and most crucial step in project planning. Objectives provide direction and purpose, outlining what the project intends to achieve. They must be specific, measurable, achievable, relevant, and time-bound (SMART). Clear objectives help align the efforts of the project team and ensure that all stakeholders share a common vision.

Example: In a construction project, the objective might be to complete a building within 12 months at a specified budget.

i. **Identify Activities:** Once objectives are set, the next step is to identify the activities required to achieve them. Activities are the individual tasks or operations that make up the project. Breaking down the project into smaller, manageable activities helps in organizing work systematically and ensures that nothing is overlooked.

Example: In software development, activities may include requirement analysis, coding, testing, and deployment.

j. **Establish Precedence Relationships:** Activities in a project are rarely independent; they often depend on the completion of other tasks. Establishing precedence relationships means determining the logical order in which activities must be performed. This sequencing ensures that tasks are carried out efficiently without delays or conflicts.

Example: In construction, the foundation must be completed before walls can be built, and walls must be erected before roofing begins.

SGOU

k. **Make Time Estimates:** Accurate time estimation is essential for effective scheduling. Each activity requires a certain duration, and estimating this helps in building a realistic project timeline. Time estimates are based on past experience, expert judgment, or statistical methods such as PERT (Program Evaluation and Review Technique).

   Example: If pouring concrete takes three days, the schedule must account for curing time before subsequent activities can begin.

l. **Determine Project Completion Time:** After estimating the duration of individual activities, the overall project completion time can be determined. This involves analyzing the sequence of tasks and identifying the critical path, the longest chain of dependent activities that dictates the project's minimum completion time.

   Example: If the critical path shows a 12-month timeline, managers can plan buffer periods to handle unforeseen challenges without jeopardizing the final delivery date.

m. **Compare Project Schedule Objectives:** Once the schedule is prepared, it must be compared with the project's objectives to ensure alignment. This step involves checking whether the planned timeline, costs, and resource allocations meet the original goals set in the Statement of Work.

   Example: If the schedule exceeds the budget or deadline, adjustments must be made to keep the project feasible.

n. **Determine Resource Requirements to Meet Objective:** Finally, resource planning ensures that the project has the necessary manpower, materials, equipment, and finances to achieve its objectives. Determining resource requirements involves analyzing each activity and identifying what is needed to complete it successfully.

   Example: A construction project may require skilled labour, machinery, raw materials, and financial investment.

4.2.6 Techniques for Project Management

4.2.6.1 Work Breakdown Structure (WBS)

The Work Breakdown Structure (WBS) is a hierarchical decomposition of the project into smaller, manageable components. It breaks down the overall project into subcomponents, activities, and tasks, making it easier to plan, assign responsibilities, and monitor progress. WBS ensures clarity by showing how each task contributes to the overall project goal.

a. Determines Subcomponents

Subcomponents are the major deliverables or sections of the project. Breaking the project into subcomponents allows managers to focus on specific areas without losing sight of the overall objective.

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Example: In a bridge construction project, subcomponents may include foundation work, pillar construction, deck installation, and finishing.

b. Activities

Activities are the specific actions required to complete each subcomponent. They represent the steps that need to be taken to achieve progress.

Example: For the pillar construction subcomponent, activities may include pouring concrete, installing steel reinforcements, and curing the structure.

c. Tasks

Tasks are the smallest units of work in the WBS. They are detailed, actionable items that can be assigned to individuals or teams. Tasks ensure accountability and make monitoring easier.

Example: Within the activity of pouring concrete, tasks may include mixing concrete to the right ratio, transporting it to the site, and filling the pillar moulds.

4.2.6.2 Gantt Chart

A Gantt Chart is a visual project management tool that represents tasks or activities against time. It uses horizontal bars to show the start and end dates of each task, making it easy to see the sequence of activities and their duration. The chart provides a clear timeline of the project, helping managers and teams track progress and deadlines.

Example: In a website development project, a Gantt Chart may show tasks such as "Design Layout," "Code Backend," "Test Functionality," and "Launch Website," each represented by bars spanning their respective timelines.

a. Task Scheduling

One of the primary uses of a Gantt Chart is scheduling tasks. It shows when each task should begin and end, ensuring that work is organized and resources are allocated efficiently. This helps prevent overlaps or idle time.

Example: In a construction project, the Gantt Chart schedules tasks like "Foundation Work" (January–February), "Wall Construction" (March–April), and "Roof Installation" (May), ensuring proper sequencing.

b. Dependencies Between Tasks

Gantt Charts highlight dependencies, meaning which tasks must be completed before others can begin. This ensures logical sequencing and prevents bottlenecks.

Example: In a product launch project, the task "Marketing Campaign" cannot start until "Product Testing" is completed. The Gantt Chart visually shows this dependency with linked bars.

c. Progress Tracking

Gantt Charts allow managers to track progress by comparing planned timelines with

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actual completion. Updates can be made to reflect delays or early finishes, giving a real-time view of project status.

Example: In a film production project, if "Editing" was scheduled for two weeks but takes three, the Gantt Chart is updated to show the delay and its impact on subsequent tasks like "Final Review."

d. Resource Allocation

By showing tasks and timelines, Gantt Charts help managers allocate resources such as manpower, equipment, or budget - efficiently across the project.

Example: In an event management project, the chart ensures that the "Venue Setup" team is scheduled before the "Decoration" team, avoiding conflicts and resource wastage.

e. Communication Tool

Gantt Charts serve as an effective communication tool, providing stakeholders with a clear overview of the project. They make complex schedules easy to understand, fostering transparency and collaboration.

Example: In a university research project, the Gantt Chart is shared with professors and students to show milestones like "Data Collection," "Analysis," and "Report Submission," keeping everyone aligned.

f. Deadline Management

By visually displaying timelines, Gantt Charts help ensure deadlines are met. They highlight critical tasks and milestones, making it easier to prioritize work.

Example: In a publishing project, the chart shows deadlines for "Manuscript Editing," "Proofreading," and "Printing," ensuring the book is ready for release on time.

