OPERATIONS MANAGEMENT

Operations Management

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Course Outcomes

The course on "Operations Management" helps you gain insights into the dynamic interactions of internal and external factors shaping business operations and their implications for operations management. Develop strategic approaches to adapt operations management practices to changes in business operations. Formulate strategies to ensure competitiveness and sustainability in evolving business operations. The book comprises the following twelve chapters:

Chapter 1: An Introduction to Operations Management - This foundational chapter commences with the concept of operations and operations management. Then it explains the functions of operations management and the role of an operations manager. Further, the chapter discusses the concept of service sector organisations vs. manufacturing sector organisations.

Chapter 2: Operations Strategy - This chapter provides an overview of strategy. Then it covers business operations strategy and technology strategy. At the end, it explains systems and processes and introduces some important concepts related to operations management.

Chapter 3: Managing Manufacturing Operations - This chapter gives insight into the concepts of manufacturing management and manufacturing strategy. Then it discusses scheduling and designing products. Further, it explains the cellular manufacturing and concept of the project.

Chapter 4: Managing Service Operations - This chapter explains the concepts of service management, service design, and process designing. It then introduces the process planning and process analysis. At the end, it discusses measuring service quality using SERVQUAL.

Chapter 5: Managing Service Processes - This chapter provides an overview of service processes, service development process, service process matrix, and engineering service processes. Further, it explores the concept of controlling service processes, service standards, and service blueprinting.

Chapter 6: Capacity Planning – I - This chapter begins with the concept of capacity. Then, it explores the concept of capacity planning. At the end, the chapter discusses capacity planning approaches.

Chapter 7: Capacity Planning – II - This chapter begins with the concept of capacity expansion strategies. Further, it describes the concept of capacity management. Then it also explains facility layout planning. At the end, it covers line loading and line balancing.

Chapter 8: Managing Quality in Operations Management - This chapter introduces the relation between quality and operations management and the concept of cost of quality. Then it discusses quality leadership and the ISO 9000:2015 quality management system. Then it describes the quality tools and Quality Function Deployment (QFD).

Chapter 9: Data Analytics and Operations Management - This chapter focuses on understanding the operations management and data analytics. Then it delves into selecting the facility location using integrated models. The chapter concludes with a using design of experiment in manufacturing and analytical tools for sourcing.

Chapter 10: Applications of Analytics in Operations Management - This chapter begins with the concept of analytical tools for aggregate production planning and control. It explores the analysis of processes for optimisation. The chapter extends to predictive analytics in operations management. At the end, the chapter describes building an analytics-driven organisation.

Chapter 11: Operations Research and Operations Management - This chapter provide an overview of the concept of the origin of operations research and operations management. Then it explores operations research and operational research applications. At the end, the chapter explains the scheduling systems.

Chapter 12: Risk Management in Operations - The final chapter explores the concept of risk in operations management. Then, it discusses the risk mitigation strategies. The chapter concludes by discussing managing uncertainty and resilience and implementing a risk management framework.

CHAPTER 1

An Introduction to Operations Management

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the meaning of operations management
- Discuss the objectives of operations management
- Outline the functions and role of an operations manager
- Describe the challenges faced in operations management
- Differentiate between service sector organisations and manufacturing sector organisations

1.1 INTRODUCTION

The importance and awareness of the principles and practices of operations management has largely increased over the period. The role of operations management has found its place in every business sector, whether manufacturing organisations, service organisations or not-for-profit organisations. Moreover, operations management relates to every business function within an organisation.

This chapter discusses the introductory concept and meaning of operations management. The term 'operations management' has been developed from the concept of production management, which majorly involves managing the conversion of raw materials into finished products for sales to customers. The management of operations is concerned with the management of all productive activities and support activities which help in the performance of the core activity of product manufacturing or service provision at an organisation. The task of operations management is to ensure that all business activities are carried out efficiently and effectively. The main goal is to ensure that customers receive the best-quality product or service in the least possible cost.

In addition, the chapter also discusses the objectives of operations management, the challenges faced by an operations manager in operations management, the role of an operations manager, and the distinction between service sector organisations and manufacturing sector organisations.

1.2 OPERATIONS AND OPERATIONS MANAGEMENT

Business operations are simply called operations. Operations are those activities of a business that are repeated over and over again to achieve certain production or service deliveries. These can be optimised through process improvements, such as automation, reducing failure, and service blueprinting.

The business activity, which is mainly concerned with designing and production of a product or delivering service in an organisation, is referred to as operations management. It is concerned with the administration, design and control of business operations to achieve the highest possible level of organisational effectiveness and efficiency.

Notes

A company could be engaged in manufacturing products like cars, cosmetics, scooters, soaps, etc., or offering services in the health or communications field. In both the cases, the process essentially involves converting certain raw materials into a value-added finished product or converting inputs into useable outputs. However, the challenge for the management remains how to ensure the finest quality in the minimum cost or how to ensure optimum utilisation of resources.

The U.S. Department of Education describes operations management as 'a field that concerns itself with managing and directing the physical and/or technical functions of a firm or organisation, particularly those relating to development, production and manufacturing'.

To understand the concept better, let us take an example of a car-manufacturing unit. Here, the factory plant could be using steel, plastic, glass, rubber and other electric fittings as raw materials. These basic inputs are transformed through certain processes into a vehicle capable of moving people from one destination to another. The challenge faced by the management is to analyse as to how to use the raw materials and resources to the best of their ability to offer the best-quality car at competitive a price. The better the functions of operations management, the higher will be the productivity and quality.

Let us take another example from the service sector. In case of a hospital, the input relates to the information regarding a patient's condition and medical history given to the consultant. By using specialised medical knowledge, equipment and diagnostic tools, the doctor provides the patient with certain treatment aimed at improving his health and condition. The challenge before the medical practitioners and support staff is again to decide as to how to ensure the best advice and treatment by the maximum utilisation of resources. The better the management of operations, the better will be the final outcome.

1.2.1 OPERATIONS AS A KEY FUNCTIONAL AREA

Operations management is responsible for planning, managing and controlling of manufacturing or production processes of business entities. It takes care of the entire activities with the aim of successful conversion of raw materials into finished products and timely delivery of products. Thus, it plays the most vital role in managing business processes. Without the aid of operations management, organisations are unable to carry out their daily routine activities seamlessly. Operations management ensures that there is judicious use of organisational resources, such as raw material, labour, money and others. Operations management, in a way, is the mainstay of a company's business operations. Allied activities like finance, distribution, sales and marketing, etc., too have an important role to play, but they cannot exist in isolation without the support of operations management. Organisations would only become more robust and competitive in the market if their operations are managed efficiently and effectively.

1.2.2 OPERATIONS AS A SOURCE OF COMPETITIVE ADVANTAGE

Every company in the market seeks to outdo others by making available the finest product to the consumer at the most competitive price. Here, efficient handling of

operations would help in gaining a competitive edge in the marketplace. By ensuring greater flexibility in systems and practices and being responsive to customer needs, operations management can ensure greater acceptance of one's product among the customers. Following are the key functions to be adopted for the achievement of this goal:

- **Cost leadership:** A 'lean and mean' operation is one that eliminates waste and maximises the utilisation of resources. Elimination of waste and higher resource utilisation can be achieved through techniques such as 5S, Just in Time (JIT) and Kanban practice, aimed at preventing variability and reducing inventory. They help in addressing issues like unnecessary stock-piling of raw material and wasteful capital expenditure to give the company a cost leadership edge in the long run.
- **Reliability:** Reliability factor is critical for growth in the market. We all know that Tata products have a wider appeal because of their insistence on quality. Inconsistent quality would lead to a lack of confidence among customers, drop in sales and product recalls in the end. As a result, the company may not be able to make accurate forecasts, and, thus, suffers losses.
- **Flexibility:** If a customer is turned away, it would not only mean the loss of business, but might also create negativity about the company through the word of mouth. Thus, a company should be flexible to take even last-minute orders.
- **Speed:** In certain types of products, especially eatables, time of delivery is significant. We have popular examples of McDonald's and Domino's before us. While McDonald's focus is on prompt in-restaurant service, Domino's USP is faster doorstep delivery to retain its competitive edge.
- **Quality:** Some companies' USP is quality, whether in product or service. While Tata and Raymond offer high-quality products, Urban Clap specialises in home delivery of quality services, in a host of areas ranging from home repairs, plumbing, home cleaning, carpentry, wellness, fitness and similar facilities. This gives them an operational quality advantage.
- **Short throughput time:** Managing efficiently the four components of throughput time, i.e., process time, inspection time, move time and wait time helps reduce costs and improve profitability.
- **Innovation:** Since Yahoo could not innovate as per market expectations, it gradually began to lose its market share to Google. Google considered innovation as a key-focus of its operations. In addition, a company named 3M has taken lead because of its innovative business practices.
- **Collaborative supply chain management:** Forging thoughtful collaborations with like-minded entities in this domain helps in reducing lead-time, improving the accuracy of forecasts and increasing inventory turnover, thus improving profit margins.
- **Integration with other functions:** Any organisation operating in silo is bound to suffer inefficiency issues. Greater harmony and integration with other business functions is the key to productivity. Integration of operations management with other functions like finance, sales, distribution, etc., enables greater transparency,

data consolidation and knowledge sharing, which leads to higher response time and cost saving.

1.2.3 OBJECTIVES OF OPERATIONS MANAGEMENT

The main motive of operations management is to improve productivity while minimising cost through maximum utilisation of resources. The objectives of operations management are listed as follows:

- **Achieving efficiency and effectiveness**: An operation aimed at achieving higher productivity should be both efficient and effective. Here, we need to understand the difference between efficiency and effectiveness. It is considered that while efficiency is concerned with doing things right, effectiveness means doing the right things. In other words, while efficency is aimed at doing things in a particular systematic way, effectiveness is essentially concerned with achieving the desired goal, even if it involves following unorthodox or trial and error ways. In the case of efficiency, the focus is on the right means and practices and, in case of effectiveness, the focus is on achievement of the goal.

  With the help of an example, let's try to learn the distinction between efficiency and effectiveness. Let's assume there is a machine which has broken down. Now, say, we have a worker 'A' who attempts to fix it by changing a part. Although he doesn't know how to do it right, but by trial and error, manages to fix it somewhere and gets the machine working. So, we can conclude that he has been effective in getting the ball rolling again.

  On the other hand, a worker 'B' oils the machine, cleanses the parts and makes it shiny before installing. So, we can say that at this stage, he has perhaps wasted valuable time by shining the machine parts which was not necessary. He has been efficient in his work but not effective.

  The difference between efficiency and effectiveness is explained in Table 1:

Table 1: Difference between Efficiency and Effectiveness

Efficiency	Effectiveness
Efficiency aims at making the operations perfect.	Effectiveness is essentially concerned with achieving the end result.
Process is the main focus.	Process is secondary, primary objective is to achieve goal.
Efficiency is limited to the current state.	Effectiveness is focussed towards long-term planning.

- **Achieving right quality and right quantity:** Ensuring the right balance between supply-demand situations is the typical feature of operations management. An imbalance can result in wastage and drop in profits. For instance, if a product is produced in excess quantities, the extra produce goes into waste. On the other hand, if production is less than demand, it results in an opportunity loss because some extra profit could have been otherwise made.

- **Achieving output at the right time and cost:** If a project takes extra time to complete, the higher cost overruns can affect the profit margins. Similar is the case with a product. By reducing the processing time, delays, waiting time and idle time, the product can be delivered in time to ensure the desired profitability.

1.2.4 CHALLENGES IN OPERATIONS MANAGEMENT

The world is becoming a smaller and competitive place day-by-day and, as a result, new challenges have been emerging in the marketplace. To give peak performance, operations managers must be aware of the main challenges. Some of these are explained as follows:

- **Inter-organisational coordination:** Closer coordination between different departments helps the operations become more efficient and meet deadlines. Managers can improve their performance by maintaining goodwill and harmonious relations with other departments and vendors dealing in input materials, logistics, data, testing and packaging.
- **Managing relations with customers:** One satisfied customer brings many more customers. Customer satisfaction can be achieved by offering better customer service, an efficient feedback system and use of technology for faster grievance redressal. Information from different sources presenting a macro-view of the organisation can be collated so as to achieve better results in this area.
- **Environment:** Smart environmental management is not only helpful in serving the social cause, but is also cost-saving in the long run. Waste management, recycling, reduction in pollution, use of renewable energy and biodegradable materials are some of the highlights of environmental management. Environmental issues are emerging as key topics in international conferences around the globe. So, to be alive to these concerns is the need of the hour.
- **Stakeholder management:** Major shareholders and top management functionaries have to be taken into confidence and satisfied in respect of budget allocations, costs and other operation indicators. It is imperative for smooth functioning of the organisation.
- **Globalisation**: Today, globalisation is an overpowering reality and needs to be kept in focus for all kinds of planning or strategies. Organisations, especially the larger ones, have much to benefit by reaping the dividends of these developments.
- **Ethics:** It refers to the way in which an organisation conducts itself in good or difficult times.
- **Communication:** Proper communication within an organisation, both upwards and downwards, helps build trust and establish transparency. Large organisations often publish in-house journals to address communication issues.
- **Increased competition reforms in the economy:** Globalisation has continued to make the world a diverse and competitive place. Besides upgradation in technology, it has also allowed for greater interaction and transaction of goods and services between different countries. Today, operations managers are facing competition not only from the same city, but from overseas countries also.
- **Increasing expectations of customers:** With greater variety of products and services being offered in the marketplace, customers are becoming more demanding. Thus, to address their concerns, an efficient operations manager needs to build trust and goodwill in both internal and external domains, i.e., with his team members, management and customers. Proper communication

skills (both written and oral) are helpful in this regard for closer interaction with stakeholders.

- **Enhanced technology:** Today, we live in an era of fast-changing and evolving technology. To improve their systems and operations, managers need to keep themselves updated on the latest global trends and technological practices. High-end hospitals and many large organisations subscribe to trade and technology journals to keep themselves abreast with the latest global developments.
- **Environmental impact and sustainability:** According to **Kay Miranda**, a management expert, sustainability in operations is defined as a, *'method of evaluating existing practices without putting future resources at risk'*. It focusses on performing business operations in such a manner as to satisfy the needs of the present without compromising on the capability of future generations to satisfy their demands.

  Three pillars of sustainability are:

  - Social
  - Environmental
  - Economic

  It is important for the operations managers to be conscious of their social obligations– as to how their work has a bearing on the welfare and safety of the community, economy and environment. Sustainability relates to the long-term impact of a company's operations on the environment. Business enterprises should operate in such a manner as to minimise the negative impacts on local or global environment, community and society as a whole.

Self Assessment Questions

1. While efficiency aims at making the operations perfect, _____ is essentially concerned with achieving the end result.
2. Operations management ensures that there is judicious use of organisational resources. (True/False)

1.3 FUNCTIONS OF OPERATIONS MANAGEMENT

The main functions of operations management are as follows:

- **Designing:** An operations manager is required to actively respond towards customer expectations, and design various components and levels of operations accordingly. The design decisions might be in relation to the product, layout of factory, selection of machinery, determination of workflow, etc.
- **Planning:** The operations manager utilises the available resources at its best to optimise the production.
- **Organising:** Organising the workflow and tasks for optimum utilisation of resources is an important function of the operations manager.
- **Leading:** This function involves fixation of responsibilities, inspiring team-members and assigning tasks among different departments/members for smooth operations.

- **Controlling:** The operations manager is responsible for controlling operations by using latest technologies and systems.
- **Managing:** By building teams, inspiring and motivating his people and developing a productive work culture, the operations manager can execute most difficult and challenging assignments without much difficulty.
- **Coordinating:** This function involves developing a close coordination between people and processes for efficient business operations.

In the following sections, we will discuss some of the issues related to operations management, which need to be kept in mind by an operations manager.

1.3.1 DESIGN ISSUES

Basic design is the foundation of a good and lasting product. Volkswagen's Beetle model has been an icon in motor designing, with an enduring appeal for decades. On the other hand, a faulty design can prove disastrous and cause major losses to the company. Recently, Honda Motors has been recalled to replace a large number of vehicles on account of faulty 'Takata' airbags. Thus, product or service designing calls for thorough planning and high degree of expertise, experience and talent. Because of effective designing, LED bulbs are big energy-savers and reduce a consumer's power bills. Proper design process acts as an enabler and it helps a company generate new ideas, break boundaries and match the customer needs with the right product and service.

Figure 1 gives an illustration to demonstrate how new ideas can be generated by using perceptual maps, benchmarking and reverse engineering:

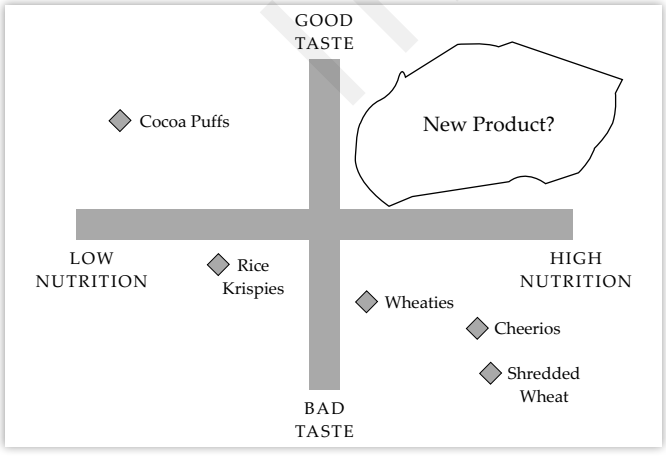

FIGURE 1: A Perceptual Map at Design Stage to Make a New Breakfast Cereal

Design decision is crucial to the long-term success of a product or service. It can affect sales strategy, manufacturing efficiencies, quality and speed of assembly and product cost. Therefore, a whole series of research studies have to be conducted before taking a final design decision. These range from feasibility study using customer surveys to focus group discussions, random sampling and pilot testing. These are further followed by economic analysis, technical analysis and strategic analysis. Final approval of the product design would only be obtained after making a thorough study and analysis of these surveys.

NOTES

Three types of designs are as follows:

- **Form design:** This refers to the physical shape of the product, its size, shape and colour.
- **Functional design:** This relates to the reliability, maintainability and usability aspect of the product.
- **Production design:** This design determines how a product would be manufactured.

  However, in case of service-oriented offerings, a service is designed by using service process matrix. This is achieved by analysing the nature of the service, i.e., whether the service to be offered is professional in nature (IT service), a service shop (beauty salon), a mass service (readymade garments) or a service factory. A specific service is designed by the following steps:

  a. Creating a blueprint of servicescapes

  b. Quantitative techniques which include waiting line analysis

1.3.2 CONTROL ISSUES

In operations management, a number of quality control and statistical process control measures are used to enhance control over different production and related processes. To prevent and pre-empt product failures, the following specialised techniques are used:

- **Failure Mode Effect Analysis (FMEA):** Firstly, causes and effects of a possible product failure are analysed. Secondly, causes are ranked in the order of degree of severity. They are systematically scrutinised, analysed and then addressed to minimise fault occurrence.
- **Fault Tree Analysis (FTA):** This method of depiction uses a tree-formation illustration for demonstration. Using two semi-circular shapes, one with a flat bottom (stands for AND) and another with a curved bottom (stands for OR), the tree lists failures and their causes. An example of Fault Tree Analysis is shown in Figure 2:

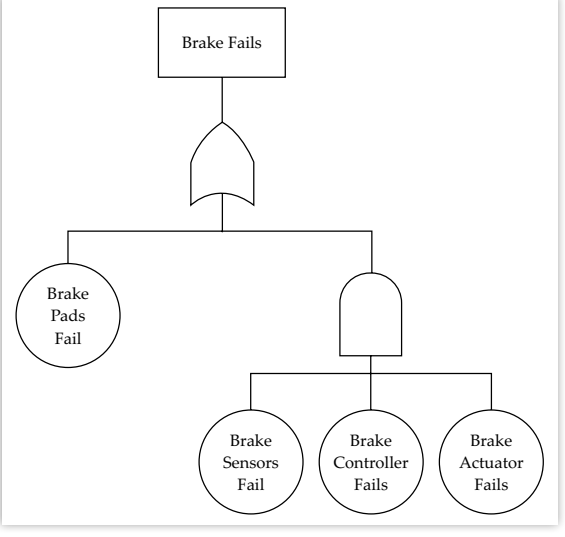

FIGURE 2: An Example of Fault Tree Analysis

- **Value Analysis (VA):** This concept, also referred to as value engineering, has been developed by GE (General Electric). By following this method, a certain value is assigned to the function of each component to determine the cost of providing that particular function. Subsequently, a ratio of value to cost is calculated and an attempt is made to improve the ratio by either increasing value or reducing cost.

1.3.3 SHORT- AND LONG-TERM ISSUES

Considering today's environmental concerns, companies need to design and develop products that meet today's requirements without compromising on concerns of the future. The concept of DFE (Design for Environment) lays emphasis on using recycled material for producing goods. New ideas and technologies are also being developed to create products that involve minimum packaging, and are easy to repair for longer use, thereby minimising negative impacts on the environment.

In this context, green sourcing is the new buzzword. It calls for using less material, recyclable material, renewable energy and organic material for reducing waste. It emphasises on digital communication, thereby minimising the use of paper and pen is also a part of this drive.

Global warming has brought together countries, and also companies, to initiate steps to arrest environmental degradation. Worldwide emphasis on green manufacturing is creating a climate for reducing pollution by minimising carbon footprint, reducing greenhouse gas effects and curbing environmental contamination. Close attention is being paid to products' manufacturing processes, transportation, warehousing, sales/distribution, usage and disposal by the ultimate customers.

Alarmed over rising pollution levels, many governments have stipulated new rules for manufacturers in this regard. A newly emerged concept called 'Extended Producer Responsibility' holds the producers responsible for their products even after their useful life is over. It means that producers are responsible (both in physical and financial terms) for the disposal or treatment of post-consumer goods. This responsibility encourages producers to prevent wastage at the source, support materials management and product recycling and foster product design, keeping in view the environmental impact. Moreover, European Union has made it mandatory for car-makers to recycle minimum 80% of used cars' weight. The Indian Government has started setting up charging stations for cars, and is planning subsidising the purchase of electrical vehicles. Many major automobile companies are going in a big way for the production of electric cars.

Self Assessment Questions

3. Which of the following is not a function of operations management?
   a. Designing products
   b. Controlling operations
   c. Coordination of operations
   d. Selection of personnel
4. _____ design refers to the physical shape of the product, its size, shape and colour.

Notes

1.4 ROLE OF AN OPERATIONS MANAGER

Business operations in a company are generally managed by different operations managers depending upon the type or size of operations. There could be a separate operations manager for different business segments like banking, retail or distribution. The role of operations manager is to ensure that the functions are carried out in an efficient manner to ascertain the best-quality output at the most economical costs.

Different responsibilities of a typical operations manager are as follows:

- Ascertaining the finest quality product as per specifications at minimum cost
- Obtaining the best raw material at the most competitive prices
- Choosing the best site for factory, warehouse, store, etc., keeping in view the operational advantages
- Ensuring the purchase of efficient equipment for production
- Establishing the finest ethical work standards
- Ensuring use of production techniques which are efficient and effective
- Thoughtful planning of capacities of plant and machinery
- Effective planning and control of manufacturing processes
- Efficient inventory management
- Close monitoring and measuring productivity to manage operational costs
- Ensuring harmonious industrial relations and managing trade unions
- Treating health and safety of the workforce as a high priority
- Proper planning of budget and other financial resources
- Proactive approach in strategic decision making
- Ensuring proper emphasis on automation
- Promoting R&D activities
- Assuring timely delivery of products and services
- Conforming to environmental rules and regulations
- Establishing and maintaining harmonious and long-term relations with vendors and suppliers
- Taking new steps to improve flexibility as per market needs and demands

Self Assessment Questions

5. Ensuring the use of efficient and effective production techniques is the responsibility of a/an _____.
6. There can be a separate operations manager for different business segments depending upon the type or size of operations. (True/False)

1.5 SERVICE SECTOR ORGANISATIONS VS. MANUFACTURING SECTOR ORGANISATIONS

To understand a company's operations, it is essential to understand the basic difference between a manufacturing organisation and a service-oriented organisation. In case of a maufacturing organisation, the product created is tangible in nature. Such products can be touched and felt with hand, for example, a car or a computer. However, in case of a service organisation, the benefits offered to customers are intangible in nature. Examples of services include advice by a doctor, repairs by a plumber, consultancy by an accountant, service by a beautician, etc. These are value-added operations which are intangible in nature. Unlike a tangible product, you cannot own or possess a service. Having acquired a basic clarity about the difference between the two types of organisations, now you can discuss the main points of differences between service sector organisations and manufacturing sector organisations. These are listed as follows:

- **Customisation vs. standardisation:** A new model of Maruti car would be produced in a large number with standard features for a certain segment of customers. However, in case of a service-oriented organisation like a beauty salon, etc., service is custom-designed varying from customer to customer. Services may be offered differently to suit the tailored specifications of each customer. One customer may need a pedicure, while the other may ask for hair-styling. So, while the operations in a manuacturing organisation are more or less standardised, in case of a service-oriented organisation, they are customised as per the needs of a particular customer.
- **Designing of production environment:** Production environment in an organisation is designed towards achievement of its ouput goals. In a manufacturing facility, machinery, equipment and workforce-facility are organised with an objective to aid smooth operations and optimum efficiency in the working environment. However, in case of a service-oriented organisation like restaurants, beauty salons, etc., the design emphasis is on food, surrounding appearance and ambience so as to please the customers.

Figure 3 exemplifies the general environment at a manufacturing organisation and a service organisation:

Figure 3: An Example of General Environment at Manufacturing and Service Organisations

It is worth mentioning here that the main objective of any company, whether in manufacturing or service sector, is to reduce cost and maximise profits, while maintaining and enhancing quality. Efficient management of resources is the key to achieve this.

NOTES

SELF ASSESSMENT QUESTIONS

7. Products of manufacturing organisations are _____ in nature.
8. Standardisation is the characteristic of products in case of service sector organisations. (True/False)

ACTIVITY

Make a presentation on manufacturing and service sector organisations. Come up with at least 10 examples each of current manufacturing organisations and popular service organisations in any industry. Give their names along with details of respective products manufactured or services rendered.

1.6 SUMMARY

- The business activity, which is mainly concerned with designing and production of a product, or delivering service in an organisation, is referred to as operations management.
- Operations management is concerned with the administration, designing and control of business activities/practices to achieve the highest possible level of organisational effectiveness and efficiency.
- Operations management is responsible for planning, managing and controlling of manufacturing or production processes of business entities. It takes care of the entire activities with the aim of successful conversion of raw materials into finished products and timely delivery of products.
- Operations management plays the most vital role in managing of business processes. Without the aid of operations management, organisations are unable to carry out their daily routine activities seamlessly.
- The objectives of operations management are achieving efficiency and effectiveness, achieving right quality and right quantity, and achieving output at the right time and at reduced cost.
- To give peak performance, operations managers must be aware of the main challenges including inter-organisational coordination, managing relations with customers, environment, stakeholder management, globalisation, sustainability, ethics and communication.
- The main functions of operations management are designing, planning, organising, leading, controlling, managing and coordinating.
- Business operations in a company are generally managed by different operations managers depending upon the type or size of operations. There could be a separate operations manager for different business segments like banking, retail or distribution.
- The role of an operations manager is to ensure that the functions are carried out in an efficient manner to ascertain the best-quality output at the most economical costs.

1.7 KEY WORDS

- **Stakeholders:** Persons such as creditors, community, directors, shareholders and employees who are directly or indirectly affected by the decisions, actions and policies of an organisation.
- **Product recycling:** The process of potential re-use and conversion of waste materials into new materials to minimise the consumption of fresh raw materials. This process aims at reduction of air pollution or water pollution and use of energy.
- **Manufacturing sector:** It comprises establishments engaged in transformation of materials, components and substances into new products. It is also called goods producing industry.
- **Service sector:** It comprises establishments engaged in production of services rather than end products. It is also called tertiary industry.

1.8 CASE STUDY: FAILURE OF RELIANCE DAIRY'S OPERATIONS TO SUSTAIN IN THE MARKET

Reliance Dairy, a subsidiary company of Reliance Retail, entered in the business of production and marketing of milk products in the year 2009. It had broughta range of dairy products, such as milk, butter, flavoured milk and curd in the market. The price charged by Reliance Dairy from its customers for milk was only rupees 28 per litre. Analysts believed that such price offered value for money to its customers. Reliance Dairy followed extremely efficient production processes ensuring that the milk products were of the best quality and were manufactured with the maintenance of strict hygiene factors in factories. In addition, the company also claimed that the dairy products were packaged by adhering to the latest technologies and were free from any preservatives or chemicals. Reliance Dairy also supplied varied milk products based on the diverse geographical locations of its customers.

Despite all these efforts on product quality and market capture, Reliance Dairy's supply chain and operations policies failed to sustain the company in the market-place. It faced tremendous difficulty to sustain in the dairy business because of highly competitive market and the presence of several already established players, such as Mother Dairy, Amul and Nestle. As a result, Reliance Dairy's business operations were discontinued in April 2017 and Heritage Foods Limited (a dairy company based in Hyderabad) acquired the business of Reliance Dairy.

Heritage Foods Limited planned to bring the dairy business of Reliance at the break-even level through:

- Completely closing of dairy products' manufacturing in loss-making segments or areas to use such resources in profit-making avenues
- Shifting of milk processing and packaging from outsourced third-party facilities to Heritage's in-house facilities to reduce cost

Heritage's business managers understood the importance of making products available to the consumers at the most competitive cost. They managed to maintain a link between demand and supply for Reliance's dairy products, and handled its operations effectively to gain a competitive advantage in the market.

(**Source:** Supply Chain Practices of Reliance Dairy | Operations | Case Study | Case Studies. (2019). Retrieved from http://www.icmrindia.org/casestudies/catalogue/Operations/OPER125.htm)

QUESTIONS

1. Does operations management help gain a competitive edge?

   (**Hint:** Yes, efficient handling of operations can ensure sustainability in market by making available products at the most competitive costs. Refer to Section 1.2.2: Operations as a Source of Competitive Advantage)

2. Which functions should be adopted by operations managers in order to address competitive issues in the market?

   (**Hint:** Refer to Section 1.2.2: Operations as a Source of Competitive Advantage)

1.9 EXERCISE

1. What do you understand by operations management?
2. Explain the objectives of operations management.
3. What challenges does an operations manager face in operations management?
4. Describe the main functions of operations management. Briefly discuss the role of an operations manager.
5. Distinguish between service sector organisations and manufacturing sector organisations.

1.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Operations and Operations Management	1.	effectiveness
	2.	True
Functions of Operations Management	3.	d. Selection of personnel
	4.	Form
Role of an Operations Manager	5.	operations manager
	6.	True
Service Sector Organisations vs. Manufacturing Sector Organisations	7.	tangible
	8.	False

1.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 2

Operations Strategy

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Outline the meaning and significance of operations strategy
- Explain the steps of strategy formulation process
- Discuss the types of operations strategies
- Differentiate between manufacturing operations strategy and service operations strategy
- Discuss the technology strategy concepts of big data and cloud computing
- Explain the important operations management concepts of ERP, CRM, VCM, CRP and PLM

2.1 INTRODUCTION

In the previous chapter, you had studied the meaning, objectives and functions of operations management. You had also studied the role of an operations manager and difference between manufacturing sector organisations and service sector organisations.

A strategy is a plan of actions to achieve a set of pre-determined and specific goals. It is a plan of measuring 'how', i.e., a means of getting from here to there.

In the modern business world, the term 'strategy' is widely used and applied in industries. For instance, strategies are adopted to gain market share from the competitors. It furnishes a platform for an organisation to perform in a better manner and achieve competitive edge. It focusses on increasing the organisational effectiveness by making a judicious use of organisational resources, such as funds, human resources, technology and infrastructure. Strategy plays a role of a linkage amidst the external market necessity, the internal organisational and technological resources, the capability and the competitive advantage. In the absence of a proper strategy, the organisational and technological resources and the capacities will be unclear and can be misdirected. Operations strategy can be defined as the effective usage of production capability and technology for the achievement of business and corporate goals. These goals may include profit, customisation, innovation, product flexibility, response, quality, delivery reliability, after-sales service, etc. Many organisations have revealed over the previous two decades that if the operations strategy is effective, it can cause a lasting competitive advantage. In other words, operations strategy is the backbone of operations management.

In this chapter, you will learn about strategy and various levels of strategy, namely corporate level, business level and functional level. You will also learn about operations strategy, its types and factors which influence operations strategy. You will also learn about capacity requirements planning, enterprise resource planning, customer relationship management, etc.

2.2 STRATEGY

Strategy is the plan of action that managers take to attain one or more of the organisational objectives. It is concerned with integrating activities and utilising and allocating organisational resources in the business environment with an objective to

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meet pre-defined goals. There is no definite meaning given to strategy, as various authors have defined strategy in different ways.

According to **Kenneth Andrews**, "*Corporate strategy is the pattern of decisions in a company that determines and reveals its objectives, purposes, or goals, produces the principal policies and plans for achieving those goals, and defines the range of business the company is to pursue, the kind of economic and human organisation it is or intends to be, and the nature of the economic and non-economic contribution it intends to make to its shareholders, employees, customers and communities.*"

According to **Johnson and Scholes**, "*Strategy is the direction and scope of an organisation over the long term, which achieves advantage for the organisation through its configuration of resources within a challenging environment, to meet the needs of markets and to fulfil stakeholder expectations.*" Some of the objectives of strategy are as follows:

- Providing direction and stability to the organisation
- Determining long-term goals of the organisation
- Facilitating the decision-making process
- Allocating resources to various departments of an organisation
- Helping the organisation to prioritise targets based on organisational resources
- Facilitating the planning and execution of long-term, medium-term, short-term and day-to-day plans

2.2.1 LEVELS OF STRATEGIES

A strategy is practised at three different levels in an organisation. These levels are depicted in Figure 1:

Figure 1: Strategic Levels in an Organisation

Let us discuss these levels in detail:

- **Corporate-level strategy:** This is the first level of strategy designed by the top management. It consists of the board of directors and the chief executive officer. It helps in achieving objectives by analysing all the available business opportunities. It is futuristic, innovative and pervasive in nature, and includes major decisions, such as mergers, takeovers, liquidations and diversification. It relates to the 'what' aspect of business. It defines the general overall strategy, outlines the markets in which the business will operate into and plans how these markets will be entered.

- **Business-level strategy:** This strategy is designed by the business heads of each Strategic Business Unit (SBU). It allocates resources among the functional areas of a business. In addition, it is more specific and action-oriented as compared to the corporate-level strategy. It relates with the 'how' aspect of the business. It defines each market's specific tactics and outlines how each business unit shall deliver such tactics. It contributes to accomplish the corporate-level strategies.
- **Functional-level strategy:** This strategy is designed by functional managers to carry out the day-to-day activities of an organisation. It ensures development and coordination of relationships among departments, business units and teams in an organisation. Its main objective is to carry out day-to-day activities to ensure accomplishment of business and corporate strategies. It defines how functional goals would be reached and monitored.

2.2.2 STRATEGIC INTENT

Strategic intent defines the objectives of an organisation in the long term. It lays down the framework for an organisation, gives an idea of what it desires to attain in future, and provides a direction to achieve organisational plans. An organisation sets its strategic intent through its vision, mission, objectives and goals, which further help in making strategies. These planning proceses are described as follows:

- **Vision:** Vision refers to the long-term goal of the organisation. In other words, vision is what an organisation wishes to become. It describes the aspiration of the organisation for the future, but does not describe the means to achieve it.
- **Mission:** Mission states the reason for the existence of an organisation, and defines the path to achieve the vision. A vision gives a forward-looking direction to an organisation, whereas a mission is what an organisation is and why it exists.

  According to **Thompson**, "Mission is the essential purpose of the organisation, concerning particularly why it is in existence, the nature of the business(es) it is in and the customers it seeks to serve and satisfy."
- **Objectives and goals:** Objectives form an important part of the plans of an organisation, as they split the vision and mission into actions to be implemented. They define the relationship of an organisation with its internal and external environment and provide the basis for strategic decision making.

They imply how the goals of an organisation should be achieved. Goals represent all the financial and non-financial aims of the organisation. It can be said that when objectives are stated in specific terms, they become goals to be attained.

2.2.3 STRATEGY FORMULATION

Strategy is important for every organisation. Therefore, every organisation aims at formulating strong strategies. The process of formulating strategies goes through various stages which are explained as follows:

1. **Analysing vision and mission of the organisation:** As strategy is a medium or process of realising organisational objectives, the first step in strategy formulation process is to fix the long-term objectives of an organisation. Vision and mission are the two elements that describe the nature, direction, future, goals, shape, hierarchy, products and services and areas of operation of the business.
2. **Scanning organisational environment:** This step involves studying the external and internal environment of a business. The business environment is complex,

dynamic and multifaceted as it consists of various factors that interact with each other and change with time. It is necessary to study the environment for knowing the strengths, weaknesses, opportunities and threats of a business. This study is called environment appraisal. It includes reviewing the position of organisation's competitors and assessing the organisation's existing product line.

3. **Setting of quantitative targets:** Under this step, the organisation fixes some quantitative target values in line with the objectives set by the organisation. These targets provide a direction for the organisation to move forward.
4. **Aiming for divisional plans:** The next step in the strategy formulation process is to identify the contributions made by each division, department or product category. On the basis of this assessment, strategic plans are developed for each business sub-unit.
5. **Analysis of performance:** This is a very critical step under which the organisation's past performance, current business conditions and desired future scenario are evaluated. This evaluation enables the organisation to identify the gaps persisting between actual reality and long-term goals of the organisation.
6. **Choosing strategy:** This is the final step in the strategy formulation process. It refers to evaluating each strategy for choosing the best optimal strategy. After evaluating all the strategies, a single strategy or combination of two or more strategies is decided by the strategist. The choice of strategy depends on the stage of business life cycle and pre-determined objectives.

Self Assessment Questions

1. The first level of strategy in an organisation is known as:
   a. Business-level strategy
   b. Corporate-level strategy
   c. Functional-level strategy
   d. None of these
2. A vision is a backward-looking view of an organisation. (True/False)

2.3 OPERATIONS STRATEGY

Operations strategies are used by organisations for examining and implementing effective systems or policies for efficient utilisation of resources, work processes and personnel for the attainment of business objectives.

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

Operations strategy is defined as a plan which details as to how an organisation utilises its resources to achieve the goals set by the top management. It includes long-term decisions related to capacity, location, processes, technology and timing. Following issues are addressed in operations strategy:

- How should the resources be structured?
- What activities should take place?

- How to ensure the quality of goods and services?
- What type of processes are to be install for manufacturing goods and services?

Operations strategy involves key operating decisions that are aligned with the overall strategic objectives of an organisation. It helps an organisation in gaining a competitive edge. Following are the basic elements of an operations strategy:

- Positioning of the production system
- Location of factories and service facilities
- Development of production process
- Effective allocation of available resources
- Design and development of products and services
- Selection of production technology

2.3.1 OPERATIONS STRATEGY FRAMEWORK

There can be many alternate approaches to develop an operations strategy for a specific organisation. For this, an analysis of the market requirements and operation's resource capabilities are to be kept in mind. The procedure for operations strategy that we cover here is Hill framework as follows:

Hill Approach to Formulate Operations Strategy

This iterative framework was outlined by Terry Hill in 2005. Under this, Hill links together an organisation's objective and the operations strategy. The corporate objectives provide the direction to the organisation and a strategy for marketing. The operations strategy defines the capabilities of the organisation to compete in the chosen market. It defines how organisation Hill framework method has following five stages:

- **Defining corporate objectives:** This step is to be kept into consideration by all types of businesses. Identification of an organisation's goals and objectives gives directions for the strategies to be constructed further.
- **Determining market strategies to achieve objectives:** After defining the objectives, an organisation must develop market strategies which would increase the growth of the organisation by winning in the particular market. Market strategies also influence other strategies of business.
- **Reviewing how different products can win sales against competitors:** This step involves questioning and finding solution to "how the products will win the orders in a given marketplace?" The gap between the market needs and the organisation's operations must match. The competitive success depends upon factors, such as pricing, delivery speed, reliability, quality of the product or service etc,.
- **Deciding the most suited approach to deliver these product sets:** Marketing of the product to customers needs to be considered. Finding an effective path to deliver products to customers should be the aim, and the strategies must be constructed by keeping this in mind.
- **Providing requisite infrastructure to enable operations:** To conduct the operations smoothly, technology, infrastructure and other resources are needed. All of these should be appropriately provided for the operations strategy to take place.

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Hill considered that an organisation needs to be as good as the competitor is. An organisation may lose its sales if it fails to match the customer expectations in regard to the competition.

2.3.2 TYPES OF OPERATIONS STRATEGIES

The kinds of operations strategies depend upon the type of organisation, products produced by the organisation, organisational structure, location of the organisation, etc. Some of the important operations strategies are discussed as follows:

- **Customer-driven strategies:** These strategies are driven by the response of the customers, and such as customer's feedback, customer's demand for new and innovative methods product customisation etc. For example, Fast-Moving Consumer Goods (FMCG) products are necessarily required to be produced and be available in large quantities and in multiple locations.
- **Product-driven strategy:** These strategies are based on product characteristics and types. For instance, cold beverages are in high demand during summers and in low demand during winters. Therefore, organisations producing soft drinks should ensure that they are able to manufacture drinks quickly to cover extensive markets in summers.
- **Failure prevention and recovery strategy:** These strategies pertain to partial or full recovery of damages arising because of the occurrence of unforeseen circumstances. Disaster related to fire, earthquake and computer failure are few examples of recovery strategy.
- **Corporate-driven operations strategy:** These strategies are drafted by the top- and executive-level management. All other strategies are formulated and implemented in accordance with this strategy.

2.3.3 FACTORS INFLUENCING OPERATIONS STRATEGY

Without a sound operations strategy, no organisation can afford to survive in the marketplace. Following factors need to be considered by an organisation while formulating its operations strategy:

- **Product:** Products produced by an organisation can be classified as made-to-order products (manufactured after an order is received from customers), made-to-stock products (manufactured in bulk and stored for long period), and assembled-to-order products (components manufactured in bulk and assembled as and when orders are received). Different types of products require different strategies depending upon the market demand generated, type of orders received and availability of resources.
- **Processes:** A production process can be of different types such as job shop production, batch production, flow production and continuous production. The selection of a production process depends on the type of product/service produced by an organisation.
- **Programs:** There are different operations programs, such as planning, scheduling and controlling of production. If plans are made properly, scheduling and controlling process will be successful.
- **Communication:** Any organisation that does not have a sound communication policy and mechanism in workplace fails to implement various activities related to

several operations. Effective implementation of strategies is not possible without proper communication between departments or functions.

- **Personnel:** The effectiveness of the operations strategy implementation depends on the skills and efficiency of the human resources. An organisation that does not have the right men for the right job at the right time fails miserably when it comes to the implementation of operations strategy.

2.3.4 MANUFACTURING OPERATIONS STRATEGY AND SERVICE OPERATIONS STRATEGY

Different operations strategies are applied in manufacturing organisations and service-oriented organisations because of the basic distinction between these two types of industries. Differences between manufacturing and service organisations operational strategy are as follows:

- **Strategy relating to the raw material procurement for producing output:** In case of manufacturing organisations, separate strategies are required for the purchase of raw materials as the output is substantial. The situation is not same in case of service-related organisations as the output is impalpable and requires no distinct raw materials. For instance, in a bread producing company, there must be a different strategy for the purchase of flour, sugar and other inputs. However, in a consultancy service, the inputs are in the form of experiences, applied knowledge, etc. Thus, in service organisations, the input is not fixed as in the case of manufacturing organisations.
- **Strategy relating to working environment structure:** While in manufacturing organisations, the plan of the working environment is prepared according to the machine designs, service organisations design the plan of the working environment to suit their clients.
- **Strategy relating to executing change:** In manufacturing organisations, strategies for change are tedious and take longer time on account of troubles associated with moving machines, etc. In case of service organisations, the change is moderately simpler and quicker to execute as no tangible product is involved.