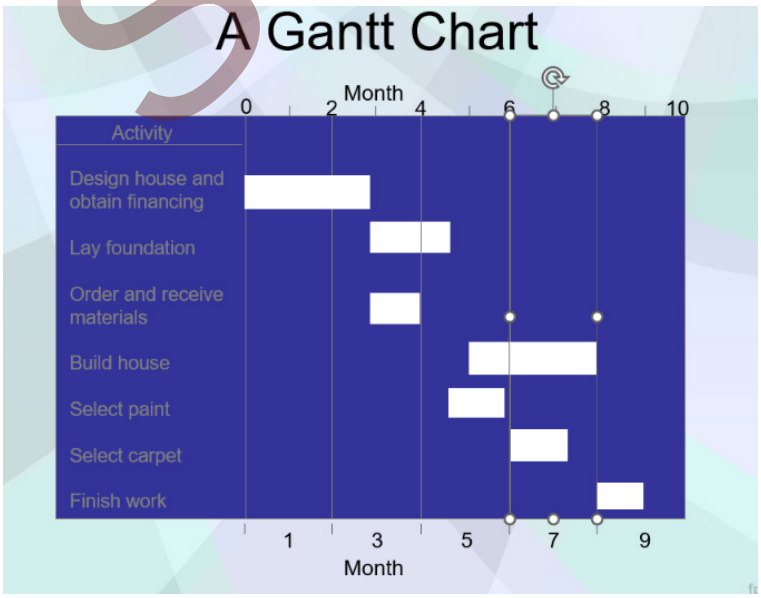


Fig 4.2.2 Gantt Chart

4.2.6.3 Precedence Diagramming (PDM

a. Network Procedures and Precedence Patterns

Precedence diagramming is a scheduling method that identifies and arranges key events into logical, precedence-related patterns. Since project activities are interdependent, proper sequencing ensures that tasks are completed in the right order. This helps managers monitor progress and evaluate performance effectively.

Example: In a construction project, laying the foundation must precede building the walls, and wall construction must precede roof installation. A precedence diagram visually represents this order to avoid mismanagement.

4.2.6.4 Critical Path Method (CPM)

The basic concept behind precedence diagramming is the Critical Path Method (CPM). CPM emphasizes task accomplishment by identifying the longest sequence of dependent activities that determines the project's minimum completion time. Any delay in critical path activities directly delays the project.

Example: In a software development project, coding the core system modules may lie on the critical path. If coding is delayed, testing and deployment will also be delayed, affecting the entire project timeline.

a. Activity Identification and Tracking

To apply CPM effectively, each activity must be clearly identified and tracked. This ensures that managers can monitor progress and detect delays early. Activity identification also helps in assigning responsibilities and resources.

Example: In an event management project, activities such as booking the venue, arranging catering, and setting up decorations are identified separately. Tracking each ensures that the event is ready on time.

b. Activity-on-Node (AON) Method

The Activity-on-Node (AON) or Precedence Diagramming Method (PDM) represents activities as nodes (rectangular boxes) in the network diagram. Arrows show the logical relationships between activities. Unlike older methods, PDM does not require dummy activities, making diagrams simpler and easier to interpret.

Example: In a product launch project, nodes may represent tasks like "Market Research," "Product Design," and "Advertising Campaign." Arrows show that design must be completed before advertising begins.

c. Ease of Use and Computer Applications

Precedence diagramming is easier to draw and has greater applications when used with project management software. Tools like MS Project or Primavera can automatically generate precedence diagrams, calculate critical paths, and update schedules.

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Example: A construction firm uses Primavera software to create precedence diagrams for a highway project, enabling real-time updates and resource adjustments.

d. Activities and Events Representation

In precedence diagrams, each activity is represented by a rectangular box identified by an activity number. The left side of the box indicates the start of the activity, while the right side indicates its completion. This structured representation makes it easy to visualize project flow.

Example: In a manufacturing project, Activity 101 may represent "Procure Raw Materials," starting on September 1 and ending on September 10, followed by Activity 102 "Begin Production."

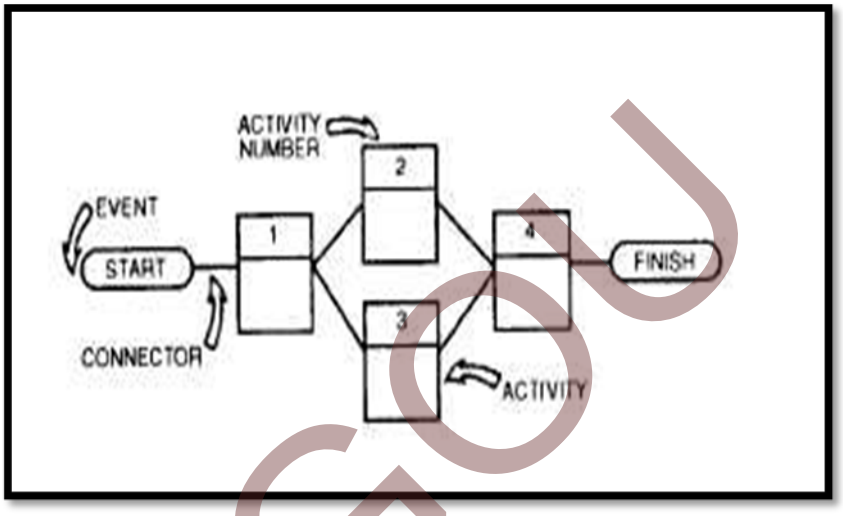


Fig 4.2.3 Precedence Diagram

e. Critical Path Method (CPM)

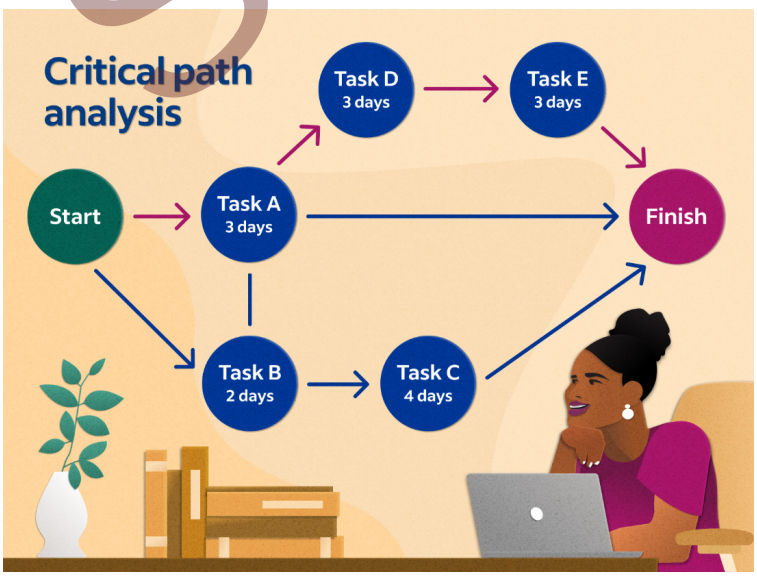


Fig 4.2.4 Critical Path Analysis

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f. DuPont & Remington-Rand (1956)

The Critical Path Method was developed in 1956 by DuPont and Remington-Rand as a way to manage complex industrial projects. It was initially used in chemical plant construction to optimize scheduling and reduce costs. CPM quickly became a standard tool in project management because it provided a systematic way to identify the most important tasks that directly affect project completion.

Example: DuPont used CPM to schedule maintenance shutdowns in chemical plants, reducing downtime and saving millions in operational costs.

g. Deterministic Task Times

CPM assumes that task durations are fixed and known in advance. This deterministic approach means that each activity has a specific, predictable time frame for completion. While this makes CPM straightforward, it is best suited for projects where activities are well-defined and stable.

Example: In a highway construction project, laying asphalt may be estimated to take exactly 10 days, and CPM schedules the project based on this fixed duration.

h. Activity-on-Node (AON) Network Construction

In CPM, activities are represented as nodes (boxes) in a network diagram, with arrows showing dependencies between tasks. This **Activity-on-Node (AON)** method makes it easy to visualize the sequence of tasks and identify the critical path, the longest chain of dependent activities that determines the project's minimum completion time.

Example: In a building project, nodes may represent tasks like "Foundation," "Walls," and "Roof." The diagram shows that walls cannot be built until the foundation is complete, and the roof cannot be installed until walls are finished.

4.2.6.5 Project Evaluation and Review Technique (PERT)

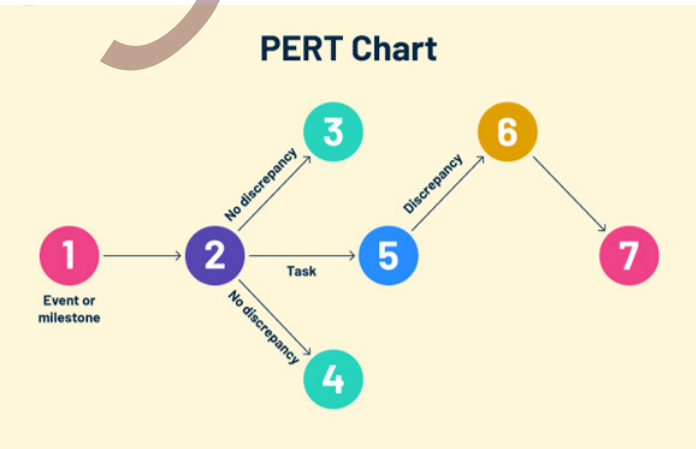


Fig 4.2.5 PERT Chart

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a. U.S. Navy, Booz, Allen & Hamilton

PERT was developed in the late 1950s by the U.S. Navy in collaboration with Booz, Allen & Hamilton to manage the Polaris missile program. It was designed to handle highly complex and uncertain projects where activity durations could not be predicted with certainty.

Example: The U.S. Navy used PERT to coordinate thousands of contractors and tasks in the Polaris project, ensuring timely delivery of the missile system.

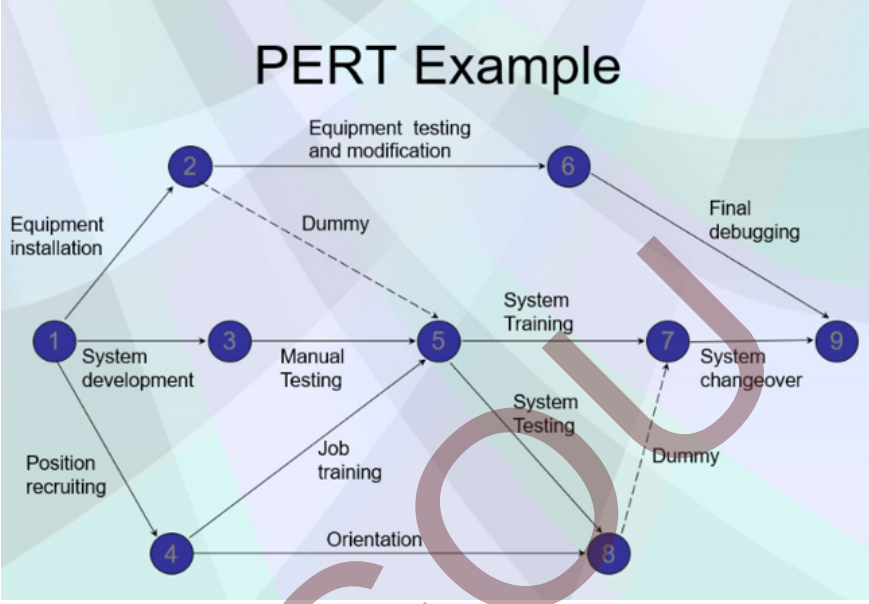


Fig 4.2.6 PERT Example

b. Multiple Task Time Estimates

Unlike CPM, PERT uses three time estimates for each activity: optimistic (best case), pessimistic (worst case), and most likely. These estimates are combined to calculate an expected duration using probability. This makes PERT suitable for projects with uncertainty and variability.

Example: In a research project, testing a new drug may take 2 months optimistically, 6 months pessimistically, and 4 months most likely. PERT calculates the expected duration to plan realistically.

c. Activity-on-Arrow (AOA) Network Construction

PERT traditionally uses the Activity-on-Arrow (AOA) method, where activities are represented by arrows and events (milestones) are represented by nodes. This approach emphasizes the sequence of events and the probabilistic nature of task completion.

Example: In a product development project, arrows may represent tasks like “Design Prototype,” “Test Prototype,” and “Finalize Design,” with nodes marking milestones such as “Prototype Ready” or “Testing Complete.”