Self Assessment Questions

3. All strategies are formulated and implemented in accordance with corporate-driven operations strategy. (True/False)
4. Without a sound _____ strategy, no organisation can afford to survive in the marketplace.

2.4 TECHNOLOGY STRATEGY

In today's era of globalisation and interconnection in the world, technology aims to touch everything, and has now become a pre-requisite in the working of business. Technology has changed the way in which business organisations conduct their operations. Implementing technologies in operations management ensures that business entities are able to reduce their costs, standardise and enhance quality, improve delivery processes, execute with flexibility and focus on customisation, thereby increasing value for customers.

Majority of organisations assume technology as a critical aspect for long-term survival in the market. But many companies fail to balance organisational talent

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gaps, capital constraints and innovation risk profiles to sustain their pledge towards technological innovation. Various strategies to incorporate technology have been adopted by organisations and various advancements have been observed. Some of these are explained in the following sections.

2.4.1 CONNECTIVITY

The network management frameworks allow organisations to dynamically arrange and control the network resources through various software applications. Advancement in connectivity gives rise to network flexibility by making it possible to organise networks that fit different types of availability requirements and performance. The building blocks of advanced connectivity include:

- **Low earth orbit satellites:** Technology has now advanced to such a level that it can easily reach the remote areas. This can help organisations working in the remote areas to connect with the shareholders, employees, retailers, customers, etc.
- **5G:** A sweeping change can be observed with the introduction of the fifth generation of the cellular wireless technology. It offers lower latency, greater speed and most prominently has the ability to connect a huge number of smart devices and sensors within a network.

2.4.2 INTEGRATION

Technology drives organisational efficiency and increases productivity of the entity. Incorporating technology in the production system is a complex issue and has to be attained by following the steps of technology acquisition, technology integration and technology verification. Integration of technology can be beneficial if utilised effectively. Certain technology integration strategies are as follows:

- It can be integrated to provide remedy for various identified weaknesses.
- It can be integrated to promote automation of the pre-requisite skills.
- It can be integrated to motivate the employees to be self-directed.
- It can be integrated to optimise scarce resources.
- It can be integrated to remove logistic hurdles.
- It can be integrated to foster creativity amongst employees.
- It can be integrated to increase knowledge for problem solving.

2.4.3 BIG DATA

Big data is both structured and unstructured data that is exceptionally large in volume and difficult to be dealt with traditional database applications. It is characterised by high velocity, variability, volume and value. As operations management relates to the management and control of production of goods and services, data sets are rapidly increasing in this field. The data in operations management is complicated and huge in volume. Therefore, there is a need for big data analytical tools in operations management. These tools help face challenges posed by big data in business operations, such as in prediction analysis of consumer behaviour, data mining, management of inventory, risk analysis, forecasting, and so on. Some big data technological tools used now-a-days are Hadoop, Map Reduce, Apache Spark, etc.

Big data analytics has allowed many organisations to increase efficiency and gain a competitive advantage in the marketplace. Organisations often use analytics as a basis for decision making. This technology will evolve and cover more arenas in the coming years. In the coming years, even the small businesses will find it hard to maintain the data using the older version. Analytics will become a guiding principle behind a business activity. In addition, organisations are required to be more automated and data-driven to compete and survive.

2.4.4 CLOUD COMPUTING

Cloud computing delivers a way for the industry to manage the computing resources online. The term 'cloud' refers to the Internet, whereas operating 'in the cloud' defines the way one stores and accesses the data through a Web connection. It allows businesses to access the information virtually, create a global and flexible way that can be checked any time and at any place. It has to be managed, like any other business tool. A well-organised and well-planned cloud service strategy has the potential of reducing the costs.

As opposed to direct server connection, information technology services and resources are retrieved directly from the internet using Web-based applications in cloud computing. It enables users to save data in a remote database over the Internet, as opposed to traditional system of keeping files in hard drives. The system of cloud computing enables employees to execute work remotely because information can be accessed from the cloud and it does not require an employee to gain access at a particular location.

Some of the advantages of using cloud computing in the management of business operations are:

- Decline in costs of hardware and capital expenditure
- Reliability and availability at all times and at all places across the globe
- Security against loss of sensitive data
- Enhanced collaboration and virtual exchange of information between different functions
- Control over document sharing, storage and maintenance
- Easily manageable

Self Assessment Questions

5. Which data is characterised by high velocity, variability, volume and value?
6. _____ allows employees to execute work remotely because information can be accessed over the internet.

2.5 SYSTEMS AND PROCESSES

A system is defined as a set of correlated elements which come together to work towards the achievement of organisational goals. It is a combination or group of things which constitute a complex whole. Organisations work as a system in order to attain the desired vision and mission. In an organisation, it comprises many sub-systems which serve different functions, such as finance, human resources, marketing, operations, production and accounting etc. All of these sub-systems work in correlation with the aim of betterment of the total system. If sub-systems

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are isolated and managed independently, they might not work efficiently. There are mainly three types of systems as follows:

- **Production system:** The function of production system is to convert a set of inputs into a set of desired outputs. It receives inputs in the form of materials, personnel and capital and produces output in the form of products or services.
- **Conversion sub-system:** Conversion sub-system is a sub-system of the larger production system wherein the inputs are converted into outputs.
- **Control sub-system:** It is a sub-system of the larger production system wherein a portion of the output is monitored against feedback signals so as to provide a corrective action, if necessary. It ensures a uniform level of system performance.

On the other hand, a sequence of activities that is intended to attain some results in order to create additional value for customers is referred to as a process. These are related activities inside a system which work together to make the system function. Process follows a set of activities which converts inputs into outputs in the production system. It utilises the organisation's resources so as to deliver something of value. Processes can be categorised into the following types:

- **Conversion processes:** These processes involve conversion of raw materials into finished products. For example, conversion of iron into steel is a conversion process. This process could be chemical, metallurgical, manufacturing or constructing.
- **Manufacturing processes:** These processes can be categorised into formation, machining and assembly processes.
- **Testing processes:** These processes involve testing and inspection of products.

Thus, while building relationships, people, activities and interactions are a system, a sequence of activities that produces outputs is process. Moreover, a process yields results through work that is done in the process and a system yields results through the collaboration of elements. Processes produce outputs and systems create outcomes. Systems support processes and processes support people. It is necessary to quote here that organisations and managers have to continuously strengthen systems and processes with a lot of care and maintenance to ensure smooth functioning of operations and attainment of organisational goals.

Self Assessment Questions

7. _____ is a sequence of activities that is intended to attain some results in order to create additional value for customers.

2.6 INTRODUCING SOME IMPORTANT CONCEPTS RELATED TO OPERATIONS MANAGEMENT

The concepts of operations management are not confined to a single department or function. They address issues relating to planning and controlling of production processes, handling of materials, inventory management through supply chain, transportation of goods and many more. Various functions of operations management are linked or interdependent and work in synergy with one another to achieve optimum efficiency in business operations. Operations management comprises some standard techniques or concepts which cater to the needs of a specific administrative function of the organisation. The integrated use of these techniques provides a robust

methodology and action plan to the organisation for smooth working of its business. Some of these concepts are depicted in Figure 2:

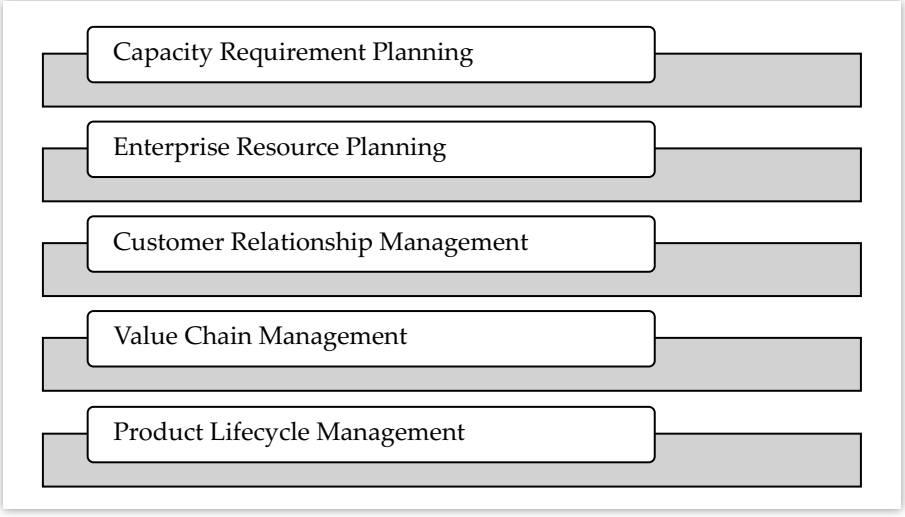

Figure 2: Important Concepts Related to Operations Management

Let us discuss these concepts in detail as follows:

2.6.1 CAPACITY REQUIREMENTS PLANNING (CRP)

One of the most important aspects of business planning to be taken care of by an operations manager is capacity requirements planning (CRP). CRP helps an organisation determine whether or not it can meet the demands of products or services. CRP answers to questions like what needs to be produced during a given period can actually be produced or not. It addresses capacity issues and develops schedules for release of capacities to be used in specific job work orders.

In other words, CRP is the process through which a business entity figures out how much it needs to produce and whether its resources are capable enough of meeting those production goals. It can take place monthly, quarterly or annually to meet the changes in demand and supply. Decisions taken by an operations manager through CRP have a bearing on short-term and long-term efficiency of production processes.

2.6.2 ENTERPRISE RESOURCE PLANNING (ERP)

Enterprise resource planning (ERP) is a business management software that is developed for managing, organising and integrating core and administrative business processes through information sharing across all functional domains. ERP automates all front and back office functions relating to production, marketing, finance, accounting, human resources and others.

There are many ERP software applications that exist to assist organisations in implementing resource planning by integrating processes that are needed to run an organisation in a solitary system. The main feature of ERP software is its comprehensive and shared database which supports the functions being performed by various business units, divisions or departments.

ERP software incorporates all the facets of an operation like product planning, developing, manufacturing, and sales and marketing using a single application, centralised database and user interface. It can be assumed as a portrayal of systems

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in which innovative information technology is used to administer all the functional areas of an organisation.

Some of the benefits of using ERP system are as follows:

- Investment in ERP helps entities stay in tune with competition
- Reduction in the need for manual information processing
- Elimination of repetitive processes
- Increase in efficiency
- Enhancement of collaboration between different departments or functions
- Flexibility to meet varied needs of businesses

2.6.3 CUSTOMER RELATIONSHIP MANAGEMENT (CRM)

Customer relationship management (CRM) is related to the combination of concepts, technologies, policies and procedures adopted by business entities to manage their relationships with customers. CRM aims to analyse customers' requirements, satisfy the needs of existing customers, and attract new customers. CRM is that art of management which deals with handling the relationship between the organisation and current and prospective customers. It comprises practices, principles and guidelines that are followed by the organisation while interacting with its customers.

CRM serves to augment customer's overall experience. Operations managers consider the importance of CRM implementation in organisations because of the following reasons:

- It gives a historical analysis view of current customers.
- It helps to foresee customer needs and improve business opportunities.
- It is useful in acquiring new customer base.
- This requires less use of paper and manual work.
- It offers a centralised system of customer information.
- It increases customer satisfaction levels by dealing effectively with customers.

2.6.4 VALUE CHAIN MANAGEMENT (VCM)

Value chain management (VCM) was introduced in the 1980s by Michael Porter who was a Harvard Business School professor and a business strategy authoritative. Over the years, VCM has evolved into a strategy that is applied universally in businesses. Manufacturing organisations generate value by acquiring raw materials and incorporating them to produce something of use. The value that is created and apprehended by an organisation is the profit margin. A value chain is comprised of a set of activities which are carried out by an organisation to create value for customers. These activities include inbound logistics, marketing and sales, service, procurement, human resource management, infrastructure, etc.

VCM aims to organise business activities which create value from the production and sale of goods and services. VCM's main objective is to increase cooperation and communication between production chain members with a view to decrease inventories, reduce delivery times and increase customer satisfaction.

Following components are required for VCM:

- Efficient supply chain
- Integrated customer insight information and data
- Integrated chain strategy, scheduling and planning
- Optimisation of interdependent chain resource management

2.6.5 PRODUCT LIFECYCLE MANAGEMENT (PLM)

All products manufactured in a business organisation have a limited life and pass through different stages of introduction, growth, maturity and decline. Product lifecycle management (PLM) concerns a set of strategies to be applied by manufacturers at different stages of the product lifecycle to effectively face challenges at each stage. PLM ensures that product sales and profits are maximised by manufacturers at each stage of the product. Therefore, PLM is referred to as a way of handling a product when it travels through the typical stages of development. It represents a vision related to management of all data involving design, support, production and ultimate discard of manufactured goods.

A sound PLM serves many benefits like getting the product in the market at a faster pace, delivering a high-quality product to the market, improving the safety of the product, increasing sales opportunities and minimising the waste and errors. For this purpose, specialised computer software exists that can assist employees to easily track PLM functions, for instance, process management, document management and design integration. These PLM systems help an organisation cope with the growing complexity and engineering challenges which can arise when designing a new product.

Self Assessment Questions

8. _____ automates all front and back office functions relating to production, marketing, finance, accounting and human resources.
9. _____ Management supports business entities to manage their relationships with customers.
10. Different stages in a product lifecycle are introduction, growth, maturity and decline. (True/False)

Activity

Research on the internet about operations management concepts related to Capacity Requirements Planning (CRP), Enterprise Resource Planning (ERP) and Value Chain Management (VCM). Name at least ten companies which have successfully adopted these techniques for streamlining their business operations.

2.7 SUMMARY

- Strategy is concerned with integrating activities and utilising and allocating organisational resources in the business environment with an objective to meet pre-defined goals.

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- The three levels of strategies are corporate-level strategy, business-level strategy and functional-level strategy.
- The process of formulating strategies goes through various stages, i.e., analysing vision and mission of the organisation, scanning organisational environment, setting of quantitative targets, aiming for divisional plans, analysis of performance and choosing strategy.
- Operations strategies are used by an organisation for examining and implementing effective systems or policies for efficient utilisation of resources, work processes and personnel for the attainment of business objectives.
- The kinds of operations strategies are customer-driven strategies, product-driven strategy, failure prevention and recovery strategy and corporate-driven operations strategy.
- The data in operations management is complicated and huge in volume. Therefore, there is a need for big data analytical tools in operations management. These tools help to face challenges posed by big data in business operations, such as in prediction analysis of consumer behaviour, data mining and management of inventory.
- Capacity requirement planning (CRP) answers to questions like what needs to be produced during a given period can actually be produced or not. It addresses capacity issues and develops schedules for release of capacities to be used in specific job work orders.
- Enterprise resource planning (ERP) is a business management software that is developed for managing, organising and integrating core and administrative business processes through information sharing across all functional domains.
- CRM is that art of management which deals with handling the relationship between the organisation and current and prospective customers. It comprises practices, principles and guidelines that are followed by the organisation while interacting with its customers.
- The main objective of VCM is to increase cooperation and communication between production chain members so as to decrease inventories, reduce delivery time and increase customer satisfaction.

2.8 KEY WORDS

- **Resources:** A stock of assets such as materials, money and staff which can be drawn by an organisation for continued and effective functionalities of business.
- **Product lifecycle:** The progression of an item or product as it passes through different stages of development in the marketplace.
- **Efficiency:** It means whatever is produced or performed is done with the least amount of time and resources. In other words, producing something with minimum expenses, wastage or unnecessary efforts is called efficiency.
- **Effectiveness:** The extent to which something is successful in reaching a desired result. For instance, the level of results achieved from the actions of managers and workers.
- **Strategic business unit (SBU):** An autonomous division or profit centre of a large organisation which focusses on a particular range of product and market segments.

2.9 CASE STUDY: ADVICE BY EFESO CONSULTING ON OPERATIONAL STRATEGIES OF ITS CLIENTS

EFESO Consulting is a leading consultancy firm offering short-term and long-term advisory services to its clients globally. With a team of over 400 specialised consultants, the firm delivers business advice in varied domains including procurement and cost management, organisational strategies, business transformation and progression, business process excellence, value chain effectiveness and many others.

Recently, EFESO Consulting resolved strategic operational issues of a world established malt producer (the company) having operations spread across multiple locations. The malt producer company aimed to double its financial growth and EBITDA within a span of 10 years, given the capital expenditure constraints. For realising this objective, the company approached EFESO for the purpose of defining its operational strategies commensurate with the set goals.

Initially, EFESO Consulting started providing services to a pilot operational region of the malt producer covering areas of Asia, Africa and South America. EFESO assessed the operations and generated strategic options for production, transportation, warehousing, logistics, procurement, quality control, make or buy decisions, acquisition of new facilities, and disinvestment of loss-making facilities. It defined a business plan and transformation plan for the company to reach the desired goals of double profitability in the long-run.

Within a time frame of 100 days, EFESO Consulting catered to the strategic needs of the malt producer by defining priorities in operations and their impacts on company's long-term goals, locating improvement procedures and identifying their contribution to company's profitability and framing fresh industrial design so as to gain competitive advantage.

After completing advisory services for the pilot region, EFESO also successfully defined and implemented organisational strategies for the rest of the business regions of the malt producer. It developed thorough methodologies for all other geographical locations of the company.

Source: *Cascading corporate strategy into operations strategy in a Malt industry. (2019). Retrieved from https://www.efeso.com/case-studies-view/40-case-studies-short/293-cascading-corporate-strategy-into-operations-strategy-in-a-malt-business*

QUESTIONS

1. What do you understand by operations strategy?

   (**Hint:** Refer to Section 2.3: Operations Strategy)

2. How did EFESO Consulting help the malt producer company in achieving the objective of double growth and profitability?

   (**Hint:** EFESO Consulting developed operational strategies for all manufacturing and business facilities of the malt producer. It designed transformational plan and new industrial footprint layout for the company.)

Notes

2.10 EXERCISE

1. Explain the meaning of strategy. Discuss the different levels of strategies.
2. What are the stages in the process of strategy formulation?
3. Describe various types of operations strategies.
4. Briefly outline the relevance of technology strategy in execution of business processes.
5. Explain the importance of capacity requirements planning (CRP).
6. Discuss the meaning of enterprise resource planning (ERP) and customer relationship management (CRM).

2.11 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Strategy	1.	b. Corporate-level strategy
	2.	False
Operations Strategy	3.	True
	4.	Operations
Technology Strategy	5.	Big data
	6.	Cloud computing
Systems and Processes	7.	Process
Introducing Some Important Concepts Related to Operations Management	8.	Enterprise Resource Planning
	9.	Customer Relationship
	10.	True

2.12 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Waters, C. (2006). *Operations Strategy*. London: Thomson Learning.
- Greasley, A. (2013). *Operations Management*. Hoboken, N.J.: Wiley.

E-REFERENCES

- Customer Relationship Management (CRM) | CCG. (2019). Retrieved from https://www.customer.com/customer-management/
- What is Cloud Computing? – Definition from Techopedia. (2019). Retrieved from https://www.techopedia.com/definition/2/cloud-computing

CHAPTER 3

Managing Manufacturing Operations

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of manufacturing management
- Discuss the different manufacturing strategies, including Aggregate Production Planning (APP), Master Production Schedule (MPS) and Material Requirement Planning (MRP)
- Describe manpower scheduling and machine scheduling
- Discuss the concept of product design
- Describe the concept of cellular manufacturing
- Discuss the five phases of the project life cycle

3.1 INTRODUCTION

In the previous chapter, you have studied the concepts of strategies including level of strategies, strategic intent and strategy formulations, operational strategy and technological strategy. In addition, the chapter also described the systems and processes and importance of the operations management.

In the present times, manufacturing industry is a growing industry. Manufacturing is a process of making products. It includes the idea of the project, design project structure, modelling and prototyping, processing or execution, testing product, and the final product. A manufacturing process requires forecasting, planning, strategies, resources and control. Manufacturing also deals with modifications and improvements to existing products.

This chapter describes the concepts of manufacturing and manufacturing strategies, namely aggregate production planning, master production schedule, material requirement planning, scheduling, product designing and cellular manufacturing. In addition, this chapter also describes the concept of the project life cycle with its stages, such as initiation, planning, execution, controlling and closure.

3.2 MANUFACTURING MANAGEMENT

Manufacturing is a process using which manufacturing organisations make various types of products. Products can be manufactured, modified and repaired in the manufacturing units. Manufacturing process turns the inputs (raw material, man-power, money, machinery, etc.) into outputs (finished goods) by operating on the inputs. Goods are often produced according to trends, customer's demands and seasonal changes. The manufacturing process is defined under a manufacturing system design. When designing a new production system, organisations need to ensure that the new production plant is installed keeping in mind the maximum capacity requirements.

When an organisation wants to produce goods, it must start by defining a well-designed manufacturing process. Before setting up the new manufacturing plant

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and before starting the manufacturing operations, the organisation must do the following:

- **Feasibility analysis:** It refers to conducting various types of feasibility checks, like checking the financial feasibility for setting up a manufacturing plant, determining whether the prospective plant location is appropriate or not.
- **Strategic analysis:** It refers to the process of analysing the environment, weaknesses and strengths of the organisation. This is done with the help of balance scorecard, strategy map, SWOT analysis, PEST analysis, blue ocean strategy, gap analysis, Porter's five forces model, VIRO framework or VIRO analysis.
- **Corporate planning analysis:** It involves determining the manufacturing objectives and goals for a manufacturing organisation. The quantity and quality of products are also determined as a part of corporate planning. The SWOT analysis is a tool used to create effective business plans. The major elements of a corporate plan are vision, mission, resources and scope, objectives and strategies. Corporate strategies with respect to manufacturing processes aim at reducing costs, clean manufacturing processes, just-in-time supply, etc.

Manufacturing is carried out through various processes. A manufacturing process is a step-by-step procedure used to produce goods from raw materials with the help of equipment, manpower and transformation methods. The steps involved in a manufacturing process are shown in Figure 1:

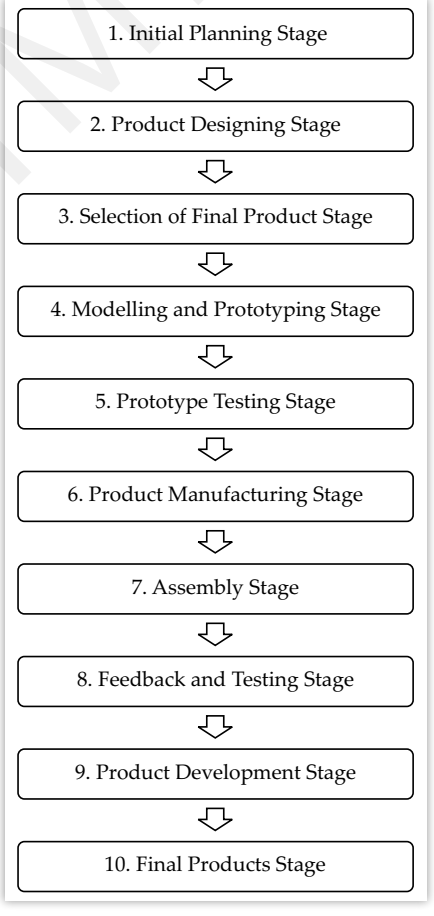

Figure 1: Manufacturing Process

There are ten stages in the manufacturing process which are as follows:

1. **Initial planning stage:** In this stage, the factors and the resources required to achieve the manufacturing goals are planned for. Here, organisations plan for different kinds of products the company is going to produce, the number of products that would be produced, etc. The planners also determine whether the resources are sufficient for manufacturing or not.
2. **Product-designing stage:** During this stage, the types and designs of the products are finalised. Different engineers prepare different designs and aim at incorporating multiple features in their products. It is essential to consider various aspects, such as product functionality, expected product life, quality of product and costing while designing the products.
3. **Selection of final product stage:** In this stage, the best product design is selected from the various alternatives available.
4. **Modelling and prototyping stage:** During this stage, the final model of the product is prepared by using Computer Aided Design software. Modelling eliminates existing drawbacks that come from plotted product designs. A prototype of the product model is prepared before finalising the product design.
5. **Prototype testing stage:** In this stage, the design of the product is tested for making it as best as possible.
6. **Product-manufacturing stage:** During this stage, the manufacturing process of products is started. Production-related decisions are also to be taken in this stage.
7. **Assembly stage:** During this stage, various parts of the overall products are assembled by using certain process or materials like the tyres are attached to the frame of cycle, etc. The quality of the products used for assembling should not be poor, else it will lower the overall product quality.
8. **Feedback and testing stage:** During this stage, feedback is taken about the product. The product can be further improved on the basis of this feedback.
9. **Product development stage:** During this stage, the final product is developed. The production quantity can be increased or decreased according to the demand.
10. **Final product stage:** During this stage, final products are produced and made available for the sale and marketing.

Self Assessment Questions

1. Different engineers prepare different designs and aim at incorporating multiple features in their products in product design stage. (True/False)
2. List any two methods used in strategic analysis.

Activity

With the help of the Internet, list the name of any manufacturing organisation and discuss its manufacturing processes.

Notes

3.3 MANUFACTURING STRATEGY

A manufacturing strategy is a part of the overall corporate strategy which consists of manufacturing objectives and tasks that are necessary to obtain the desired results. Manufacturing strategies must be compatible with other functional or corporate strategies.

According to **Marucheck, Pannesi and Anderson,** manufacturing strategy is a collective pattern of coordinated decisions that act upon formulation, reformulation and deployment of manufacturing resources and provide a competitive advantage in support of the overall strategic initiative of the firm or the SBU.

According to **Platts,** manufacturing is a pattern of decisions, both structural and infrastructural, which determines a capability of manufacturing system and specify how it will operate in order to meet a set of manufacturing objectives which are consistent with overall business objectives.

Organisations can make dominant strategies to improve product quality and increase productivity. Some examples of manufacturing strategies are waste minimisation, material effectiveness, process maintenance, eco-efficiency and reserve competence. Manufacturing strategies can be flexible, lean and service-based. These are discussed as follows:

- **Flexible manufacturing strategy:** Under this manufacturing strategy, customised products can be developed. These strategies can be easily modified according to change in products and their volume. Flexible Manufacturing Systems (FMS) are used for customising manufacturing processes as per the requirements.
- **Lean manufacturing strategy:** In this type of manufacturing strategy, manufacturing process is made more efficient by eliminating inventories, reducing wastages of raw materials and labour, etc. Quality control methods are used to improve the efficiency of manufacturing. Lean manufacturing strategy is also known as just-in-time manufacturing.
- **Service-based manufacturing strategy:** In this type of manufacturing strategy, customers are provided repairing services after the sales of goods. It provides services in case of long life-span of products and items on lease. This strategy focusses on profitability and not on the sale of the products.

3.3.1 AGGREGATE PRODUCTION PLANNING (APP)

Aggregate Production Planning (APP) is associated with various aspects of production, such as determination of inventory, production, time required for production, quantities of materials and production volume to fulfil changing demands. An organisation can make its production plans on the basis of demand forecasting. To fulfil market demands, supply should match the demand and APP makes it easy by forecasting demands. Aggregate plans are made six to eighteen months in advance and they estimate the market demand and the production factors required. There are two types of aggregate planning, which are as follows:

- **Manufacturing aggregate planning:** It refers to the aggregate planning used to allocate appropriate resources for manufacturing processes to minimise costs

and time required for manufacturing. A plan is created for allocating labour, raw materials, components/parts and machines required for manufacturing.

- **Service aggregate planning:** It is used for managing the demand and capacity of the production unit. During the periods of slack demand, there is a need of store inventories which are used when demand is high.

The concept of APP is widely used to determine the overall volume of the products that must be manufactured. Aggregate plans do not specify the actual dates of ordering raw materials. However, APP determines factors of production which are classified into internal and external factors as shown in Figure 2:

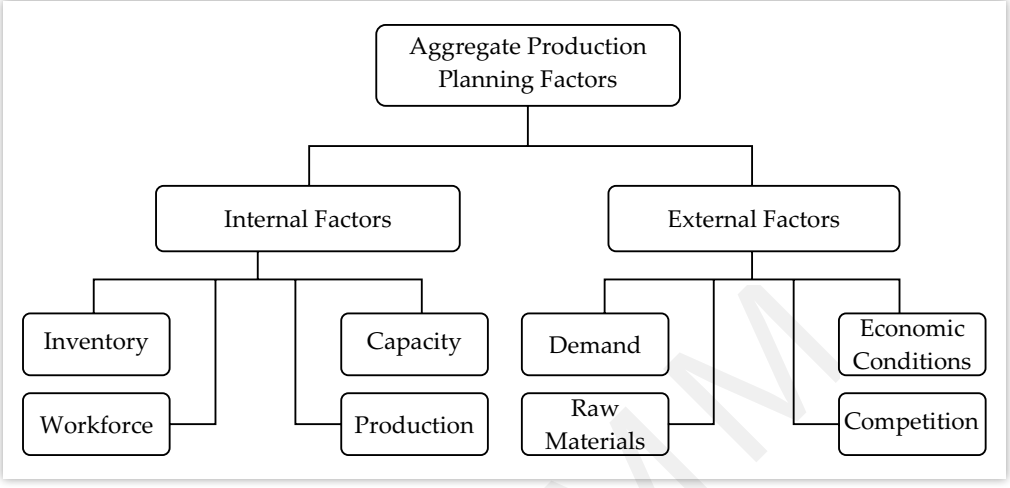

FIGURE 2: Factors of Aggregate Production Planning

Internal factors and the APP are discussed as follows:

- **Inventory:** It refers to the building where the stock of raw materials is kept in periods of slack demand and using that inventory when demand is raised.
- **Workforce:** It refers to the persons or labourers hired for manufacturing organisations. They can be hired temporarily or permanently.
- **Production:** It refers to the quantity of goods to be produced and specify production completion criteria.
- **Capacity:** It refers to managing organisational resources, such as workforce capacity, production capacity and inventory.

External factors of APP are described as follows:

- **Demand:** It refers to forecast demand and set production criteria to fulfil changing demands. It is necessary that production volume must satisfy the market demands.
- **Raw material and components:** Materials, parts and components must be ordered from external parties for manufacturing the goods. Primary raw material can be accessed from natural resources. Without raw materials, manufacturing is impossible.
- **Competition:** It refers to identifying and analysing similar or substitute products available in markets before manufacturing goods.

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- **Economic conditions:** It refers to the impact of manufacturing on economy. A good manufacturing process can generate higher revenues by producing quality of goods.

3.3.2 MASTER PRODUCTION SCHEDULE (MPS)

Master Production Schedule (MPS) is an effective plan developed by the organisation for producing goods according to the time. MPS is also used in case of inventory costs, production costs, forecasting demands and staffing. A plan indicates how much commodities are demanded by customers. MPS is based on aggregate planning. The time horizon covered by the master schedule depends on the type of commodities. Some MPS cover a short time period while some cover more than a year.

Multiple functions can be performed with the help of MPS. Some of them are discussed as follows:

- **Translate plans into specific end items:** It helps in determining the level of operations that must be performed to meet the changing market demands with raw materials, equipment and components.
- **Evaluate alternative schedules:** It refers to the use of simulation models to evaluate alternative schedules. MPS is a trial schedule that gives alternative flows to production.
- **Generate capacity requirements:** It refers to a prerequisite for capacity planning. Capacity requirements are derived from the MPS.
- **Facilitates information processing:** MPS used for determining delivery schedules in advance so that products can be delivered on time. It collects information from marketing, finance and personnel departments before preparation of schedules.
- **Effective utilisation of capacity:** Periodical statements are prepared according to the capacity requirements related with manpower, machines and inventories.

A sample MPS is presented in Figure 3 as follows:

Aggregate Plan		
Month	1	2
	1700	2000

Week	1	2	3	4	5	6	7	8
Item A	300	200	100		400	100		250
Item B		400		400		300	500	
Item C	100		200		250			200

Figure 3: Master Production Schedule

3.3.3 MATERIAL REQUIREMENT PLANNING (MRP)

Material Requirement Planning (MRP) is a computer-based planning which is used for production scheduling and inventory control. It creates plans for inventory management. Under MRP, it is ensured that the stock of goods should be available when it is demanded by the customers. MRP is a system for calculating the materials and the available components that are required to manufacture products. The major characteristics of MRP are as follows:

- Measures current stock of inventory
- Plans manufacturing and delivery activities
- Measures requirements of raw materials, components and parts which are necessary to fulfil delivery schedules
- Includes purchase activities for fulfilling the requirements of the manufacturing units
- Maintains the lowest possible levels of inventories

MRP also has some objectives which are discussed as follows:

- **Inventory reduction:** To determine how many components are required to meet the master schedule. It helps produce components or materials when needed and avoids building up of excessive inventory.
- **Reduction in the manufacturing and delivery lead times:** MRP helps identify materials and component quantities, timing schedules, availability and procurement and activities required to meet demand schedules.
- **Realistic delivery commitments:** MRP helps in obtaining timely information regarding delivery times from production activities.
- **Increased efficiency:** MRP also helps coordinate among the various working material units that are helpful to control the interrupted flow of materials through the product line. This increases the efficiency of production system.

The components of MRP are presented in Figure 4 as follows:

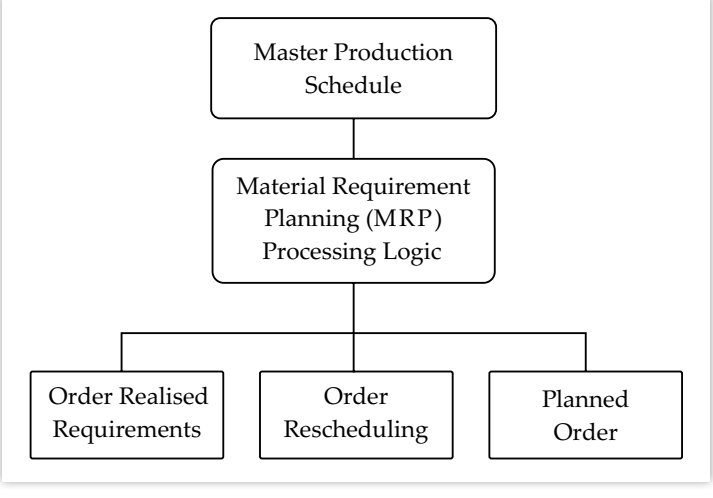

FIGURE 4: Master Requirements Planning

NOTES

Let us now discuss these components in detail:

- **Master Production Schedule (MPS):** An MPS refers to a periodical plan for each commodity that a company produces. It indicates how many units are to be produced and when.
- **Inventory Status File:** It refers to a file which gives complete information on available quantities of materials, gross requirements, scheduled receipts and planned order releases for an item.
- **Bill of Materials (B/M):** It refers to the bill that indicates how a product is manufactured, specifies all components or subcomponents of items and the sequence of build-up. This information can be obtained from design documents, workflow analysis and standard manufacturing information.

SELF ASSESSMENT QUESTIONS

3. Manufacturing strategies can never be dominant by nature. (True/False)
4. Manufacturing aggregate planning and service aggregate planning are the types of APP. (True/False)
5. MRP is a computer-based planning which is used for production scheduling and _____.

3.4 SCHEDULING

Scheduling can be defined as a process of arranging manufacturing activities according to their starting and completion times. It controls and optimises work in a production process. Scheduling is used while allocating various types of resources like plants, machinery, etc., to manufacturing processes. The main aim of scheduling is to minimise the production time and costs, and to maximise the efficiency of the organisation. Scheduling can be categorised as follows:

- **Forward scheduling:** In this process, manufacturing activities are arranged in such a way that the next activity will be started when the previous activity is finished. The step-by-step procedure is followed by the manufacturing unit to implement this strategy in the forward direction.
- **Backward scheduling:** In this process, the start and finish time are determined for waiting jobs by assigning them time slots. Time slots enable each job to be completed when it is due.

3.4.1 MACHINE SCHEDULING

Machine scheduling refers to the act of assigning jobs to machines during manufacturing. It is a short-term execution plan for manufacturing. In case of machine scheduling, multiple tasks/activities can be assigned to a single machine. A schedule describes which activities must be performed and how the facility resources should be utilised to execute them. Machine scheduling usually assumes a fixed number of parameters such as tasks, time estimates for each operation, required resources, necessary sequential constraints, and no cancellations.

Scheduling processes work on the basis of time. Suppose a set of ten jobs has to be processed and there are four machines available to execute the jobs starting at zero time. Each machine can handle only one job at a time. So, a machine can execute the next pending job only when the first one is completed. Jobs can be divided according to the time.

Table 1 shows the scheduling of 10 jobs:

Table 1: Scheduling of Jobs

Jobs	1	2	3	4	5	6	7	8	9	10
Time in minutes	17	14	16	11	13	16	18	9	12	15

A feasible solution can be represented by the Gantt chart as shown in Figure 5:

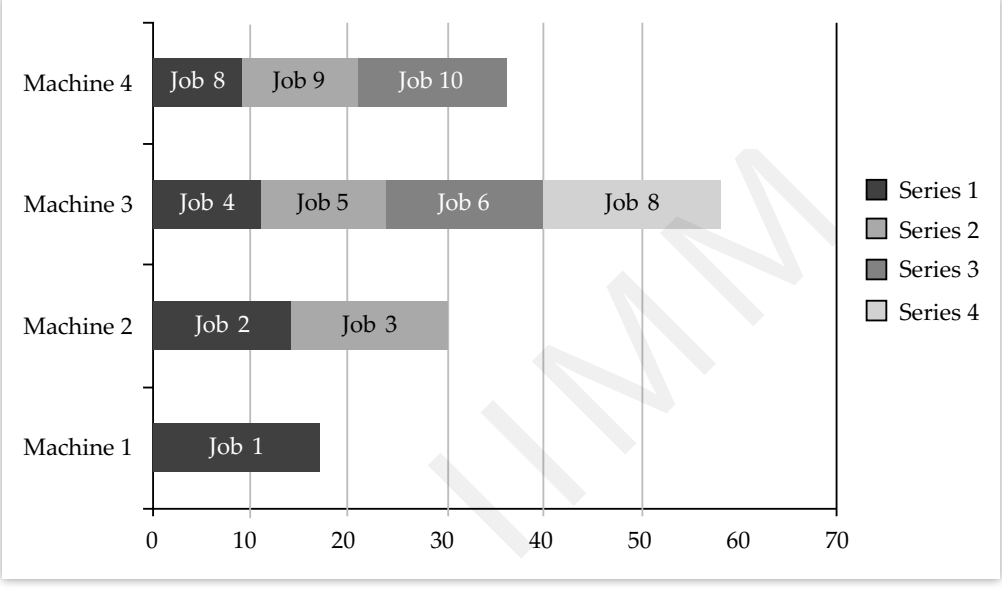

Figure 5: Representation of Machine Scheduling

There are ten jobs which are assigned to four machines. Job 1 is assigned to the first machine, jobs 2 and 3 are assigned to the second machine, jobs 4, 5, 6 and 7 are assigned to the third machine, and jobs 8, 9 and 10 are assigned to the fourth machine.

Machine scheduling can be classified into:

- **Single machine scheduling:** It refers to a simple machine scheduling in which a number of jobs are performed by a single machine. Here, the ready time for each job is zero.
- **Flow shop scheduling:** It refers to an arrangement of machines so that the jobs can visit all the machines in similar order. If there are a number of jobs that are performed by a number of machines, then the first task of every job is done by machine 1 and the second task is done by machine 2, and so on. The flow of tasks is unidirectional in case of the flow shop scheduling.
- **Job shop scheduling:** It refers to an arrangement where jobs visit machines according to the given order. The flow of tasks needs not to be unidirectional.

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3.4.2 MANPOWER SCHEDULING

Manpower scheduling refers to the process of selecting workers for doing certain tasks as per their skillsets. An effective manpower scheduling plan has the following characteristics:

- It avoids delay in the manufacturing process due to lack of manpower.
- It also removes interruptions to manufacturing because of manpower constraints.
- It prevents repeated hiring.

The manpower scheduling is considered to be most efficient when the scheduled work surpasses the available manpower by at least 15%. In every shift, supervisors should have more work than previous works. Now, the question is how they can achieve their goals. If the scheduled work is not performed due to any reason, then there is always another work to be performed. Manpower scheduling also prevents delays in manufacturing by effective utilisation of manpower. Various strategies are used while preparing manpower scheduling. Some of them are discussed as follows:

- **Balancing manpower:** A manpower schedule is used to fit a fixed, limited and manpower pool. This process is also called levelling manpower. Manpower is balanced by planning and scheduling. Personnel are selected for jobs according to their capabilities or skills. Printed reports indicate that both actual manpower requirements and levelled manpower are based on slack time of activities.
- **Overtime and time/cost trade-offs:** People think that days are more appropriate for work as compared to nights. Nights are less productive than days for organisations. The reason behind this is that a worker's sleep pattern reduces his alertness and energy. It also slows down the work due to poor visibility. So, most of the schedules are made on the basis of days rather than nights. In maximum cases, organisations give priority to day shifts rather than night shifts.

Self Assessment Questions

6. _____ refers to assigning jobs to machines during manufacturing.
7. Which kind of scheduling refers to a process of selecting manpower according to their skills?

3.5 DESIGNING PRODUCTS

A product is a thing that is manufactured and marketed to customers. Products are made for use by end customers. Physical goods are tangible products while services are intangible or perishable products. Digital goods such as mobile apps and software are some examples of intangible products. A new product may be developed because of following reasons:

- To fulfil the demand of the customers
- To challenge competitors' products
- To fulfil the market demands which were not catered to by the previous producers
- To modify existing products as per the customers' feedback

Before the development of a new product, it is necessary to analyse the product markets for its sale. 70% to 90% of manufacturing costs are spent on product quality, reliability and serviceability of the products. Product markets and market segments should be analysed by surveys, and study about the industry is important. The demand of a product can also be forecasted by discussions with experts. After analysing the scope of a product, organisations can start designing its structure. While designing products, following aspects must be taken care of:

- Design products that solve real-world problems.
- Avoid complex product designs so that the design should be related with the customers' requirements.
- Design products that promote an organisation for its quality of products.

3.5.1 PROCESS OF DESIGNING PRODUCTS

The process of designing products is a step-by-step procedure followed by organisations to design the structure of the products. Figure 6 illustrates the product development process:

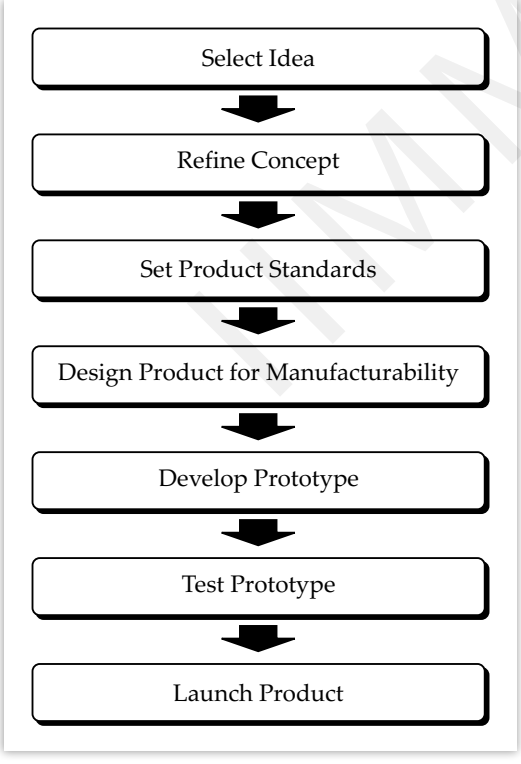

FIGURE 6: Product Development Process

1. **Select idea:** It is the first stage of the product development process wherein the product idea is reviewed and selected by the product design team. Ideas can be given by organisational staff, customers and others. The product design team chooses one product design idea from all the available alternatives.
2. **Refine concept:** It refers to the stage of generating the initial product concept from the chosen idea. To refine the product idea, the product design team discusses with organisational people and potential buyers to know about their needs. This

Notes

will finalise the product specifications and answers the questions like how the product will look like? What features will it have? and How will it work?