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d. Project Network concepts (AON, AOA, Events, Dummy Activities)

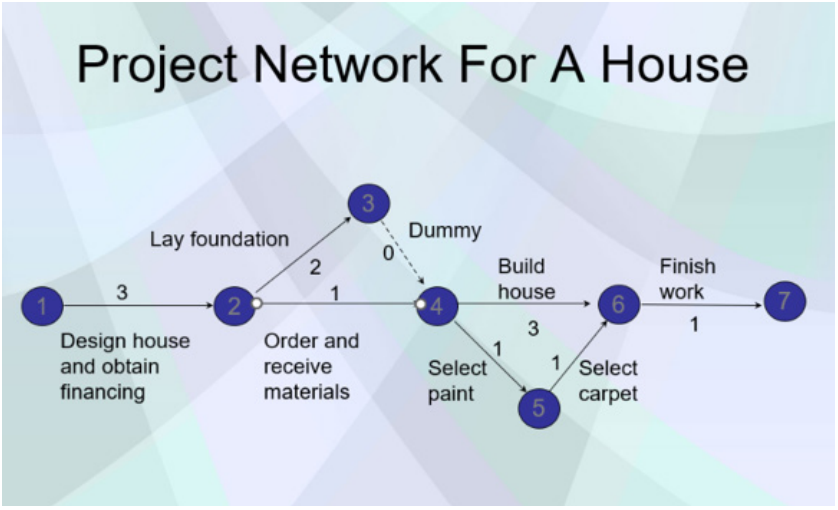


Fig 4.2.7 Project Network for a House

e. Activity-on-Node (AON)

In the Activity-on-Node (AON) method, activities are represented by nodes (rectangular boxes), and arrows show the precedence relationships between them. This makes it easy to visualize which tasks must be completed before others can begin. AON is widely used in modern project management because it is straightforward and works well with computer-based scheduling tools.

Example: In a house construction project, nodes may represent activities like "Lay Foundation," "Build Walls," and "Install Roof." Arrows show that walls cannot be built until the foundation is complete, and the roof cannot be installed until walls are finished.

f. Activity-on-Arrow (AOA)

In the Activity-on-Arrow (AOA) method, activities are represented by arrows, while nodes represent events (milestones in time). Each arrow shows the work to be done, and nodes indicate the start or completion of activities. AOA was traditionally used in PERT (Project Evaluation and Review Technique) and is useful for emphasizing event sequencing.

Example: In a product development project, arrows may represent tasks like "Design Prototype" and "Test Prototype," while nodes mark milestones such as "Prototype Ready" or "Testing Complete."

g. Events

An event in project networking represents a point in time, either the beginning or completion of an activity. Events do not consume resources or time themselves; they simply mark milestones that indicate progress. Events help managers track when critical stages of the project are reached.

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Example: In a marketing campaign project, the event "Campaign Launch" marks the completion of activities like "Design Advertisements" and "Finalize Media Plan."

h. Dummy Activities

A dummy activity is used in AOA diagrams to show precedence relationships between tasks when two activities share the same start and end nodes. Dummy activities do not represent actual work or consume resources; they are simply placeholders to maintain logical sequencing in the network.

Example: In a software project, suppose both "Develop Login Module" and "Develop Payment Module" depend on "Design Database." A dummy arrow may be used to show this dependency clearly, even though no real task is performed.

4.2.6.6 Project Crashing

a. Crashing Reduces Project Time by Expending Additional Resources

Project crashing is a technique used to shorten the overall project duration by allocating extra resources such as manpower, equipment, or budget. It is applied when deadlines are tight or when delays threaten project completion. By intensifying efforts on critical path activities, managers can reduce the time required without changing the project scope.

Example: In a highway construction project, additional workers and machinery may be deployed to speed up road paving, thereby reducing the overall project timeline.

b. Crash Time is the Amount of Time an Activity is Reduced

Crash time refers to the shortest possible duration in which an activity can be completed when extra resources are applied. It is the reduced time achieved by crashing, but it cannot be shortened indefinitely there is always a practical limit.

Example: If building a wall normally takes 10 days, crash time may reduce it to 7 days by hiring more masons and working double shifts.

c. Crash Cost is the Cost of Reducing an Activity's Time

Crash cost is the additional expense incurred when resources are added to shorten activity duration. This may include overtime wages, renting extra equipment, or purchasing faster technology. Managers must weigh the benefits of time savings against the increased costs.

Example: In a software project, hiring extra developers to complete coding faster increases labour costs, which is considered the crash cost.

d. The Goal of Crashing is to Reduce a Project's Duration at Minimum Cost

The ultimate objective of crashing is to achieve the shortest possible project duration while incurring the least additional cost. Managers analyze which activities on the

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critical path can be shortened most cost-effectively and prioritize those. This ensures deadlines are met without overspending.

Example: In a product launch project, managers may decide to crash the "Marketing Campaign Preparation" activity by outsourcing design work, which reduces time at a lower cost compared to crashing "Product Testing," which would require expensive equipment.

e. Time-Cost Relationship in Project Crashing

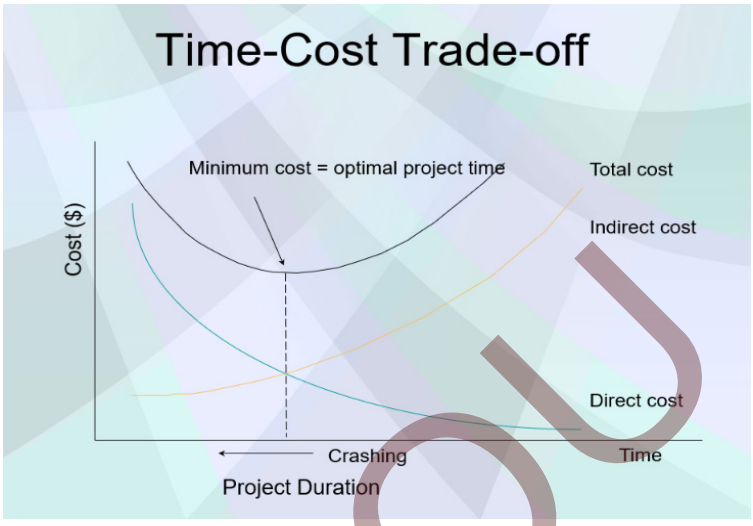


Fig 4.2.8 Time – Cost Trade - off

f. Crashing Costs Increase as Project Duration Decreases

When project managers attempt to shorten the project duration by crashing, they must allocate additional resources such as overtime labor, extra equipment, or specialized technology. These added resources increase costs because the project is being accelerated beyond its normal pace. The faster the project is forced to finish, the higher the crashing costs become.