3. **Set product standards:** In this stage, the product design team decides what will be the features of the product and what are the resources required for its production. It is necessary that the product is safe so that it can be handled easily.
4. **Design product for manufacturability:** It refers to the practice of designing product according to its manufacturing conditions. It is designed in a way that a higher quality product can be produced with possible minimum costs and resources.
5. **Develop prototype:** A prototype model of the product can be developed by Computer Aided Designing (CAD). Prototypes are tested by customers to identify any possible changes.
6. **Test product:** It refers to the stage in which product samples are tested to check the errors. Samples are demonstrated to customers for testing and feedback. Errors can be identified and removed after receiving the customers' feedback.
7. **Launch product:** This is the final step of the product development process. Organisations start manufacturing products and make them available for the final launch.

3.5.2 DESIGN FOR ROBUSTNESS

Design for robustness is a method that improves the function of the product. Design for robustness is also called the robust design or Taguchi method. It is developed by Dr. Genichi Taguchi to improve engineering productivity. This method is used to reduce variations from a product without eliminating the causes of variations. Let us consider some variations in a product:

- Variation during assembling of a product
- Manufacturing variation
- Product usage variation
- Variation because of inappropriate cost

A P-diagram refers to the method that is used to classify variables in the form of control, noise, signal and response factors. The parameter diagram receives signals from customers regarding variations in products and gives the response signal regarding improvements.

- **The Signal-to-Noise (S/N) ratio:** It refers to a forecasting method that is used to forecast the product quality by laboratory experiments.

The design of the robustness process is as follows:

1. **Problem formulation:** It refers to the stage of identifying the main function and developing the P-diagram. The ideal function and S/N ratios are defined under this step. Orthogonal arrays are used to plan experiments that involve changing the control, noise and signal factors.
2. **Collect data and simulation:** It refers to the stage of collecting data from customers and using simulation models to improve the product performance.

3. **Analyse factor effects:** It refers to the stage of calculating the effects of control factors. Analyse results to select the best and optimum setting of control factors.
4. **Predict and confirm performance:** It refers to the stage of forecasting the product design performance under baseline and optimum settings. This is done to validate optimum conditions of control factors. Experiments are performed under these conditions and results are compared with the forecasted performance.

3.5.3 DESIGN FOR ENVIRONMENT

The concept of environment was introduced into the manufacturing design processes in 1980s. In 1992, the concept of design for environment (DFE) was conceived by several electronic firms with the aim to develop environmental awareness in product development. American Electronics Association was the pioneer of DFE. The design for environment is a design process that is used to reduce the environmental impact on products. It is helpful in preserving earth's resources. The main objectives of DFE are as follows:

- **Protecting environment:** To protect environment by ensuring that air, water and ecological systems will not be polluted by the manufacturing of products
- **Assuring health and safety:** To ensure that the health of people and animals will not be affected by production activities
- **Sustaining natural resources:** To ensure that the resources used for manufacturing will not put bad impact on the availability of earth's resources

Figure 7 shows the driving forces behind the design for environment:

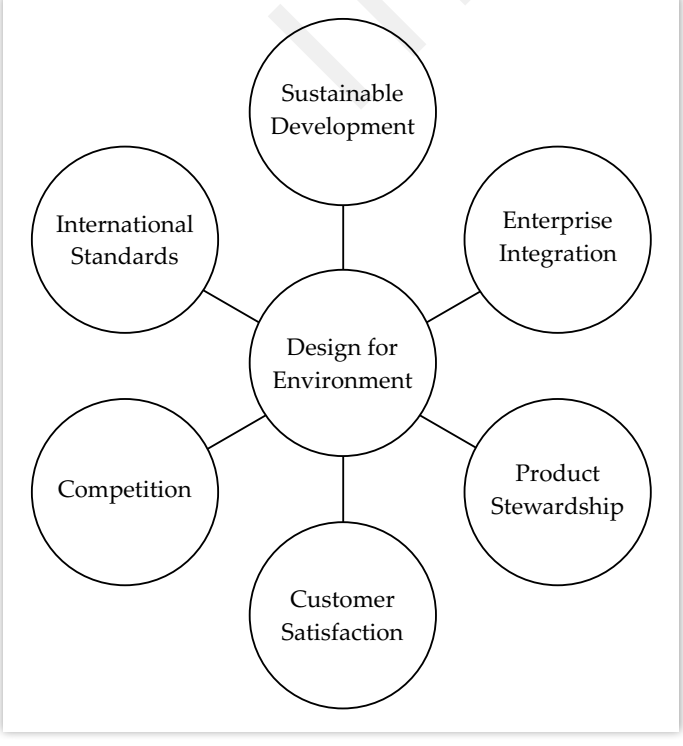

Figure 7: Driving Forces Behind DFE

NOTES

DFE evaluates the level of products at which they are manufactured. These levels, micro, meso and macro, are explained as follows:

- **Micro scale:** Here, only parts or units of a product are produced at a small scale.
- **Meso scale:** Here, the entire product is developed, but at a medium scale of production.
- **Macro scale:** Here, the entire product is developed at a large scale.

SELF ASSESSMENT QUESTIONS

8. Design for environment is a design process that is used for reducing environmental impact on products. (True/False)
9. To protect environment means to ensure that air, water and ecological systems will not be polluted by the manufacturing of products. (True/False)

3.6 CELLULAR MANUFACTURING

Cellular manufacturing is a manufacturing approach wherein machines and workstations are arranged within a cell. A cell is a small product unit, which is responsible for producing products of a similar group. Parts of the product or products are manufactured within cells. A cellular arrangement is often a U-shaped layout. This is helpful to get feedback from other workstations regarding operations when problems arise. Training is provided to workers to perform multiple tasks. Each worker is able to perform multiple tasks.

The aim of cellular manufacturing is to design cells to achieve an optimum level of performance. In traditional manufacturing systems, the similar machines are placed together, parts are processed and then moved to departments having large cells. This system is more vigorous to machine breakdown and supports high product differentiation. It reduces the distance travelled by materials, workers and other resources used for the production of products. Cellular manufacturing is beneficial from various perspectives. Some of the benefits of cellular manufacturing are as follows:

- Reduced material-handling costs
- Increased operator involvement to operate machines
- Improved quality, productivity and profits of organisations
- Advantageous from the perspective of competition

Cellular manufacturing systems provide multiple benefits. Cells can be formed with the use of some methods, which are discussed as follows:

- **Neural networks:** These methods are flexible and robust in nature that is why, these are used in cell formation.
- **Mathematical programming:** It refers to the use of mathematical methods that can include several design logics in the objective function and constraints in cell

formation. Goal programming, linear programming and dynamic programming are used in cell formation.

- **Cluster analysis:** It refers to an analytical technique that classifies objects in a complex data set. Various clustering algorithms are rank order clustering (ROC), modified rank order clustering (MODROC), bond energy analysis (BEA) and direct clustering algorithm (DCA).
- **Heuristics:** It refers to the technique that does not provide the optimum solution in case of cell formation. It gives the alternative for cell formation.
- **Metaheuristics:** It refers to the appropriate technique that is used to solve a wide range of optimisation problems. Combinatorial problems can be solved with the metaheuristics method. It provides an approximate solution to the problem. Clustering algorithms in metaheuristics method are genetic algorithm (GA), tabu search and simulated annealing.

SELF ASSESSMENT QUESTIONS

10. Cellular manufacturing is a manufacturing approach where machines and workstations are arranged within a cell. (True/False)
11. A cellular arrangement is often in a _____ layout.
12. Which method of cell formation is flexible and robust by nature?

3.7 CONCEPT OF PROJECT

A project is a collection of tasks which need to be completed to achieve organisational objectives. A project management team handles projects from the initial phase to the completion phase. Concepts of manufacturing and project management are different by nature, but manufacturing industry can provide help to shape project management. A project is managed under certain constraints. These constraints are time, cost and scope. Some ways to incorporate the project management process are discussed as follows:

- Discussing the type and requirements of a project
- Selecting the project management methodology
- Using project management tools
- Tracking the progress of a project
- Implementing the risk management process

3.7.1 PROJECT LIFE CYCLE PHASES – INITIATION, PLANNING, EXECUTION, CONTROLLING AND CLOSURE

The project life cycle is a five-step process in which an organisation starts working on projects from the initial stage till the final stage. Every project has essential turning points from start to end. The project life cycle helps in achieving organisational objectives. In case of the project life cycle, a process starts from the idea of a project,

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defines its goals, plans for execution and moves it towards completion. A project life cycle has five major phases, such as initiation, planning, execution, controlling and closure. These are represented in Figure 8:

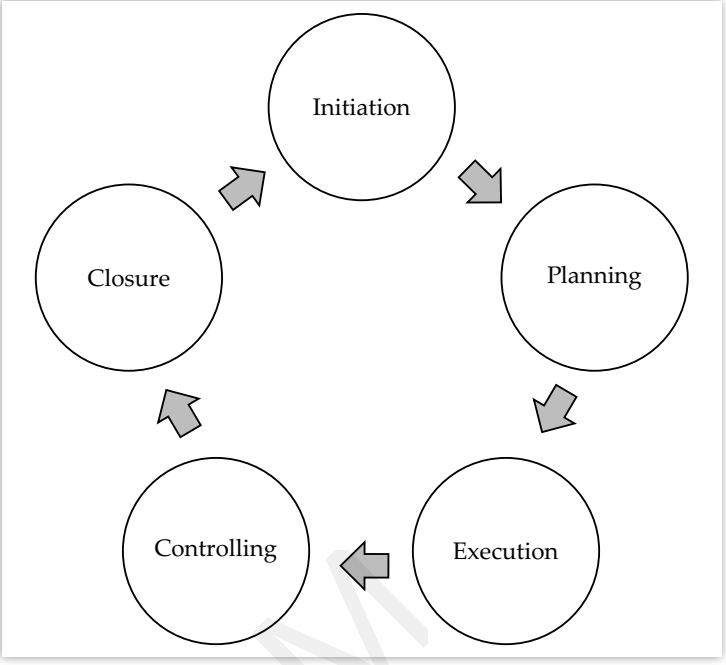

Figure 8: Project Life Cycle

Let us discuss about project life cycle phases:

- **Initiation phase:** It refers to the stage from where the project starts. During this stage, the meeting of the project management team is called for. Team members discuss goals of the project, details of the project, and their expectations from the project. In the initial stage, there are some questions to answer: What is the objective? Why this project? Is this project beneficial?
- **Planning phase:** It refers to the next stage of the project life cycle that is used to make plans regarding project execution. Tasks related with project and resource requirements are identified during this phase. Labour, material and equipment costs can be estimated from relevant information or past records of similar projects.
- **Execution phase:** When work starts on projects, the project life cycle planning stage changes to the execution stage. Monitoring and controlling are required to maintain executed projects. Some important things of the execution phase are problem management, work reports, and weekly meetings. The execution stage is also known as the implementation stage.
- **Controlling phase:** It refers to measure the product performance and ensure that everything is happening according to planning or not. Different techniques are used by project managers to measure performance, such as Management Software and Key Performance Indicator (KPI). KPI is used to determine if the work is on track or not. Some KPIs that measure the product performance are objective of the project, quality, track costs and performance of the project.

- **Closure phase:** It refers to the last stage of the project life cycle. It is the phase where a project is completed. After completion, the project management team identifies the strengths of the project, weaknesses of the project, valuable team members and benefits of project. After the evaluation of the project performance, a team meeting is called and the project is finally closed with the decision of the team manager.

SELF ASSESSMENT QUESTIONS

13. A project life cycle has three major phases: planning, monitoring and closure. (True/False)
14. What is the last phase of the project life cycle during which the project is closed?

3.8 SUMMARY

- Manufacturing is a process using which organisations make products. It turns the inputs (raw material, manpower, money, machinery, etc.) into outputs (finished goods) by applying operations on inputs.
- A manufacturing process is used to produce goods from raw materials with the help of equipment, manpower and transformation methods.
- A manufacturing strategy is a part of the overall corporate strategy, which consists of manufacturing objectives and tasks that are necessary to obtain the desired results.
- Aggregate Process Planning is associated with determination of inventory, production, time required for production, quantities of materials and production volume to fulfil changing demands. Two types of aggregate planning are manufacturing aggregate planning and service aggregate planning.
- Master Production Schedule is an effective plan developed by the organisation for production of goods according to the time. MPS is also used in case of inventory costs, production costs, forecasting demands and staffing.
- Material Requirement Planning is a computer-based planning for production scheduling and inventory control.
- Scheduling can be defined as a process of arranging manufacturing activities according to their starting and completion times. It controls and optimises work in a production process. Scheduling is used while allocating various types of resources, such as plants, machinery, etc., to manufacturing processes.
- Design for robustness is a method that improves the function of a product. Design for robustness is also called robust design or Taguchi method.
- Cellular manufacturing is a manufacturing approach where machines and workstations are arranged within a cell.
- A project life cycle has five major phases, such as initiation, planning, execution, controlling and closure.

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3.9 KEY WORDS

- **SWOT analysis:** It is the analysis of strengths, weaknesses, threats and opportunities to the organisation.
- **PEST analysis:** It studies the impact of environment to the organisation. The factors considered for PEST analysis are political, economic, social and technical.
- **Workstation:** It is the collection of computers attached with each other by a network. A workstation can increase the efficiency of work because it is more powerful than a single desktop computer.
- **Key Performance Indicator (KPI):** KPI indicates the factors which play a vital role in organisational success. It is used to track cost, quality and improvements in business projects.

3.10 CASE STUDY: NEED FOR PIONEER PRIVATE LIMITED TO IMPLEMENT MATERIAL REQUIREMENTS PLANNING (MRP)

Pioneer Private Limited is a manufacturing and selling company of highly technical equipment tailored to the specifications of different customers. The company is known for its quality and customer-focussed policies. A major part of the revenue of the company comprises technical equipment units designed according to customers' descriptions by the engineering department and produced by the production department on a job-by-job basis.

In the past, the company was facing problems because of its substantially slow process of raw materials procurement. Due to lack of an effective system of materials procurement, Pioneer was missing on heavy discounts from suppliers, and there were long overdue claims of suppliers lying unpaid for the materials received by Pioneer. Moreover, there was no segregation of responsibilities between the stores department and the purchasing department. As a result, production lines were frequently under-stocked, order processing cycle was slow in purchasing department, and desirable cost reductions could not be achieved. Moreover, engineering and operating departments were not timely notified on receipt of raw materials from purchasing departments.

The management of the company is concerned about finding a permanent solution for the above problems. The manager of the purchasing department has come up with the idea of implementing MRP in the company. He considered that MRP implementation would act as a tool for planning and assembling all operations of production. It will help suppliers to be aware of the materials required by each unit of production along with their related time limits. By proper coordination between stores and purchasing departments, the information about materials needed in the production process would ensure that they are timely procured and made available for production. It would enable to maintain regular levels of stocks and products to ensure smooth flow of production.

QUESTIONS

1. What do you mean by Material Requirement Planning (MRP)?

   (**Hint:** It is the process of computing the amount of components and materials required for manufacturing the products.)

2. How would MRP implementation solve the problems of Pioneer?

   (**Hint:** MRP implementation would enable the company to know the needed materials for the production requirements, create coordination among store, purchase and production departments, fix timelines for purchase of materials from suppliers, and smoothen the process of procurement of raw materials.)

3.11 EXERCISE

1. Describe the concept of manufacturing management.
2. Define manufacturing strategy. What is Master Production Schedule?
3. What is scheduling? What are different types of scheduling?
4. Describe the concept of cellular manufacturing.
5. What is product development process? Discuss the steps of project development process.
6. What is project life cycle? What are the phases of project life cycle?

3.12 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Manufacturing Management	1.	True
	2.	SWOT Analysis, PEST Analysis
Manufacturing Strategy	3.	False
	4.	True
	5.	inventory control
Scheduling	6.	Machine scheduling
	7.	Manpower scheduling
Designing Products	8.	True
	9.	False
Cellular Manufacturing	10.	True
	11.	U-shaped layout
	12.	Neural network method
Concept of Project	13.	False
	14.	Closure phase

Notes

3.13 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 4

Managing Service Operations

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Describe the service
- Differentiate between a service and tangible goods
- Explain different types of services
- Explain the service design process
- Describe different service design tools

4.1 INTRODUCTION

In the previous chapter, you had studied about the concept of manufacturing management, and manufacturing strategy. It also described scheduling, designing products, cellular manufacturing and concept of project.

Service is an intangible economic activity which can neither be stored nor result in ownership. Services are consumed at the point of sale. Services are one of the two key components of economies, the other being goods. Examples of services include transfer of goods and certain specialised services. Transfer of goods can be done using the postal service, courier service, etc. An example of specialised services are the services provided by a doctor or by a Chartered Accountant.

Services have now become an integral part of society. Roads, hospitals, hotels and restaurants, etc., are all part of services. The service provider's goal is to maximise customer satisfaction. Moreover, service providers are nowadays designing their services keeping in mind the requirements of customers. In other words, all service providers design their offerings in order to provide maximum value to customers. Some other services include salon services, laundry and dry cleaning, cobbler services, tailoring services, providing coaching or schooling, etc.

In this chapter, you will learn about the concept of service management, types of services, service design and process designing. You will also learn about the process planning and process analysis, and measuring service quality using SERVQUAL.

4.2 CONCEPT OF SERVICE MANAGEMENT

Service provided to any customer or client is basically work done for the client or customer in an intangible manner by the service provider. In this way, the core concept of service management lies in customer satisfaction. If you are a service provider, then you need to manage your team in such a way that they should be able to give their maximum to satisfy clients.

Service management can be understood better in the following steps:

1. First of all, know what **type of service** is being provided. There are many types of services offered in the world. Thus, before managing services, it is important to know which category our service belongs to.

2. Then **target the customers or clients**. Now, it is time to determine what type of customers, their class, their age or gender we are targeting. By knowing the type of customers, service which has to be provided can be customised accordingly.
3. Then know **the needs and requirements of targeted clients**. By knowing their needs, the service provider could better manage and offer his services.
4. Then **manage the staff** to work upon the need of targeted customers. This is the most important task for the service provider. It needs to very well manage internal team to take action on the plan.
5. Take proper **feedback from customers or clients**. A prompt service provider will always take continuous feedback from his customers.
6. Take **spontaneous action.** If any pessimistic feedback is drawn by any customer, the service provider must take spontaneous action.

By following above steps, any service provider can very well understand the concept of service management and can satisfy his clients accordingly.

4.2.1 TYPES OF SERVICES

The term 'service' includes multiple activities that are provided by the service provider to his clients or customers. Factually, the services provided do not directly relate to manufacturing, agriculture, mining, etc. Services are totally different activities than production or manufacturing. A service offered is actually work done for someone else. Thus, what a service factually involves are four different aspects. First, the involvement of labour who will perform the service. Second, the management who will manage the skills of all labour. The work of managers is really crucial, as they allot the work to labour according to their skills and capabilities. Third, the training of labourers as per the desired needs of service to be provided. Last, the value additions, which mean what a service provider is providing to his customers and what values should be added to his services. A dynamic service provider will always bring changes to his work and will do everything to satisfy his customers. There are many types of services that you receive in daily life. For example, your doctor is a service provider. He gives his service by curing you and, in return, you pay him when you visit any restaurant for dinner or something else, then there too you are reaping the benefits of service which is provided by the service provider. You travel from airplanes, cabs, autos, etc., which is also a types of service that you are taking. Beauty parlours and salons are also providing you with a different kind of service. Thus, you can see there is a variety of ranges in types of services. Various services offered can be broadly categorised in the following categories:

Skilled or professional services

Professional services are provided by individuals who have specific skills in their fields. To render professional services, one must be professionally skilled. This skill can be attained by any degree or diploma course. Usually, individuals render professional services to earn their livelihood. Professional service providers charge their fees from their clients in return for their services. For example, your chartered accountant who is providing you accounts-related services, your tax consultant who

is guiding you on how to save tax, your architect, your interior designer, all are professional service providers who provide you services using their skills which they attained from their diploma or degree.

Individual services

Some services are provided on an individual level or, say, a personal level. These kinds of services are offered by the service provider to us on a personal basis. There is no group or more than one people who take these services. These services cannot be offered to any corporate body or organisation or private entity. These can only be offered to one single individual. Different doctors, whether dentists, neurologists, gynaecologists, etc., who treat you on a personal basis, provide you with individual services. Beauty salons also provide you with individual services.

Health care services

As suggested by the name, these are services which are carried by those experts who are expert in health care. Health care services are the most vital services, as in case of emergencies, these service providers prove to be like a saviour to their clients. These services need to be carried by most educated professionals who have the required skills in their respective fields. Some examples of such services are health care of school children, public health services, dental care, neurology services, gynaecology services, etc.

Environmental services

Environmental services are those services which are provided to take care of the ecosystem of any particular region. Ecosystem means the surroundings of the environment which includes care of surrounding flora and fauna, roads, infrastructure, etc. For example, services provided by the government in making roads, infrastructure, supplying with water services, exploitation of natural resources, etc. You pay taxes to your government in return for these services. These services are given to people on a large scale and given as a whole. The value of these services is as important as of other services.

Subsidiary services

As suggested by the name, these are the services which are provided in ancilliary or subsidiary works that are required by people. Some services are offered in direct mode and some are offered in indirect mode. Services which are offered in indirect mode are known as a subsidiary or ancillary services. There are many examples of such services. In the construction of a house, the direct services are provided by architects, labourers, etc. But the electrician who fits all the electricity wiring in the houses and the plumber who fixes water pipes provide subsidiary services.

Directory services

The meaning of directory is a website or a book which contains the list of organisations or individuals with their basic details, like name, phone numbers, address, etc. The directory service providers possess contacts and links of other service providers in their respective tasks. They act as a bridge between a normal service provider and customer. They connect them on one single platform. Today everyone can get the

services offered while sitting at home. They just need laptops or smartphones and an Internet connection to order for different service providers. Some examples of directory service providers are Justdial and Zomato. All you need is to search for your requirements on these applications and they will provide you with a list of names of service providers in that particular field.

Self Assessment Questions

1. _____ Services are provided by service providers who possess contacts and links of other service providers.
2. Personal services can also be provided to companies or body corporates. (True/False)

4.3 SERVICE DESIGN

Services have a vast category into which different services are categorised. Different services are categorised in professional, personal, ancillary, etc., kinds of services. But these services can be utilised only if the recipient is willing to take and pay for these services. Services involve more of human activity, like in a restaurant, the behaviour of waiters and staff will be very much important for customer satisfaction. Thus, a good service provider will design his services in such a way that he could give his best to his customers. Like in private airline services, the behaviour of an air hostess will always create a good impact on customers. Even when you watch movies in theatres, serials in your television, listen to news on radio channels, these are also different kinds of services.

In modern times, the difference between goods and services is narrowing. This is because of advancement in technologies. Information and communication technology (ICT). ICT provides a facility for customers to reap the benefits of services without their physical presence. Through ICT, services can be provided by using different software and applications. Thus, by sitting on your couch, you can take benefits of services which are being provided by service providers from different locations. All the applications in your mobile phone are good examples of services which are enabled because of ICT.

Following are some characteristics of services:

- **Intangible in nature:** It is the utmost basic and fundamental nature of a service. Services are intangible in nature as unlike products or goods, they cannot be seen or touched physically. Services are basically the actions performed by the service providers for the utility or benefits of the service recipient. A service provider performs deeds or actions as per the needs and requirements of the service recipient. The best example suited here is an example of services provided by doctors. For your medical treatments, doctors diagnose you with the required treatments, give you the required prescriptions, and perform any surgery on the patients. Patients cannot see, touch or take possession of any goods or products. They can only touch the hospital infrastructure, medical equipment, etc., but cannot take possession of any of them. In a similar way, when you watch a movie, you take entertainment services. You cannot see or touch any physical goods or products but you do take entertainment services. This is the intangible nature of services. However, there

is one big disadvantage of this nature of service. Due to intangibility, customers do not really realise what is the actual value of services provided. They often tend to underestimate the value of services provided to them. As it is difficult to value something which cannot be touched or seen, therefore, it creates a lack of confidence among the consumers in regard to the service provider.

If you talk about goods and products, then you all know that the core value of a product is built in a factory, but that is not the same in case of services. In case of services, the core value is built in between the seller's and the buyer's personal interaction. While receiving services, customers ought to look upon the quality of services and other attributes too in order to avoid uncertainties regarding services. The perfect example that can be quoted here is of a beauty salon. When you take services of a beauty salon, all that you are looking for would be the quality of services. As you cannot really touch or see anything and neither you would be taking possession of any goods, thus, in this intangibility factor, all that you would care about will be quality of services. However, it is not necessary that the industries which produce and manufacture tangible goods only offers tangible goods to their customers. Sometimes there are hidden services which are attached to those products. The offerings of products can be broadly categorised as follows:

- **Fully tangible goods:** Fully tangible goods refer to those goods which can be touched and seen and whose possession can be taken by the end consumer. For example, land, building, etc.
- **Tangible goods with supporting services:** Although these goods can be seen, touched and their possession can be taken by the customer, but these also have accompanying and supporting services with them. For example, when you buy goods like refrigerators, cars, etc., you take possession of goods that you see and also get supporting services with them.
- **Tangible goods with major factor services:** In these kinds of goods, you get major services and supporting goods. When you eat food in restaurants and hotels, those services come under this category.
- **Full services:** In some services, you only get intangible services and not any kind of physical goods. Services provided by chartered accountants, legal advisors, etc., fall under this category.

The intangible nature of services generates following key implications:

- It becomes difficult for customers to evaluate the value of services provided.
- It is difficult to advertise and quote prices of services.
- For service providers, it becomes difficult to ascertain the per unit cost of service provided.

❍ **Inseparable nature of services:** When production and consumption are simultaneous and both cannot be separated from each other, this kind of attribute of services is known as inseparable nature of services. The implication of this kind of attribute of services is that at the time of sale, the service provider is an integral part of the service. Without the presence of a service provider, the transaction cannot be completed. The service provider is in a sense inseparable from the service. Contrary to this nature of service, when you purchase a car, the car is

produced and manufactured by someone else at another period of time and you are consuming the same at a later period of time. However, services provided by a doctor in a hospital, a beautician in a salon, a teacher in a classroom are all inseparable in nature. The presence of doctor, beautician and teacher is necessary at the time of providing services. Due to the inseparability nature of services, ownership of goods does not transfer from buyer to seller. Just like the service provider, the physical presence of the customer is also necessary in some cases. For example, while availing the services of hotels, airlines, hospitals, etc., a consumer needs to be necessarily present at the time of service. The key implications which can be derived from the inseparability attribute of services are as follows:

- It is necessary that the service provider must be well trained regarding the service he is providing.
- Such service providers are critical to find.
- As the presence of both service provider and receiver at a single point is necessary, the opening hours and location of a service provider need to be convenient for the consumer.
- It is not necessary that all customers are same. Some customers' bad behaviour can create hindrance in productivity.
- At certain times, more than one customer are present at the location of a service provider. Thus, the behaviour of customers with each other also needs to be handled by the service provider.
- The service provider also needs to manage the waiting time of customers. Sometimes, he even needs to expand service-providing timing.

❍ **Heterogeneity in services:** Heterogeneity refers to differentiation. This means when the quality of service provided by different service providers is different from one another, this characteristic of service is developed. This is obvious too as different services are provided by different people and their behaviour is different from one another. Even the quality of services provided by a service provider can change. For example, a beautician will give the best massage or other services in the first hour of the day, but as the day will pass, the quality of her services will go down. One more important factor works here – the quality of service can also change from customer to customer. The customer's behaviour also affects the quality of service provided to him. Like, in a salon, few customers get acquainted very well with the service provider and few do not. Thus, the quality of service can vary from customer to customer. Therefore, this character of services raises a serious question of uniformity. To maintain service standards, careful monitoring of customer satisfaction is necessary. Also, service providers should be personally trained to attain customer satisfaction. Heterogeneity gives rise to the following implications:

- It is really difficult to achieve consistency.
- If services can be provided by machines, then, in such a case, variability can be reduced.
- As per the expectations of customers, services should be customised.

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- **Perishable nature of services:** The perishable nature of services denotes that services cannot be stored. These services are one time and cannot be stored for the future. The best example of this is that when in an airplane a seat goes vacant, then that is an entire loss of the service provider at that particular time. If a bed is vacant in a hospital or a room remains vacant in a hotel, then there is no way this loss can be undone, there is no storage for the future. That loss is permanent for the time being. One more example of lost opportunities is when a doctor remains free for the entire day or an hour. In case of goods, they can be sold in the future and then there would be no loss for the service provider, but in the case of service providers, they do suffer a loss at the time they are vacant or do not have any customers. If the demand for any service is steady and continuous, then, in such a case, perishable nature of service does not create any problem. However, if the demand for any service is changing, like sometimes it is going high and sometimes it is going low then, in such a case, the perishable nature can create a problem for the service provider. Like, during vacations, flights would be flooded by passengers, and the service provider could not fulfill the needs of all customers, then those customers will choose some other flight. They cannot be given services in future. In off-seasons, hotel rooms go vacant. They cannot be filled for future. However, one good thing about perishability is that service providers can improve their services. For example, if you aren't satisfied with a massage in the salon, then you can order them to redo the same. Key implications of perishability are as follows:
  - The services cannot be stored for future.
  - Services have sensitivity in demand.
  - These can be recovered.
  - Technology can improve efficiency.

4.3.1 SERVICE DESIGN PROCESS

Service design is all about preparing plans, facility, materials, and infrastructural and communication components. The sole purpose of service design is to improve its quality. Any service needs many components to make a service available to its customers. These components are like infrastructure, staff to interact, etc. If a service provider will very well design his plan of services, then he will be able to meet customer's requirements and to satisfy his customers to the maximum. For a service design, a service provider should follow the steps given below:

1. **Lay a plan:** The first step in service design should be to lay a plan. He should make strategies on how he is going to provide services to his customers.
2. **Set up infrastructure:** Then he should set up the required infrastructure to ensure that customers will be convenient and comfortable at his location.
3. **Manage staff:** He should be able to employ and manage the required staff for providing services.
4. **Monitor:** Continuous monitoring is also necessary in order to ensure customer satisfaction.

The basic principle of service design is, first of all, determining the process of service. A service should be designed in such a way that it must deliver value to the customer. Lara Penin introduces crucial aspects of service design and also clarifies the challenges which are faced in handling those aspects. Following are some of the aspects that are to be considered in a service design process:

1. **Labour relationships:** While designing a service, it is of utmost importance that labourers share healthy relations with each other. Then only they can work in an efficient way.
2. **Management:** For a big service-providing organisation, it is also of utmost importance that management should be able to perfectly coordinate with labourers and bring out their best and achieve customer satisfaction.
3. **External factors:** External factors like government policies, environmental changes, market share, requirements of consumers, etc., also need to be considered.

The process of service design is a repetitive one or, say, an iterative one. This signifies that if you are running a service design process, then you may have to go back and monitor previous steps and even change and repeat. Following are the series of steps that should be followed in a service design process:

1. **Customer's survey:** First of all, a service provider must conduct a survey on customers and their behaviour.
2. **Deducing the problem:** Then the service provider must know what the problem is and how to solve it.
3. **Collaborate:** If necessary, the service provider can collaborate with other stakeholders in order to get the maximum customer satisfaction.
4. **Customer interaction:** A touch point should be facilitated where customers could interact with the service. Example: website or app.
5. **Testing:** Before adopting the final service, a rapid test should be done of the entire service process.

The main advantage of the service design process is that it helps individuals or firms increase their performance levels. Some of the benefits of the service design process are as follows:

- **Reduces costs:** A pre-designed service plan will always help cut future costs.
- **Makes customers loyal:** By a better service design, you would be able to make your customers loyal towards yourself.
- **Increases sales:** When you have gained your present customer's loyalty, those existing customers will help you gain other customers. This way sales will automatically increase.
- **Builds brand image:** When your customers and sales will increase, the brand image of your service in the marketplace will improve automatically.

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- **Saves time:** A service design process will reduce future timings by removing duplication.
- **An increment in efficiency:** Service design process helps reduce or eliminate bottlenecks and wastage at the initial point.

Service design process can be understood through the following steps:

1. **Determine your goal and vision:** This step is to formulate the firm's strategy and know the goals and long-term vision of the organisation. This determines what exactly the organisation wants to provide to its customers.
2. **Collect ideas:** Then the next vital step is to collect ideas from all stakeholders and from those collective ideas, build a strategy as more number of ideas can give the best output.
3. **Analyse the market:** It is also important to study the market, such as the market's size, company's prospective share, its trends and drives.
4. **Understand the limitations:** It is also important to understand the present barriers and limitations in market related to the service. Then the service provider needs to know how these limitations or problems can be overcome**.**
5. **Know the customers:** This step is made to know who the actual customers are, what are their needs and requirements and, then, accordingly provide services to them.
6. **Test by a prototype:** A prototype should be made to test and know how customers will react with the service providers and what could be their feedback.
7. **Conduct a survey:** By conducting a survey, the customer's experience can be recorded by asking him various questions.
8. **Collect feedback to improve service:** Customer's honest feedback should be taken and according to his feedback, required action should be taken.

4.3.2 SERVICE DESIGN TOOLS

Various tools are available for service design. These tools may be used in an iterative manner. Some of these are:

- **Service Plot TM:** To help understand the service philosophy and vision
- **Persona Overview:** To capture the motivation and behaviour of customer
- **Service Location Planner:** To specify which service will be provided, by whom, at what time and at which location
- **Customer Journey Map:** To help visualise the usage of service and identify points of interaction of customer with the service
- **Service Blueprint:** To show how the staff at the front end will provide a service and how the staff at the back end will provide support services

Some other tools are Texts, Graphs, Narratives, Games, Cognitive Walkthrough, Evidencing, Affinity Diagram, Group Sketching, Moodboard, Mockup, Role Playing, Story Board, and Tomorrow's Headlines, as shown in Figure 1.

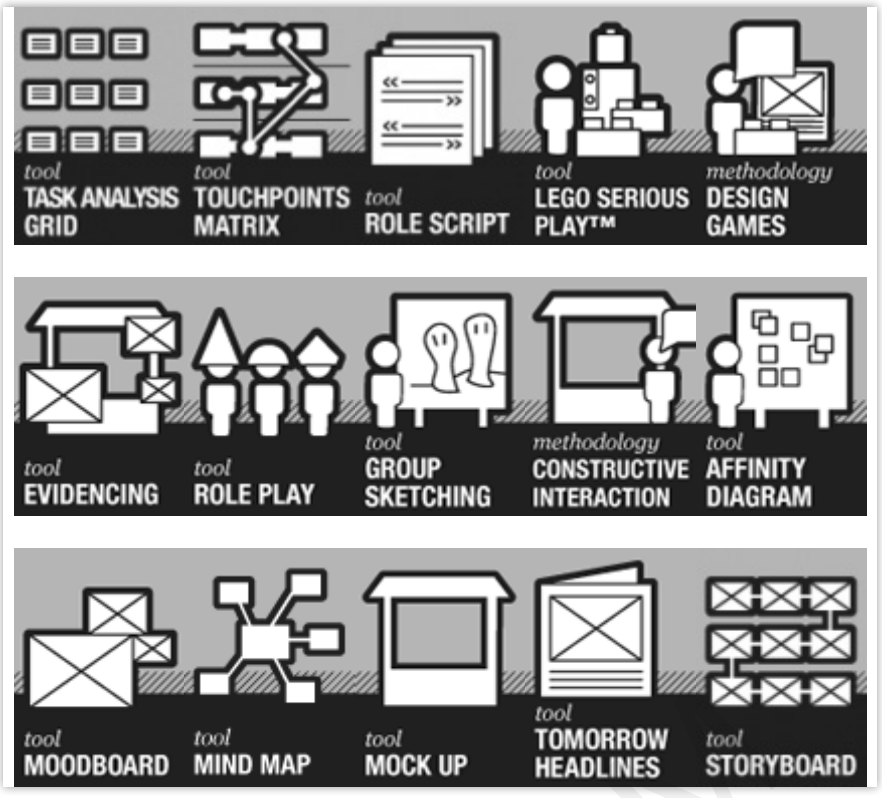

Figure 1: Service Design Tools

These service design tools aid the achievement of target, stage-wise, by applying these tools during the development process.

Self Assessment Questions

3. _____ is the characteristic of services which implies that services cannot be seen or touched.
4. Which of the following features of services means that services cannot be stored?
   a. Intangibility
   b. Heterogeneity
   c. Perishability
   d. None of these

4.4 PROCESS DESIGNING

The process designing is used to break down a large assignment into manageable parts. Scientists, consultants, engineers and architects use the design process to solve many problems. The process designing comprises following six steps:

1. **Problem definition:** Seek clarity of the problem and identify the root cause. The clearer the problem definition, the more accurate will be the solution.

Notes

2. **Information collection:** Gather photos, documents and data. The more information you have, the wider will be your perspective.
3. **Brainstorming:** Generate ideas on how the information impacts the design. Ideate which solution will work the best in terms of cost, efficiency and customer delight.
4. **Solution development:** Develop solutions on a small scale first. The solution should meet the desired parameters of customer experience.
5. **Feedback:** Take feedback, and share this with others. Review specifications if required and revise them as needed to arrive at the best possible service design.
6. **Improvement:** Analyse the feedback and make the improvements in the service.

Self Assessment Questions

5. The design process is used to break down a large assignment into _____.
6. How many steps are there in process designing?

4.5 PROCESS PLANNING AND PROCESS ANALYSIS

Process planning in organisations can result in higher productivity, better quality and faster response time. A process is a series of steps which result in a desired output. It involves preparing specific work instructions to make a component or provide a service. It helps convert design information into specific instructions. Computer-Aided Process Planning (CAPP) is an automated form of process planning. Figure 2 shows process planning:

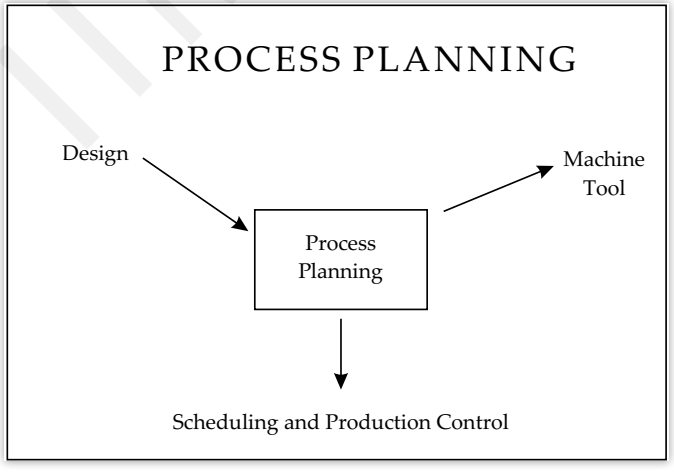

Figure 2: Process Planning

Process planning is the basis for designing facility layouts, factory buildings and choosing production equipment. It also influences job design and quality.

Objective

The main objective of process planning is to modernise and augment the methods of an organisation. It helps to update design specifications into service instructions and make products within the same function at a minimal cost. It helps eliminate bottlenecks. It enables process selection and identify conditions of the process. It

can be compared to an engineering drawing. Figure 3 shows process planning and competitive advantage:

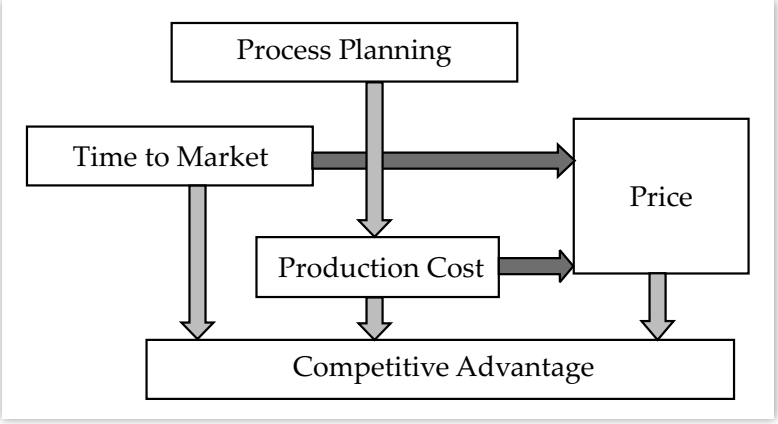

FIGURE 3: Process Planning and Competitive Advantage

Principles of Process Planning

Following principles of process planning can be used to improve processes:

- Define output, identify inputs to achieve output.
- Define goals of the process using specific measures.
- Map the process. It should look like a logical flow forward.
- Document all steps needed in the process. The step which is not documented should not be performed in the process.
- Consult stakeholders to have the most up-to-date information.

Process planning starts with demand forecasting, drawings and specifications. The output of planning are specified operations, their sequence, work centres, standards and tools & fixtures.

Automated process planning using CAPP has many advantages. It can reduce the time taken for process planning, generate more consistent plans, the accuracy of such plans is higher, improves productivity and reduces the lead time.

To sum up, process planning is a critical part of an organisation which validates processes, instructions and materials which are utilised to make a product or service. It optimises movement of service or product, the customer touch-points and efficient use of resources. It also helps prioritise the workload.

On the other hand, process analysis is the study of work flow in firms. It helps understand and improve the processes in a business. It studies the movement of work from one person to another, taking into consideration the input and output, describing each step during the movement, and the utilisation of resources. Process analysis is used for:

- Getting a description of the process in writing, e.g., job descriptions, internal rules, communication to vendors

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- Automating processes, e.g., automatic approval of leaves of staff members, introduction of new systems, such as ERP or HRM applications
- Improving re-engineering processes to simplify them or to improve their speed

The aim of process analysis is to improve the productivity, efficiency, effectiveness, cost or profitability. It usually results in process maps. The output may be as graphs or a document. It may be done by an internal employee or an external consultant. Some of the techniques used for conducting process analysis are:

- Histogram
- Pareto Principle (80/20 rule)
- Affinity Diagrams
- Scatter Diagram
- Brainstorming
- Critical Path Method (CPM)
- Theory of Constraints (TOC)
- Ishikawa or Fishbone Diagram
- Force Field Analysis (FA)
- Failure Mode Effect Analysis (FMEA)
- Plan Do Check Act (PDCA or Deming cycle)
- Value Stream Analysis (VSA)

Figure 4 shows Ishikawa diagram:

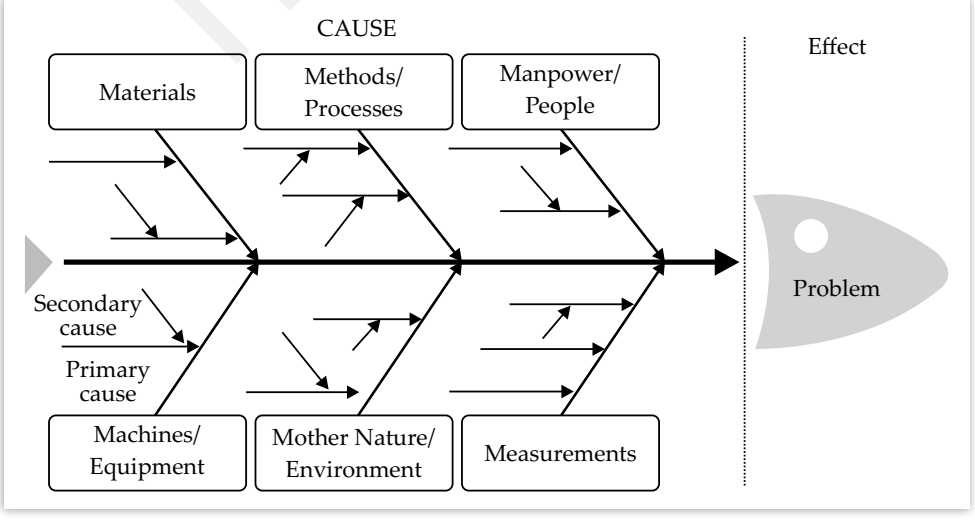

Figure 4: Ishikawa Diagram

Self Assessment Questions

7. Histogram is a technique used for conducting process analysis. (True/False)
8. _____ is an automated form of process planning.