Example: In a construction project, reducing the time for laying concrete from 10 days to 7 days requires hiring more workers and renting additional mixers. This shortens the schedule but significantly increases costs.

g. Indirect Costs Increase as Project Duration Increases

Indirect costs are expenses that accumulate over time, such as administrative overhead, site maintenance, utilities, and supervision. The longer a project runs, the higher these costs become. Extending project duration means paying for prolonged management, security, and operational expenses.

Example: In a highway project, if construction extends by six months, the company must pay additional salaries for supervisors, rent for equipment storage, and utility bills for the site office, all of which increase indirect costs.

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h. Project Length Should be Reduced as Long as Crashing Costs are Less than Indirect Costs

The optimal strategy is to shorten the project duration only when the cost of crashing is lower than the indirect costs saved. This balance ensures that the project is completed faster without overspending. Managers analyze the trade-off between crashing costs and indirect costs to determine the most economical project duration.

Example: In a software development project, crashing the testing phase by hiring extra testers may cost $10,000, but it saves $15,000 in overhead costs by reducing project duration by one month. Since crashing costs are less than indirect costs, it is financially beneficial to shorten the project.

4.2.7 Maintenance Management

Maintenance is defined as the function of production management concerned with keeping the physical plant in good working condition. It deals with day-to-day problems such as equipment breakdowns, wear and tear, and ensuring smooth operations. Without proper maintenance, production efficiency declines, costs rise, and safety risks increase.

Example: In a textile factory, regular maintenance of weaving machines prevents frequent breakdowns and ensures continuous production.

4.2.7.1 Maintenance Management

Maintenance management involves planning, organizing, and directing resources to control the availability and performance of industrial plants at a specified level. It ensures that equipment and facilities are reliable, efficient, and safe. Proper maintenance management balances cost, downtime, and productivity.

Example: An automobile company schedules preventive maintenance for assembly line robots to avoid unexpected stoppages and maintain production targets.

4.2.7.2 Primary Functions of Maintenance

a. Maintenance of Existing Plant and Equipment

This function ensures that machinery and equipment are kept in working order through regular servicing, repairs, and replacements. It prevents breakdowns and extends the life of assets.

Example: In a steel plant, regular servicing of blast furnaces ensures they operate safely and efficiently without unexpected failures.

b. Maintenance of Existing Plant Buildings and Grounds

Buildings and grounds must be maintained to provide a safe and efficient working environment. This includes structural repairs, painting, cleaning, and landscaping.

Example: In a pharmaceutical company, maintaining clean and sterile production areas is critical to meeting health and safety standards.

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c. Equipment Inspection and Lubrication

Inspection and lubrication are preventive measures to detect issues early and reduce wear and tear. Regular checks ensure that machines run smoothly and avoid costly breakdowns.

Example: In a printing press, lubricating rollers and inspecting gears prevent overheating and ensure high-quality printing.

d. Utilities Generation and Distribution

Maintenance also covers utilities such as electricity, water, gas, and compressed air. Proper management ensures uninterrupted supply and efficient distribution across the plant.

Example: In a food processing plant, maintaining boilers and refrigeration systems ensures consistent energy supply and product quality.

e. Alterations to Existing Equipment and Buildings

Sometimes equipment or buildings need modifications to meet new requirements or improve efficiency. Maintenance teams handle these alterations to adapt to changing production needs.

Example: A factory may alter its ventilation system to improve air quality after expanding production capacity.

f. New Installations of Equipment and Buildings

Maintenance also includes installing new machinery or constructing new facilities. Proper installation ensures that equipment operates correctly and integrates smoothly into existing systems.

Example: In an electronics company, installing new automated assembly machines requires careful setup and testing by the maintenance team.

4.2.7.3 Secondary Functions of Maintenance Management

a. Storekeeping

Storekeeping involves managing spare parts, tools, and maintenance materials required for plant operations. Proper storekeeping ensures that essential items are available when needed, reducing downtime caused by waiting for supplies. It also involves inventory control to avoid overstocking or shortages.

Example: In an automobile factory, the maintenance department keeps spare parts like gears, belts, and lubricants in a store. When a machine breaks down, technicians can quickly access the required parts without delays.

b. Plant Protection (Including Fire Protection)

Plant protection ensures the safety of equipment, buildings, and personnel. It includes

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fire protection systems, security measures, and safety protocols to prevent accidents and damage. Effective plant protection safeguards both assets and workers.

Example: In a chemical plant, fire extinguishers, sprinkler systems, and emergency alarms are installed to protect against fire hazards. Security guards and surveillance cameras also protect the plant from theft or vandalism.

c. Waste Disposal

Waste disposal involves managing and removing industrial waste generated during production. Proper disposal prevents environmental pollution, ensures compliance with regulations, and maintains workplace cleanliness.

Example: In a paper mill, waste paper and chemical residues are collected and sent for recycling or safe disposal, ensuring that production areas remain clean and environmentally safe.

d. Salvage

Salvage refers to recovering usable parts or materials from damaged or obsolete equipment. This reduces costs by reusing components instead of purchasing new ones. Salvage also minimizes waste.

Example: In an electronics factory, when old machines are dismantled, usable motors and wiring are salvaged and reused in other equipment, saving money and resources.

e. Insurance Administration

Insurance administration ensures that the plant and equipment are covered against risks such as fire, accidents, or natural disasters. Maintenance management coordinates with insurance providers to maintain policies and handle claims when needed.

Example: A textile factory insures its machinery against fire damage. If a fire occurs, the insurance claim helps the company recover financially and replace damaged equipment.

f. Pollution and Noise Control

Pollution and noise control are essential for maintaining environmental standards and protecting worker health. Maintenance teams ensure that equipment operates within permissible limits of emissions and noise.

Example: In a power plant, filters and scrubbers are maintained to reduce air pollution, while soundproofing measures are applied to turbines to minimize noise levels for workers.

4.2.8 Types of Maintenance

a. Breakdown Maintenance (Corrective Maintenance)

Breakdown maintenance, also called corrective maintenance, is performed after equipment fails or breaks down. It focuses on repairing or replacing faulty components

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to restore normal functioning. While it is unavoidable in some cases, relying solely on breakdown maintenance can lead to costly downtime and production losses.