4.6 MEASURING SERVICE QUALITY USING SERVQUAL

SERVQUAL conceptualises service quality that measures quality of service as perceived by customers. It is a complex schema, but it remains a prominent model to evaluate service quality, especially when the service is used in a modified form. A. Parasuraman, Professor of Marketing, conducted exploratory investigation in retail banking, credit card, securities brokerage, and product repair and maintenance to develop the SERVQUAL scale.

Customers evaluate service quality by comparing expectations and perceptions of the service based on quality dimensions. A. Parasuraman divided SERVQUAL into five dimensions: tangibles, reliability, responsiveness, assurance and empathy.

Retailers can use multiple-item scale of SERVQUAL to understand service expectations and perceptions, as SERVQUAL has good reliability and validity. It tracks service quality trends, solicits and analyses customer suggestions and complaints. The application of SERVQUAL determines relative importance of the five dimensions that influence customer's quality perceptions. The most crucial dimension of service quality is reliability, and it is followed by assurance, tangibles, responsiveness and empathy. The quality of service is determined by the overall gap between expected and delivered service by using SERVQUAL.

SELF ASSESSMENT QUESTIONS

9. _____, conceptualises service quality that measures quality of service as perceived by customers.
10. Who can use multiple-item scale of SERVQUAL to understand service expectations and perceptions, as SERVQUAL has good reliability and validity?

4.7 SUMMARY

- A service is any kind of work done or performed or any advice given by the service provider to the service recipient.
- Service is a very broad term which includes many types of services in it. For example, skilled or professional services, personal services, directory services, etc.
- The core concept of service management is customer satisfaction.
- Service design is a series of process through which a service provider designs the entire process from the core. It includes laying a plan, managing staff and labour, etc.
- The characteristics of services are intangibility, heterogeneity, perishability, etc.
- Services have a major limitation that its value cannot be determined easily and therefore, often customers end up undervaluing services.
- A service design process involves a series of steps right from determining goals to taking experiences of customers.
- The design process is used to break down a large assignment into manageable parts. Scientists, consultants, engineers and architects use the design process to

Notes

solve many problems. A process planning also involves a series of steps to be followed.

- Process planning in organisations can result in higher productivity, better quality and faster response time. A process is a series of steps which result in a desired output.
- The aim of process analysis is to improve the productivity, efficiency, effectiveness, cost or profitability. Process analysis usually results in process maps.
- SERVQUAL conceptualises service quality that measures quality of service as perceived by customers.
- Customers evaluate service quality by comparing expectations and perceptions of the service based on quality dimensions.

4.8 KEY WORDS

- **Service:** A service is any task or work done by the service provider for the service recipient.
- **Vision:** A vision is a company's long-term objective that defines what it wants to do.
- **Process:** A process refers to a series of actions taken together.
- **Stakeholders:** The persons who are having securities of a company, whether equity or debt.
- **Feedback:** A review or comment given, whether positive or negative.

4.9 CASE STUDY: SERVICEMAX'S FIELD SERVICE OPERATIONS MANAGEMENT

Electrolux AB is a multinational organisation headquartered at Stockholm, Sweden. It manufactures home utility and electronic appliances. It is one of the largest appliance makers in the world. Electrolux has a subsidiary unit in Brazil called Electrolux Brazil.

During 2010-11, Electrolux was managing its field service operations by using a combination of 1,800 field technicians and 900 service partners through a mix of emails, sticky notes and phone calls. With respect to its field service operations, Electrolux was facing certain challenges as follows:

- Absence of visibility in partner performance against the Service Level Agreements (SLAs)
- Presence of multiple systems for managing service functions and partners resulted in data loss
- Low rate of customer satisfaction than expectation
- Incorrect warranty data negatively influenced the costs

To resolve all their challenges, Electrolux Brazil chose ServiceMax. To provide a complete field service management solution, ServiceMax integrated company's on-premise ERP solution, financial, inventory and production planning systems. It also performed company's internationalisation into Brazilian Portuguese. With the help of partner portal, Electrolux Brazil's inventory is now visible to its service partners, and the company can effectively manage partner performance against SLAs.

As a result of ServiceMax's efforts, Electrolux Brazil realised the following results:

- Higher customer satisfaction
- Increased revenues
- Increased volume of service requests
- Increases service partner efficiency
- Streamlined service processes
- Technicians were scheduled on the basis of their skills to meet a service request

Electrolux Brazil chose ServiceMax as its field service partner and witnessed improved customer satisfaction. The company has a better and correct track of warranty data and service delivery now.

Source: *https://www.servicemax.com/cp/service-operations-management-case-study*

QUESTIONS

1. How Electrolux Brazil was monitoring its tech and service partners?

   (**Hint:** emails, phones)

2. What challenges were faced by Electrolux Brazil?

   (**Hint:** visibility, multiple system, customer satisfaction, cost)

4.10 EXERCISE

1. What is the difference between directory services and professional services?
2. How can service management help in attaining customer satisfaction?
3. How can service design process help in achieving customer satisfaction?
4. List various service designing tools.
5. What is process designing?
6. List the steps of process designing?
7. What are the three main components of process planning?
8. What are the principles of process planning?
9. What does SERVQUAL do?
10. How do customers evaluate service quality?

NOTES

4.11 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Concept of Service Management	1.	Directory
	2.	False
Service Design	3.	Intangibility
	4.	c. Perishability
Process Designing	5.	manageable parts
	6.	Six
Process Planning and Process Analysis	7.	True
	8.	Computer Aided Process Planning (CAPP)
Measuring Service Quality using SERVQUAL	9.	SERVQUAL
	10.	Retailers

4.12 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Penin, L. *An Introduction to Service Design*.
- Wright, J., & Race, P. (2012). *The Management of Service Operations*. South Melbourne, Vic.: Cengage Learning Australia.

E-REFERENCES

- Goods and Services: Meaning and Classification of Goods and Services. (2019). Retrieved from http://www.economicsdiscussion.net/articles/goods-and-services-meaning-and-classification-of-goods-and-services/2014
- Service Design 101. (2019). Retrieved from https://www.nngroup.com/articles/service-design-101/

CHAPTER 5

Managing Service Processes

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Describe the concept of service process
- Discuss the management of service processes
- Elaborate the steps in engineering service processes
- Describe how the service processes are controlled
- Explain the concept of service standards
- Describe service blueprinting

5.1 INTRODUCTION

In the previous chapter, you studied about the management of service operations to achieve customer satisfaction. For delighting the customers, a service-oriented business provides the best possible customer services and support. This can be done by identifying the ways to improve customer satisfaction, which, in turn, is done by defining and monitoring service delivery and related processes.

Service-oriented businesses operate on intangibles and it is difficult to manage the service processes. Services are person-specific and they are shaped and delivered as per the needs of customers. For example, the service experience of different customers visiting the same hotel may be different. For one customer, hotel facilities may be good, and for the other, the same facilities may not be satisfactory. Therefore, service processes should be implemented in such a way as to satisfy all customers.

In this chapter, you will study about the service processes and their management. You will also study about the steps involved in engineering service processes. In addition, you will study about the concept of controlling service processes. Towards the end, the chapter discusses the concept of service standards and service blueprinting.

5.2 SERVICE PROCESSES

Services incorporate individuals, innovation and procedures required to gain customer satisfaction and loyalty. Service processes include practices intended to achieve customer loyalty. Overseeing service processes is a perplexing and troublesome task. This is because the service-oriented businesses, being intangible, are exposed to variations. Therefore, to manage intangibles, separate systems are created. Since all customers usually need customised services, same service process cannot be used for all customers. Customised services, according to the requests of customers, may require new resources. Therefore, there ought to be a steady supply of resources in minimum amount of time to achieve customer demands.

NOTES

For managing service operations, organisations use innovative procedures and trained staff members to deliver the services. Service processes are extremely significant because of the following reasons:

- Service processes guide an organisation regarding the jobs and duties of various staff members.
- Service processes help employees adapt rapidly to the processes. They are also aware that all their activities are recorded and data is maintained for the same. Adapting to service processes also reduces the learning time.
- Service processes decrease the operational expenses as the cost of modifying, overhauling and repairs is reduced drastically.
- Service processes help in extending the business of an organisation.
- Service processes introduce transparency in operational processes.
- Service processes empower an organisation to work effectively as all the jobs, obligations and the authority are laid out.
- Service processes help an organisation gain a competitive advantage as the modification or rework time is reduced drastically.

Service processes also help in:

- Advancing analytical abilities
- Minimising operating costs
- Meeting monitoring requests
- Forcing changes into the business operations
- Changing the processes

SELF ASSESSMENT QUESTIONS

1. Service processes help in minimising the operating costs. (True/False)
2. To customise services according to the requests of customers, it may require new_____.

5.3 SERVICE DEVELOPMENT PROCESS

The Service Development Process encourages the customers and the service providers to come together and do the following:

- Plan the resources required for executing the services
- Determine the human resources required for delivering the services
- Specify important considerations in service delivery on the basis of customers' needs and the overall direction of the organisation
- Generate ideas for improving the services

Various stages of the service development process are shown in Figure 1:

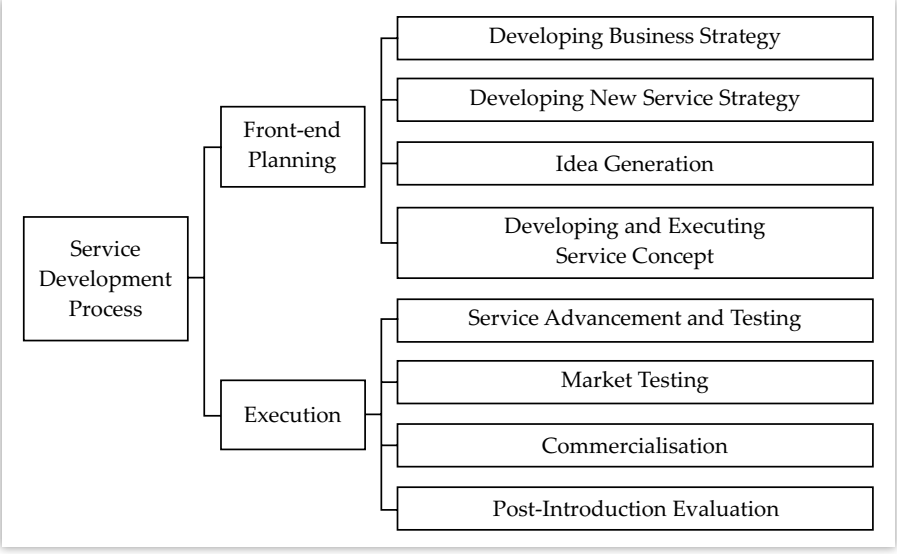

FIGURE 1: Service Development Process

Let us discuss these stages in detail.

1. **Front-end Planning:** There are four steps under this stage, which are as follows:
   a. **Developing business strategy:** In this step, vision and mission of the organisation are assessed.
   b. **Developing new service strategy:** In this step, structure of the organisation and the service portfolio is characterised. This is done by using the Ansoff Matrix as shown in Figure 2:

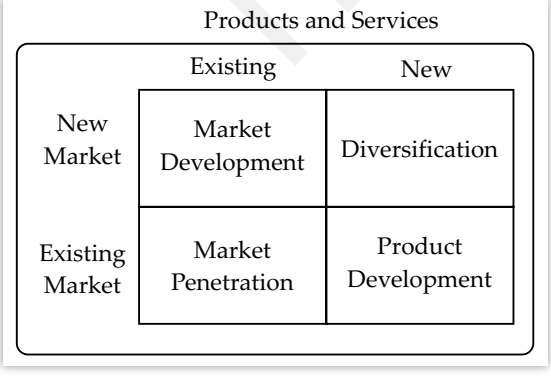

FIGURE 2: Developing New Service Strategy

   Ansoff matrix empowers an organisation to distinguish among different zones of development. The organisation establishes an office for new services advancement. This office is responsible for developing new service ideas and the organisation can launch a stream of new services.
   c. **Idea generation:** In this step, the ideas of various customers, representatives and other contenders are accumulated and conceptualised.
   d. **Developing and executing service concept:** This step includes preparing a service description along with all the features of the service. In this step, feedback is also acquired from customers.

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2. **Execution:** There are four steps in this stage which are as follows:
   a. **Service advancement and testing:** In this step, a prototype of the service is evaluated by the customers that they may accept or reject it. Additionally, the service idea can be refined as well.
   b. **Market testing:** A small number of target audience is chosen for the pilot testing of the service. The feedback of the target audience is registered and evaluated.
   c. **Commercialisation:** In this step, the service is made available to the customers at large.
   d. **Post-introduction evaluation:** In this step, the services that have been introduced newly are assessed, and, if required, any changes like in staffing, delivery, etc., are to be incorporated.

Self Assessment Questions

3. _____ process encourages customers of the service and providers of the service to come together.
4. In _____, a small number of target audience is chosen for the pilot testing of the service.

5.4 SERVICE PROCESS MATRIX

Service processes are classified on the basis of service process matrix. The service process matrix classifies the service processes based on their characteristics. Service process matrix was developed by Roger Schmenner in 1986.

Figure 3 presents a service process matrix:

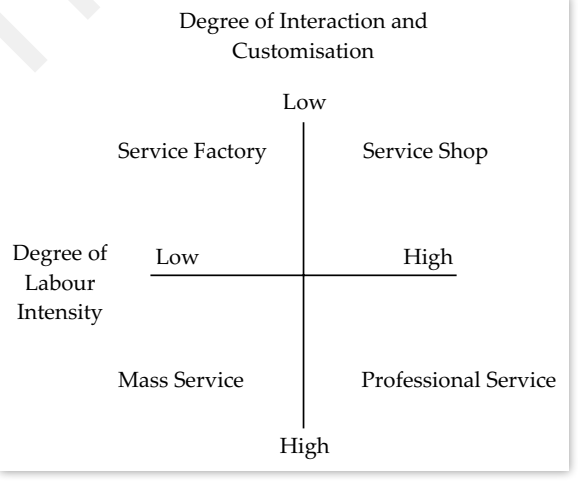

Figure 3: Service Process Matrix

Source: *Adapted from Schmenner, Roger W. Service Operations Management, Englewood Cliffs, NJ: Prentice Hall, 1995, page 11*

As per Figure 3, service processes depend upon two measurements which are as follows:

- **Degree of labour intensity:** Labour intensity is the proportion of labour cost to the cost of plant and equipment. Organisations whose products or services require

large amount of time and effort with relatively less plant and equipment costs are called labour-intensive.

- **Degree of interaction and customisation:** Customer interaction is how much a customer gets engaged with the service process. High level of correspondence guarantees that clients can request customisation in services.

With respect to these two measurements, service processes can be grouped into four classes as follows:

- **Mass services:** As shown in Figure 3, the lower left quadrant contains organisations with a high level of labour intensity, but a low level of cooperation and customisation. This quadrant is named as mass service. Instances of such services incorporate wholesalers, full-service retailers, onlooker sports and extensive classes at schools. In mass services, specifications are under strict control and processes are standardised. Because of standardised services, there is high yield and processes are repeatable. Need of skilled labour may differ as the processes are very standardised and the employees need not interact regularly with customers.
- **Professional services:** As shown in Figure 3, the lower right quadrant contains organisations with a high level of labour intensity and a high level of cooperation and customisation. This quadrant is considered for professional services that incorporates specialists such as legal advisors, bookkeepers, planners and venture brokers are a few instances of specialist organisations that will, in general, have high level of labour intensity along with high level of customisation. Specialists often interact with customers to understand customers' needs and provide customised services.
- **Service shops:** As shown in Figure 3, the upper right quadrant incorporates organisations that have low level of labour intensity, yet a high level of collaboration and customisation. This quadrant is named as service shop. Processes under service shops include frequent cooperation between employees and customers. Significant consideration is given to the customers' needs. As the customisation of services is high in service shops, employees' ability levels must be high as compared to a mass service or service manufacturing plant process that gives standardised services. In this, employees must deal with new or extraordinary services on customers' interest. Emergency clinics, repair shops and gourmet eateries are some of the instances of such services.
- **Service factories/processing plants:** As shown in Figure 3, the upper left quadrant incorporates organisations that have low level of labour intensity and a low level of communication and customisation. This quadrant is called service-processing plant. Because of low labour intensity and exceptionally less customer communication or customisation these organisations exploit economies of scale and may hire low-cost unskilled manpower. Instances of such services incorporate open transportation, cinemas, back-room tasks in banking, protection, postal service offices, cleaners, air terminal baggage handling and index stores. In such sort of processes, the contact that happens among representatives and clients is for standardised services. Also, if the client is engaged with the process, it is in self-service structure.

NOTES

SELF ASSESSMENT QUESTIONS

5. Mass services have a _____ level of labour intensity but a _____ level of cooperation and customisation.

5.5 ENGINEERING SERVICE PROCESSES

At the first instance, let us discuss the process of designing service processes. Fundamentally, structuring of service processes requires a cautious and detailed investigation about different angles, such as customer necessities and company assets. The planning of service processes, in some cases, is known as engineering service processes. The steps required in the designing of service processes are explained as follows:

1. **Determining the goal of the service which would be given by a service administrator:** It is the most vital and basic step. It incorporates the principle objectives of an organisation that are identified by customers. For example, a foundation providing PC training to the understudies will have the following goals:
   - Basic instruction of PC programs
   - Practical training of the considerable programs
2. **Determining the processes that are required for meeting the targets:** It includes choosing the processes for satisfying the objectives. For example, taking the previous example of PC instruction, the processes would be:
   - **Enquiry:** Taking care of process for addressing the questions of the students.
   - **Computer programs design:** For example, utilising CDs for students' preparation.
3. **Documenting and controlling the processes:** Once the process has been resolved, it is required to be recorded and controlled. Archiving the processes implies that the processes ought to be made accessible at all the concerned places through either duplicate or printed copy. Controlling the processes includes checking and redressing the processes.
4. **Implementing and assessing the processes:** Once the processes are recorded, they are required to be executed according to the arrangement. The execution is additionally trailed by assessment.

   Each process must have a well-defined methodology covering the following highlights:
   - Responsibility and authority
   - Measurement of the recognised parameters, which would give an idea of the process ability
   - Participation of everyone in the organisation

SELF ASSESSMENT QUESTIONS

6. Engineering Service Processes is related to _____of service processes.

7. Determining the _____ of the service is the most vital and basic step of designing the service processes.

5.6 CONTROLLING SERVICE PROCESSES

Controlling service processes can be characterised as directing the processes so that the outcomes accomplished are under acceptable limits as far as possible. Let us take a case of a service organisation, which is into the assembling of stray pieces. As far as possible, the limits for defects are set to ±0.2%, which suggest the breaking point within which the blemished pieces would be satisfactory or else it would be rejected. Amid the assembling of these parts, defects were under the control of management. However, after some time, the quantity of deformities expanded generously. Thus, this implies that the process is leaving control and some steps are required to address or correct the issue.

A number of tools and techniques utilised in the controlling of processes are discussed as follows:

- **Control outlines:** These are the graphic markers that are utilised to delineate the conduct of processes over the long haul. These graphs demonstrate the focus at which the process goes out of control. By utilising control outlines, the management can distinguish conceivable anomalous occasions that left the process in an uncontrolled situation.
- **Testing:** It is like inspection, except that in case of inspection, check is done by taking a sample from the output, while in the event of testing, confirmation is relevant to the whole parcel. The intention is to reveal defects. The merchandises that satisfy the quality models are acknowledged, though the products that come up short are rejected.
- **Audits:** These tools check that the service processes are properly carried out and not against the requirements as determined by the client or the quality service framework. Audits are arranged exercises that confirm the execution of the status of the framework.
- **Inspection:** It is another instrument that works on the product instead of the processes. The motivation behind utilising examinations is to identify damaged products.
- **Reviews:** It is a proactive task, which begins as soon as the process begins. As testing comes late in the cycle, the reason for using reviews is to reveal defects as fast as they could be expected under the circumstances.

Self Assessment Questions

8. Which of the following are the tools and techniques utilised in the controlling of service processes?
   a. Testing
   b. Audits
   c. Reviews
   d. All of these

Notes

9. _____ are the graphic markers that are utilised to delineate the conduct of processes over the long haul.

5.7 SERVICE STANDARDS

Service standards are the delivery targets comprised of duties set by the organisation while delivering a service. These standards represent customers' expectations from the services. Service standards are also known as customer-defined service standards.

Customer-defined standards are used for:

- Comprehending specific client requirements
- Translating customer conduct into specific practices and actions
- Facilitating behavioural changes in employees

Service standards are important because an organisation is responsible for the sevices it delivers. These standards permit customers and service providers to know where they stand and what results they ought to anticipate. Organisations that can fulfill or surpass service standards will increase their customers' loyalty and the overall organisational performance.

There are two types of service standards, which are discussed as follows:

- **Hard customer-defined standards:** These standards are determined through audits. For example, time in line, exchange time, number of mistakes, tallies of grins, utilising customers' name, infringement of clothing standard, accessibility of frameworks, number of errors, number of complaints received, return on resources, number of repetitions, precision of request, special cases to methodology and infringement of regulatory codes are the hard customer-characterised measures. These standards guarantee the speedy service delivery.
- **Soft customer-defined standards:** These are the opinion-based measures that cannot be observed. However, these standards can be gathered by communicating with customers. For example, security, comfort, tidiness, accessibility, consistency, accommodation, believability, exactness of exchange, politeness of employees, proficient staff, supportive staff, costs, value received and service experience are the soft customer-defined standards. These standards give the direction and feedback to the employees to determine the customer satisfaction.

5.7.1 DEVELOPING SERVICE STANDARDS

An organisation needs to fix service standards for performing better in the market. The standards can be set on the basis of customers' choices. The organisations have shifted their focus on customer-defined service standards.

Figure 4 describes the process of developing customer-defined standards:

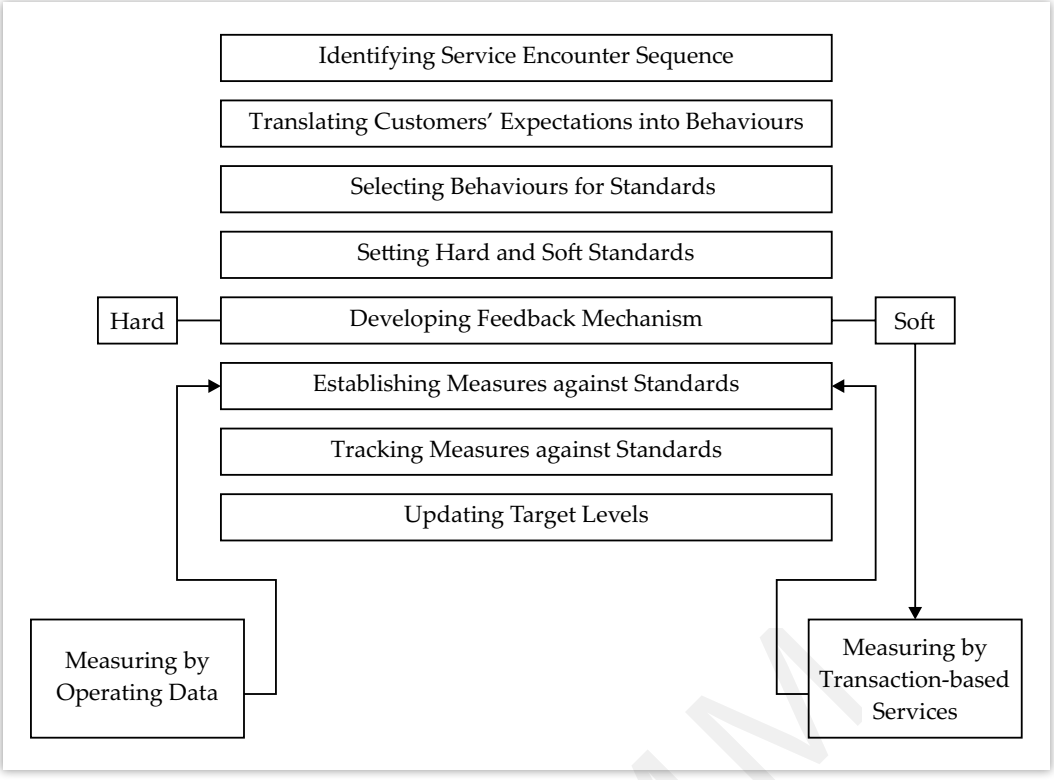

FIGURE 4: Process for Developing Customer-defined Standards

The various components of the process to develop customer-defined standards shown in Figure 4 are explained as follows:

- **Identifying service encounter sequence:** It is the first step of the process where the current and the desired service interaction is defined.
- **Translating customers' expectations into behaviours:** In this step, the customer expectations are translated into specific behaviours related with each customer experience.
- **Selecting behaviours for standards:** In this step, the organisation prioritises the behaviour and activity of the customers. Standards include performance that must be improved or kept up.
- **Setting hard and soft standards:** This step involves deciding the appropriateness of the hard and soft standards to capture the customers' behaviour.
- **Developing feedback mechanism:** In this step, a mechanism is developed for implementing the hard and soft standards for the feedback. Hard standards involve mechanical or technology-enabled measurements whereas soft standards involve monitoring of employees through customer feedbacks.
- **Establishing measures against standards:** In this step, the organisation's expected level of customers' satisfaction is compared with the actual performance of behaviour.

Notes

- **Tracking measures against standards:** In this step, all the wrong performances are detected and they must be prevented from occuring again.
- **Updating target levels:** After comparing, the organisation must try to match the level as per the changing levels of customers' satisfaction.
- **Measuring by operating data:** In this step, the customer-defined service standards are determined based on day-to-day operations.
- **Measuring by transaction-based services:** In this step, the customer-defined service standards are determined on the basis of customer feedback.

Self Assessment Questions

10. Hard customer-defined standards refer to the standards that can be determined through _____.
11. Organisations that can maintain their service standards observe an increase in customers' loyalty. (True/False)

5.8 SERVICE BLUEPRINTING

A service blueprint is a schematic, graphical or visual instrument that speaks about the stream of processes associated with rendering a service. It delineates the service process, the purposes of customer's contact and proof of service from customers' perspective. It works within the service engineering process that helps in service improvement. It is a tool which helps in service planning and is utilised for improving existing services and developing new imaginative services.

Service blueprint indicates links between different parts of a service delivery. It sequentially maps several customer-employee associations and relating interactions that occur when customers and organisation meets. Service blueprint additionally represents difficulties at all the phases of service experience. It recognises the customers' encounters and the frameworks that work behind the stage to guarantee smooth service delivery.

The components of service blueprint are:

- **Customer actions:** These are the steps or activities that are performed by the customer for purchasing and availing a service.
- **Onstage contact employee actions:** These are the activities that are visible to the customer and are performed by an employee.
- **Backstage contact employee actions:** These are the activities that are performed by an employee to support onstage actions. These are rarely visible to customers.
- **Support processes:** These are the activities and actions that help employees in delivering services to customers.

An example of service blueprint is shown in Figure 5:

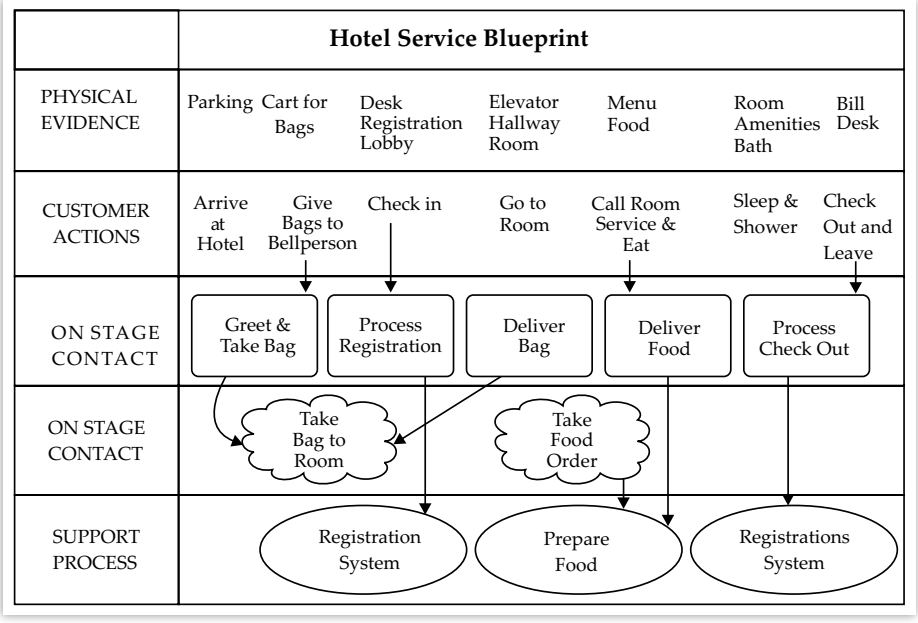

FIGURE 5: Example of Service Blueprint

Service blueprint is an adaptable and effective tool in portraying a service at various dimensions. It encourages in the refinement of making of a whole service process. It assesses the execution of a service from customer's viewpoint. Service blueprint can be utilised for the following tasks:

- Designing and developing new services, and assessing and improving existing services by:
  - Testing of assumptions on paper to identify the fail points
  - Cutting down time and inefficiency of random service development
  - Calculating the time taken in service process
  - Comparing the differences in basic services, processes and standards
  - Capturing of processes, architecture and systems in association with internal business perspective
- Applying as a communication tool by:
  - Providing a focus for conversations
  - Inspiring corporate-wide change directed at integrating customer focus across the organisation
  - Describing precisely than verbal descriptions, and less subject to misinterpretation
- Implementing a new service process by:
  - Representing new service for a staff member to see during integration activity
  - Forming a common point of reference for all parties, such as project team, affected staff and management concerned with achieving a successful launch
  - Storing electronically for later reference

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- Becoming a reference for planning and change
- Facilitating comparison of the desired and actual service

Self Assessment Questions

12. Onstage contact employee actions are the activities that are visible to the customer and are performed by an _____.
13. Which one of the following should be a component of service blueprint?
    a. Customer actions
    b. Backstage contact employee actions
    c. Support processes
    d. All of the above

5.9 SUMMARY

- Service processes include practices intended to achieve customer loyalty. The service-oriented businesses, being intangible, are exposed to variations.
- Service processes also help in minimising operating costs.
- The Service Development Process encourages customers and service providers to come together.
- Ansoff matrix empowers an organisation to distinguish among different zones of development.
- The service process matrix classifies the service processes based on their characteristics.
- Service processes depend upon two measurements: Degree of labour intensity and degree of interaction and customisation.
- Structuring of service processes requires a cautious and detailed investigation about different angles such as customers' necessities and company assets.
- Controlling service processes can be characterised as directing the processes so that the outcomes accomplished are under acceptable limits as far as possible. The limits for defects are set to ±0.2%.
- Service standards are the delivery targets comprised of duties set by the organisation while delivering a service.
- A service blueprint is a schematic, graphical or visual instrument that speaks about the stream of processes associated with rendering a service.

5.10 KEY WORDS

- **Commercialisation:** A term used for the practice of management or running of a business or non-business activity that is usually done for the purpose of financial gains.
- **Vender:** In a supply chain, a vender refers to an individual or an organisation which offers merchandise or services for sale.
- **Customisation:** It means changing or modifying a product as per customers' specifications or preferences.
- **Transaction:** A transaction is an event when a purchaser and a merchant exchange goods, services or money-related instruments.

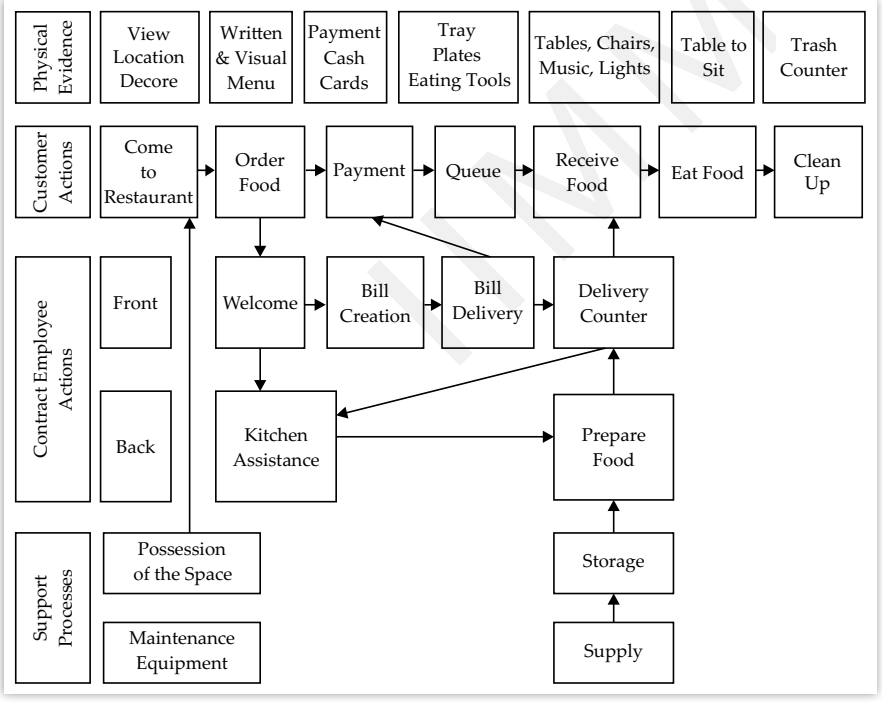
5.11 CASE STUDY: SERVICE BLUEPRINTING OF THE WOK KITCHEN

Wok Kitchen is a chain of restaurants. One of its outlets is located in the food court of Mitt i City. Mitt i City is a prominent shopping mall in Karlstad city of Sweden. Since 1999, Wok Kitchen has been starting its operation. In 2017, a few researchers selected this outlet and analysed the restaurant's existing service processes and made a service blueprint for the same.

At the time of research, Wok Kitchen Karlstad's outlet contained around 40 large- and small-sized tables with around 120 seats. Therefore, about 120 people could take their meals at any given point of time. Wok Kitchen serves Chinese and Thai foods. They are serving overwhelming dinner packages with truly reasonable pricing rate.

The shopping centre is one of the busiest places in the city and has a heavy footfall. The major customers of this restaurant are the customers of the shopping centre and the people working in adjacent business areas who search for normal lunch at reasonable prices. The restaurant has a culture of self-service for the customers. Under the supervision of a manager, three representatives work all day. They include a chef, an associate chef, and a front worker who serves food in the delivery counter.

The existing service blueprint of the Wok Kitchen is shown in the following figure:



As per the above-shown blueprint, customers can choose food item from the menu board placed adjacent to the money counter and can look at the foods available through visual menus. Customers can see other people and select similar foods. Cash and cards both are accepted for payment. The eatery gives its customers plates and other eating devices, like the spoon, fork, knife, etc. Music and lighting add some additional values to ambience of restaurant. Before leaving, the customer is required to take his plates and the leftover food scraps to the trash counter.

Customer part of the blueprint depicts the actions of the customers. As shown in the blueprint, first, the customer arrives and places his order. He/She goes to the counter to place an order. The person on the money counter welcomes him/her and

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generates two bills—one for the customer and the other for the delivery counter. The customer pays the bill and, in the meantime, the delivery person arranges to serve the food. During this time, the customer remains in a queue at the delivery counter. After receiving their food, customers go to the table and eat food. After eating, they clean up the table and take the rubbish to the waste counter.

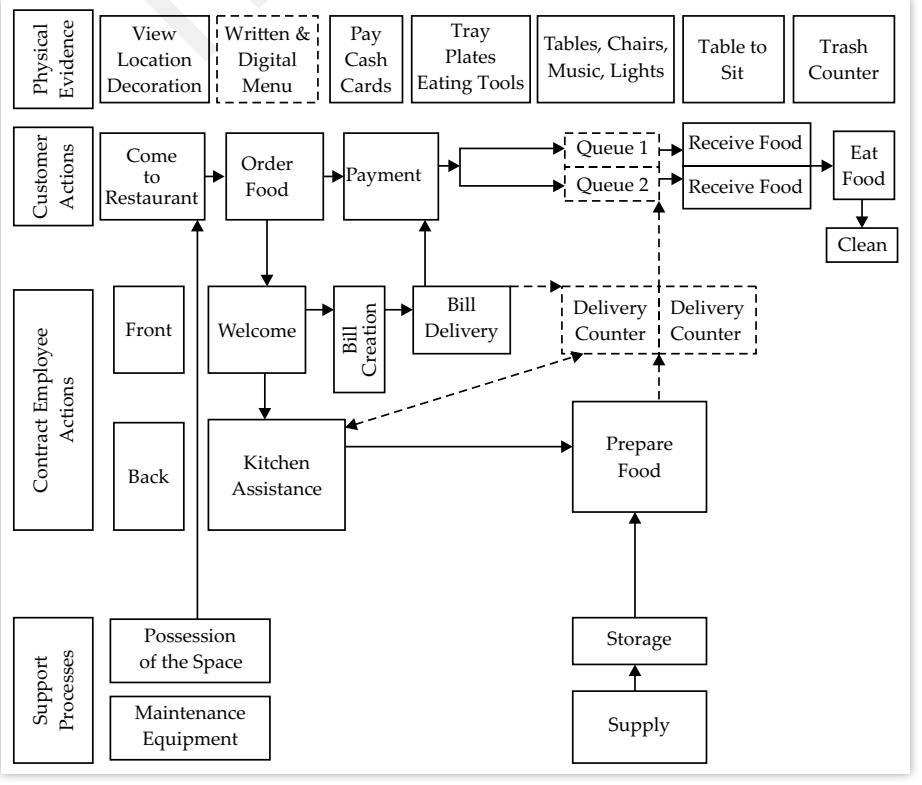
As shown in the blueprint, the contact focusses between the customer and the service workers. It tends to be divided into two parts, the front part and the back part. Food packages are constantly prepared and supplied at the delivery counter. The money counter and the delivery counter remain in contact with the kitchen colleagues to supply the food in the delivery counter. At the point when food is about to finish, the kitchen colleagues are informed and they begin preparing more food to deliver on time.

As shown in the blueprint, support service is the last piece of the blueprint. The restaurant space has been taken on a lease from the shopping centre. It is the main component of the service procedure. There is a fixed supplier who supplies raw materials and helps in running the production easily by delivering on time. The space at the back of the restaurant contains storage area where raw materials are stored for cooking.

The researchers find two shortcomings in the blueprint of the restaurant:

1. All the items displayed in the menu are not constantly available. The availability of things varies everyday, and there are no signs or checks on the menu for displaying it.
2. At peak hours, the queue gets very long, making customers wait for longer time. This may cause genuine disappointment among customers.

To fulfil the shortcomings, researchers develop a new service blueprint for the restaurant as follows:



To address the first shortcoming, they modified menu board and it could be changed now and again. An electronic display showing only the available items was placed.

To address the second shortcoming, researchers suggested placing an extra frontline worker in the delivery counter to serve food. This was applied only for peak hours and by recruiting workers on hourly payment basis.

Source: *https://file.scirp.org/pdf/AJIBM_2017071210185686.pdf*

QUESTIONS

1. What are the shortcomings in the service process design of Wok Kitchen?

   (**Hint:** All the items displayed in the menu are not constantly available.)

2. What are the improvements suggested in the service process design of Wok Kitchen?

   (**Hint:** Modified menu display and recruitment of an extra frontline worker.)

5.12 EXERCISE

1. Describe the significance of service processes.
2. What are the stages of Service Development Process?
3. What is the Service Process Matrix?
4. What are the steps required in the designing of service processes?
5. What are the tools and techniques utilised in the controlling of processes?

5.13 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Service Processes	1.	True
	2.	resources
Service Development Process	3.	Service Development
	4.	market testing
Service Process Matrix	5.	high, low
Engineering Service Processes	6.	planning and designing
	7.	goal
Controlling Service Processes	8.	d. All of these
	9.	Control outlines
Service Standards	10.	audits
	11.	True
Service Blueprinting	12.	employee
	13.	b. Customer responsibility

Notes

5.14 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Bill Hollins & Sadie Shinkins, 2006, *Managing Service Operations: Design and Implementation*: SAGE Publications Ltd.
- Johnston Robert, Clark Graham & Shulver Michael, 2017, *Service Operations Management: Improving Service Delivery*: Pearson Education

E-REFERENCES

- https://deden08m.files.wordpress.com/2013/02/chapter-8-designing-and-managing-services-processes1.pdf
- https://www.researchgate.net/publication/222515477_Blueprinting_the_Service_Company_Managing_Service_Processes_Efficiently

CHAPTER 6

Capacity Planning – I

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the meaning of capacity
- Explain the types of capacity
- Differentiate between capacity and demand
- Describe the concept of capacity planning
- Describe the capacity planning process
- Describe the different capacity planning approaches

6.1 INTRODUCTION

In the previous chapter, you studied about the management of service processes including the process for service development and service blueprinting. The chapter also discussed important service management concepts, such as engineering service processes and service process matrix.

When an organisation produces goods or provides any kind of service, they need to consider several factors. One such factor is capacity planning. The word 'capacity' means the ability of an organisation to produce goods at a given point of time or the ability to provide services to customers at a given point of time.

Initially, organisations determine the amount of goods they must produce and how many customers they can serve. As the market does not remain same at all times, demand usually fluctuates. Thus, organisations need to plan their capacity so that they can meet the actual demands of the market. Capacity is planned to ensure that there is no shortage in the market and also to ensure that there is no overproduction as it may lead to losses for the organisation.

In this chapter, you will study the basic concepts of capacity, capacity planning and the various approaches to capacity planning.

6.2 CAPACITY

The term,'capacity' means the ability to accomplish any task. In organisational context, capacity means the ability to produce any given unit or quantity of products by using the available resources. Here, available resources are the limiting factor. The organisation's capacity might be more in terms of production units, but if it has limited resources, then, in such a case, it would not be able to produce a higher number of units. Thus, production will always be limited to the availability of resources. The term 'resources' here includes raw material, labour, staff, money, management, etc. If any organisation has unlimited raw material but limited labour, then, in such a case, most of the raw material will not be used for producing finished goods. Consequently, the capacity of the organisation will reduce. Similarly, if an organisation is having

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both labour and raw materials in abundance, but no management staff to manage them, then, in such a case too, the capacity of the organisation will reduce. Therefore, we can conclude that the availability of resources plays a vital role in deciding the capacity of an organisation or firm.

Any organisation or firm's capacity can be displayed in terms of output or input. This means we can come on a numerical figure for determining the total capacity of a production unit or organisation. For example, the capacity of a laptop-making company can be expressed in the numeric figure, denoting laptops manufactured per month. In the case of laptops, capacity is being expressed in terms of output. But there are certain cases where it becomes difficult or complicated to express in terms of output. Then, in such cases, capacity is expressed in terms of input. The example which can be quoted here is of a hotel. In case of a hotel, the capacity is being expressed in terms of rooms. However, if we talk about a production plant, then noticeably we can say that the capacity of a production plant depends upon various factors. These factors are the demand of the goods, cost per unit and market share in terms of sale. The capacity of the production will be determined by taking into consideration all such factors. Lack or, say, limitation of any of these factors will hamper or reduce the capacity of the organisation. The capacity will be calculated as a blend of all these interrelated and mutual factors.

It is rather easy to measure capacity in a few cases. For example, the number of rooms in a hotel can be easily measured. In these cases, the concept of aggregation can be easily implied. Aggregation here means the calculation while using a standard average production rate and expressing capacity in terms of standard product. If we talk about services provided by airlines, then in case of airlines, total capacity is measured by counting the number of seats in a plane. In this case, the capacity is being measured and expressed in terms of input. But, in a few cases, it is rather not easy to calculate and determine the capacity. For example, in the case of services provided by a beautician, you cannot estimate or, say, predict how many customers will come per day, for how many customers' seats are reserved, etc.

The needs of future capacity can be determined from a short-term or long-term perspective. The perspective of short term can be determined on the basis of a time horizon which varies from 12 to 18 months. The prediction of future demand can be made by using the past data and the number of actual orders received by the organisation. The organisation should adjust the existing capacity in accordance with demand. For example, in case if in a year, a car owner gets demand for a thousand cars, but he was able to produce only eight-hundred cars, then, in such a case, for the next year, he should be able to produce a thousand cars. He needs to change his capacity and resources accordingly. However, when you think of a long-term perspective, you must understand that requirements and needs should be met either by reducing or expanding the existing capacity. Resources should also be altered accordingly.

For example, if in the past few years, a car owner is noticing a decline in its sale, then he must reduce its production in the coming years.

6.2.1 TYPES OF CAPACITY

The capacity can be understood in its different types. Figure 1 shows different types of capacity:

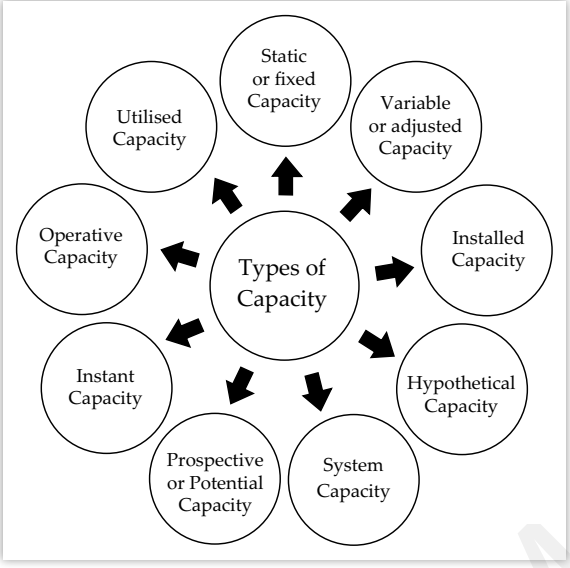

FIGURE 1: Different Types of Capacity

Let us discuss them in detail.

- **Static or fixed capacity:** Static or fixed capacity denotes that capacity of an organisation which does not change in a short period of time. As its name suggests, it remains same and unchanged in a short period of time. The production per year, sales per year, variable costs per year, etc., do not change in the given period of time. The best example of this type of capacity is capital assets of an organisation i.e., land and building, office premises, furniture, etc.
- **Variable or adjusted capacity:** This type of capacity changes from time to time and, therefore, is variable in nature. It may even change in a short span of time. The number of labourers in the company, raw material available, employees working on a weekly basis, the number of shifts, etc., are all examples of this type of capacity.
- **Installed capacity:** Also known as designed capacity, it is capacity which tells the planned rate of output of services and goods in a full-scaled or normal operating conditions.
- **Hypothetical capacity:** The theoretical capacity of an organisation is known as the hypothetical capacity. As per its name, it is basically an ideal goal which is set by the organisation. It is a target which the organisation wants to achieve, but barely can achieve the same in practical life. Sometimes, it can be measured on the basis of capacity of machine hours in full time.
- **System capacity:** This capacity determines the output of the given services or goods or a mixture of goods and services which can be produced by a given system in a particular point of time.

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- **Prospective or potential capacity:** This capacity refers to the capability of an organisation to produce goods or services from the decision of management. It is actually the maximum number of goods that can be produced by an organisation in a given period of time. This type of capacity helps the management in taking important decisions about the growth, investment or business of the organisation.
- **Instant capacity:** As per its name, it is the capacity which is immediately available. It denotes the availability of production of goods or services in the current budget.
- **Operative capacity:** Operative capacity can also be termed as the effective capacity of the organisation. It is actually the maximum number of output which an organisation can achieve practically. It is always less in number than the design capacity because, evidently, the organisation will design more than the practical.
- **Utilised capacity:** Actual capacity of an organisation is known as utilised capacity. The actual output achieved by the organisation in a given time is known as the actual or utilised capacity. Because of inconsistent production levels, the change in demand, the absence of employees, etc., the utilised capacity can be less, more or even equal to rated output.

6.2.2 MANUFACTURING CAPACITY AND SERVICE CAPACITY

The term 'manufacturing' means the ability to produce or make any kind of goods or products by the given process of manufacturing in an organisation or anywhere. Thus, manufacturing capacity in this context means the capacity of an organisation to produce or manufacture a certain number of units or products in a given period of time. For example, if a car manufacturer can produce a maximum of thousand cars in a year, then its manufacturing capacity will be thousand cars. The term 'service' means doing any kind of work which someone needs in exchange of money from him. Thus, service capacity can be said to be a capacity of serving any number of customers in a given period of time. For example, an airplane having one hundred seats can serve up to one hundred customers at one time. Then its service capacity would be one hundred.

The business model of manufacturing and servicing is different, but they have few similarities when it comes to manufacturing capacity and service capacity. The first similarity between them is that like every business model, both aim at satisfying their customers. The second similarity is that both shape their planning as per the demand. This means according to demand, they will alter their actual capacities. The calculations of manufacturing capacity and service capacity are different in nature. It is rather easy to calculate manufacturing capacity than calculating service capacity. This is because, today, production is done by machines and tools. Counting a machine's capacity does not differ as it gives uniform results every time. For example, if a machine in a marble industry can shape one hundred marbles in an hour, then it will shape one hundred marbles every hour. But, in case of services, some services are given by humans and, unlike machines, humans cannot give a uniform result every time. For example, a beautician in a salon can serve ten customers in the first hour of day, but as the day will pass, she will not be able to serve ten customers every hour as her capacity will reduce.

6.2.3 CAPACITY AND DEMAND

The term 'demand' means the requirement of any goods or services by the consumers in a given market and at a particular time. The demand for any goods or services can change as per geographical boundaries, culture, time, etc. Various factors altogether decide what demand is for any goods or services. For example, wool's demand would be more in North India, especially in Kashmir, where winter season remains all twelve months. But demand for wool in South India would be almost nil. The demand for crackers would be high during Diwali and New Year in comparison to other days.

After understanding demand and its factors, we can easily understand how demand can affect capacity. If the demand for any goods will rise in a particular period of time, then consequently, the manufacturer or service provider will have to increase its per unit capacity. Here, we can quote a live example. We have seen that in recent times, because of the increasing use of the Internet, people are buying a large number of smartphones. Consequently, the android phone manufacturers have started producing a large number of phones to meet the demand. The demand also depends on the availability of resources. So, these companies have started deploying more resources in their organisations. For example, if the demand of any beautician's services will increase in any region, she will also increase her capacity of serving by increasing the number of helpers or employees in her salon.

On the other hand, if the demand for any particular goods or services will decrease, then the organisation will have to reduce its capacity per unit, otherwise its resources will go waste and unutilised. For example, Nokia company failed to meet the requirements of its customers in terms of Android phones in recent times. As a result, Nokia had to reduce its per unit capacity.

So, we can conclude that the capacity is directly proportionate to demand. If demand will increase, then a manufacturer or service provider will have to increase capacity of goods or services and if demand will decrease, then a manufacturer or service provider will have to decrease capacity of goods or services.

6.2.4 CAPACITY AUGMENTATION

The term 'augmentation' means the process of increasing anything in size or amount. Capacity augmentation, thus, means increasing the capacity per unit of any goods or services. If any product is present in the market for a long time, then, in such a case, the decision of capacity building is not hard to take. This is because an organisation can easily determine the demand by comparing past years' trends and analysis. For example, a car manufacturer will only produce a number of cars which were being demanded by the end consumers in the past years.

However, for any given product, which is being characterised by short lifetime and high uncertainty of demand, you need to cautiously invest in the capacity build-up. If this is not done, then either the market share will go waste or else the capacity will go unutilised. For example, the demand of talcum powder is limited to summers. So, the talcum manufacturers will have to cautiously determine the demand and utilise their maximum capacity.

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In the capacity augmentation, an organisation must follow the given steps below, in order to ensure that the maximum capacity of the organisation is utilised and market share demand is also met:

1. **Ascertain the company's current capacity:** To increase the total capacity of the company, it is vital to know the current per unit capacity of the company.
2. **Analyse the market demand:** The first and foremost step is to study the whole market demand of the given product or service.
3. **Determine the company's share:** Then, it is also important to determine what is the actual share of demand of the organisation in the whole market demand.
4. **Estimate the difference:** Then, the organisation should estimate what is the difference between demand and current capacity. This can be analysed by knowing what is the current capacity and what should it be to meet demand. For example, if an airline is getting one hundred persons' demand in a particular flight, but has only eighty seats, then, in such a case, it needs to augment its capacity up to one hundred.
5. **Evaluate what resources are required:** Then, the organisation should evaluate or determine what kinds of resources are required to increase the capacity.
6. **Implement:** Then, accordingly, an organisation should increase the resources and, thus, increase the capacity.
7. **Monitor:** A constant monitoring or watch is necessary to see whether increased capacity is working as per the requirements or not.

6.2.5 CAPACITY MEASUREMENT

The capacity per unit of any organisation or even an individual can be measured by using certain measures. It can be measured in terms of output, or in terms of input or even in terms of a combination of input and output. For example, a mobile-manufacturing company can calculate its capacity on the basis of mobile phones manufactured by it in a year, month or any given period of time. It is calculated on the basis of ratings as well as theoretically. The maximum output at a given point of time is known as theoretical capacity. It does not allow for any downtime. This means it measures capacity on a short-term basis. On the other hand, rated capacity is measured on a long-term basis.

For a smooth functioning of its business operations, it is important for an organisation to determine the capacity of its production plant. An organisation needs to be careful while measuring its production capacity. This is because if the capacity is overestimated, there may be excess production of goods. On the other hand, if the capacity is underestimated, there may be a number of pending customer orders, which cannot be fulfilled because of lack of capacity. An organisation uses different methods for measuring its capacity. One of these methods is linear programming explained as follows:

Linear Programming

Linear programming is a mathematical term and in this context, it is a mathematical method used by manufacturers or service providers for solving optimisation

problems. For example, minimisation and maximisation problems of manufacturing enterprises. In these types of problems, variables having linear relationships are included. For optimisation of problems under given conditions and allocation of resources, the best solution is linear programming. Since minimum information is being provided about the work of economy by this method, its economic application is not used much.

While solving any problem with linear programming, following assumptions are made:

- **Continuity:** As linear programming is a mathematical technique, therefore, a basic assumption is made, that is, all variables are measurable only if they have a numeric value. It is being assumed that continuity in variables can only be brought by a numeric value.
- **Linearity:** The process of problem-solving through linear programming assumes that there is a linear relationship between output and input of production. This is even a required condition that there must exist a linear relationship between input and output. This assumption of linearity states that an equal return is achieved in the short run by the factor of production. This relationship is being represented in a linear equation. For example, a manufacturing company requires 1 tonne of raw material (R), 26 men (W) (Manual labour) and 13 machine hours (M) for production of one unit of output. Then the linear relation will be 1R + 26W + 13M = 1O. This assumption is limited to linear relationship between input and output only.
- **Proportionality:** A proportionate relationship is being assumed among the variables. This means that the variables will remain the same while you are finding out the solution to the problem. This assumption also indicates that at every level of output, the proportionate relationship between the variable will be the same. For example, if a given product requires 10 units of input for the production of 1 unit of output, then, in such a case, 100 units of input will be required for the production of 10 units of output. This assumes a uniform proportionality among the variables.
- **Independence:** This assumption states that variables and their numeric values are independent of the value of other variables. This also signifies variables are randomly selected and within specified limits.
- **Additivity:** This assumption states that different variables of a production programme can be added together easily. If this cannot be possible, then they cannot be solved through linear programming.
- **Same price:** This assumption states that regardless of quantity purchased or sold, the price remains the same or constant.

Let us discuss a business problem's solution through linear programming:

The technique of linear programming is mostly used for solving profit maximisation problems. Let us take an example of an organisation which is producing two products X and Y, which are being produced by inputs A and B. 200 units of A and 400 units of B are being required for producing X and Y. The profit earned by one unit of X is ₹3 and the profit earned by one unit of Y is ₹2.

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Table 1 shows conditions for producing products X and Y:

Table 1: Conditions for Producing Products

Input	Availability of input	Per unit requirement	Per unit requirement
		X	Y
A	200	2	4
B	400	4	6

Now you need to find out the total number of units of X and of Y, which should be produced using available inputs of A and B. The combination of production of X and Y should be able to give maximum profit. Now in order to find out the best and optimal combination of production of X and Y, you need to follow the given steps:

1. **Forming the objective function:** To solve the problem, you need to formulate the objective function as the first step. Using the data given in the above table, you can formulate the objective function. It can be represented as follows:

   In the above table, X and Y is the quantity of output, which needs to be multiplied by per unit profit of the given products. The technique of linear programming is being used to find out how many units of X and Y should be produced, in order to maximise the overall profit of the company.

2. **Constraint equation:** The second step helps in assessing the need for producing one unit of output of both the products, in order to further maximise the profit. The word 'constraint' means restriction or limitation. Here, limited availability of raw materials will decide how many goods of each product will have to be produced. This is done because if you will produce only one product, then you will suffer the loss of profit of the other. Thus, in given inputs, you need to maximise the profit of the company. In the given situation, the constraint equation of A can be expressed as follows:

   You can see that the total supply of raw material A is 200 units. To produce one unit of X, we require 2 units of A and to produce one unit of Y, we require 4 units of A.

   In a similar manner, you can assess the constraint equation of B.

   As you already know, the total supply of raw material B is 400 units. For producing one unit of X, you require 4 units of B and for producing one unit of Y, you require 6 units of B.

3. **Non-negativity condition:** This condition is being required by the linear programming method, in order to get a more realistic solution. Linear programming is a mathematical technique and a mathematical problem may have any variable's solution as a negative solution. But we cannot produce any product in negative quantity, neither we would require a negative number of raw materials for producing any product. Thus, because of this situation, adoption of the non-negative condition is being done. In the above business problem, non-negativity can be expressed as follows:

   $X > \text{or} = 0$, $Y > \text{or} = 0$.

Let us assume the maximising function to be expressed in terms of Z. Then the equations would be as under:

Maximise Z = 3X + 2Y

which is subject to constraints:

where A > or = 0 and B > or = 0

The linear equations would be as under:

200 = 2X + 4Y

400 = 4X + 6Y

SELF ASSESSMENT QUESTIONS

1. Capital assets of a company in any given period of time are known as _____.
2. How can you mathematically solve any business problem of capacity measurement?

6.3 CAPACITY PLANNING

The process of assessing the level of capacity as needed in manufacturing a given product with a given quantity of raw material is known as capacity planning. Capacity planning is affected by several factors. Few examples of such factors are number and quality of machines available, their maintenance, number of skilled, semi-skilled and unskilled labourers, number of suppliers, the productivity of employees, rules and regulations of government, etc.

Capacity planning has the following advantages:

- **Efficiency:** If you will adopt and follow effective capacity planning, then it will enhance the present productivity and efficiency of the organisation. By adopting a capacity plan, the production process gets organised and smooth.
- **Meeting demand on time:** If you will make an effective capacity plan, and you are able to adopt it practically too, then automatically you will be able to meet your customer's demand on time. This will increase the customer's loyalty towards the brand.
- **Scheduling:** The delivery supply's schedule and the shipping schedule of finished goods is a must for a profit-earning and growing organisation. If you are planning your capacity, then you can always make an effective schedule for everything from production to final sale. Moreover, if demand will rise at any particular time, then through capacity planning, resources can be arranged timely and demand can be met.
- **Analysing needs:** A better capacity planning can in advance learn about the future needs of staff, raw materials and other resources that are required in producing the given quantity of a product.
- **Monitoring costs:** Market is not the same all the time. Sometimes there is recession and sometimes there is growth. Capacity planning can help monitor and reduce costs in all situations.

Notes

6.3.1 CAPACITY PLANNING CONSIDERATIONS

We have already understood what capacity planning is. Now it is time to understand what major considerations in capacity planning are. The five major capacity planning considerations are as follows:

- **Total demand for product:** The most important thing while planning the capacity of an organisation is analysing the total demand for the product in the whole market. A detailed study should be made for calculating the total demand for the product in the market.
- **Market share:** There is no doubt that the organisation is not going to produce the product equal to the total market's demand. The company should also make a detailed study of its own market share. Own market share means how many consumers will buy the company's product. Both excess production and limited production will result in a loss.
- **Total cost of production:** It is the most important consideration while planning the capacity. Capacity should be calculated by considering all the variable and fixed factors and then comes the total cost of production. Variable costs are the cost of labour, the cost of raw materials, etc. Fixed costs are the cost of machine, land and building, etc.
- **Availability of resources:** A thorough understanding should be made about what sort of resources are available with the organisation. Resources include both monetary and non-monetary items.
- **Policy of management:** After considering all other factors, management should also consider its own policy regarding targets, goals and objectives. This will surely affect capacity planning, as management is the one that knows where it is standing and where it wants to reach.

6.3.2 CAPACITY PLANNING PROCESS

The capacity planning process is the process of assessing the capacity of production by given resources in order to meet the demand. Following steps need to be followed for an effective capacity plan:

1. Know what kind of product you are manufacturing or service you are giving.
2. Identify the resources that are needed for the production of the said product or providing the said service.
3. Assess or measure how many units of raw materials (inputs) are required to produce the finished goods (output).
4. Assess the total cost of production.
5. Map how much profit you are expecting per unit.
6. Come to a certain number that you can produce.
7. Implement the above plan.
8. Constantly monitor the demand and above plan and know whether you need to increase or decrease your demand.

SELF ASSESSMENT QUESTIONS

3. How many capacity planning considerations are there?
4. The process of assessing the capacity of production by the given resources in order to meet the demand is known as _____.

6.4 CAPACITY PLANNING APPROACHES

There are various approaches to capacity planning, such as decision tree method, capacity requirements planning (CRP), capacity requirements forecasting, etc. Let us discuss them in detail.

6.4.1 DECISION TREE METHOD

The decision tree model is used to take decisions by any enterprises, company, organisation or individual. In this model, a tree kind of structure is made as per the given variables and factors. Through this, the solution to the problem is concluded. Decision tree chart flows from left to right. Numeric figures and probability are used in this method. Figure 2 displays a decision tree model:

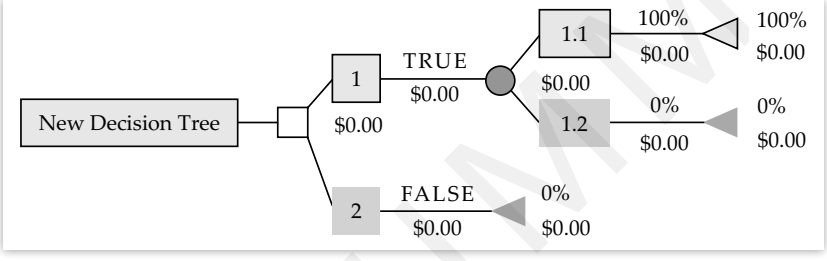

FIGURE 2: A Decision Tree Model

Source: http://www.epmptools.com/

Now, we will understand the decision tree with the help of an example. Let us assume that a movie theatre owner wants to expand the number of seats of the theatre, as he finds that per day demand is increasing. He has two options available with him. First, he might expand his theatre's seats on a large scale with the risk of a smaller demand. Second, he might expand on a smaller scale with the expected loss of profit, as after one year the demand would go high.

This decision can be explained in Figure 3 using the decision tree:

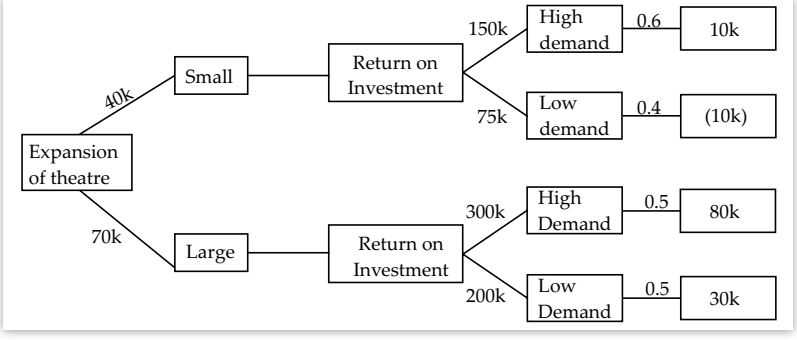

FIGURE 3: Decision Tree for Movie Theatre Expansion

Notes

The above decision tree shows investment at both small scale and large scale. Now we will discuss what could be the outcomes of the above two investments. For example, the investment on a small scale would be of ₹40,000 and at large scale, it would be ₹70,000. Outcomes of both of these investments could be high demand or low demand in the future. The forecasted result of future in one year of time is as follows:

At small scale:

On high demand = 150000

On low demand = 75000

There is 0.6 probability for high demand and 0.4 probability for low demand.

Calculation of profit on given probabilities:

Profit on high demand = 150000 * 0.6 – 40000 = 10000

Profit on low demand = 75000 * 0.4 – 40000 = –10000 (Loss)

At large scale:

On high demand = 300000

On low demand = 200000

There is 0.5 probability for high demand and 0.5 probability for low demand.

Calculation of profit on given probabilities:

Profit on high demand = 300000 * 0.5 – 70000 = 80000

Profit on low demand = 200000 * 0.5 – 70000 = 30000

The above calculations say that if the investor will invest at a large scale, then he will have a higher profit of ₹80,000 in case of high demand. In case of low demand too, he is having a higher profit of ₹30,000, only if he invests at a large scale, else he will suffer a loss of ₹10,000. Therefore, evidently, he should invest at a large scale.

6.4.2 SERVICE CAPACITY PLANNING

You have already understood what capacity planning is in terms of a manufacturer or producer. Now you will know about service capacity planning. Service capacity planning contextually means how many customers you can serve at a given point of time with available resources. It can be done by considering all factors like cost of providing services, available labourers, estimated profits, management policy, etc. Accordingly, capacity can be increased if service provider sees any kind of growth in future. For example, a beautician serves 50 customers a day, but she sees that since customers are increasing in her salon, she could expand by increasing labourers and other resources.

6.4.3 CAPACITY REQUIREMENTS FORECASTING

The term 'forecasting' means predicting the future, or foreseeing what could happen in future. In capacity planning, it is necessary to determine whether demand will

rise or fall in future. It is not necessary that in capacity planning, you always need to expand. Sometimes, to avoid loss, you can even cut short the current production. In case of expanding, a future plan or map could be made what all we would be requiring in future. Generally, what a manufacturer could require is fund, land, furniture, raw materials, etc. A service provider may require labourers, fund, land, etc. A pre-planned and forecasting should be made about resources you might require in the time of expansion.

6.4.4 CAPACITY REQUIREMENTS PLANNING (CRP)

We understood that we might require resources at the time of expansion in future. Capacity resource planning (CRP) is planning to make those resources available at the time of expansion. Following steps should be followed in CRP:

- **Make forecasting:** First of all, study whether or not you would be requiring expansion.
- **Come to a numeric figure:** If you are producing any product, then come to a figure by how many units you would be expanding in the given period of time. If you are a service provider, then too you can come on a numeric figure by calculating how many more customers you would be serving.
- **Determine what resources you would be requiring:** Then you should make a detailed study on what sort of resources you would be requiring at the time of expansion.
- **How you will arrange funds:** You should have a clear idea of how you would be arranging funds in case of expansion.
- **Monitor:** Do not just sit back and relax after making a one-time CRP. Always, keep monitoring and make changes if required.

Self Assessment Questions

5. Name one capacity planning approach.
6. What is the full form of CRP?

6.5 SUMMARY

- Capacity planning refers to the ability to produce any particular goods at a given point of time with available resources.
- There are various types of capacity planning, such as static or fixed capacity, adjusted capacity, designed capacity, etc.
- The business model of manufacturing and servicing is different, but they have quite a few similarities when it comes to manufacturing capacity and service capacity.
- The demand for any goods or services can change as per geographical boundaries, as per culture, as per time, etc.
- Capacity augmentation means increasing the capacity per unit of any goods or services.

Notes

- Linear programming is a mathematical technique to measure the capacity.
- There are different capacity planning approaches, like decision tree method, CRP, etc.
- Capacity resource planning (CRP) is a type of planning to make resources available at the time of expansion.

6.6 KEY WORDS

- **Resource:** Resource in the context of capacity planning refers to labourers, funds, raw material, etc., required to produce goods or provide services.
- **Demand:** Demand means requirement of any given product or service in a particular market.
- **Planning:** Planning refers to making a map of doing what to do in future.
- **Augmentation:** The term 'augmentation' means 'increasing'.
- **Service:** Service refers to any kind of work done for someone in exchange of money from him.
- **Linear programming:** A mathematical technique to solve any problem in capacity measurement.
- **Decision tree:** A flow chart to solve a problem using probability and numeric figures.

6.7 CASE STUDY: CAPACITY EXPANSION BY ROAD KING TYRES

Road King Tyres is a Bhopura-Sahibabad-based dealer and manufacturer of tyres. Its vision is to offer quality products and services to its customers. It manufactures and markets a variety of tyres including tyres for motorcycles, cars and bikes. In addition, it also offers alloy wheels, car accessories, motorcycle accessories and other related maintenance services. The organisation has adopted a customer-centric approach. It is one of the largest and most reputed tyre dealers and manufacturers in Delhi and NCR region.

By the end of 2009, most of the organisation's sales came from the northern and eastern zones. However, there was also a steady increase in the demand from the western zone as well. As per the internal research of the organisation, there was a lot of potential in the western zone. The organisation had estimated the sales forecast from the western zone. The sales forecast put forward by it for 2010 was as follows:

	Q1	Q2	Q3	Q4	Q1 (2011 onwards)
No. of tyres	40,000	60,000	80,000	1,00,000	1,20,000

The organisation wanted to set up a new manufacturing unit in the western zone as its existing manufacturing facility was already running at its full capacity. Therefore, to service the forecasted demands, it needed to set up a new manufacturing plant.

It was expected that after the manufacturing plant is set up and after all the necessary machinery has been installed, the overall capacity utilisation would be 90%. Moreover, there was an expected 5% wastage and rejection rate.

The tyre assembling involves using the tyre and the tube which are made of vulcanised rubber. The important parts of a tyre include tread (outer part of the tyre which makes contact with the ground), plies (the body of the tyre which is made up of a combination of rubber and nylon fabric), beading (the inside periphery of the tyre consisting of metallic rings) and tube (compressed air is filled inside the tubes of the tyres).

Road King Tyres acquired various raw materials at different rates as follows:

Raw Material	Rate/tyre-tube
Rubber	400
Chemicals	250
Nylon fabric	100
Bead wires	45
Miscellaneous	5

Steps involved in the manufacturing process of tyres are:

1. Mix rubber and chemicals and then carry out the rolling process
2. Roll mixed rubber into sheets
3. Draw out treads
4. Insert tubes and fit all the valves
5. Combine rubber sheets with the nylon fabric
6. Prepare bead
7. Assemble the tread, plies, beads and tube to form a tyre
8. Cure the tyres

The rate of tyre production, quantity per tyre assembly, machine-running cost and crew size of the manufacturing unit were as follows:

Tyre-manufacturing machinery	Production rate tyre assemblies per shift	Qty. per tyre assembly	Machine running cost ₹/hr	Crew size
Rubber mixer	1200	1	400	3
Rolling of mixed rubber	960	1	30	2
Tread extruder	100	1	20	2
Bead-making	200	2	4	1
Tube-extruders	120	1	15	2
Ply-making	480	4	25	2
Tyre-building	24	1	30	2
Tyre-curing	12	1	50	1
Helpers required per shift				6

The manufacturing was to be done by deploying employees in 2 shifts each of 8 working hours and there were a total of 25 working days in a month. The average labour rate was ₹30 and average labour efficiency was 90%. Overheads were worth 25% of labour cost. By managing labour, manufacturing process, setting up a new plant in the west zone, the company was able to meet the demand and expand its

NOTES

capacity. A transport truck carried around 200 tyres per trip and the average cost per trip was ₹1200.

Source: *Lele, U. (2011). Retrieved from https://www.academia.edu/21954347/Case_study_in_Capacity_Planning_A_Tyre_Manufacturing_Company*

QUESTIONS

1. Before setting-up the new manufacturing plant, where was Road King's major sales incurred from?

   (**Hint:** East and North)

2. What was the final stage of the tyre manufacturing process?

   (**Hint:** Curing tyres.)

6.8 EXERCISE

1. What is capacity planning?
2. State different types of capacities and explain them.
3. Define capacity augmentation.
4. Explain decision tree method with an example in capacity planning.
5. What is service capacity planning?
6. Define CRP.

6.9 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Capacity	1.	Static or fixed capacity
	2.	Linear programming
Capacity Planning	3.	Five
	4.	capacity planning process
Capacity Planning Approaches	5.	Decision tree method
	6.	Capacity Resource Planning

6.10 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 7

Capacity Planning – II

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the meaning and strategies of capacity expansion
- Discuss the concept of capacity management
- Describe the relevance of facility layout planning
- Outline the features of process layout design and product layout design
- Explain the meaning of line balancing and line loading

7.1 INTRODUCTION

In the previous chapter, you have studied about the meaning and types of capacity, capacity measurement and capacity planning. This chapter focusses on some ancillary topics related to capacity planning including capacity management and capacity expansion strategies.

Capacity management is the process of ensuring that a business entity maximises its production output and runs efficient operational activities at all times and under all circumstances. Capacity refers to the amount of production an organisation can achieve in a given period of time. Since the capacity is influenced by a number of factors, such as demand fluctuations, industrial changes and unexpected macroeconomic issues, capacity management ensures that a company is agile enough to meet constantly changing expectations in a cost-effective manner. On the other hand, entities which fail to manage their capacity effectively may encounter decreased revenues, customer dissatisfaction, diminished market share and unattended orders.

In addition, capacity expansion is concerned with planning resources to meet the increasing business demands. Some of the strategies to increase the capacity in line with steady growth of market demand are capacity lead strategy, capacity lag strategy, average capacity strategy and incremental expansion strategy. The chapter also describes the concept of facility layout planning. In order to achieve efficient and effective manufacturing activities, facility layout should be given special attention. It deals with the structuring of factory space, equipment, materials, workstations and personnel so as to ensure a smooth and steady flow of production operations.

7.2 CAPACITY EXPANSION STRATEGIES

As we know, capacity planning is related to the concept of determination of capacity required by a business organisation in order to tackle changing demands for its products and services in the market. Capacity relates to the maximum amount of job/production work a company is capable of undertaking and completing during a given period of time due to constraints such as material handling, personnel, equipment and machinery quality. Capacity planning is essential for eliminating discrepancies between capacity of a business entity and customer demands. Such

discrepancies may lead to inefficiencies either on account of unfulfilled customers or under-utilised resources.

Capacity expansion deals with increasing the capacity of a business to meet rising demands of products and services. Capacity in terms of labour, infrastructure facilities and equipment needs to be scaled to increase the business production output. Capacity expansion decisions should take into account various factors, such as future demand, likelihood of technological obsolescence, future input prices, probability of capacity expansion by competitors, future industry capacity market share. Capacity can be increased by introducing new materials, equipment and techniques; by increasing the number of machines or workers; by purchasing additional manufacturing facilities; etc. Some of the most crucial decisions to be made are deciding about how to increase and when to increase the capacity in relation to the steady growth of demand. The common strategies used for capacity measurement and planning are shown in Figure 1:

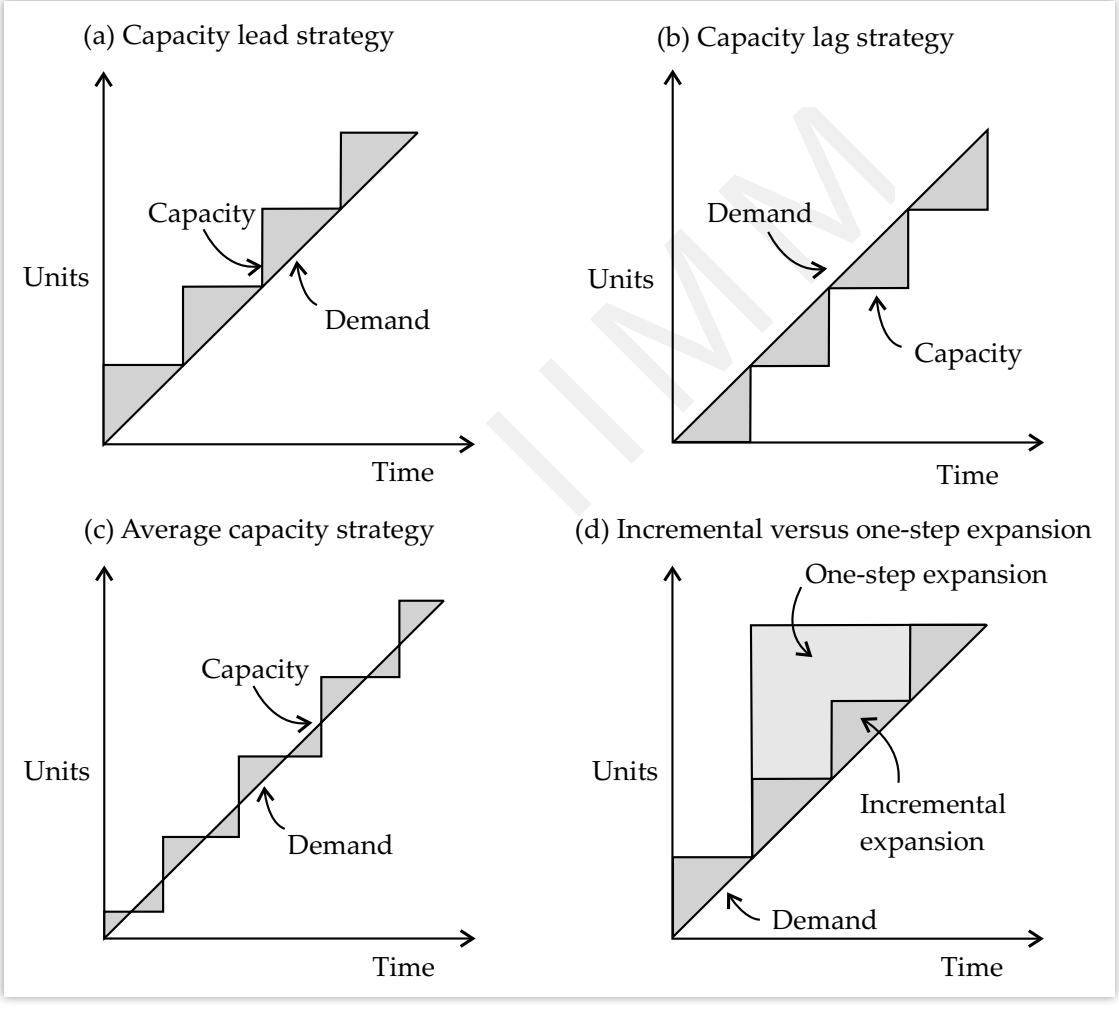

FIGURE 1: Strategies for Capacity Measurement and Planning

Let us discuss these strategies in detail in the following sections.

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7.2.1 CAPACITY LEAD STRATEGY

In this strategy, capacity is added even before the occurrence of the actual demand. This strategy is exercised by the organisation in order to level up the production at a manufacturing plant, especially when the orders are not piling up. Organisations give preference to this approach as it minimises risks. For every organisation, customer satisfaction stands over and above everything. No organisation would want to lose the confidence of the customer by failing to meet the delivery dates because of the lack of capacity. An organisation takes appropriate measures to increase its capacity when it anticipates prospects of growth. This is done to gain a firm stand in the rapidly expanding market and to lure customers from other competitors, who may have capacity constraints. This is also known as the aggressive strategy.

The aggressive strategy also provides organisations with a competitive advantage. For instance, in the rainy season, umbrella manufacturers increase the production of umbrellas. They increase the capacity according to the anticipated demand. Apart from the benefits listed above, this strategy has some limitations as well. If the demand does not turn up as anticipated, it may cause huge losses to the organisation in terms of the capital invested in the production process. The lack of demand for the products, produced in large numbers, may compel organisations to sell them at lower prices.

7.2.2 CAPACITY LAG STRATEGY

After an increase in the product demand has been documented in the market, capacity is expanded accordingly. This is also known as the moderate strategy. Here, the managers are confident enough that they shall be able to market/sell at least a major portion of the additional output produced.

Capacity lag strategy is considered as the reverse of the lead capacity strategy. In this case, the organisation will not level up the capacity until there is a demand from the market. Though the use of this strategy may not guarantee success, it offers some advantages, for instance, it reduces risks up to a certain level by saving the undue investment in the capital assets at low demand levels. In addition, the organisation will gain profitability as compared to others, who invested in capacity enhancement. This strategy may lose customers in the process, but produces a higher return on investment.

7.2.3 AVERAGE CAPACITY STRATEGY

Under this strategy of capacity expansion, the capacity is increased with a view to coincide with average expected market demand. This is also known as the moderate strategy. Here, the business managers are confident enough that they will be able to market/sell at least a major portion of the additional output produced. The average demand is matched with the capacity of production and facilities.

7.2.4 INCREMENTAL VS. ONE-STEP EXPANSION

Under incremental strategy of capacity expansion, capacity is increased in one large step or incrementally over the period of process. This strategy is costlier, but less risky for managers. When the maximum capacity is about to be reached, additional capacity is added in small increments. For instance, a factory production plant may add 20 drilling machines when its capacity reaches 80 percent.

Here, it can be considered that outsourcing of operations is an effective alternative to expand the capacity wherein the risk of meeting demand uncertainty is borne by the outsourcing supplier.

Self Assessment Questions

1. Under _____ strategy, capacity is increased with a view to coincide with average expected market demand.
2. Capacity planning is essential for eliminating discrepancies between capacity of a business entity and customer demands. (True/False)

7.3 CAPACITY MANAGEMENT

Operations managers are always involved in taking the responsibility of planning and management of capacity of the organisation. Capacity management has bearing on all other operation planning aspects. Capacity management attempts to sync the capacity of the operating system with the demands placed on that system.

Capacity of a system is directly influenced by the resources needed to perform its functions. For example, a production system has the capacity to produce if it has the necessary equipment, raw materials, labour, etc. Therefore, the capacity of an operation can be understood as the highest level of an activity that the process can achieve under normal operating conditions in a given period of time.

Capacity management involves setting an effective operations capacity in order to respond to the market demands in aggregated terms. Operations managers need to adjust the operations capacity in medium-term and short-term range. Capacity in aggregated terms involves grouping of different products and services to get a wider perspective of demand and capacity.

There are two approaches to capacity management problems:

- The first approach attempts to plan the capacity required and then manipulate the capacity so that it matches with the changing demands placed on it. If insufficient capacity is provided, it will be possible to meet only some portion of demand, and, therefore, some customers might have to wait or go elsewhere. If too much capacity is provided, it may result in under-utilisation of resources.
- The second approach attempts to adjust the demand to match the available capacity. The demand might be increased through advertising, increased promotion, lower prices, etc., and this might help avoid under-utilisation of the available capacity. However, if sufficient capacity is not available, demand may be allowed to fall.

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The combination of these two approaches is considered to be the best practice and is often used by organisations. Operations managers always try to ensure that a forecast or given demand can be satisfied. Uncertainty of demand is the main concern for operations managers. Fixed and familiar demands are easily managed by operations managers. Fluctuating demands can also be managed considerably by forecasting the demand accurately. However, in the absence of accurate forecasting, complex capacity problems arise. Uncertainty of demand can be caused by:

- Uncertainty about the demand received
- Uncertainty about the resources required

7.3.1 CAPACITY MANAGEMENT STRATEGIES

There are two basic capacity management strategies which can be used to tackle the problem of uncertain and fluctuating demands. These strategies are discussed in the following subsections.

Provide for Efficient Adjustment or Variation of System Capacity

Normally, system capacity can be changed to a certain limit with very little manipulation and minimum delays. Capacity utilisation can be increased by providing more resources and/or ensuring the optimum utilisation of the available resources. Similarly, capacity utilisation can be decreased temporarily by the transfer of resources to other functions or reduction in the resources at hand or the input rate of the resources consumed.

Strategies of varying system capacity are widely applied in supermarkets to accommodate fluctuating demand levels. In periods of low demand in supermarket, many resources such as workers can be transferred to other functions such as re-stocking shelves. During periods of increased demand, staff resources can be transferred from other functions to production/retail for more intensive utilisation of resources.

This strategy can also be applied in manufacture systems. In periods of low demand, manufacturing units can go for rectification or service work, while peak demand periods might be accommodated by a temporary increase in the resource levels through overtime working and more intensive use of equipment. During high demand periods, system capacity can also be increased by subcontracting of work.

Organisations dealing with transport services are best suited to use this strategy of capacity management. In transport services, systems maintenance and service work might be scheduled for periods of low demand, and overtime might be employed during the periods of high demand.

Eliminating or Reducing The Need for Adjustments in Capacity

In many cases, it might not be possible to provide for temporary changes in the system capacity at a very short notice. This is especially true for an organisation which employs large quantities of a large variety of resources. Complex process plants, which normally work twenty-four hours, offer little scope for capacity adjustments

to meet temporary demand increases. In addition, when demand is reduced, it leads to the under-utilisation of resources. Moreover, organisations where skilled labour is used have very little scope for making temporary capacity adjustments.

In these cases, the strategy of eliminating or reducing the need for adjustments in system capacity is more desirable. This type of strategy has the provision of keeping excess capacity and, therefore, the probable occurrence of considerable under-utilisation of resources might be there to increase the probability of being able to meet high or even maximum demand.

Such strategy is very much logical where customer service is of paramount importance and the possibility of adjusting temporary increases in capacity is minimum. Emergency ambulance service is a good example of such strategy. Manufacturing units, which produce goods and services that are subject to seasonal demand fluctuations such as manufacture of Christmas cards and fireworks can be managed through this strategy.

In cases where excess capacities are not sufficient to meet maximum demand, either customers will be lost or they may wait in queue until the demand levels fall. Some characteristics of the strategy of reducing the need for adjustments in system capacity are listed as follows:

- Provision of inventories of goods for smooth adherence to changing demands
- Use of relatively stable resource levels
- Optimum utilisation of resources
- Customers to be provided with goods and services with minimum delay
- Resources cannot be readily used for other purposes

Self Assessment Questions

3. Uncertainty of demand is the main concern for operations managers. (True/ False)
4. The two capacity management strategies include providing for adjustment or variation of system capacity and _____ the need for adjustments in capacity.

7.4 FACILITY LAYOUT PLANNING

Facility layout and design forms an essential part of an organisation's overall business strategy and is required for increasing the effectiveness of production as well as meeting employees' needs. Facility layout or plant layout refers to the arrangement of physical facilities, equipment, machinery and inventories in a factory or plant. An ideal layout ensures a continuous flow of production leading to maximum productivity and minimum costs. It is the act of planning an optimum structural design for interactions among personnel, operating machines, materials, storage space and other support services.