Example: In a textile mill, if a weaving machine suddenly stops due to a broken belt, corrective maintenance is carried out to replace the belt and restart production.

b. Preventive Maintenance

Preventive maintenance involves scheduled inspections, servicing, and minor repairs to prevent equipment failure before it occurs. It is based on time intervals or usage cycles and aims to extend the life of equipment while reducing unexpected breakdowns.

Example: In an automobile factory, machines are serviced every three months, including oil changes, filter replacements, and calibration checks, to prevent sudden stoppages.

c. Predictive Maintenance

Predictive maintenance uses monitoring tools and data analysis to predict when equipment is likely to fail. Sensors and diagnostic systems track performance indicators such as vibration, temperature, or noise, allowing maintenance to be performed just before a failure occurs. This reduces unnecessary servicing and minimizes downtime.

Example: In a power plant, vibration sensors on turbines detect abnormal patterns. Maintenance teams intervene before the turbine fails, preventing costly outages.

d. Routine Maintenance

Routine maintenance refers to regular, day-to-day activities that keep equipment in good working condition. It includes cleaning, lubrication, minor adjustments, and inspections. Routine tasks are simple but essential for smooth operations.

Example: In a printing press, operators clean ink rollers and lubricate gears daily to ensure consistent print quality and avoid minor issues escalating into major breakdowns.

e. Planned Maintenance

Planned maintenance is a structured approach where maintenance activities are scheduled in advance based on production requirements and resource availability. It ensures that maintenance does not disrupt operations and is carried out efficiently. Planned maintenance can include preventive, predictive, or corrective actions, but with proper scheduling.

Example: In a steel plant, planned maintenance is scheduled during low production periods to service furnaces and machinery, ensuring minimal impact on output.

4.2.9 Total Productive Maintenance (TPM)

a. Combining TQM with Strategic Maintenance

TPM integrates the philosophy of Total Quality Management (TQM) with a strategic view of maintenance. It emphasizes that maintenance is not just a repair activity but

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a proactive, organization-wide effort that begins at the design stage of equipment and continues through preventive maintenance. This ensures that processes and machines are reliable, efficient, and aligned with quality goals.

Example: In an automobile factory, TPM ensures that machines are designed for easy maintenance, operators are trained to handle minor issues, and preventive schedules are followed to avoid breakdowns all contributing to consistent quality output.

b. Zero Breakdown / Zero Downtime Goal

The ultimate aim of TPM is to achieve zero breakdowns and zero downtime. By involving all employees in equipment care and preventive measures, TPM minimizes unexpected failures and ensures continuous production. This goal enhances productivity and reduces costs associated with interruptions.

Example: In a food processing plant, TPM practices such as regular cleaning, lubrication, and operator checks help achieve uninterrupted production, ensuring that perishable goods are processed without delays.

c. Total Employee Involvement

The "Total" in TPM highlights that every employee, from top management to shop-floor workers, is responsible for maintenance. Operators are trained to perform routine checks and minor repairs, while managers provide resources and support. This collective responsibility fosters ownership and teamwork.

Example: In a textile mill, machine operators are trained to detect early signs of wear, such as unusual noise or vibration, and report them immediately. This involvement prevents small issues from becoming major breakdowns.

d. Total Equipment Effectiveness (Zero Breakdown)

TPM focuses on maximizing Overall Equipment Effectiveness (OEE) by reducing breakdowns, defects, and accidents. Equipment effectiveness is measured through availability, performance, and quality. Achieving zero breakdowns ensures that machines operate at their full potential.

Example: In a steel plant, TPM initiatives reduce furnace downtime, improve performance efficiency, and ensure consistent product quality, thereby maximizing OEE.

e. Total Maintenance Delivery System

TPM establishes a structured maintenance delivery system that integrates preventive, predictive, and corrective maintenance. This system ensures that maintenance activities are planned, monitored, and continuously improved. It creates a culture where maintenance is not reactive but proactive and strategic.

Example: In an electronics factory, TPM involves scheduled preventive maintenance, predictive monitoring using sensors, and corrective actions when needed, all coordinated through a centralized system to ensure smooth operations.

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4.2.9.1 Requirements of Total Productive Maintenance (TPM)

a. Design Products that can be easily Produced on Existing Machines

TPM emphasizes designing products that are compatible with the organization's current machinery. This reduces the need for frequent modifications or new installations, ensuring smoother production and lower costs. By aligning product design with machine capabilities, companies achieve efficiency and reliability.

Example: A beverage company designs new bottle shapes that can be produced using its existing filling and packaging machines, avoiding costly equipment changes.

b. Design Machines for Easier Operations, Changeover, and Maintenance

Machines should be designed to simplify operations, allow quick changeovers, and facilitate easy maintenance. This reduces downtime and increases productivity. User-friendly designs also empower operators to handle minor adjustments and preventive care.

Example: In an automobile plant, machines are designed with modular components so that changing from one car model to another requires minimal setup time, improving flexibility and efficiency.

c. Train and Retrain Workers to Operate Machines

TPM requires continuous training and retraining of workers to ensure they can operate machines effectively and safely. Skilled operators can detect early signs of malfunction, perform routine maintenance, and prevent breakdowns. Training also keeps workers updated on new technologies.

Example: In a textile factory, operators are trained to recognize unusual vibrations in looms, enabling them to report issues before a breakdown occurs.

d. Purchase Machines that Maximize Productive Potential

When new machines are purchased, TPM encourages selecting equipment that offers maximum productivity, reliability, and ease of maintenance. This ensures long-term efficiency and reduces the likelihood of frequent breakdowns.

Example: A pharmaceutical company invests in automated packaging machines that not only increase speed but also reduce errors, maximizing productive potential.

e. Design a Preventive Maintenance Plan Spanning the Life of the Machine

TPM requires a preventive maintenance plan that covers the entire life cycle of the machine. This includes scheduled inspections, servicing, and replacements to ensure consistent performance and avoid unexpected failures. A life-long plan ensures machines remain reliable and cost-effective.

Example: In a power plant, turbines are maintained according to a preventive schedule that includes regular lubrication, vibration monitoring, and part replacements, ensuring uninterrupted energy generation throughout their lifespan.

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Summarised Overview

Project and Maintenance Management integrates structured planning with systematic upkeep of organizational assets. A project is defined as a temporary endeavour with specific objectives, characterized by a clear life cycle, initiation, planning, execution, monitoring, and closure. Techniques such as Gantt Charts, Critical Path Method (CPM), and Program Evaluation and Review Technique (PERT) provide managers with tools to schedule, allocate resources, and monitor progress effectively. These methods ensure that projects are completed on time and within budget by identifying dependencies, critical tasks, and potential delays.