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Figure 2 shows an image of the facility layout in a manufacturing sector organisation:

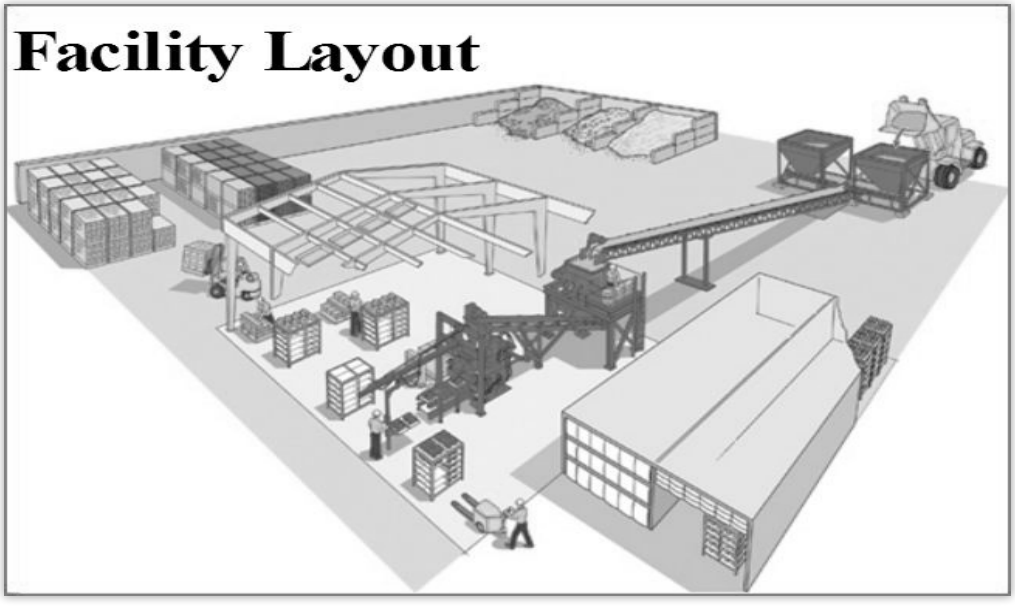

FIGURE 2: Facility Layout in a Manufacturing Sector Organisation

Certain principles to be kept in mind while designing facility layout and design are flexibility to permit modifications, minimum travelling time between workstations, minimum investment capitalisation costs, safety and use of operations, ease and satisfaction in performance of operators' functions, optimum utilisation of space, sequence of operations to be followed in design, and integration of all processes.

The better the facility layout is designed, the better is the efficiency and ambience of the workplace. It increases the efficiency of human resources, reduces the number of factory accidents, improves employee morale and productivity, and reduces overall manufacturing costs. Every organisation must pay attention to its facility layout in order to have an efficient and effective production unit.

Facility layout covers various aspects including available space for the plant, design of the product and the plant, safety of users and workers, etc. Effective facility planning ensures smooth and unidirectional flow of production, reduced operations costs and better working conditions. By carefully planning the facility layout, an organisation can achieve long-term benefits in its manufacturing, production and distribution activities. Facility layout planning essentially focusses on the following issues:

- It ensures easy routing of information and jobs in production processes.
- It helps in the reduction in material handling efforts, optimises storage and ensures efficient utilisation of machinery/equipment requirements.
- As each machine is capable of producing varied quantities of a number of products, good facility planning assesses the suitability of the product mix to be produced according to the requirements of market and layout.

- The layout should be designed in such a manner as to meet variable demands in cases of peak seasons or seasonal variations.
- Proper capacity planning helps take care of the increase in the product demand in the long-run. In such cases, the whole facility including machinery and equipment must be such that it can be appropriately increased by adding additional space.
- It ensures minimum traffic or congestion in the movement of machinery, workers, supervisors and jobs to meet safety standards.
- The layout should be capable of handling changes in technology and in the process of manufacturing of goods or delivery of services.
- It considers a complete layout of office building, shop floor and the whole property to achieve efficient manufacturing operations of goods and services.

The choice of facility layout is determined depending upon the process of production. The two major types of facility layout are the product-oriented facility layout (also called the line layout) and the process-oriented facility layout (also called the functional layout).

Following sections discuss various types of facility layouts.

7.4.1 PROCESS LAYOUT DESIGN

In this type of facility layout, machines are placed on the basis of their functions and how different materials move to and through them in the factory. The machines executing similar operations are grouped together. It is also known as the functional layout because materials and machinery are grouped together depending upon their functions. For instance, machines performing boring operations are placed in the boring department and machines performing drilling operations are placed in the drilling department.

In this type of layout, process is given more importance as compared to the product. During the production process, a product is moved from one department to another where similar types of machines are grouped together.

In the product layout, following points should be kept in mind while grouping machines:

- There should be shorter distance among departments.
- There should be proper inspection of machines and operations.
- The principle of sequence of operations should be followed while grouping machines in their respective departments.

Following are the advantages of the process layout design:

- It does not interrupt the production flow due to machine breakdowns.
- It ensures optimum utilisation of equipment.
- It requires minimum investments in machines.

Notes

- It enhances the flexibility of an organisation by producing different products without changing the arrangement of machines.
- It facilitates specialised supervision.

Disadvantages of the process layout design are as follows:

- It requires a large floor area, which can be expensive for an organisation.
- It requires prolonged processing time.
- It requires back-tracking and long-routing of processes, which increases material-handling cost.

7.4.2 SERVICE LAYOUT DESIGN

While the facility layout in the manufacturing environment results in the optimisation of production results, the facility layout in the service industry results in customer satisfaction. The techniques of facility layout and conventional concepts can be applied to all businesses including services. For example, the process-oriented facility layout can be used for hospital services and the line-balancing layout with sequential assembly can be used for restaurants adopting self-service. Some of the requirements of a good service layout design include easy entrance to facilities, well organised walkaways and parking lots, and easily accessible areas.

The service layout design of an organisation should be determined depending upon the services needed by customers and the degree of customer contact. In processes involving substantial customer contact, customers generally look for how close a particular service facility is. The location of the service facility has a great impact on business sales and customer satisfaction levels.

Unlike manufacturing operations, service operations are more customer-oriented. As compared to the manufacturing sector where activity planning and workload forecasts are more accurate, the service sector environment is characterised by seasonal demand of diverse nature with varying execution times. The services are intangible in nature and inventory management cannot be used for adjusting demand and production levels.

Hence, following points must be considered for deciding about the service facility layout design:

- The company has to perform or deliver services to customers according to their specific requirements.
- The layout has to be developed keeping in mind customer satisfaction rather than focussing on operations.
- Those areas which are in direct connection with customers are required to be made more appealing and attractive.
- The creation of work flow is based on the presence of the customer.

7.4.3 PRODUCT LAYOUT DESIGN

This signifies a layout where machines are arranged in a sequence required in the production process. A product layout is also known as the straight-line layout. In this layout, materials pass through each machine as sequenced in the process. In this layout, each stage of operation is carried out by a specialist machine. Therefore, the product layout requires a larger number of machines as compared to the process layout. The product layout is generally implemented by paper and sugar industries. In this type of layout, special-purpose machines are used for production. Under this type of layout, materials and machinery are placed on the basis of the path of products. They are arranged in one line in the sequential order in which they are used while manufacturing the product.

An organisation using the product layout design should consider following points while grouping different machines:

- Two machines should not be coinciding with each other.
- All the machines and equipment should be arranged in a sequence as required in operations.

Following are the advantages of the product layout design:

- It reduces manufacturing time.
- It requires minimum inspection.
- It requires minimum material-handling cost.
- It reduces bottlenecks in the production process.
- It provides a better control of the production process.

However, following are the disadvantages of the product layout design:

- It requires the execution of individual incentive schemes, which can be difficult for an organisation.
- It lacks specialised supervision.
- It provides lesser flexibility.
- It requires huge investments for arranging and grouping different machines.

Self Assessment Questions

5. Facility layout means the _____ of physical facilities, equipment, machinery and inventories in a factory or plant.
6. Under which layout design are materials and machinery placed on the basis of the path of products?
   a. Process Layout design
   b. Service Layout design
   c. Product Layout design
   d. None of these

Notes

7.5 LINE LOADING AND LINE BALANCING

Line balancing is used in case of assembly lines of product facility layout. An assembly line is a progressive line connected with several material handling machines or devices. The job works start from the beginning of the line and end with finished products. The raw material begins from the starting point of the line, moves through various workstations as work-in-progress and ends at the last point of the line as a finished product. Line balancing is the process of assigning all the tasks over a series of workstations. The objective of line balancing is to divide the network amongst several sub-stations and allocating operations to each sub-station without disturbing the precedence relationships and without going beyond the cycle time. It means that the operations should be so divided that the sum of times taken for operations of each work station should not exceed the total cycle time. Moreover, the tasks are assigned over the assembly line in such a manner that the unassigned time across all job work stations is minimised. The precedence relationship refers to the relationship among tasks that exists because of the sequence of product design and process technologies.

There are two methods of line balancing:

- **Heuristic methods:** The following steps are followed under the heuristic line balancing:
  1. Explaining the sequential relationship among tasks based on precedence relationship.
  2. Determining the cycle time required.
  3. Assessing minimum number of workstations necessary to fulfil the cycle time required. The formula used is N = Sum of all task times ÷ Cycle time.
  4. Assigning the tasks to the work stations, one at a time, until the sum of all task times is less than or equal to the required cycle time, i.e., until the required cycle time is reached.
  5. The precedence relationship must be maintained.
  6. Determining efficiency of line balancing. The formula used is E = Sum of all task times ÷ (No of workstations × Cycle time).
- **Computerised line balancing:** Heuristic methods of line balancing become difficult when the number of tasks assigned to workstations increases. In such cases, computerised software solutions are more viable for handling even more than hundred tasks in a line.

Line loading is the process of assigning jobs to various work centres and to their corresponding devices/machines at each work centre. It is easier to process a job on only one machine. However, the assignment process gets difficult when a job is to be loaded on multiple machines and wok centres and there are a number of jobs to be processed. In such cases, jobs should be assigned to the work centres in such a manner that processing time, set-up time, idle time and throughput time are minimised.

There are two methods of line loading to work centres:

- **Infinite loading:** Under this method, jobs are loaded to the work stations without giving consideration to the capacity of the work station. Jobs are assigned to the work stations based on some priority rules. In these cases, long queues may occur unless there is excessive capacity.
- **Finite loading:** Under this method, the capacity of each work station is considered and compared with the processing time so that the process time is not more than the capacity levels. This method estimates the start and stop times of every job at each workstation.

SELF ASSESSMENT QUESTIONS

7. _____ of line balancing become difficult when the number of tasks assigned to workstations increases.
8. Under infinite loading, jobs are loaded to work stations without giving consideration to the capacity of work stations. (True/False)

ACTIVITY

Search on the Internet about the practical usage of capacity expansion techniques by companies. Quote an example each of capacity lead strategy, capacity lag strategy, average capacity strategy and incremental vs. one-step expansion strategy as applied by different companies.

7.6 SUMMARY

- Capacity expansion deals with increasing the capacity of business to meet rising demands of products and services. Capacity in terms of labour, infrastructure facilities and equipment needs to be scaled to increase the business production output.
- The common strategies used for capacity measurement and planning are capacity lead strategy, capacity lag strategy, average capacity strategy and incremental vs. one-step expansion.
- Operations managers are always involved in taking the responsibility of planning and management of capacity of the organisation. Capacity management has bearing on all other operation planning aspects. Capacity management attempts to sync the capacity of the operating system with the demand placed on that system.
- Facility layout or plant layout refers to the arrangement of physical facilities, equipment, machinery and inventories in a factory or plant. An ideal layout ensures a continuous flow of production leading to maximum productivity and minimum costs.
- The better the facilities layout is designed, the better is the efficiency and ambience of the workplace. It increases the efficiency of human resources, reduces the number of factory accidents, improves employee morale and productivity, and reduces overall manufacturing costs.

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- Under process layout design, machines are placed on the basis of what they perform and how different materials move to them in the factory. The machines executing similar operations are grouped together.
- The service layout design of an organisation should be determined depending upon the service needed by customers and the degree of customer contact. In processes involving substantial customer contact, customers generally look for how close a particular service facility is.
- Under product layout design, materials and machinery are placed on the basis of the path of products. They are arranged in one line in the sequential order in which they are used in manufacturing the product.
- Line balancing is the process of assigning all the tasks over a series of workstations. The objective of line balancing is to divide the network amongst several substations and allocating operations to each substation without disturbing the precedence relationships and without going beyond the cycle time.
- Line loading is the process of assigning jobs to various work centres and to their corresponding devices/machines at each work centre. It is easier to process a job on only one machine.

7.7 KEY WORDS

- **Cycle time:** The total time required from the beginning till the end of the process of production of making a product or delivering a service.
- **Heuristic:** A method employing problem-solving techniques or practical tools of self-discovery to arrive at a rational result to meet a pre-specified goal.
- **Strategy:** The plans of action proposed and defined for attaining long-term objectives of an organisation.
- **Facilities:** These include places, provisions, equipment or other amenities used for the purpose of running business operations of producing goods or delivering services.

7.8 CASE STUDY: RATIONALISING PLANT LAYOUT IN AUTOMOBILE INDUSTRY

Simmens Auto Ltd. is a growing automobile company which manufactures cars and their accessories. As the company is experiencing healthy growth in product revenues, it is deliberately considering the purchase of new process machinery. For justification of the proposed investment, Simmens has accorded the plant manager with the responsibility of machinery selection and analysis of area where it would best fit in the production process to maximise the benefits.

The company is seriously concerned about the plant layout this time because there were instances in the past when new machines were simply installed at convenient spaces rather than the most effective locations. Such practices failed to reap the complete benefits which could otherwise accrue from the purchase of equipment. As more and more machinery was installed, not only did the flow of operations become poor, but also excessive costs were added towards material handling and overheads.

To prevent re-occurrence of such inefficiencies, Simmens Auto Ltd. is constantly concerned about the improvement of its plant layout at each new machinery investment. On the current purchase of new process machinery, the plant manager performed following actions to assess rationality of facility layout:

- Evaluation of existing operations to identify opportunities and weaknesses for improvement
- Identification of critical details of process and product information
- Clubbing together categories or subcategories of items with similar processing requirements and materials
- Obtaining knowledge of the workflow as production operations move from one process to the other
- Preparing a chart of sequence of activities including receipt, movement through different machines, and shipping
- Routing the process of production and installing machinery at the most efficient places to match suitability of product stage with functions performed by equipment.

Thus, the company followed the policy to refresh its plant layout after every significant acquisition of machinery or equipment. The development of plant-wide movements and careful placement of workstations helps the company maximise its production efficiency.

QUESTIONS

1. What do you understand by facility layout?

   (**Hint:** An arrangement of facilities such as equipment and machinery within the factory or plant to achieve steady flow of production ensuring maximum productivity)

2. What are the expected benefits of designing a plant layout with effective consideration?

   (**Hint:** Easy routing of jobs in production processes, reduction in material-handling costs, most efficient utilisation of machinery, minimum congestion in the movement of machinery, materials and workers, etc.)

7.9 EXERCISE

1. What is capacity expansion? Explain the strategies which can be adopted by business entities for expanding their operations.
2. Explain in detail the concept of capacity management.
3. Briefly describe the meaning of line balancing and line loading.
4. Why is facility layout planning essential in an organisation?
5. What do you understand by process layout design and product layout design?

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7.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Capacity Expansion Strategies	1.	average capacity
	2.	True
Capacity Management	3.	True
	4.	eliminating
Facility Layout Planning	5.	arrangement
	6.	c. Product Layout design
Line Loading and Line Balancing	7.	Heuristic methods
	8.	True

7.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Kumar, S., & Suresh, N. (2009). *Operations Management*. New Delhi: New Age International.
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CHAPTER 8

Managing Quality in Operations Management

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Discuss the relationship between quality and operations management
- Explain the concept of costs of quality
- Discuss the importance of quality leadership
- Explain the ISO 9000:2015 Quality Management System
- Describe the major quality tools
- Explain the Quality Function Deployment (QFD) process and the Kano Model

8.1 INTRODUCTION

In the previous chapter, you have studied about the strategies for capacity expansion and capacity management. The chapter also introduced the concepts of facility layout planning.

The field of operations management is very deeply connected to the practice of quality management. Organisations need to ensure that their operations are streamlined and lead to the generation of outputs which adhere to the quality specifications as specified by the industry or the regulatory authorities. They must also ensure that the customers' requirements are somehow translated into product specifications. Therefore, to achieve quality, organisations need to adopt quality management in all its processes.

When an organisation ignores quality maintenance, it may incur costs known as the cost of quality, which is divided into three types known as cost of prevention, cost of inspection and cost of failure. An organisation needs certain leaders to lead the quality movement and they are called quality leaders. These leaders help in developing a culture of leadership in the organisation.

Various national and international organisations have developed Quality Management Systems (QMSs). One such widely used QMS is the ISO 9000:2015 system. Organisations also use an array of tools for maintaining, monitoring and improving quality of products and processes such as the activity network diagram and control charts.

In this chapter, you will study about the importance of maintaining quality in an organisation's operations. The chapter also discusses the different costs of quality, Quality Leadership, ISO 9000:2015 QMS, quality tools, Quality Function Deployment (QFD) and the Kano Model.

8.2 RELATION BETWEEN QUALITY AND OPERATIONS MANAGEMENT

In manufacturing and services, quality refers to a measure of excellence or a state in which the product or service is free from any defects, deficiencies and variations. An organisation, whether it is engaged in manufacturing or in providing services, can manage quality of its products or services by optimising its operations. Operations

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can be managed to ensure that defects do not occur. Managing quality requires focussing on how the process is leading to the creation of defects.

To produce products and deliver services that are free from any defects requires a great deal of effort from all the members of an organisation. The cycle of maintaining quality starts with the product design. Quality also depends upon the production process and must also reflect in the customer service. Maintaining quality requires time and commitment. In the absence of the required level of quality, business may lose its sales and revenues. When quality product is not delivered to the client as promised or claimed by the organisation, it may result in product liability claims.

There has been a tremendous change in the way quality was viewed traditionally and how it is viewed now. The traditional focus was related to motivating employees and measuring the workers' performance. The contemporary focus is related to processes, how the process would be carried out, how the barriers can be removed and how a process can be measured.

Quality is directly related to operations and operations management. The performance of a process is measured with the help of parameters such as quality of product or service as per specifications of the customer, response time between the customer request and the delivery of the product or service, dependability or the degree of consistency with which the product/service is delivered to the customer, flexibility or adaptability to market conditions, and cost of planning, delivery and improvement of product/service.

When the quality of a product or service is improved, it increases dependability, customer satisfaction and reduces cost. Improving quality requires changing the culture of an organisation.

Various quality tools and techniques such as TQM, Kaizen and Six Sigma have been devised to improve the quality of products and services. These techniques stress everyone's participation, customer focus, continual search for improvement and innovative methods.

Participation of employees starts from the participation of the line workers who are actually engaged in the production process. These are the persons who can best identify the areas that need improvement and execute the improvement program.

Continual improvement or Kaizen can be implemented by an organisation by using the PDCA cycle. PDCA cycle is also known as Deming's Wheel, as shown in Figure 1:

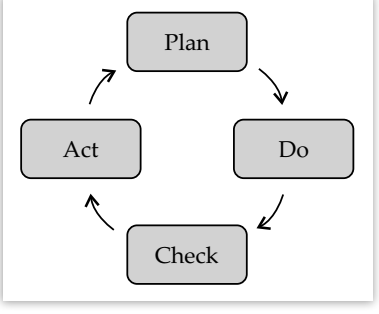

Figure 1: PDCA Cycle

In the plan phase of the PDCA cycle, the problem is identified and an improvement plan is prepared. In the Do phase, plans are executed and data is collected for study. In the Check phase, data so collected is analysed in order to understand the improvement or change required. In the last stage, improvement programs are implemented if the preliminary analysis shows that the improvement program would yield some definite results.

The PDCA cycle lays the foundation for the Six Sigma methodology of DMAIC (Define, Measure, Analyse, Improve, Control).

SELF ASSESSMENT QUESTIONS

1. Product A has 10 defects; Product B has 15 defects. Quality of Product A is better than the quality of Product B. (True/False)
2. Complete the following chain of events: Plan → _____ → Check → Act.

8.3 COST OF QUALITY

Maintaining quality in products and services is not a simple activity. It takes time, effort and the most important factor, cost. The cost of quality is wrongly understood as the amount spent on producing quality products and services. On the contrary, cost of quality is associated with the number and intensity of defects in the product/service and the costs incurred in providing the after-sales services. In case there are defects in the products, the organisation must rectify those defects and rework on its production process to ensure that the defects can be removed or minimised. All this increases the cost for the organisation and is called the cost of quality.

What you just studied is the most widely accepted explanation of the cost of quality. However, there are various quality gurus, such as Edward Demings, Joseph Juran and Genichi Taguchi who have defined quality in different ways. Some of the quality gurus equate quality cost with the cost incurred for achieving a desired level of quality while still others equate quality with the cost incurred to improve the poor quality of products. Rework on a product may involve retesting, resampling, rebuilding or reprocessing. Majority of the quality gurus agree that the cost of quality is related to the extra cost incurred by an organisation due to poor or bad quality of the product or service.

Organisations estimate the cost of quality in order to quantify the impact of the problems and to take effective measures. They can also identify opportunities for reducing their costs. One of the most important factors due to which it becomes essential to estimate the cost of quality is to find out the ways in which customer dissatisfaction can be reduced and the risk associated with the product saleability can be minimised.

Having understood the relevance of quality, organisations now develop tools to maintain and improve the quality of their products and services. This is necessary to survive in the competitive business environment. Organisations adopt a quality cost program to determine the cost of quality and its impact on the business. Incorporating a quality cost program helps an organisation control and minimise the costs related to waste, scrap and rework.

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Cost of quality is the sum total of three types of costs of quality, as shown in Figure 2:

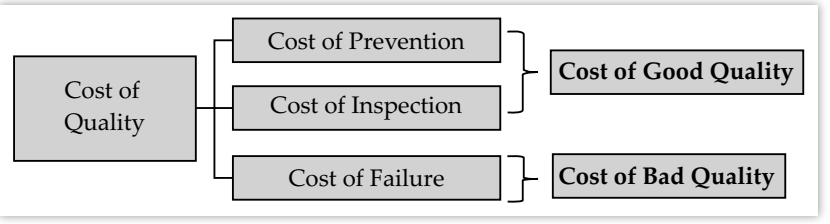

Figure 2: Cost of Quality

Let us now briefly discuss the various costs of quality in the upcoming sections.

8.3.1 COST OF PREVENTION

Costs of prevention refer to those costs that are incurred by an organisation to prevent or avoid error-free work or to avoid any quality problems. Prevention costs are planned expenses of an organisation, which it expends on activities which presumably lower the future occurrence of any defects. Organisations can safeguard their products from defects by incurring prevention costs. Defects occur when the product produced by the organisation does not meet the established quality standards.

An organisation spends prevention costs on the following activities:

- Formally developing and documenting the quality specifications
- Developing the designs of processes and products in such a way as to produce quality standards
- Evaluating new products and services in such a way as to ensure that they adhere to the quality standards
- Evaluating the capabilities of suppliers
- Preparing and implementing quality improvement programs
- Implementing one or more defects prevention techniques, such as statistical process control, quality circles, quality engineering and benchmarking

A few examples of prevention costs include system development costs, costs for quality engineering, quality training costs, costs incurred in statistical process control, etc.

8.3.2 COST OF INSPECTION

Inspection costs are those costs that an organisation incurs in ensuring whether the products or services of an organisation are compliant with the established standards. Inspection costs are those costs that are incurred by an organisation on the following activities:

- Testing materials received from suppliers
- Conducting product, process, and service audits
- Measuring equipment performance

- Engaging in inspections at the stage of processing and after the final product has been developed
- Conducting internal and external inspections to ensure that the quality of the products/services is at par with the established quality standards

8.3.3 COST OF FAILURE

Costs of failure refer to those costs that are incurred when a product does not conform to its design or performance specifications. Failure costs are incurred when defective products or services have been produced or have been delivered to the end users. Failure costs are broadly divided into two categories, namely internal failure costs and external failure costs.

Internal failure costs are those costs that are incurred after a product has been produced but before it is delivered to the end customer. These costs are related to the costs for identifying the causes of defects in the rejected products that are singled out during inspections. If the inspection activity is done in a strict and formal manner, there are better chances of catching defects in a product before it is delivered to the dealers, stockists and customers. Some examples of internal failure costs include costs of scrap, costs of spoilage, costs incurred on rework, costs of reinspection, costs of disposing defective products, costs of downtime due to quality problems, costs of analysing the causes of defects in the production, costs of debugging in case a product is a software, etc.

External failure costs are those costs that are incurred after defective product(s) have been delivered to a customer. After defective products reach end customers, the customers usually return the defective products to the dealers/company for repair or replacement. When an organisation receives such complaints regarding its products, it regards such failures as feedback and uses the same to eliminate the defects in its products or to improve its products. In case an organisation is providing services to its customers, it formalises a Service Level Agreement (SLA), which is a contract between the customer and the service provider and this defines the level of service that can be expected from the service provider. SLAs also define the level of commitment of the organisation against external failures. Some examples of external failure costs include costs of field servicing, costs of repairs and replacements, costs of handling complaints, costs of lost sales, loss of reputation, costs of product recalls, etc.

SELF ASSESSMENT QUESTIONS

3. The cost of quality is associated with the number and the intensity of _____ in the product/service.
4. Which two costs are considered as costs of good quality?

8.4 QUALITY LEADERSHIP

According to USA's National Center for Biotechnology Information (NCBI), an organisation cannot manage its quality in the absence of quality leadership. Quality depends heavily upon the type of organisational leaders and how they structure and

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direct an organisation. It also depends on how organisational leaders behave within an organisation. Quality leadership is indispensable for achieving effective quality management.

As per Deming, an organisation is a big unit and is made up of smaller units or parts. Quality leaders can be viewed as connectors who connect all different parts of the organisation. Quality leaders help in integrating and supporting different parts of the organisation and help in making the organisational system a sustainable entity.

In the absence of an understanding of the inter-relationships between different parts of an organisation, each part starts considering itself as a complete unit and builds up bureaucratic walls which make it difficult for other parts of the system to communicate with it. In such a condition, quality leaders need to collect data and analyse it and share with other members of the organisation who may need it. It is the responsibility of the quality leader to ensure that all the decisions of the organisation are based on fact and data. Quality leaders must help the organisational members understand that all the processes within the organisation are inter-related and the organisational productivity can be improved if the variations in various processes can be controlled and by understanding the real root cause of variations.

Customer satisfaction can be increased by making all the processes stable. For this, quality leaders should follow the PDCA cycle and make it an important part of the organisational culture and way of working. It is important for quality leaders to have a good understanding of human psychology because change and quality initiatives can only be achieved by human contributions. Ideally, quality leaders should value each individual's contribution and mould their behaviour in such a way that they understand the significance of collaborating and working as one unit or as a part of the system. Quality leaders help in building an organisational culture that is focussed on continuous improvement, delivering quality and gaining customer satisfaction.

In an organisation, quality leaders strive to achieve the following:

- Achieve a strategic alignment between the internal systems and the external environment
- Ensure a vision that is shared by all the organisational members
- Foster a culture that encourages innovation and creativity
- Develop a culture of teamwork
- Empower and motivate people
- Engage employees
- Develop a culture of trust and awareness
- Ensure a supportive work culture

According to Joseph Juran, quality leaders must lead the quality initiative from the front. According to Edwards Deming, a quality leader leads the organisational members daily, learns from them and with them. He/she also counsels and mentors organisation's employees and facilitates their efforts. A good-quality leader usually does not judge his team members. All the quality leaders possess certain attributes, such as self-motivation, honesty, high level of integrity, optimistic attitude, competency, charismatic personality, high level of confidence and a remarkable understanding of business.

SELF ASSESSMENT QUESTIONS

5. A quality leader must engage in organisational politics. (True/False)
6. Quality leaders help in building an organisational culture that is focussed on _____, delivering quality and gaining customer satisfaction.

8.5 ISO 9000:2015 QUALITY MANAGEMENT SYSTEM

A formal system which contains a thorough documentation of the processes, procedures and responsibilities for achieving the desired levels of quality is referred to as a Quality Management System (QMS). Organisations can develop their own quality management systems. However, there exist various domestic and international quality management systems that can be used by organisations to ensure management of quality. The International Organization for Standardization (ISO) has defined various quality standards. For example, ISO 9000:2015 is one of the most recognised and widely used QMS prepared by ISO.

Initially, QMSs came into being during the World War II. The characteristics of a QMS are:

- **Credibility:** QMSs are credible as the quality certifications are awarded only after conducting third-party audits. These audits ensure that an organisation's systems are well documented and followed.
- **Universality:** QMSs can be applied to a variety of businesses across industries.
- **Success:** It is an established fact that implementing QMSs results in continued improvement of the business operations.

Quality certification helps organisations in gaining trust and confidence of customers. Quality certification ensures that all systems and processes used by the certified organisation are not based on ad-hoc decisions. Certified organisations are confident that they will be able to deliver on the customer's expectations and maintain high quality as well. More than a million organisations across the globe have been ISO 9000:2015 certified.

ISO 9000:2015 certification ensures that the top management is involved in monitoring, controlling and improving quality.

It is beneficial for organisations to get an ISO 9000:2015 certification because of the following reasons:

- Better coordination among organisational members leads to reduction in internal costs.
- Better role clarity among organisational members as the different roles are defined clearly.
- Some organisations conduct their business only with quality-certified organisations which increase the scope of business.
- Organisation's employees can communicate among themselves and with other stakeholders in a better manner.
- Organisational risks can be identified in a better way.

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- Organisational members are better able to understand the internal processes of the organisation which leads to a synergistic effect.
- Quality management systems lead to increased employee engagement.
- Organisations using a QMS have a defined system or steps that they must take in case some problems arise.
- Quality-certified organisations have well-defined processes.
- Quality-certified organisations comply with statutory requirements.

Self Assessment Questions

7. List any two characteristics of a QMS.
8. Using ISO 9000:2015 system, the _____ can be identified in a better way.

Activity

List three most widely used Quality Management certifications in India.

8.6 QUALITY TOOLS

For the past three-four decades, the focus on maintaining and improving the quality of products, services and processes has increased manifold. Quality control and improvement with respect to products is concerned with identifying defects, validating project deliverables, etc. On the other hand, process quality control and improvement focus on process capabilities. Process quality control and improvement serve as the starting points for quality assurance activities.

Various organisations use different types of quality control and improvement tools and techniques, such as cause and effect diagrams, control charts, flow-charting, histogram, stratification, pareto chart and pareto analysis, bench-marking, run charts, scatter diagrams, statistical sampling, inspection, Six Sigma, Statistical Quality Control (SQC) and acceptance sampling.

An explanation of all these methods is beyond the scope of this book. However, some of the most widely used tools and techniques for quality control and improvement are shown in Figure 3:

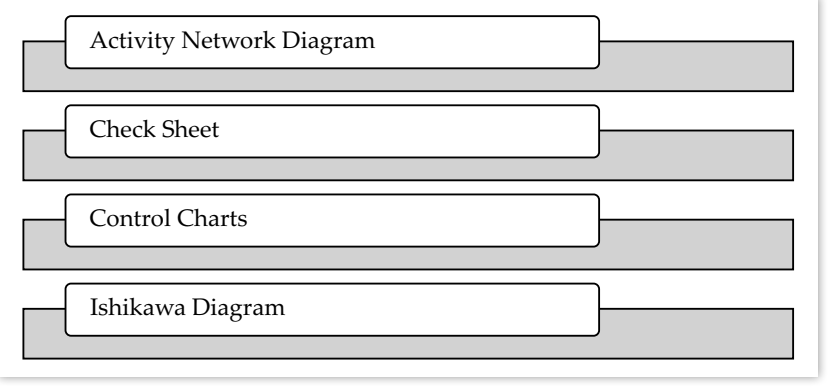

Figure 3: Tools for Quality Control

8.6.1 ACTIVITY NETWORK DIAGRAM

An activity network diagram is used to schedule the activities and subactivities in a pre-determined order. After the network of activities has been drawn, a critical path can be traced. By managing the critical path, quality problems can be solved. Determining a critical path is an essential part of project scheduling and monitoring techniques, such as Project Evaluation and Review Technique (PERT) and Critical Path Method (CPM). The critical path helps project managers in finding the most efficient path.

An activity network diagram is created by using two components, circles or boxes and unidirectional arrows. The activities are denoted by either numbers or letters or a combination of both. The activities are marked on the inside of the boxes/ circles. The activities which have no predecessor are placed on the extreme left-hand side. The successors to each activity are placed on their immediate right-hand side and are connected by a unidirectional arrow. This is done for all the activities and subactivities in a project. An activity network diagram covers all the activities. Figure 4 shows a sample network diagram:

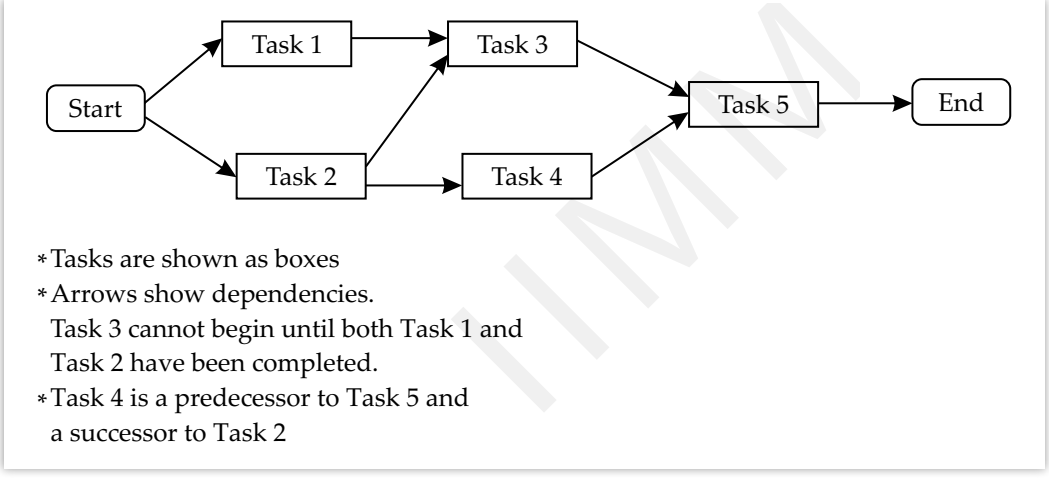

Figure 4: An Activity Network Diagram

8.6.2 CHECK SHEET

Check sheet is a method used to collect data. Organisations use check sheets to collect data to identify the quality issues and the reasons for defects in products and the strategies to improve the quality of products. For example, a refrigerator manufacturer has been receiving complaints in a particular model of fridge. In such a case, the manufacturer needs to find out the reasons for the presence of technical problems in the fridge. For this, the manufacturer requires collecting data related to the production process, materials used, the quality check procedures adopted, etc. After the data has been collected, the organisation needs to analyse the data to discover the areas from which the defects are generated. Check sheet may be prepared in various forms. However, most commonly, the check sheets appear in the tabular form. In this form, the number of occurrences of various phenomena is recorded in the form of frequency.

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A sample check sheet is shown in Figure 5:

Motor Assembly Check Sheet

Name of Data Recorder: Lester B. Rapp

Location: Rochester, New York

Data Collection Dates: 1/17 - 1/23

Defect Types of Event Occurrences	Dates							TOTAL
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	
Supplied parts rusted		9	5	4	2			20
Misaligned weld			3			2		5
Improper test procedure								0
Wrong part issued		1		2				3
Film on parts								0
Voids in casting				4	2			6
Incorrect dimensions						2		2
Adhesive failure								0
Masking insufficient					1			1
Spray failure			5					5
TOTAL		10	13	10	5	4		

FIGURE 5: A Sample Check Sheet

8.6.3 CONTROL CHARTS

Control charts are also known as Shewhart charts and Process-Behaviour charts. Control charts are statistical tools that are used to control quality. These charts are used to monitor and analyse processes, analyse process variables, determine process capabilities and monitor the difference between the actual and target performances. It is also used to identify the causes of deviation in a process. It also helps in determining the predictability of a process.

A sample control chart is shown in Figure 6:

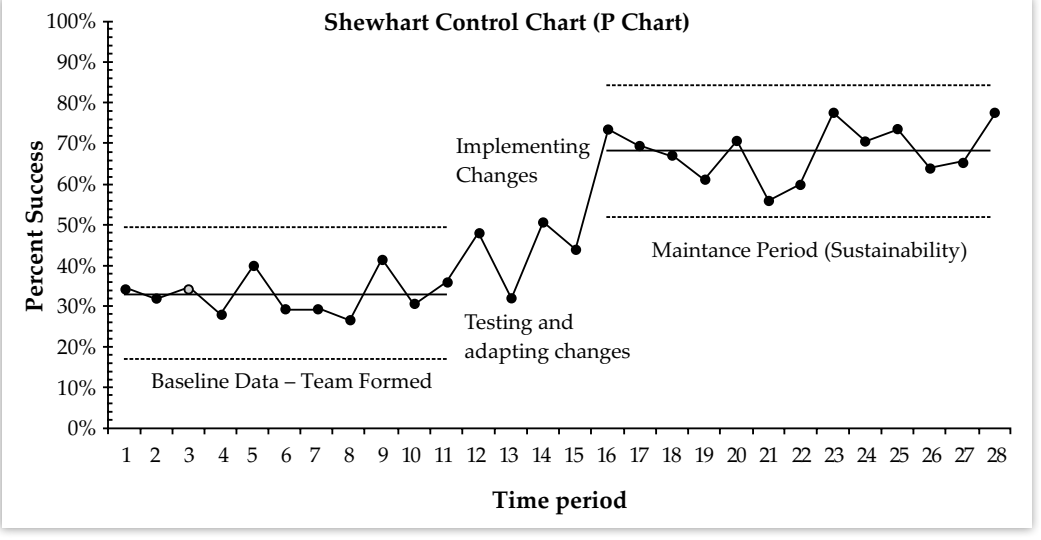

FIGURE 6: A Sample Control Chart

Source: *https://www.healthcatalyst.com/insights/control-charts-healthcare-drive-4-improvement-basics*

In a control chart, the vertical (Y-) axis represents the process value and the horizontal (X-) axis represents the time. Control charts are helpful in studying the variations in the processes. In the given figure, the solid (non-dotted) line represents the average or mean value, whereas, the dotted lines represent the upper and lower control limits. A process is said to be out of control when one reading lies outside the control limits or when nine successive readings appear on the same side of the average line. A control chart can be used by a steel sheet manufacturer to track the dimensions of the sheets that are being produced. Also, hospitals can use control charts to visualise their process variations. At times, when changes are made to processes, control charts can help determine when the changes lead to improvement. Most importantly, control charts are also used to detect product values and defect rates.

8.6.4 ISHIKAWA DIAGRAM

Ishikawa diagram or the Fish Bone diagram or the Cause and Effect diagram was developed by Kaoru Ishikawa. This diagram appears similar to the skeleton of a fish; therefore, it is also named as the Fish Bone diagram. For each incident, a Fish Bone diagram is drawn. In a Fish Bone diagram, the head of the fish must face towards right. After the head, the central spine of the diagram is drawn and all the major causes of the incident are represented. All the bones emanating from the spine represent causes and the spikes emanating from each bone represent subcauses.

A sample Fish Bone diagram is shown in Figure 7:

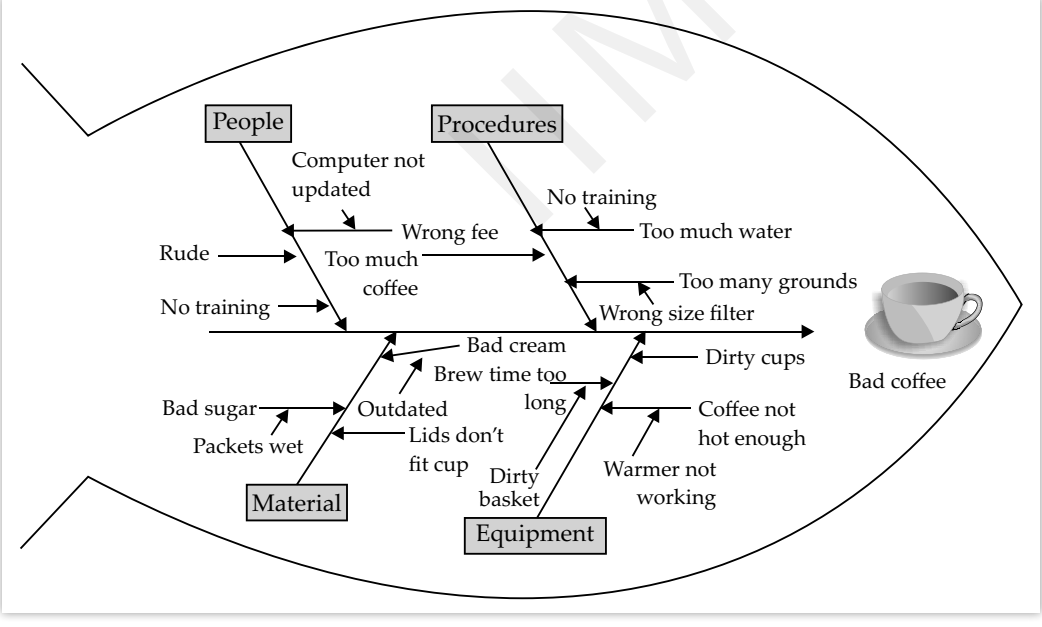

FIGURE 7: Ishikawa Diagram

Source: *https://www.pinterest.com/pin/93097917276592472/*

SELF ASSESSMENT QUESTIONS

9. In an activity network diagram, activities which have no predecessor are placed on the extreme _____-hand side.
10. What is the other name for the Ishikawa diagram?

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8.7 QUALITY FUNCTION DEPLOYMENT (QFD)

Quality Function Deployment (QFD) was developed by Yoji Akao, a Japanese, in 1966. It is a quality control and improvement process and is used to change the voice of the customer into engineering characteristics. The QFD process requires the help of the House of Quality tool. House of Quality helps in transforming the qualitative user requirements into quantitative parameters. The House of Quality works by categorising the desires of the customer, ranking them according to their importance, and listing out the engineering characteristics for them. In this manner, the priorities for the system requirements are also decided. The process of QFD using the House of Quality is shown in Figure 8:

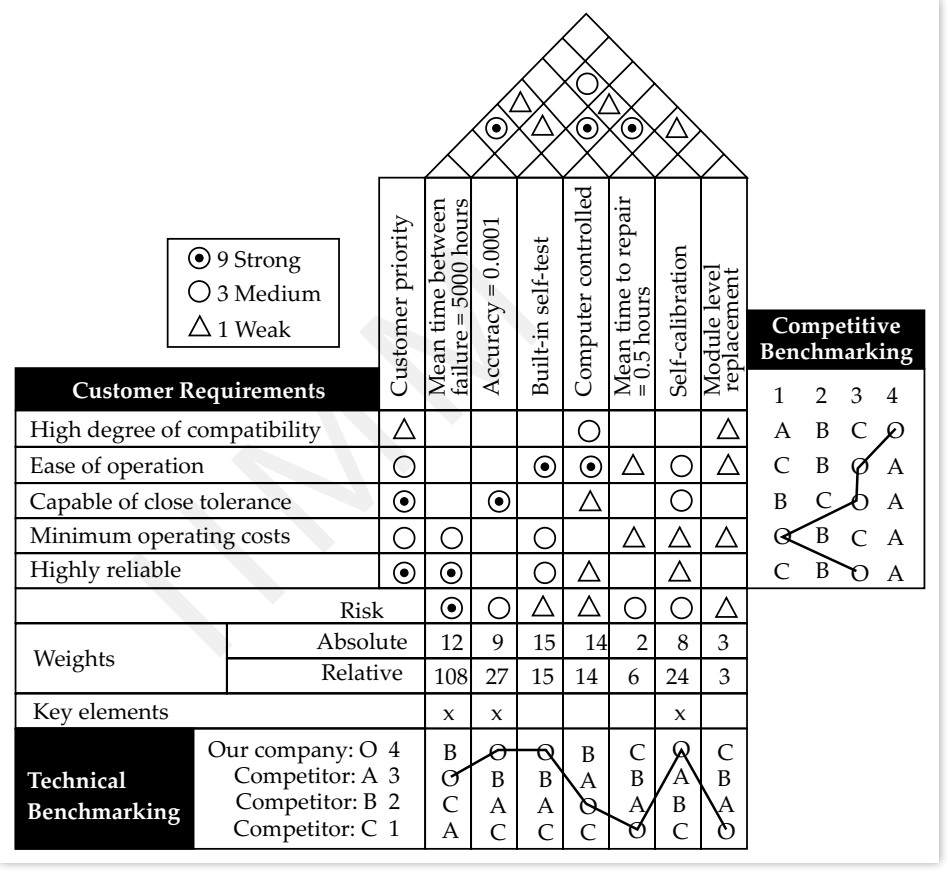

Figure 8: QFD using HOQ

Customers perceive quality or value of a product in qualitative terms. They want to derive maximum value for a minimum price. Therefore, in order to determine the drivers of customer perception, organisations collect data regarding customer wants and preferences called the Voice of the Customer. Organisations try to incorporate the Voice of the Customer into the product and service design by using the Quality Function Deployment process.

8.7.1 KANO MODEL

Kano model was developed by Prof. Noriaki Kano in the 1980s. This model helps in understanding the customer requirements for developing products and achieving customer satisfaction.

Figure 9 presents the Kano model as follows:

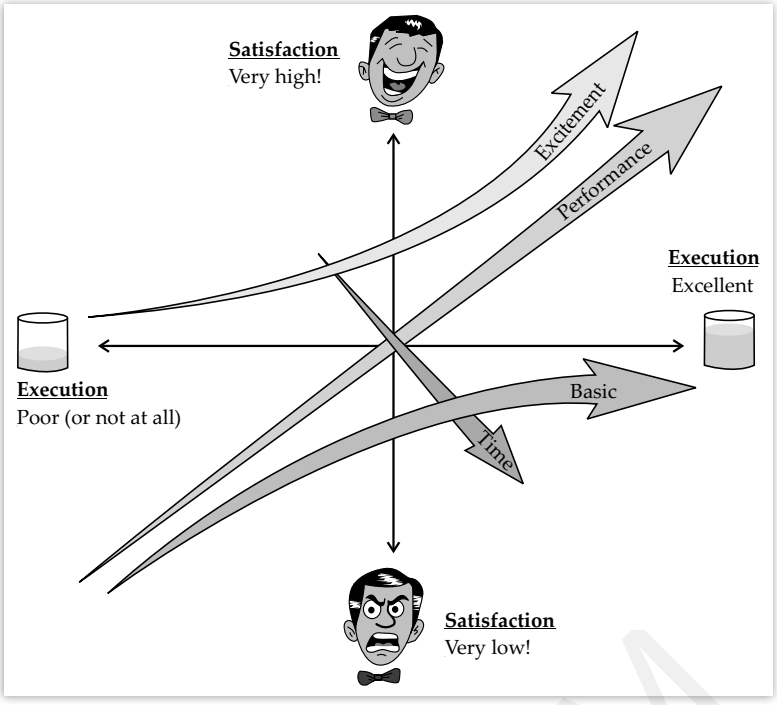

FIGURE 9: Kano Model

Source: *https://www.kanomodel.com/*

The Kano model categorises customer requirements or potential features into following five types:

- **Must-be:** These are the requirements that a customer expects in a product/service. It means they "must-be" present in the product/service. These are also called the Threshold Attributes. For example, it is expected that a detergent must clean dirt from the clothes.
- **One-dimensional quality:** The product features which when present satisfy a customer and the absence of which dissatisfies the customer are called uni-dimensional quality features. These are also known as Satisfiers and Performance Attributes. For example, when the quantity of Maggi Noodles offered at ₹10 is increased by 5%, it is a satisfier and if 5% quantity is reduced in the same ₹10 packet, it is a dissatisfier.
- **Attractive quality:** These are the product or service features which increase the satisfaction level when present, but they do not lead to dissatisfaction when they are absent. These are also known as Delighters or Excitement Attributes. For example, a free packet of biscuit with a packet of tea leaves.
- **Indifferent quality:** These are the product or service features that do not have any effect on the satisfaction or dissatisfaction. For example, the packing of a pen set with or without a ribbon.
- **Reverse quality:** These attributes are related to a high degree of achievement, but these may not be important for some customers. For example, some customers

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prefer a highly advanced mobile phone, whereas many others may be happy with just a simple smart phone.

Self Assessment Questions

11. Organisations collect data regarding customer wants and preferences called the Voice of the Customer. (True/False)
12. _____ are the product or service features which increase the satisfaction level when present, but do not lead to dissatisfaction when absent.

8.8 SUMMARY

- Quality refers to a measure of excellence or a state in which the product or service is free from any defects, deficiencies and variations.
- An organisation can manage quality of its products or services by optimising its operations.
- Operations can be managed to ensure that defects do not occur.
- Continual improvement or Kaizen can be implemented by an organisation by using the Plan-Do-Check-Act (PDCA) cycle.
- One of the most important factors due to which it becomes essential to estimate the cost of quality is to find out the ways in which customer dissatisfaction can be reduced and the risk associated with the product saleability can be minimised.
- Incorporating a quality cost program helps an organisation control and minimise the costs related to waste, scrap and rework.
- The cost of quality is the sum total of three types of costs of quality: cost of prevention, cost of inspection and cost of failure.
- A good-quality leader usually does not judge his team members. All the quality leaders possess certain attributes, such as self-motivation, honesty, high level of integrity, optimistic attitude, competency, charismatic personality, high level of confidence and a remarkable understanding of business.
- ISO 9000:2015 is one of the most recognised and widely used QMS prepared by ISO.
- Various organisations use different types of quality control and improvement tools and techniques, such as cause and effect diagrams, control charts, flow-charting, histogram, stratification, pareto chart and pareto analysis, bench-marking, run charts, scatter diagrams, statistical sampling, inspection, Six Sigma, Statistical Quality Control (SQC), acceptance sampling, etc.
- An activity network diagram is used to schedule the activities and subactivities in a pre-determined order. After the network of activities has been drawn, a critical path can be traced.
- Check sheet may be prepared in various forms. However, most commonly, the check sheets appear in the tabular form.

- Control charts are statistical tools that are used to control quality. These charts are used to monitor and analyse processes, analyse process variables, determine process capabilities and monitor the difference between the actual and target performances.
- In a Fish Bone diagram, the head of the fish must face towards right. After the head, the central spine of the diagram is drawn and all the major causes of the incident are represented. All the bones emanating from the spine represent causes and the spikes emanating from each bone represent subcauses.
- Quality Function Deployment (QFD) is a quality control and improvement process and is used to change the voice of the customer into engineering characteristics.

8.9 KEY WORDS

- **Critical path:** The longest sequence of activities in an activity network diagram and the activities in this sequence must be completed on time in order that the overall project is completed on time.
- **Defect rate:** The percentage of the total production output that fails to meet the quality standards.
- **Process capabilities:** A statistical measure of the ability of a process to continuously produce parts or outputs that lie within the specified limits.
- **Quantitative parameters:** The parameters whose data is measured in numerical values and is continuous in nature.

8.10 CASE STUDY: QUALITY MANAGEMENT AS A COMPETITIVE ADVANTAGE

XYZ Limited is an international manufacturing firm that produces heavy trucks and buses. It has been offering commercial transport services across various countries. It has attained supreme reputation in the market because of its high-quality products and services. This organisation delineates the perfect example of achieving competitive advantage with the help of quality management. It has been using the total quality management (TQM) to gain superior position in the market. Quality and quality-related issues are the prioritised concern of the organisation in order to fulfil the needs and requirements of its customers. The organisation facilitates continuous improvement of the products and services.

Now, let us study the quality strategy of XYZ Limited. XYZ Limited has been incorporating lean production, six sigma, just-in time and TQM as an integrated quality management approach to maintain safety, supreme quality and environmental care. The five key principles of XYZ Limited production system are teamwork, just-in-time, built-in-quality, continuous improvement and process stability.

XYZ Limited follows various quality maintenance practices to foster the above mentioned five-key principles in its operations. Following are a few quality maintenance practices:

- **Specialised Quality Board:** XYZ Limited has formulated an internal quality board that offers suggestion to improve quality management. Members of this board

monitor and keep a check on production process in order to reduce the wastage of time, efforts and material to foster efficiency in the processes.

- **Quality Function Deployment (QFD) approach:** As per the QFD approach, an organisation identifies and assesses the critical area of services which are required to be analysed and taken care of. XYZ Limited fosters QFD to meet and exceed customer expectations.
- **ISO certifications:** XYZ Limited has achieved ISO 14001 and ISO 9000 certification that represents the superior quality of its products and services. ISO 14001 certification ensures environmental management that plays a major role in quality management. ISO 9000 ensures the good quality management practices within the organisation.
- **Implementing improvement plans:** Continuous improvement requires constant quality check on the production process so as to attain quality excellence. Such practice also ensures high-quality production safety and reduction in wastage.

Apart from the above-mentioned practices, experts from each department offer suggestions to improve the quality of goods and services produced within the organisation.

One can analyse the importance of continuous improvement by mapping quality management practices and efforts of XYZ Limited. Continuous improvement leads to total quality management. TQM is the major strategy used by XYZ Limited to attain competitive advantage. TQM has helped XYZ Limited to sustain in the highly competitive market.

Hence, any organisation producing supreme-quality goods and services can attain a competitive edge and operational excellence using continuous improvement and TQM.

QUESTIONS

1. What all quality maintenance practices have been used by XYZ Limited to foster continuous improvement within the organisation?

   (**Hint:** ISO certifications, specialised quality board, lean production, TQM)

2. Do you think the quality practices adopted by XYZ Limited are cost-effective? Comment critically.

   (**Hint:** Helps in gaining a competitive advantage which provides benefit in the long-run.)

8.11 EXERCISE

1. Discuss the relation between quality and operations management.
2. List and describe the three types of costs of quality.
3. Explain the characteristics of quality leadership.
4. Explain the ISO 9000:2015 Quality Management System.

5. Describe a few important quality tools.
6. Explain the relevance of Quality Function Deployment (QFD) process.
7. Describe the five types of customer requirements as per the Kano Model.

8.12 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Relation between Quality and Operations Management	1.	True
	2.	Do
Cost of Quality	3.	defects
	4.	Cost of inspection and cost of prevention
Quality Leadership	5.	False
	6.	continuous improvement
ISO 9000:2015 Quality Management System	7.	credibility and universality
	8.	risks
Quality Tools	9.	left
	10.	Cause and effect diagram
Quality Function Deployment (QFD)	11.	True
	12.	Delighters or Excitement Attributes

8.13 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Dale, B., & Oakland, J. (1994). *Quality Improvement through Standards*. Cheltenham: Stanley Thornes.
- Heizer, J., Render, B., & Munson, C. (2016). *Operations Management*. Pearson Education UK.

E-REFERENCES

- What is House of Quality / QFD Example. (2019). Retrieved from https://www.whatissixsigma.net/house-of-quality-qfd/
- Fishbone diagram by Kaoru Ishikawa including a Template | ToolsHero. (2019). Retrieved from https://www.toolshero.com/problem-solving/fishbone-diagram-ishikawa/

CHAPTER 9

Data Analytics and Operations Management

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of analytics in operations management
- Discuss the integrated models for facility location
- Describe the design of experiment in manufacturing
- Explain the various analytical tools for sourcing

9.1 INTRODUCTION

In the previous chapter, you have learnt about the concept of quality management in operations management. In order to improve the quality of products, process and services, data analytics can do wonders. Data analytics helps in gaining new customer and production insights which helps in the improvement of products and services. It has become a new source of competitive advantage by fostering fact-based decision making. Many organisations strive to improve product and service quality and some have made providing superior quality a strategic intent (Liedtke et al., 2010). Scorecards, DoE and TQM have helped an organisation in creating visibility of quality performance with the help of real-time data collection.

In this chapter, you will gain insights into the data analytics in operations management. This chapter also discusses the integrated models for selection of facility location, application of DoE in manufacturing and analytical tools in sourcing.

9.2 OPERATIONS MANAGEMENT AND DATA ANALYTICS

Operations management can be defined as *"an administrative activity that is concerned with planning, designing and controlling all the operations of the organisation"*. In today's competitive world, managing the operations effectively and efficiently is not enough. It is equally important to improve the operational capabilities of an organisation. Various key areas of operations management, such as demand forecasting, process design, facility location and sourcing provide actionable insights that can save time and cost. Every organisation contains large data set that needs to be analysed in order to facilitate operational efficiencies and fact-based decisions. Hence, it becomes crucial to learn the application of analytical tools in operations management. Analytics involve application of statistical and quantitative methods or tools to map the patterns in the large set of data in order to foster fact-based decision making and strategic planning.

OECD (2013:4) suggested that *"the exploitation of data promises to create added value in a variety of operations ranging from optimising the value chain and manufacturing production to more efficient use of labour and better customer relationships."* Data analytics refers to the process of examining raw data for the purpose of gaining actionable insights. It provides valuable, reliable and timely information for decision making. Large set of data offers promising result-oriented knowledge that helps in revealing interesting

patterns and cause-and-effect relationship among various factors, such as spend and demand. It aids in performance improvement and cost reduction by assessing the spend analytics and past trends of price volatility.

Analytics helps in improving existing operations. There are various tools, such as data mining, predictive analysis and DoE. which are applied in various operational fields, such as aggregate planning, capacity management and sourcing in order to foster data-driven decision making. Data analytics plays a vital role in operations management as it aids in production planning, coordinating, organising and controlling operations.

SELF ASSESSMENT QUESTIONS

1. Analytics involves application of _____ and _____ methods or tools to map the patterns in the large set of data in order to foster fact-based decision making and strategic planning.
2. Data analytics provides valuable, reliable and timely information for decision making. (True/False)

9.3 SELECTING FACILITY LOCATION USING INTEGRATED MODELS

Facility location is one of the crucial decisions of an organisation as it affects the delivery of goods and services. It is the backbone of operational success of an organisation as it drives economies of scale and competitive advantage. Selecting a facility location is a strategic planning decision for every organisation. It is a long-term decision and involves huge capital expenditure. A good-facility location fulfils the demand of consumers as and when required. Retail stores in good-facility location can be accessed easily and cost effectively by customers. For example, an organisation that is located near the market would be able to launch its products in the market quicker as compared to an organisation located in a remote area.

It is equally important to assess the risk factor involved in the selected location at the preliminary stage only. An informed decision should be made by applying appropriate foresight in facility location planning and considering long-term operational characteristics. There are various kinds of risks involved in a facility location. For instance, while selecting the location of a bakery, the first step is to acquire land, either on purchase or long-term lease and equip it with essential resources. If the location is not appropriate, it can cause major financial crunch for the organisation as it will be expensive to relocate or close facilities once operations have been started at a particular location. Hence, facility location decisions should be taken with due diligence.

It is important for every organisation to select its facility location by keeping in mind various factors, such as proximity to raw materials, proximity to customers, availability of labour and environmental policy in order to avail the maximum growth opportunities and avoid adverse effects on its operations. Figure 1 illustrates some factors affecting facility location:

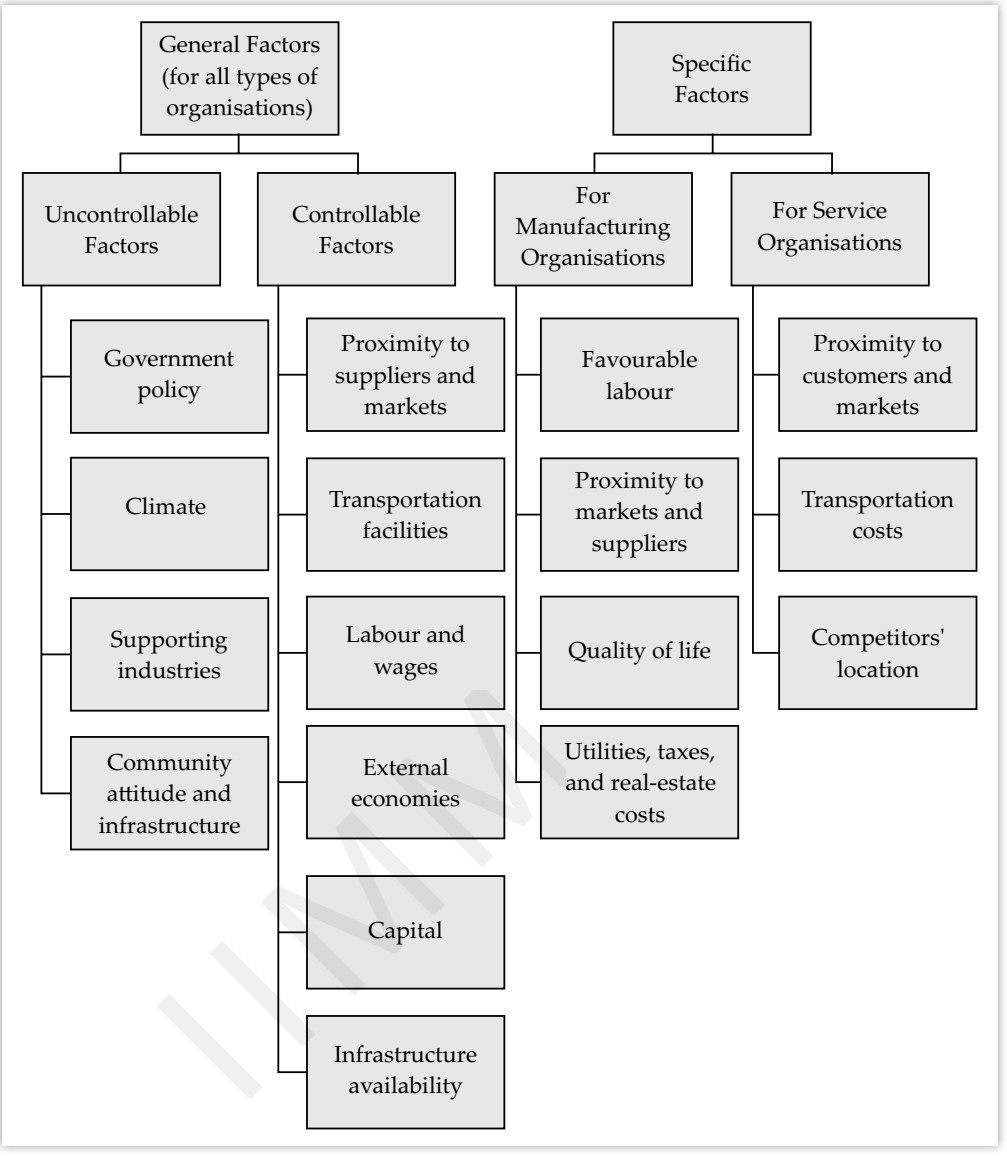

Figure 1: Factors Affecting Facility Location

The figure represents some controllable and uncontrollable factors. Controllable factors are internal factors that require a trade-off between cost and service level. Service level is defined as the proximity and accessibility of facility by users. It can be improved when proximity between a facility and its users reduces. Similarly, user accessibility gets improved, when the distance between the facility location and users is short so that they do not need to travel long distances to avail it. Strategic planning is required to select a facility location in order to serve specific sets of dispersed consumers. Following are some integrated models which consider strategic, tactical and operational factors while selecting a facility location:

- **Factor rating method:** Various locations are rated on the basis of key location factors as per their relative importance. Every location attains rating for a factor according to its merit for the factor. Then, the rate for each location is calculated by multiplying assigned factors for each location with the given factors. Then, the product for each factor is added. Finally, the location that has obtained the highest total is selected.

- Table 1 illustrates the location factors, factor rating and score for two potential sites for a hospital:

Table 1: Location Factors for Hospital

Location factor	Factor rating (A)	Rating (B)		Total rating	
		Location 1	Location 2	Location 1 (A x B1)	Location 2 (A x B2)
Facility utilisation	8	3	5	24	40
Total patients per month	5	4	3	20	15
Average time per emergency trip	6	4	5	24	30
Land and construction costs	3	1	2	3	6
Employee preferences	5	5	3	25	15
Total				96	106

Source: *https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/location-models-9476.html*

So, the total score of location 2 is greater than location 1. Hence, location 2 is selected for the hospital facility.

- **Weighted factor rating method:** This method is the result of intermingling of qualitative and quantitative factors by allocating weights, on the basis of relative importance. For each location, allocated weightage score is determined. Finally, the site that obtains highest weighted score is opted. Table 2 represents location factors, weights and scores (1 = poor and 5 = excellent) for two potential locations for the hospital site:

Table 2: Location Factors for Hospital

Location factor	Weight	Scores		Weighted score	
		Location 1	Location 2	Location 1	Location 2
Facility utilisation	25	3	5	75	125
Total patients per month	25	4	3	100	75
Average time per emergency trip	25	3	3	75	75
Land and construction costs	15	1	2	15	30
Employee preferences	10	5	3	50	30
Total				315	335

Source: *https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/location-models-9476.html*

On the basis of total weighted score, location 2 is chosen for the hospital.

- **Load distance method:** This quantitative model assesses various locations on the basis of proximity factors. The location that reduces the total weighted loads

moving into and out of facility is selected. The distance between two points is determined by allocating the points to grid coordinates on a map. For example, a new distribution centre is to be located in a metro city A, which will receive shipments from a neighbouring town B. If shipments are transported by road, the distance depends on the highways and the specific routes. For the long distance method, a rough distance is calculated, which may be:

- **Euclidean distance**: This is the shortest possible path between two points A and B, as shown in Figure 2:

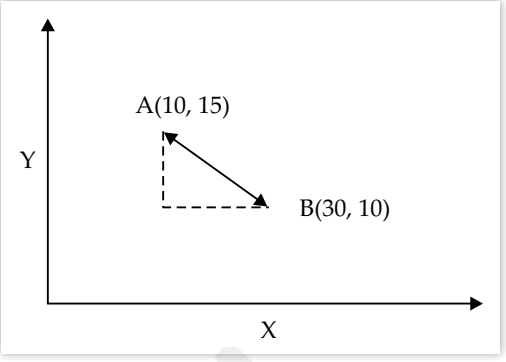

Figure 2: Distance between Points A and B

Point A on the grid = Possible warehouse location in town A

Point B on the grid = Supplier's location in town B

The distance between points A and B is the length of the hypotenuse of a right triangle.

$$d_{AB} = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2}$$

Here,

d_{AB} = Distance between A and B

X_A = x-coordinate of A

Y_A = y-coordinate of A

X_B = x-coordinate of B

Y_B = y-coordinate of B

- **Rectilinear distance:** This is the distance between two points A and B, which is orthogonal (90-degree turns) to each other. It is the sum of two dashed lines representing the base and side of the triangle in Figure 2. The distance towards the x-direction is the absolute value of the difference in x-coordinates of points A and B. If this distance is added to the absolute value of the difference in y-coordinates, then the following value is given:

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

Example: A hospital wants to serve 7 census tracts in a city. Table 3 shows each census tract's coordinates along with the population. Customers will need to travel

from the 7 census tracts to the new hospital. Two possible locations for the hospital are being considered: Census tracts C (5.5, 4.5) and F (7, 2).

Table 3: Coordinates for Centres of 7 Census Tracts

Census tract	(x, y)	Population (l)
A	(2.5, 4.5)	2
B	(2.5, 2.5)	5
C	(5.5, 4.5)	10
D	(5, 2)	7
E	(8, 5)	10
F	(7, 2)	20
G	(9, 2.5)	14

Source: https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/location-models-9476.html

Now, the load distance score for each tract is calculated by using the following formula:

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

Table 4 shows the calculated load distance score for each tract:

Table 4: Coordinates for Centres of 7 Census Tracts

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

Source: *https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/location-models-9476.html*

The location in census tract F with the total load distance score of 168 is a better location.

- **Centre of gravity method:** Cost is the most important consideration in this method. Various factors, such as locations of plants and markets, transportation costs and the volume of goods transported are considered while selecting the location of a plant. The centre of gravity delineates the location where the weighted distance between two locations is balanced. This method randomly places locations on a coordinate system, which accurately illustrates relative distances.

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The centre of gravity is determined by the following formula:

$$C_X = \Sigma D_{ix}.W_i / \Sigma W_i$$

$$C_Y = \Sigma D_{iy}.W_i / \Sigma W_i$$

Example: Let's consider Table 3 again to find the target area using the centre of gravity method. Table 5 expands the information:

Table 5: Centre of Gravity of 7 Census Tracts

Census tract	(x, y)	Population (l)	L_x	L_y
A	(2.5, 4.5)	2	5	9
B	(2.5, 2.5)	5	12.5	12.5
C	**(5.5, 4.5)**	**10**	**55**	**45**
D	(5, 2)	7	35	14
E	(8, 5)	10	80	50
F	**(7, 2)**	**20**	**140**	**40**
G	(9, 2.5)	14	126	35
	Total	68	453.5	205.5

Source: *https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/location-models-9476.html*

Now, $C_x = 453.5/68 = 6.67$

$C_y = 205.5/68 = 3.02$

The centre of gravity is (6.67, 3.02), which can be used to find the best location.

- **Break-even analysis:** Break-even can be defined as a state where cost is equal to profit. In every organisation, there comes a time, when the total revenue is equal to the total cost. Break-even analysis is a method which is used to identify the point at which the cost and revenue balances each other. The point where cost equals to revenue, is called break-even point. At this point, no profit and no loss are made.

For example, Table 6 shows the cost structures of the potential locations X, Y, and Z:

TABLE 6: Break-Even Point Analysis

	Location X	Location Y	Location Z
Fixed costs	INR 150,000	INR 350,000	INR 950,000
Variable costs	INR 10	INR 8	INR 6

Source: *https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/location-models-9476.html*

For the crossover between X and Y:

10X + 150,000 = 8X + 350,000 2X = 200,000X = 100,000 units

For the crossover between Y and Z:

8X + 350,000 = 6X + 950,000 2X = 600,000X = 300,000 units

Thus, at volume of 130,000 units, Y is the appropriate strategy. According to Figure 3, the location X is suitable up to 100,000 units, location Y is suitable up to between 100,000 and 300,000, and location Z is suitable if the demand is more than 300,000 units.

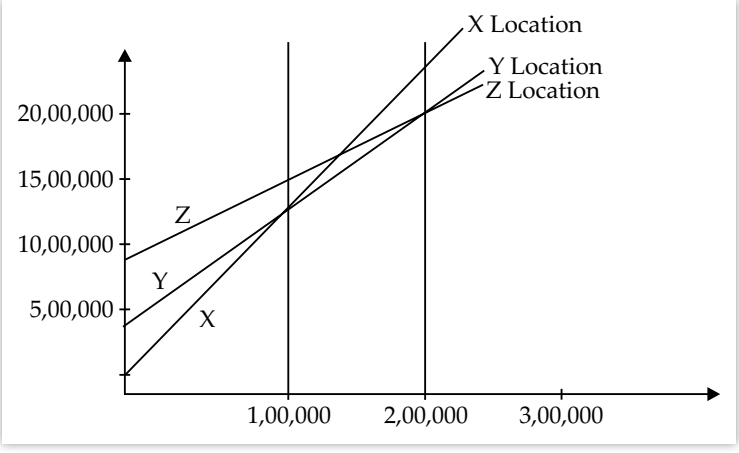

Figure 3: Break-even Point (BEP) Chart

Source: *https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/location-models-9476.html*

Self Assessment Questions

3. Load distance integrated model evaluates locations based on cost factor. (True/False)
4. Which one of the following integrated models uses cost consideration?
   a. Factor rating b. Weighted factor rating
   c. Centre of gravity d. Load distance
5. At _____ point, profit is equal to loss.

9.4 USING DESIGN OF EXPERIMENT IN MANUFACTURING

Design of experiments (DoE) is one of the vital tools of Six Sigma for experimentation. DoE involves the application of statistics in experimentation in order to solve quality problems in key processes. Linderman states: *"Six sigma is an organised and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer-defined defect rates."* DoE is a systematic approach of drawing a valid conclusion from a plethora of experiments in order to foster process and product improvement. It conducts various experiments in order to identify the relationship between factors affecting a process and the output achieved from the process. It is a valuable and affordable technique that is used to map the cause-and-effect relationship of input and output.

DoE is defined as "a systematic, rigorous approach to engineering problem solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusions" (Firka,

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2011). It aids in cost reduction by developing various kinds of systems and processes for experimentation in order to find out the most suitable and optimum process design. It can be used for robust designing, system optimisation variable, screening, transfer function identification, etc.

DoE involves a series of steps which are as follows:

1. **Setting objectives:** The first step involves the formulation of objectives for experimentations, which defines the purpose of conducting experiments. An organisation can either set objectives to adopt a new process or to improve the existing one. The main aim of performing various experiments is to attain the most suitable process design. There are other secondary goals as well in order to foster efficiency within the organisation.
2. **Defining response variable:** When objectives are set, it is equally important to define various metrics for selection of the best process design from various alternatives. In this step, response variable is defined in order to easily select the most viable alternatives.
3. **Identifing dependent and independent factors:** Fishbone diagram is a widely adopted tool to identify various factors that affect response variable. This step identifies the nature of factors and how various factors affect the response variable. Hence, independent and dependent factors are identified.
4. **Illustrating experimental design type:** This is an action-oriented step which involves a screening design that is used to identify the relationship between significant factor and response variable. Various test samples are performed to determine the relationship between various factors and their impact on response variable.
5. **Analysing of sample experiments using design matrix:** In this step, various sample experiments which are conducted in the previous step are analysed. It establishes a valid conclusion for the final selected process design.
6. **Analysing data:** In this step, the final conclusion is drawn using regression so as to validate the implementation of the result. Various recommendations are also provided to practically implement the results.

Self Assessment Questions

6. _____ helps in reducing design cost of a product by developing and optimising various types of systems and processes.
7. Design of experiments (DoE) is one of the vital tools of Kanban. (True/False)
8. DoE can be used in which of the following:
   a. Robust design
   b. Facility location
   c. Procurement
   d. None of these

9.5 ANALYTICAL TOOLS FOR SOURCING

Sourcing can be defined as 'the reorganisation of tasks, functions and services of an organisation, whereby the more effective managing of organisational and operational

processes is the main issue (Huibers and Schut, 2006). In simple terms, sourcing refers to a decision-making stage that ascertains the quantity of raw material and other components required in an organisation for production. It takes the decision related to vendor and supplier selection, quantity of raw material required, when it is required and how it will be ordered. The main aim of sourcing is cost reduction and quality improvement.

Analytics plays a pivotal role in sourcing as it not only reduces the procurement cost but also results in value addition in sourcing activities by gaining insights into the operational and performance characteristics. It ensures right optimisation of procurement decision making by studying the spending of the organisation on suppliers and other procurement-related activities. It helps in gaining a competitive advantage using statistics, machine learning and artificial intelligence. Analytics refers to the computational analysis of a large set of data accumulated in an organisation's database. It helps in drawing meaningful insights with the help of quantitative methods. It helps in facilitating fact-based negotiation and informed decision making by analysing the past trends and patterns.

Let us discuss various types of analytical tools.

9.5.1 PREDICTIVE ANALYTICS

Predictive analytics is an advanced tool widely adopted by organisations to make future predictions about sourcing activities. It analyses past and current data in order to make future predictions which results in informed decision making within the organisation. It enhances the accuracy of demand and production forecast that minimises the chance of stock-outs. It determines future course of action on the basis of historical data. Application of predictive analytics in sourcing leads to fact-based contract negotiations with suppliers. There are various advantages of predictive analytics, such as cost reduction, spend visibility, saving management and risk tracking. Tools like statistics modelling, artificial intelligence, data mining, machine learning, etc., are used in predictive analytics.

It is a proactive approach of risk management in sourcing as it results in improved spend visibility and cost reduction. It forecasts spend on the basis of past trends. It helps in identifying any kind of fraud in procurement-related activity and facilitating effective and efficient sourcing strategies.

9.5.2 DATA MINING

Data mining is an exploratory knowledge discovery technique that maps new useful pattern in the huge data set. It helps in making insightful decisions by understanding an organisation's current and past situation and accordingly make future predictions about spending, external pricing trends and supplier performance. It uses statistics, artificial intelligence, information theory, etc., to identify patterns in huge data set. It aids in formulating strategic sourcing strategies, such as vendor ranking, quality improvement, etc., by analysing procurement and spend pattern in a structured way. It represents the valuable information in the form of graphs, charts and spreadsheet which is easy to understand.

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Data mining is a knowledge discovery approach and offers details regarding the operational and performance characteristics using algorithms. It uncovers patterns in the data set in order to make reasonable predictions about future by analysing the relationship between spend analysis, past trends, price volatility and performance in order to make smart procurement decisions and plan your future budget for sourcing.

9.5.3 SCORECARDS

Scorecard is a performance measurement tool which is used by organisations to assess the performance of suppliers. It measures how suppliers are performing in terms of quality, cost and other metrics. It first defines the objectives to be attained and Key Performance Indicators (KPIs) for each objective which aid in monitoring and controlling of procurement-related activities. It helps in predicting the supplier's performance in order to foster effect-based supplier selection criteria. It further aids in assessing the performance or progress of a contract with the help of effectiveness and efficiency metrics. It defines real-time graphical representation of the performance of supplier and contract. It helps in vendor evaluation, demand forecasting, contract management and spend analytics, etc., as it captures potential information about a supplier's goals and objectives and measurement parameters in order to make an informed decision.

9.5.4 SLICE-AND-DICE ANALYSIS

Slice-and-dice analysis is a technique which analyses the unstructured content by segmenting and comprehending large set of data. It performs a systematic sorting of huge data set into smaller parts in order to yield more valuable information to derive decisive insights in context of selection of suppliers, spend analysis and contract management. It sorts the data on the basis of different criteria, such as supplier's relationship, spend information contract management. Key concepts are extracted from a large set of data in order to attain a clear and detailed view of the analysis. In this analytical tool, solutions are derived by slicing and dicing the data accumulated in an organisation from suppliers, geographical location, time and contract which help in mapping the spending pattern of an organisation.

The application of analytical tools provides following benefits to an organisation:

- It tracks key sourcing activities which further helps in monitoring the results.
- It gathers, cleans and categorises all enterprise data.
- It detects fraud using spend analytics.
- It improves demand forecast accuracy and fact-based negotiations.
- It builds strategic supplier management and category sourcing.
- It aids in research and development in order to find new sources for procurement.
- It helps in mitigating suppliers' risk strategically as decisions are not made on assumptions and anticipation.

SELF ASSESSMENT QUESTIONS

9. _____ is an advanced analytical tool that is used to make future predictions.
10. Which of the following sorts the data on the basis of different criteria, such as supplier's relationship, spend information and contract management?
    a. Predictive analytics
    b. Slice-and-dice analysis
    c. Scorecards
    d. Data mining
11. Data mining is a knowledge discovery approach. (True/False)

9.6 SUMMARY

- Analytics involves application of statistical and quantitative methods or tools to map the patterns in the large set of data in order to foster fact-based decision making and strategic planning.
- There are various tools, such as data mining, predictive analysis and DoE, which are applied in various operational fields, such as aggregate planning, capacity management and sourcing in order to foster data-driven decision making.
- Facility location is one of the crucial decisions of an organisation as it affects the delivery of goods and services. It is the backbone of operational success of an organisation as it drives economies of scale and competitive advantage.
- It is important for every organisation to select its facility location by keeping in mind various factors, such as proximity to raw materials, proximity to customers, availability of labour and environmental policy in order to avail maximum growth opportunities and avoid adverse effects on its operations.
- Design of experiments (DoE) is one of the vital tools of Six Sigma for experimentation. DoE is a systematic approach of drawing a valid conclusion from plethora of experiments in order to foster process and product improvement.
- Analytics plays pivotal role in sourcing as it not only reduces the procurement cost, but also result in value addition in sourcing activities by gaining insights into the operational and performance characteristics.
- Predictive analytics is an advanced tool widely adopted by organisations to make future predictions about sourcing activities.
- Data mining is an exploratory knowledge discovery technique that maps a new useful pattern in the huge data set.
- Scorecard is a performance measurement tool which is used by organisations to assess the performance of suppliers. It measures how suppliers are performing in terms of quality, cost and other metrics.
- Slice-and-dice analysis is a technique which analyses the unstructured content by segmenting and comprehending a large set of data.

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9.7 KEY WORDS

- **Response variable:** The outcome or result of an experiment.
- **Stock-outs:** An event in which demand of a product is not fulfilled with current inventory.
- **Key Performance Indicators (KPI):** A performance metric that evaluates the success of an organisation.
- **Demand forecasting:** A field of predictive analytics that makes future predictions about the demand of products and services in the market.

9.8 CASE STUDY

ABC Limited is a steel-manufacturing organisation. It has been dealing in Asian market for the last 2 decades. It has currently started using data analytics in order to improve the competitiveness and efficiency. The main aim is to achieve cost reduction and quality improvement with the help of data analytics. It has identified various issues, such as unsold or excess inventory, wastage of resources, idle machine time and labour efforts that are leading to additional cost. Continuous monitoring of the process data is done in order to identify the root cause of such critical issues prevailing in the production processes. It has been observed that the organisation is running at high operational cost due to inaccurate capacity and inventory planning. With due diligence and strategic planning, various insights are drawn from processed data that has helped the organisation in solving production process issues. Such initiative led to reduction in lead time and inventory. The organisation started observing cost reduction and quality improvement due to constant monitoring and control.

Source: *https://www.capgemini.com/wp-content/uploads/2017/07/going_big-_why_companies_need_to_focus_on_operational_analytics.pdf*

QUESTIONS

1. What other analysis can be performed by ABC Limited in order to improve its operational capabilities?

   (**Hint:** It can use DoE in order to gain effective and efficient process design.)

2. Do you think data analytics has helped this organisation in cost reduction?

   (**Hint:** Reduction in lead time and inventory saves time and cost.)

9.9 EXERCISE

1. Describe various types of integrated models for facility location.
2. Explain the importance of design of experiment (DoE).
3. Define the role of data analytics in sourcing. What are various analytical tools used for sourcing?
4. What is the role of data analytics in operations management?

9.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Operations Management and Data Analytics	1.	statistical, quantitative
	2.	True
Selecting Facility Location Using Integrated Models	3.	False
	4.	c. Centre of gravity
	5.	break-even
Using Design of Experiment in Manufacturing	6.	DoE
	7.	False
	8.	a. Robust design
Analytical Tools for Sourcing	9.	Predictive analytics
	10.	b. Slice-and-dice analysis
	11.	True

9.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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CHAPTER 10

Applications of Analytics in Operations Management

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Define the meaning of aggregate production planning
- Explain the analytical tools used for aggregate production planning and control
- Describe the significance of predictive analytics in operations management

10.1 INTRODUCTION

In the previous chapter, you had studied about the concept of data analytical tools in operations management. This chapter further describes in detail the role and applications of analytics in the management of business operations. Firstly, the tools for aggregate production planning and control are discussed. In every organisation, the annual and half-yearly business plans are broken down into medium-range production requirements to determine material, personnel and working capital needs. This process of determining the production requirements by maintaining balance between long-term goals and available facilities or resources is dealt with by aggregate production planning. Aggregate production planning matches demand with supply while minimising costs.

Further, the chapter highlights the significance of predictive analytics in operations management. Predictive analytics can forecast spend behaviour (i.e., pattern of amount spent on procurement) on the basis of past data, and also helps in fraud detection and foster more efficient sourcing strategies by mitigating disruptions.

In addition, the chapter also discusses the importance of building an analytics-driven organisation to aid in the decision-making process. Analytics should be tied directly with the process of decision making, taking appropriate actions and delivering value additions for improving the business performance. For attaining these business outcomes, the analytics operating model should satisfy three main requirements, namely infusing analytics into decision making, governing organisation-wide analytics capabilities, and recognising and deploying analytics talent.

10.2 ANALYTICAL TOOLS FOR AGGREGATE PRODUCTION PLANNING AND CONTROL

Demand for a product varies depending upon various factors, ranging from social, cultural and economical to political. A company, thus, needs to adjust its production keeping in mind the changing market conditions. The business activity which is concerned with maximum utilisation of resources to address changes in demands is referred to as aggregate production planning and control. It involves determination of levels of inventory, production and manpower to meet varying demands over a planning range of six months to one year. The tools used for aggregate production planning are mainly divided into two segments as follows:

A. **Qualitative tools:** These tools involve built-in assumptions and include the following:

- **Non-quantitative haggling:** In the same organisation, different departments often have different priorities and conflicting interests. To achieve consensus, one may begin by bargaining in a non-economic way. However, it may not be possible to reach an objective decision as people with influence and persuasive skills often tend to dominate discussions.
- **Adjustment of last year's plan:** One common practice among manufacturers is to use prior year's plan and tweak it upwards or downwards, according to their assessment of the current situation. This assumes that the previous plan was near optimal and this assumption may not be a correct assessment. Thus, the company may be relying on poor plans which lead to flawed decisions.
- **Graphical methods:** All the proposed plans are compared by presenting them in the graphical form which allows users to visualise the varying effects of different plans. These methods may lead to the selection of an ineffective proposal. These methods do not test for optimality and generate static plans which are difficult to implement. These are especially true in a scenario where multiple products could be competing for the same facilities or resources.

B. **Quantitative tools:** These are mathematical tools used for aggregate production planning and control, as shown in Table 1:

Table 1: Quantitative Tools in Aggregate Production Planning and Control

Quantitative tool	Cost structure	Parameter estimation	Forecast requirement	Decision variables	Computability	Optimisation technique
Linear decision rule (LDR)	Quadratic approximate for layoff and hiring, overtime and regular payroll, inventory and shortages	Historical curve fitting for estimates	Monthly shipments over yearly horizon	Linear decision rule for P_t, W_t as a function of W_{t-1}, I_t	Differentiation for first time; easily applied rules	Matrix inversion of differentiated cost
Goal programming	Linear approximation to quartic cost as above	Historical curve fitting or estimates	Same as LDR	P_t = Production W_t = Workforce level at t	Easy and must be run in each time period	Linear programming
Range programming	Sectioning search	Not required	Demand	P_t, W_t, C_t	Easier than goal programming	Range programming (transportation technology)
Linear programming	Linear approximate for layoff and hiring, overtime and regular payroll, inventory and shortages	Same as LDR, except piecewise linear approximation	Monthly shipments over 6-month horizon (multi-period computation is difficult)	Optimal values of P_t, W_t	Easy and must be run in each time period	Linear programming (transportation technology)
Dynamic programming	Minimise cost of production, inventory shortages, and production change	Historical curve estimation	Depends on the problem	Production rate at t	Is not efficient, difficult	Dynamic programming

Self Assessment Questions

1. Aggregate production planning is used to address the changes in demands. (True/False)
2. The tools used for aggregate production planning are mainly divided into quantitative and _____ methods.