On the maintenance side, management focuses on sustaining plant and equipment performance through various types of maintenance, corrective, preventive, predictive, routine, and planned. A strategic approach like Total Productive Maintenance (TPM) combines quality management principles with proactive equipment care, aiming for zero breakdowns and maximum efficiency. TPM emphasizes total employee involvement, equipment effectiveness, and a comprehensive maintenance delivery system. Together, project management and maintenance management ensure operational reliability, cost efficiency, and long-term sustainability across industries.

Self-Assessment Question

1. Explain the meaning and nature of a project. Describe the major characteristics of a project.
2. Explain the different phases of the project life cycle and discuss the major activities performed during each phase.
3. Define project management and explain its importance in achieving project objectives.
4. Explain the major techniques used in project management and discuss their importance in planning, scheduling and controlling projects.
5. Explain the meaning, steps and importance of Work Breakdown Structure (WBS) in project planning.
6. Describe the Gantt Chart and explain how it helps in scheduling and monitoring project activities.

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7. Explain Precedence Diagramming Method (PDM) and discuss the relationships between project activities.
8. Explain the Critical Path Method (CPM) and discuss its importance in identifying critical activities and determining project duration.
9. Explain the Project Evaluation and Review Technique (PERT) and discuss the role of time estimates in project scheduling.
10. Explain project crashing and discuss its objectives and importance in reducing project completion time.
11. Explain the meaning and importance of maintenance management. Describe the primary functions of maintenance.
12. Explain the secondary functions of maintenance management and discuss their contribution to the effective functioning of an organisation.
13. Describe the different types of maintenance and explain their major features.
14. Explain the concept and objectives of Total Productive Maintenance (TPM).
15. Explain the major requirements of Total Productive Maintenance (TPM) for successful implementation in an organisation.



Assignments

1. A company plans to introduce a new product into the market. Explain how the phases of the project life cycle can be applied to plan and execute the project.
2. A construction company needs to complete a building project within a fixed deadline. Explain how WBS and Gantt Charts can be used to plan and monitor the project.
3. A project consists of several interdependent activities. Explain how PDM can be applied to establish the sequence and relationships between these activities.
4. Apply CPM to a project with multiple activities to identify the critical path, calculate the project completion time and determine the activities that cannot be delayed.
5. A project manager faces uncertainty in the time required to complete dif-

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ferent activities. Explain how PERT can be applied to estimate project duration and manage scheduling uncertainty.

6. A company must complete a project earlier than its original schedule. Explain how project crashing can be applied to reduce the completion time while considering additional costs.

7. A manufacturing company experiences frequent machine breakdowns. Explain how suitable types of maintenance can be applied to reduce down-time and improve equipment reliability.

8. Analyse the relationship between maintenance management and Total Productive Maintenance (TPM). Explain how employee participation and equipment effectiveness contribute to productivity.



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PRACTICAL ACTIVITY

Identify a common service or product (like food delivery or a school event) and use a simple tool such as a control chart or fishbone diagram to identify possible quality issues.

Solution

Identifying Quality Issues Using a Fishbone Diagram

1. Selected Service: Food Delivery

Objective:

To identify the possible causes of quality problems in a food delivery service using a Fishbone (Ishikawa/Cause-and-Effect) Diagram.

2. Quality Problem Identified

Problem:

Customers receive food late, cold, or incorrectly ordered.

This problem can affect customer satisfaction, ratings, repeat orders, and the reputation of the food delivery company.

3. Fishbone Analysis

The possible causes can be grouped into six major categories:

1. Manpower (People)

- ◊ Delivery staff may be insufficient during peak hours.
- ◊ Delivery personnel may not know the location properly.
- ◊ Restaurant staff may make mistakes while preparing or packing orders.
- ◊ Lack of employee training.

2. Method (Process)

- ◊ Inefficient order-processing system.
- ◊ Poor coordination between restaurant and delivery personnel.
- ◊ Orders may not be checked before dispatch.
- ◊ No proper procedure for handling peak-hour orders.

3. Machine/Technology

- ◊ Delivery app may malfunction.
- ◊ GPS/navigation errors may cause delays.

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- ◊ Restaurant order-printing system may fail.
- ◊ Poor internet connectivity can delay communication.

4. Materials

- ◊ Poor-quality packaging may cause food leakage.
- ◊ Inadequate packaging may not retain food temperature.
- ◊ Wrong ingredients may be used.
- ◊ Packaging materials may be unavailable during busy periods.

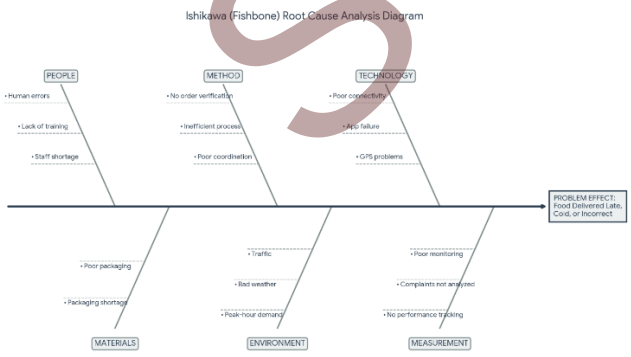
5. Environment

- ◊ Heavy traffic can delay delivery.
- ◊ Bad weather can affect delivery time.
- ◊ Road construction or diversions may increase travel time.
- ◊ High demand during lunch/dinner hours.

6. Measurement/Control

- ◊ Delivery time may not be monitored properly.
- ◊ Customer complaints may not be analyzed.
- ◊ No regular measurement of order accuracy.
- ◊ Poor tracking of restaurant and delivery performance.

4. Simplified Fishbone Diagram



5. Major Causes Identified

After examining the possible causes, the most important causes may be:

1. Heavy traffic during peak hours.
2. Poor coordination between restaurant and delivery personnel.

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3. Incorrect order packing.
4. Inadequate food packaging.
5. Shortage of delivery personnel.
6. GPS or application-related problems.

6. Suggested Corrective Measures

Quality Issue	Corrective Action
Late delivery	Increase delivery staff during peak hours
Cold food	Use insulated delivery bags
Wrong order	Introduce order verification before dispatch
Poor packaging	Use appropriate leak-proof and temperature-resistant packaging
GPS problems	Provide reliable navigation and route alternatives
Poor coordination	Improve communication between restaurant and delivery staff
Repeated complaints	Regularly analyze customer feedback

7. Conclusion

The Fishbone Diagram helps identify the root causes of quality problems rather than focusing only on the visible problem. In food delivery, quality depends on people, processes, technology, materials, environment, and measurement. By identifying and addressing these causes, the service provider can improve delivery time, order accuracy, food quality, customer satisfaction, and overall service performance.

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Space for Learner Engagement for Objective Questions

Learners are encouraged to develop objective questions based on the content in the paragraph as a sign of their comprehension of the content. The Learners may reflect on the recap bullets and relate their understanding with the narrative in order to frame objective questions from the given text. The University expects that 1 - 2 questions are developed for each paragraph. The space given below can be used for listing the questions.

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Model Question Paper- set-I

Second Semester Master of Business Administration

(MBA) Examination

Discipline Core Course - M25BS08DC

Production and Operations Management

(CBCS - PG)

2025-26 Admission

Time: 3 Hours Max Marks: 70

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Section A

(Answer any 5, each carries 2 marks) (5x2=10)

1. Describe production management.
2. What is product design?
3. What is the centre of gravity model?
4. What is line balancing?
5. Define reorder level.
6. What is production control?
7. What is the Deming Wheel or PDCA Cycle?
8. What is project crashing?

Section B

(Answer any 6, each carries 5 marks) (6x5=30)

9. Differentiate between production management and operations management.

10. Explain the different levels of a product with suitable examples.

11. An automobile company needs 1,200 alloy wheels per year. The fixed cost to make them in-house is ₹90,000, and the variable cost per wheel is ₹800. The supplier offers to sell them at ₹950 per wheel with no fixed cost. Should the company make or buy the wheels?

12. Explain the basic types of plant layouts: process layout, product layout and fixed-position layout, with suitable examples.

13. Describe the types of material handling systems: equipment-oriented, material-oriented, method-oriented and function-oriented systems.

14. A business consumes 6,000 units of a raw material annually at ₹18 per unit. The ordering cost is ₹75 per order, and the annual holding charge is 20% of the unit cost. Normal lead time is 6 days and maximum lead time is 10 days.

15. Describe the three main stages of PPC and explain the major functions performed at each stage.

16. Explain the functions of the PPC department and describe its organisational structure.

17. Explain ISO 9000, its categories and benefits. Also discuss Six Sigma and the quality management tools used in its implementation.

18. Describe the different phases of the project life cycle and explain the importance of each phase.

Section C

(Answer any 2, each carries 15 marks) (2x15=30)

19. What is a make-or-buy decision? Explain the factors influencing make-or-buy decisions and discuss their economic evaluation using break-even analysis.

20. Explain the different types of plant layouts in detail, including process layout, product layout, fixed-position layout, cellular layout, flexible manufacturing systems (FMS) and mixed-model assembly lines. Give suitable examples.

21. Define Total Quality Management (TQM). Explain its principles, W. Edwards Deming's 14 points, the PDCA Cycle and the strategic implications of TQM.

22. An automobile components manufacturer wants to establish a new factory to produce spare parts for cars and commercial vehicles. Three possible locations have been identified.

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Location factors	Weight	Site 1	Site 2	Site 3
Skilled labour availability	0.20	85	90	75
Proximity to suppliers	0.25	95	80	85
Electricity and water supply	0.15	80	90	85
Land and building cost	0.15	70	85	90
Road and transport facilities	0.15	90	85	80
Environmental suitability	0.10	75	80	95
Total weight	1.00			

Apply the Qualitative Factor Analysis method to determine the most suitable factory location.

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Model Question Paper- set-II

Second Semester Master of Business Administration

(MBA) Examination

Discipline Core Course - M25BS08DC

Production and Operations Management

(CBCS - PG)

2025-26 Admission

Time: 3 Hours Max Marks: 70

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Section A

(Answer any 5, each carries 2 marks) (5x2=10)

1. What is meant by the production function?
2. Define process planning and process selection.
3. What is qualitative factor analysis in plant location?
4. What is a fixed-position layout?
5. List the different types of inventories.
6. Describe scheduling and mention any two elements of scheduling.
7. What is Statistical Process Control (SPC)?
8. What is a Gantt chart?

Section B

(Answer any 6, each carries 5 marks) (6x5=30)

9. Describe the Five P's of operations management and explain their significance.

10. Discuss process planning, process selection, process strategy and process management.

11. A bakery requires 400 customised cake boxes monthly. The fixed cost to make boxes in-house is ₹20,000, and the variable cost per box is ₹30. Buying from a supplier costs ₹50 per box with no fixed cost. Should the bakery make or buy the boxes?

12. Explain the steps involved in layout planning and discuss the criteria for selecting a suitable plant layout.

13. Describe hybrid layouts, including cellular layout, flexible manufacturing systems (FMS) and mixed-model assembly lines.

14. A manufacturing company requires 800 units of a component per month. Each unit costs ₹30, the ordering cost is ₹120 per order, and the annual carrying charge is 20% of the average inventory value. The supplier offers a 2% discount for orders of 1,500 units or more.

15. Explain capacity planning, its objectives, importance and major approaches.

16. Explain Materials Requirement Planning (MRP), its objectives, inputs, outputs and importance in production management.

17. Explain the methods of identifying quality problems and analysing their causes.

18. Explain the primary and secondary functions of maintenance management.

Section C

(Answer any 2, each carries 15 marks) (2x15=30)

19. Explain the steps involved in plant location selection, including the selection of a country, region, locality or community, and the final site. Discuss the important factors at each stage.

20. An e-commerce company wants to establish a delivery hub to serve three customer zones. The coordinates and daily parcel demands are given below. Find the suitable location using the Centre of Gravity method.

Customer zone	X-coordinate	Y-coordinate	Daily demand (parcels)
Zone A	10	20	80
Zone B	20	30	120
Zone C	30	10	100

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21. What is aggregate production planning (APP)? Explain its objectives, central concepts, inputs, outputs and major techniques, with suitable examples.

22. Explain the major techniques used in project management, including Work Breakdown Structure (WBS), Gantt charts, Precedence Diagramming Method (PDM), Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT).

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