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10.3 ANALYSIS OF PROCESSES FOR OPTIMISATION

To examine the effectiveness of the selected process, and assess whether it is the ideal one chosen to ensure maximum optimisation of resources, there are different parameters and performance measures available. These mainly include the following:

- **Cycle time:** Whenever any production operation is started, it leads to production of units or products, and units are produced till the time the production is halted by the production department. The time lapsed between two successive outputs is called the cycle time. For example, if a packet of biscuits comes out of the system every ten seconds, then cycle time would be ten seconds.
- **Throughput time:** It is also referred to as the lead time. This is the total time taken and invested from the order of production to the final manufacturing of the product. For instance, if the order for the car was issued at 6 pm on Monday, and the product finally comes out of the assembly line at 12 pm on Tuesday, then throughput time taken is calculated as 18 hours.
- **Bottleneck:** No process can work with clockwork precisions. Some snag or obstruction may delay the process. A bottleneck in the manufacturing parlance is defined as a process, in a chain of processes, which tends to slow down the capacity of the whole chain. It is considered as a limiting factor that affects the overall cycle time, but is unavoidable due to the existence of different factors.

In any production process, it is imperative to take into account the above-mentioned factors. However, a judicious and smart management of these factors can help any organisation to maximise production with optimum utilisation of resources, thus reducing cost and improving profit.

Self Assessment Questions

3. A _____ is considered as a limiting factor that affects the overall cycle time.
4. Cycle time is the elapsed time between two successive outputs. (True/False)

10.4 PREDICTIVE ANALYTICS IN OPERATIONS MANAGEMENT

As we know that in our effort to achieve optimum utilisation of resources and cutting costs, sourcing remains a key factor. Sourcing is the decision-making process that seeks to procure the most suitable raw material and services as per the current needs at minimum costs, to reduce overall expenses and achieve higher productivity.

As market continues to become more and more competitive, it is essential for an organisation to gain insight into the analytics involved in sourcing to get a competitive advantage in the market. Analytics is the computational analysis of historical and current data using quantitative methods. It helps in reviewing historical data in an organised manner which ultimately facilitates fact-based decision making. It generally involves tracking the amounts spent on sourcing, behaviour of vendors over time, setbacks suffered, ease of deals and other supplier and procurement-related issues. Needless to say, the better the management of this system and insight gained through it, the more competitive would be the procurement process. Salient

features highlighting the role of analytics application in sourcing materials and services are as follows:

- Key sourcing activities are tracked, which, in turn, help in monitoring the results and outcomes
- All enterprise data can be gathered, clubbed and categorised
- By using spend analytics, frauds are detected which forewarn the company
- Demand forecast accuracy and fact-based negotiations are facilitated
- An improved strategic supplier management and category sourcing can be achieved
- Aids in R&D efforts in order to find new sources and vendors for procurement
- As decisions are not made on mere conjecture or assumptions, it reduces suppliers' risk strategically

An advanced analytical tool in this scenario is predictive analytics, which is used to make forecast about future market fluctuations and make predictions. By tracking the past facts and historical data, a computational analysis is done that determines what could happen in the future. Consequently, it aids in cost-reduction, spend visibility, saving management and risk tracking. This system uses many techniques such as statistics modelling, artificial intelligence, data mining, machine learning, etc., to analyse past and current data and arrive at intelligent conclusions.

Predictive analytics is a proactive approach of identifying risk and opportunities by analysing the transactional and historical structured data. It helps in making predictions by improving the visibility of procurement patterns. In simple terms, it is a system that follows a strategic approach beginning with a collection of past data in order to determine what could happen in future. After collection of data, different reports are made and analysed. The past data offers an insight into the pattern of sourcing, and the smooth areas and places where bottlenecks may occur. It also gives some glimpses of malpractices or fair dealings by vendors or suppliers and offers a comprehensive analysis for undertaking the futuristic planning. Figure 1 illustrates the broad framework of predictive analytics:

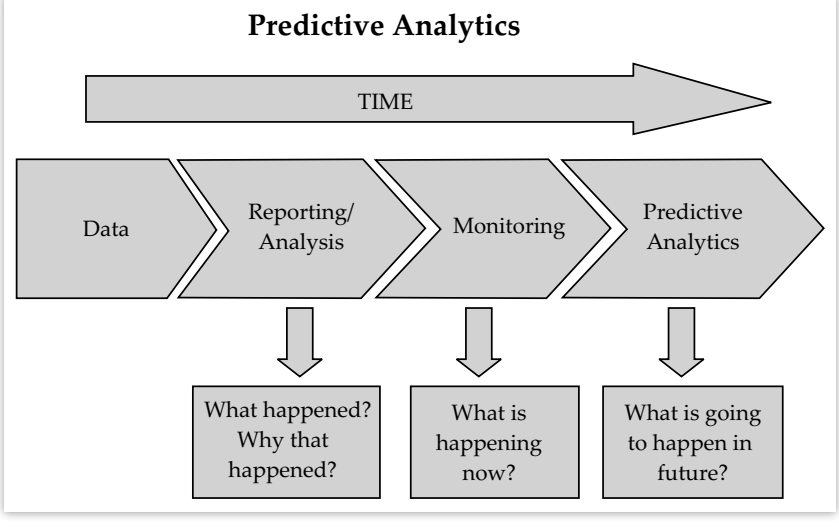

FIGURE 1: Predictive Analytics

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The step-by-step approach of predictive analysis process includes following steps:

1. **Define project:** Firstly, one needs to define the objectives and goals of the predictive analysis. In terms of sourcing, spend management and sourcing management, the goal here is the improvement of processes leading to cost savings and effectiveness.
2. **Data collection:** Analytics offers data-mining tools to collect and collate data from different departments and sources. The more comprehensive the transactional data, the better the overview and insight it offers for considered decisions.
3. **Data analysis:** Data analysis is a specialised job that aims to study, analyse and transform the data with predetermined objectives to identify threats and opportunities and find the best solutions.
4. **Statistics:** A variety of statistical models are used to validate the hypothesis of testing and analysis, and determining the action.
5. **Modelling:** This involves scrutinising possible future scenarios by evaluating a multi-model structure of the data and analysis reports, in an effort to find an ideal solution.
6. **Deployment:** This method focusses on everyday decision-making process in order to project future outputs.
7. **Model monitoring:** Gauging the accuracy of predictions is critical. Therefore, different processes are monitored to assess the accuracy of forecasting and evaluate how far they are accurate and successful in achieving objectives.

Many other tools, such as score cards, slice-and-dice analysis, etc., can be used as analytics in sourcing. Scorecards can be defined as real-time graphical representation of the performance of procurement. Moreover, slice-and-dice analysis represents the data on the basis of different criteria, such as spend information, contract management, suppliers' relationship, etc. Although a whole range of analytical tools are available and used by different companies, predictive analytics remains as the most preferred choice in ensuring promising results, competitive advantage and cost benefits in the long run.

Self Assessment Questions

5. Analytics is the computational analysis of historical and current data using quantitative methods. (True/False)
6. Predictive analytics helps in making predictions by improving the visibility of _____ patterns.

10.5 BUILDING AN ANALYTICS-DRIVEN ORGANISATION

Nowadays, every organisation understands the value and reality of analytics and has appointed specialised teams to provide analytics services or capabilities. Organisations are using data analytics across the business for enhancing decision-making in existing business processes. Organisations need to reengineer decision making in business units and functions by being more and more analytics-driven and relying on data analysis. We know that the concept of analytics, backed by

computational analysis, is comparatively a new concept; however, it promises wide-ranging benefits to business organisations.

Analytics is a relatively new field. Therefore, the organisations which want to adopt it are usually not very aware of the issues related to analytics, such as spanning data, methods, organisation and technology. One flaw observed is that organisations take decisions only on the basis of the past data rather than taking future trends into account.

The main aim of applying data analytics in organisation is to achieve higher cost savings and more profit. To achieve these results, an analytics-operating model needs to fulfil following three core requirements:

- **Making analytics a part of decision-making process:** Nowadays, it is important to adopt 'Analytics first' philosophy in business operations. The management can benefit if they are able to use the relevant data and analyse it to reengineer their business decisions.
- **Planning, organising and governing analytics capabilities across the organisation:** While planning any analytics capabilities, organisations must construct and allocate resources on the basis of the maturity and needs of the business. Organisations must ensure that they are able to effectively manage the supply and demand situation for analytics services across all operations.
- **Given its challenging nature, it is difficult to find analytics talent, especially the kind that has industry-specific experience:** Organisations need to revise their talent management processes on a regular basis to ensure that they are able to acquire personnel who have analytics talent with relevant industry experience. Talent management policies must take care of different aspects, such as sourcing, development, recognition and retention of analytics personnel. Although we do not have a single 'right' operating model that is ideal for every organisation, we could focus on several components, such as sponsorship, governance and data insights that should be addressed to shape the appropriate operating model.

10.5.1 ROLE OF ANALYTICS IN THE DECISION-MAKING PROCESS

With IT making new strides, it has become possible to make more accurate and informed data-driven decisions. Earlier, the decision-making process used to be driven by experience, wisdom and intuition because of the lack of data storage and computer devices. However, now data analytics helps in finding non-obvious answers in record time. There is a growing consciousness that if organisations are looking to improve performance, they have to be strong on facts, and use them in discussions and decisions for taking actions across brand marketing, sales planning, field sales, supply chain and retailer domains.

For analytics-driven insight to be fully effective, organisations would need to ensure speed, end-to-end process assessment and re-engineering. To attain full value of analytics, it is desirable to build a sustainable, enterprise-wide analytics capability. Ideally, it should be adapted in cross-functional processes, activities, roles and responsibilities to infuse analytics into daily decision-making, and improve productivity. Today, not a single organisation relies on intuitions as the new mantra

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is 'facts analysed'. In short, organisations will also have to take a hard look at their ability and willingness to re-engineer processes so that regular functions, such as marketing, sales and supply chain work more collaboratively and harmoniously in conjunction with the use of analytics.

There is an increasing need to opt for data analytics in order to increase the organisational capabilities, as well as institutionalise its use in everyday decision making. Let's take the example of a progressive organisation like P&G. This organisation has fostered data-based culture by using smart tools like 'Business Sphere' in order to ensure analytics-based decision making. Organisations can begin by re-engineering decisions, and should consider conducting an analytics diagnosis in order to identify what insight is needed, when and by whom. This would ensure that the insights delivered are relevant, actionable and timely.

In this context, it is important to relate strategies and tactics to the insights generated by analytics. Organisations need to have clarity about the objectives to be achieved. They need to experiment with developing mechanisms that identify, track and realise the value of analytics efforts. This data analytics approach will help move organisations from a data-based mindset to an outcomes-based mindset.

10.5.2 ORGANISING AND GOVERNING ANALYTICS CAPABILITIES ACROSS AN ORGANISATION

In order to maximise benefits from analytics, an organisation needs to address some basic organisational and management issues. These issues include sponsorship issues, responsibility for funding, direction and control of analytics, leadership issues, etc.

In order to develop analytics capabilities, the organisation requires a good amount of funds. Even after an organisation has developed analytics capabilities, it needs funds to maintain these capabilities. The extent of analytics, its use and positioning in the organisation is also important. As analytics technology and systems are yet to receive wider acceptance, a leader needs to convince the management about the value realisation of these programs. A leader should to be able to build alignment and reinforce the analytics culture in an organisation, which helps to advance the analytics capability and improve its decision making.

10.5.3 SOURCING AND DEPLOYING ANALYTICS TALENT

Given the crucial role of analytics and its impact on the overall performance of an organisation's performance and operation, it is not surprising that there is a great dearth of talent in the field. Such a challenge affects the operations of various organisations in order to function as an analytics-driven organisation with ambitious goals. Accenture is a leading IT organisation and Accenture Institute of High Performance is one of its premier institutes. In one of its recent studies, Accenture Institute has found that only one out of 10 qualified university graduates accepts industry-based analytics positions. Moreover, the other 9 opt for careers in fields, such as investment banking, consulting and IT organisations.

It is very difficult to find right people in the market for analytics, especially for the positions of business intelligence analysts and visualisation experts. With its demanding analytical skills, real talent is hard to come in this field. Today, organisations need analysts that have advanced analytics skills and familiarity with the complexity of distribution networks and the volume of structured and unstructured data. Although many organisations have been finding it comparatively easy to fill vacancies in the area of descriptive analytics, the challenge is finding suitable candidates with predictive and prescriptive abilities.

Although there is a shortage of talent in this field, data analytics has been emerging as a booming and reputed professional field. Various professional institutions are offering certified courses for predictive analytics and business intelligence.

SELF ASSESSMENT QUESTIONS

7. The main aim of applying data analytics in organisation is to achieve higher cost savings and more profit. (True/False)
8. A _____ should to be able to build alignment and reinforce the analytics culture in an organisation.

10.6 SUMMARY

- The business activity which is concerned with maximum utilisation of resources to address changes in demands is referred to as aggregate production planning and control.
- The qualitative tools used for aggregate production planning and control include non-quantitative haggling, adjustment of last year's plan and graphical methods. The quantitative tools used for aggregate production planning and control include linear decision rule (LDR), goal programming, range programming, linear programming and dynamic programming.
- In a continuous operating process, cycle time is termed as the elapsed time between two successive outputs.
- Throughput time is the total time taken and invested from the order of production to the final manufacturing of the product.
- Sourcing is the decision-making process that seeks to procure the most suitable raw material and services as per the current needs at the minimum costs, to reduce overall expenses and achieve higher productivity.
- Predictive analytics is a proactive approach of identifying risk and opportunities by analysing the transactional and historical structured data. It helps in making predictions by improving the visibility of procurement patterns.
- Although a whole range of analytical tools are available and used by different companies, predictive analytics remains as the most preferred choice in ensuring promising results, competitive advantage and cost benefits in the long run.
- The organisations are using data analytics across the business for enhancing decision making in existing business processes. Organisations need to re-engineer

decision making in business units and functions by being more and more analytics-driven and relying on data analysis.

- The main aim of applying data analytics in organisation is to achieve higher cost savings and more profit.
- To attain full value of analytics it's desirable to build a sustainable, enterprise-wide analytics capability. Ideally, it should be adapted in cross-functional processes, activities, roles and responsibilities to infuse analytics into daily decision-making, and improve productivity.
- In order to maximise benefits from analytics in every possible way, an organisation would have to address some basic organisational and management issues. These would range from sponsorship to who would have the responsibility for funding, direction and control of analytics.

10.7 KEY WORDS

- **Quantitative tools:** Techniques related to measurement, verification and use of numbers and figures of different variables in a proposed problem statement.
- **Qualitative tools:** Techniques related to description, value, experience and subjective quality of the different variables in a proposed problem statement.
- **Operating model:** A visual representation of how an organisation functions and runs.
- **Leadership:** The action of guiding a group of people or organisation

10.8 CASE STUDY: OPERATIONAL ANALYTICS AT WNS

WNS is one of the world leaders in offering business process management solutions to its clients by combining industrial knowledge with innovative technology and analytics expertise. It is common knowledge that operational decisions are generally high-volume and repetitive in nature. Thus, analysis of a huge volume of data from sources, such as contact centre, customer relationship management and enterprise resource planning help identify opportunities for optimising operational efficiencies, reducing costs and enhancing profits.

WNS implements cutting-edge operational analytics solutions. As a result, WNS is able to transform data into insights which helps in better decision making, lowers costs and enhances the service levels. As a result, the client company is able to outperform competition through in-depth and focussed analysis of its performance in key operational areas, such as sales and operations planning, including demand forecasting, inventory management, network optimisation, contact centre operations and human resource operations.

The WNS Advantage

Customers of WNS can achieve the desired results because WNS follows a customer-centric approach. In addition, WNS also has deep domain expertise and global delivery network. WNS focusses on attaining operational excellence with the help of innovative analytics solutions.

Some of the advantages offered are:

- Leveraging the talent of analytics and technology professionals leads to delivering superior business value
- WNS offers proprietary Customer Experience Management solutions which help in enhancing the customer's web experience
- Organisations are inspired and enabled to scale the analytical maturity curve through WADE^{SM}-WNS' proprietary predictive analytics solution framework.
- Process performance is improved by using the Embedded Process Intelligence (EPI) technology.
- WNS offers various cutting-edge decision analytics and data mining tools, such as SAS, R, SQL, Business Objects, Cognos, Teradata, Python and MATLAB.

Source: *https://www.wns.com/solutions/functional-solutions/analytics/operational-analytics*

QUESTIONS

1. What is the main service provided by WNS?

   (**Hint:** It offers cutting edge business process management solutions to its clients across the world.)

2. How are WNS services successful?

   (Hint: Integration of technology and analytics, development of digital transformational solutions, deep business domains' expertise to outperform competition, customer-centric approach with focus on operational excellence, etc.)

10.9 EXERCISE

1. Explain the meaning of aggregate production planning. Which tools and methods are used for aggregate production planning and control?
2. Which parameters are used to analyse processes for optimisation?
3. What do you understand by predictive analytics? Briefly describe its role and step-by-step process to make future predictions in operations.
4. Describe how an analytics-driven organisation can be built.
5. Discuss the role of analytics in decision-making process.

10.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Analytical Tools for Aggregate Production Planning and Control	1.	True
	2.	qualitative
Analysis of Processes for Optimisation	3.	bottleneck
	4.	True

NOTES

Topic	Q. No.	Answer
Predictive Analytics in Operations Management	5.	True
	6.	procurement
Building an Analytics-Driven Organisation	7.	True
	8.	leader

10.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Greasley, A. (2013). *Operations Management*. Hoboken, N.J.: Wiley.
- Kumar, S., & Suresh, N. (2009). *Operations Management*. New Delhi: New Age International.

E-REFERENCES

- Predictive IT Operations Analytics (ITOA) - Machine Data | Micro Focus. (2019). Retrieved from https://www.microfocus.com/en-us/products/operations-analytics-operations-analysis/overview
- Building an Analytics-driven Organization - Intuceo. (2019). Retrieved from https://www.intuceo.com/building-analytics-driven-organization/

CHAPTER 11

Operations Research and Operations Management

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LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the history of operations research and operations management
- Describe the operations research framework with an example
- Identify the scope and applications of operations research
- Describe the theory and application of dynamic programming
- Describe the theory and application of branch and bound method
- Explain the different types of scheduling systems

11.1 INTRODUCTION

World War II was a defining period in the human history. Apart from the disastrous consequences of the war to human life, the period also led to the adoption of new technologies and development of new concepts for improving efficiency and effectiveness in systems. One such concept was operations research. Today this concept influences almost all the major decisions whenever one has to allocate a limited number of resources to competing demands. Whether it is related with production, transportation, national planning, budget allocation, agriculture or education, operations research is involved in all the fields.

This chapter introduces the concept of operations research. Starting with its history, you will learn about the framework, scope and applications of operations research. You will also learn about the two widely used operations research models, dynamic programming and branch and bound method. Finally, this chapter delves on scheduling system problem

11.2 ORIGIN OF OPERATIONS RESEARCH AND OPERATIONS MANAGEMENT

Operations research began in England during 1937. It was conceived when the British Royal Air Force developed radar defence systems. A British Air Ministry official, A.P. Rowe formulated teams to do 'operational researches' on the communication systems and control rooms of the radar stations to improve their operational efficiency. This new approach spread across other departments. A physicist named P.M.S. Blackett led an operations research project group and highlighted the need for a scientific approach to manage complex operations. From England, operations research travelled to the US. Phillip Morse, who is known as the father of operations research in the US, led the operations research group in the US Navy's Mine Warfare Operations.

The first major application of operations research was during World War II. Post war, it expanded its reach to the civilian operations, such as scheduling, inventory control, strategic planning and resource allocation. The expansion of operations research was also due to some other significant developments:

- Formulation of the simplex algorithm for linear programming (by George Dantzig in 1947)

- Rapid expansion of digital computers
- Development of operations research techniques, such as non-linear, integer and dynamic programming; computer simulation; queuing theory; inventory models; game theory; etc.

Note that although theories of operations research were established much earlier during 1913-1917 (Table 1), their successful practical implications were only realised during 1950–1970.

Table 1: Theoretical Developments Leading to Operations Research

Contributor	Significant Contribution(s)
Adam Smith (1776)	Concept of scientific management in the book 'The Wealth of Nations', division of labour concept
Charles Babbage (1883)	Specialisation of tasks concept
F.W. Taylor (1859–1915)	Father of scientific management, time study rules
Frank Gilberth	Association between physical effort and workers' output, therbligs in books 'Motion Study' and 'Applied Motion Study'
Henry Fords (1913)	Mass production, assembly lines
Henry Gantt (1913)	Gantt chart
F.W. Harris (1914)	Economic Order Quantity (EOQ)
Walter Shewhart (1924)	Statistical quality
F.H. Dodge (1931)	Sampling inspection
L.H.C. Tippett (1937)	Work sampling

Operations research is the approach to solving complex decisions using advanced analytics. Operations management, on the other hand, is the management of production processes, services, supply chains to improve operations processes. Both operations research and operations management are:

- Mathematically oriented
- Scientific method applications
- Provide information for executive decision-making

However, operations research is primarily a mathematical technique associated with modelling a problem to find an optimal solution. Operations management is a managerial activity that utilises crucial production resources to strategic growth and competitive advantage of the organisation.

Self Assessment Questions

1. Operations research began in which year?
   a. 1913 b. 1917
   c. 1929 d. 1937
2. Who introduced the specialisation of tasks?
   a. F.W. Taylor b. Henry Ford
   c. Charles Babbage d. Adam Smith

Notes

11.3 OPERATIONS RESEARCH

Operations research is a methodical approach to problem-solving and decision-making through the use of analytical tools. Instead of relying on subjective and expert-based methods, it uses objective and well-defined analytical methods to make better and consistent decisions. However, it does not entirely do away with the use of experts. It considers them as complementary to the analytical methods.

Operations research is not an absolute method of making decisions. It should be considered as a method that facilitates effective decision-making process. All it does is that it provides a decision-maker with several robust and scientifically derived alternatives to solve a problem or situation. The final decision still has to be of the decision-maker.

To help make effective decisions, operations research proposes the following framework (Figure 1), which can be applied to a generic problem.

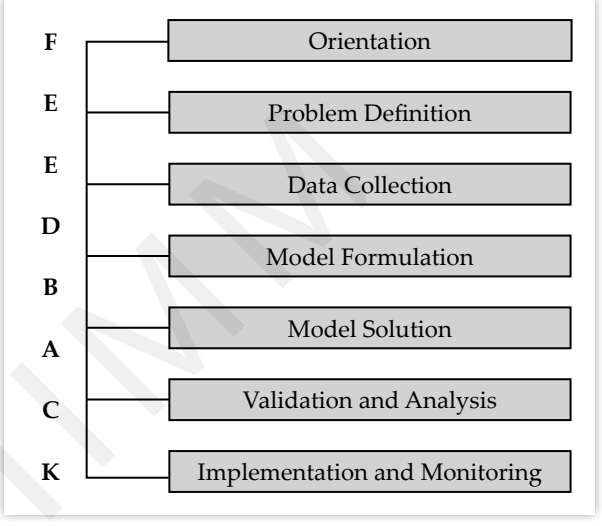

Figure 1: Operations Research Framework

Source: *https://www.pitt.edu/~jrclass/or/or-intro.html*

Let's understand the operations research framework through an example. Suppose a manufacturer is planning production for the next month. It has two main product lines and three main limited amounts of resources. Each product has a different profit margin and requires different amount of each resource. Under these constraints, the company has to plan the next month's production to realise maximum profitability.

- **Orientation:** The company forms a multifunctional team to address the given problem. The team members may include members from engineering, production planning, sales and marketing, accounting, and information systems. The team analyses the problem and defines its relationship with different operational aspects of the system. Then, they arrive at a consensus on the primary objective of the project. For instance, the objective of the project is to plan production of two products over the next month so that maximum profits are realised.
- **Problem definition:** In this step, the problem is more specifically defined in terms of its scope and expected results. For example, the objective in our case will be to maximise profit over the next month from the sales of two products, A and B. Then, specify the factors that impact the objective. These factors can be controllable or

uncontrollable. For example, the planned production rates can be controlled, but the actual product demand cannot be controlled. Finally, specify the constraints on the alternative courses of action. For example, the planned production must not exceed the expected availability of resources.

- **Data collection:** In this step, data is collected to translate the defined problem into a model. Data can be collected from direct observation or from company standards providing cost-related information. Table 2 lists the data collected for planning optimum production of A and B over the next month:

Table 2: Data Collection for Products A & B

	Product A	Product B
Profit margin	$10	$9
Resource 1 requirement	7/10 unit	1 unit
Resource 2 requirement	1 unit	2/3 unit
Resource 3 requirement	1/10 unit	1/4 unit
Availability of Resources Next Month		
Resource 1	630 units	
Resource 2	708 units	
Resource 3	135 units	

Note

Table 11.2 displays a simplified version of data collection. In real life, data collection requires extensive analysis, and the final value may require compromise between different functional members of the team.

- **Model formulation**: A model is an abstract representation of reality. If a model accurately represents a system, then the conclusions derived from analysing the model can be appropriately extrapolated to the original system. Traditionally, operations research has been associated with mathematical models. A mathematical model is a mathematical representation of an actual system or situation. It can be deterministic (uses known parameters, such as CPM) or probabilistic (uses uncertain parameters, such as PERT). Most mathematical models have three main elements:
  - **Decision variables:** These elements are used to model specific controllable actions.
  - **Constraints:** These elements are used to set boundaries on the range of values that each decision variable can assume.
  - **Objective function:** This is a mathematical statement of a performance measure. It is expressed as a function of the decision variables of the model.

  In our example, suppose two decision variables G and W represent the number of products A and B, respectively, to be produced and sold next month. Then, the mathematical model is:

  Maximise {Profit = 10G + 9W}, subject to

  - 0.7G + 1W ≤ 630 (For resource 1, the production of 0.7 unit of G and 1 unit of W should not exceed 630 units)

- 1G + 2/3W ≤ 708 (For resource 2, the production of 1 unit of G and 2/3 unit of W should not exceed 708 units)
- 0.1G + 0.25W ≤ 135 (For resource 3, the production of 0.1 unit of G and 0.25 unit of W should not exceed 135 units)

❍ **Model solution:** In this step, the solution of the problem represented by the model is determined. The techniques used are:

- **Simulation techniques:** These are used to analyse simulation models.
- **Mathematical analysis techniques:** These are used to solve mathematical models which do not have a clear objective function or constraints. They include common statistical techniques such as regression analysis, analysis of variance, queuing, and Markov chains.
- **Optimum-seeking techniques:** These are used to solve the mathematical programs to find the best values for decision variables. They include linear, nonlinear, dynamic, and goal programming.
- **Heuristics:** These techniques do not guarantee the best solution, but give a near-optimal solution. These methods have become popular because they are simple to use and they exploit specific features of a problem to get good results.

To solve our model example, linear programming will give the following result: G = 540 and W = 252. Thus, the production plan that yields maximum profits suggests producing 540 units of product A and 252 units of product B. This will generate a profit of $7668 and will completely utilise the first two resources and leave 18 units of the last resource 3 unutilised.

❍ **Validation and output analysis:** In this step, the solution is verified to ensure that it is feasible and accurately represents the system. Next, the solution is analysed for post-optimality to find out how robust it is with respect to deviations in the essential assumptions in the model and in the values of the parameters. For example, in our example, you can test the solution by asking questions such as:

- Will the optimum production plan change if the profits related with product B were overestimated by 5%? If yes, then how?
- If it is possible to purchase an additional amount of resource 2 at a premium, then will it be worth buying it? If yes, then how much?
- If the resource 3 availability reduces by 8% due to machine unreliability, then what effect will it have on the optimal policy?

Managers and decision-makers analyse such questions to determine a recommended course of action, with a wide range of applicability and sensitivity to parameters.

❍ **Implementation and monitoring:** Finally, the solution is implemented by developing operating procedures, instruction manuals, and production schedules. After implementation, the system is regularly monitored by an operating team to ensure that the implemented results are valid in regular operating environment. For example, in our example, if a worker's strike creates a shortage of manpower (say, resource 1), then the plan should be revised to derive an alternative course of action.

11.3.1 SCOPE AND APPLICATIONS OF OPERATIONS RESEARCH

Whether a problem is simple or complex, operations research is useful in every area that requires optimum utilisation of resources. Table 3 displays an illustrative list of areas where operations research has been widely used:

Table 3: Scope and Applications of Operational Research

Fields	Applications
Accounting	Effective assignment of audit teams; analysis of credit policy; cash flow planning; and development of standard costs and costs for by products
Construction	Project scheduling, monitoring, and control; workforce determination and deployment; and resource allocation
Facilities planning	Decision on factory location and size; estimation of required number of facilities; transportation loading and unloading; and warehouse location decision
Finance	Developing cash management models; capital allocation; financial planning models; investment analysis; and portfolio optimisation
Manufacturing	Inventory control; marketing balance projection; and production scheduling and smoothing
Marketing	Allocation of advertising budget; timing of product introduction; selection of product mix; and selection of packaging
Human resources	Staff planning; employee recruitment; skill mapping; scheduling of training programs; and organisational structure
Purchasing	Optimal buying and reordering; and materials transfer
Research and development	R&D projects control; budget allocation; and product launch
Defense services	Planning and scheduling of defense projects; evaluation of potential 'threats'; developing defense strategies and new technologies; evaluation of tenders; and transportation and supply
Transportation	Forecasting of public transport requirements; optimum routing; railways project management and network distribution
Country development	Five-year plans; annual budgets; estimation of GNP and GDP; employment generation
Agriculture and irrigation	Dam construction; optimum allocation of supply of seeds or fertiliser; and agricultural outputs
Education and training	Optimum number of schools with their locations; optimum mix of students-teacher ratio; optimum financial outlay

Self Assessment Questions

3. Which of the following statements is not true about operations research?
   a. It is an absolute method of decision-making.
   b. It is used to objectively analyse problems.
   c. It does not require expert judgement at all for the final decision.
   d. It uses a team of highly specialised personnel from a single function.
4. An abstract representation of reality is called a/an _____.
5. The Critical Path Method is a probabilistic model. (True/False)

Notes

6. The technique that does not guarantee the best solution, but gives a near optimal solution is called:
   a. Heuristics
   b. Markov analysis
   c. Range programming
   d. Computer simulation

11.4 OPERATIONAL RESEARCH APPLICATIONS

Operations research requires the application of various quantitative models which can be applied on various real-life problems to find optimal solutions. In this section, we will learn about two quantitative models, dynamic programming and the branch and bound method.

11.4.1 DYNAMIC PROGRAMMING

Dynamic programming is a technique that divides a large, complex problem into smaller, workable problems. The solution of smaller problems will provide an optimal solution to the large problem. In most applications, it generates solutions by working backward from the end of a problem to the beginning.

Some of the most common features of dynamic programming are:

- A problem can be divided into stages, where a decision is required at each stage. These decisions are interrelated. Each decision is associated with one stage of the problem. The stage is the total elapsed time since the beginning of the problem.
- Each stage has various states associated with it. The states are various possible conditions in which the system might be at the stage of the problem. The number of states may be finite or infinite.
- The decision selected at any stage describes how the state of the current state will be converted into a state associated with the beginning of the next stage. Thus, a dynamic programming problem can be interpreted as a network where:
  - Each node corresponds to a state.
  - Each column of nodes corresponds to a stage. The network will have various columns of nodes. The flow from a node can go only to a node in the next column to the right.
  - Each link from a node to nodes in the next column corresponds to the possible policy decision on which state to go to next.
  - The value assigned to each link corresponds to that policy decision's instant contribution to the objective function. This objective is usually related to finding the shortest or the longest path in the network.
- Dynamic programming finds an optimal decision for the overall problem. It uses the principle of optimality. Given the current state, the optimal decision for the remaining stages must be independent of the decisions adopted in precedent stages.

- There is a recursive relationship that determines the optimal policy for stage n, given the optimal policy for stage n + 1. This recursive relationship is:

$$f_n^*(s_n) = \max_{x_n}\{f_n(s_n, x_n)\} \quad \text{or} \quad f_n^*(s_n) = \min_{x_n}\{f_n(s_n, x_n)\},$$

Here,

N = Number of stages

n = Label for current stage (n = 1, 2,…,N)

s_n = Current state for stage n

x_n = Decision variable for stage n

x_n^* = Optimal value of (given)

f_n (s_n x_n) = Contribution of stages n, n + 1,…., N to objective function if system starts in state at stage n, instant decision is x_n, and optimal decisions are made subsequently

The recursive relationship keeps recurring as the solution procedure moves backward stage by stage. When the current stage number n is decreased by 1, the new $f_n^*(s_n)$ function is derived by using the $f_{n+1}^*(s_{n+1})$ function, which was derived from the previous iteration, and this process keeps repeating.

- In this recursive relationship, the solution procedure starts at the end and moves backward stage by stage. In each stage, it determines the optimal policy for that stage. Finally, it finds the optimal policy starting at the initial stage. This optimal policy at the initial stage provides an optimal solution for the entire problem.

Dynamic programming can be applied to solve various optimisation problems, including inventory control, evaluation of investment opportunities, long-term corporate planning and resource allocation.

11.4.2 BRANCH AND BOUND METHOD

The branch and bound method is linked with integer programming problem. It divides the feasible solution space into smaller subsets of solutions. These smaller subsets are then determined systematically until the optimal solution is found. For example, a machine shop owner plans to purchase some presses and lathes. He has estimated that each new press will increase profit by $100 per day and each new lathe will increase profit by $150 per day. Table 4 shows the purchase price and the required floor space of each machine:

TABLE 4: Machine Purchase Prices and Space Requirements

Machine	Purchase price ($)	Required floor space (sq. ft.)
Press	8000	15
Lathe	4000	30

His budget is $40,000 and the available floor space is 200 square feet. He wants to know the quantity of each machine that he should purchase to get maximum profit.

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The branch and bound method for this problem is as follows:

1. Find the optimal solution to the linear programming model with no integer restrictions (relaxed integer restrictions) as follows:

   Maximise Z = $100x_1 + 150\ x_2$, subject to

   $8000x_1 + 4000\ x_2 \leq 40{,}000$

   $15_x 1 + 30_x 2 \leq 200$

   $x_1\ x_2 \geq 0$ and $x_1 = 2.22$, $x_2 = 5.56$, Z = 1055.56

2. The solution process is visually represented through nodes and branches, as shown in Figure 1. The initial node contains the following two bounds:

   - Upper bound (UB) = \$1,055.56. This is the Z value for the relaxed solution, $x_1 = 2.22$ and $x_2 = 5.56$.
   - Lower bound (LB) = \$950. This is the Z value for the rounded-down solution, $x_1 = 2$ and $x_2 = 5$.

The optimal integer solution will be between these two bounds, as shown in Figure 2:

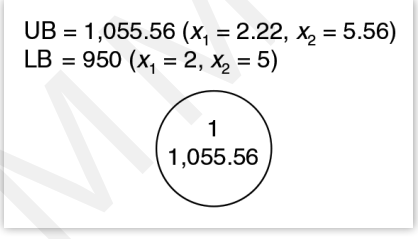

FIGURE 2: Initial Node

Source: *http://web.tecnico.ulisboa.pt/mcasquilho/compute/_linpro/TaylorB_module_c.pdf*

1. From the above relaxed solution, two new solution subsets are created by observing the relaxed solution for each variable:

   $x_1 = 2.22$

   $x_2 = 5.56$

   Now, the variable with the greatest fractional part is used for branching. For this, find which relaxed solution is farthest from the rounded-down integer value. Here, the .56 portion of 5.56 is the greatest fractional part. Thus, x_2 will be used for branching.

2. Two new constraints for this branching variable are created to depict the partitioned integer values. The constraints for x_2 are:

   $x_2 \leq 5$

   $x_2 \geq 6$

   Thus, x_2 can be 0, 1, 2, 3, 4, 5, or 6, 7, 8, etc. But it cannot be a value between 5 and 6, such as 5.56. These two new constraints are the two solution subsets, which will be added to the model to determine the next relaxed solution.

3. Two new nodes are created, one for the ≥ constraint and the other for the ≤ constraint. In Figure 3, the solutions at nodes 2 and 3 are the new relaxed solutions:

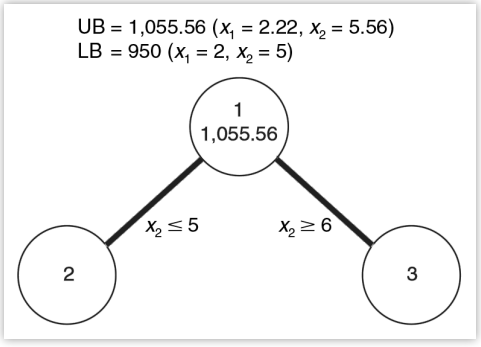

FIGURE 3: Solution Subsets x_2

Source: *http://web.tecnico.ulisboa.pt/mcasquilho/compute/_linpro/TaylorB_module_c.pdf*

4. The relaxed linear programming model is solved with the new constraints. First, the solution at node 2 is determined by solving the model with the constraint $x_2 \leq 5$ added:

   Maximise $Z = 100x_1 + 150x_2$ subject to

   $8000x_1 + 4000x_2 \leq 40{,}000$

   $15x_1 + 30x_2 \leq 200$

   $x_2 \leq 5$

   $x_1 \; x_2 \geq 0$

   The optimal solution with relaxed integer restrictions is $x_1 = 2.5$, $x_2 = 5$, and $Z = 1000$

   Next, the solution at node 3 is determined by solving the model with $x_2 \geq 6$:

   Maximise $Z = 100x_1 + 150x_2$ subject to

   $8000x_1 + 4000x_2 \leq 40{,}000$

   $15x_1 + 30x_2 \leq 200$

   $x_2 \geq 6$

   $x_1 \; x_2 \geq 0$

   The optimal solution for this model with integer restrictions relaxed is $x_1 = 1.33$, $x_2 = 6$, and $Z = 1033.33$

   These two solutions with $x_2 \leq 5$ and $x_2 \geq 6$ show the partitioning of the original relaxed model into two subsets.

Notes

5. The relaxed solution is the upper bound at each node. The existing maximum integer solution (at any node) is the lower bound. Figure 4 shows the resulting solution subsets obtained from step 5:

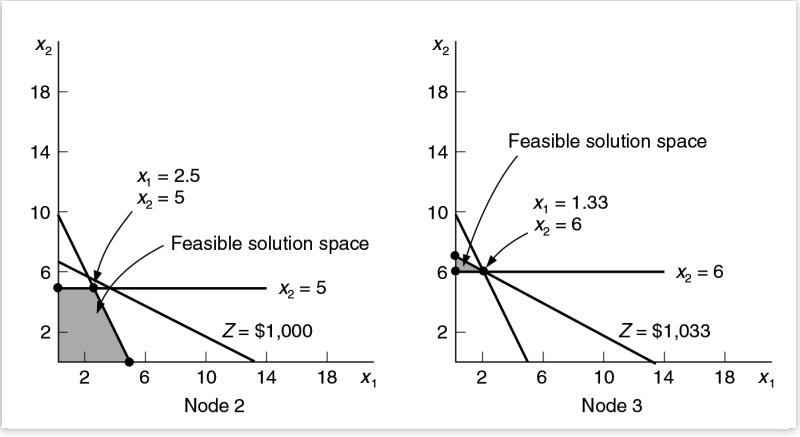

Figure 4: Feasible Solution Spaces for Nodes 2 and 3

Source: *http://web.tecnico.ulisboa.pt/mcasquilho/compute/_linpro/TaylorB_module_c.pdf*

In node 2 graph, the solution point $x_1 = 2.5$, $x_2 = 5$ results in a maximum Z value of $1000. This is the upper bound for this node.

In node 3 graph, the solution point $x_1 = 1.33$, $x_2 = 6$ results in a maximum Z value of $1033.33. This is the upper bound for this node.

The lower bound at nodes 2 and 3 is the maximum integer solution. Since neither of these relaxed solutions is entirely integer, the lower bound remains $950 (integer solution value at node 1 for the rounded-down integer solution).

Figure 5 shows the upper and lower bounds at each node:

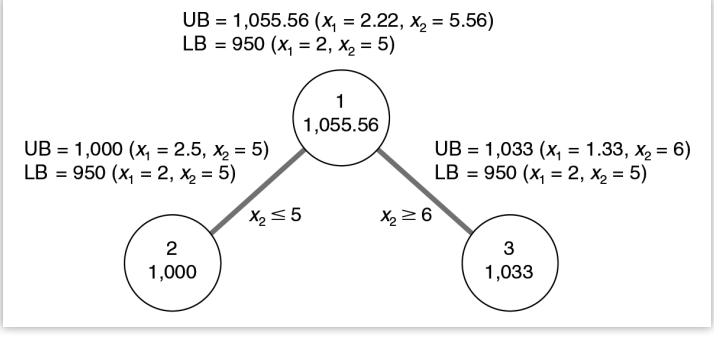

Figure 5: Upper and Lower Bounds at Nodes 2 and 3

Source: *http://web.tecnico.ulisboa.pt/mcasquilho/compute/_linpro/TaylorB_module_c.pdf*

6. If the process produces a feasible integer solution with the greatest upper bound value of any ending node, the optimal solution is reached. If there is no feasible integer solution yet, then branch out from the node with the greatest upper bound. In the example, since a feasible integer solution is not yet derived, node 3 is branched out because it generates a higher maximum possible value of $1,033, as compared to node 2.

7. Return to step 3. The steps for branching are repeated until the optimal solution is generated. Figure 6 shows the final branch and bound diagram with the optimal solution at node 6:

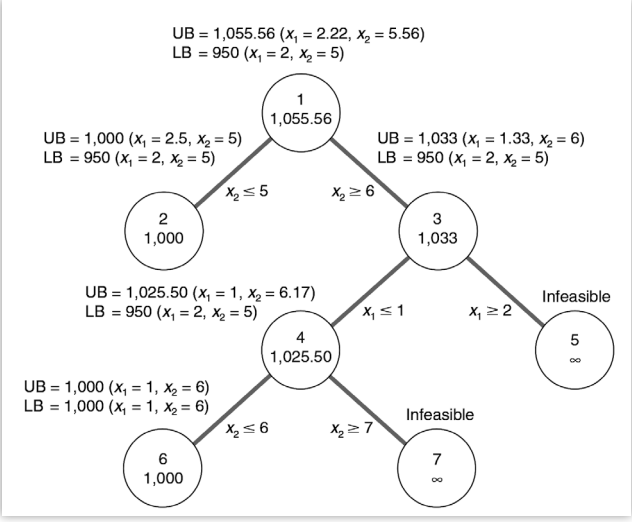

FIGURE 6: Optimal Solution at Node 6

Source: *http://web.tecnico.ulisboa.pt/mcasquilho/compute/_linpro/TaylorB_module_c.pdf*

At node 6, the value of $1000 is the possible maximum (upper bound) integer value. It is not possible to achieve any higher value by further branching from node 6. The upper bound at node 2 is 1000 (same as node 6), and, thus, can result in no improvement. Solutions at nodes 5 and 7 are infeasible. Thus, if the owner purchases one press and six lathes, he will have a daily profit of $1000.

SELF ASSESSMENT QUESTIONS

7. Which technique working backward from the end of a problem enables you to divide a problem into smaller, tractable parts?
   a. Goal programming b. Linear programming
   c. Dynamic programming d. Integer programming
8. The branch and bound method is linked with _____ problem.

11.5 SCHEDULING SYSTEMS

Operations research is used to help decision-makers in planning an optimal production schedule. A schedule is the time-table to perform a sequence of activities. There are three types of scheduling systems:

- **Single machine shops:** This is the simplest job shop problem that consists of a single machine and *n* jobs. Each job has one operation to be performed. The ready time is set to 0 for all jobs. All jobs are processed on the single machine. The jobs are sequenced based on the following rules:
  - **Shortest Processing Time (SPT):** When the single machine is made available, the shortest job ready at the time will begin processing.
  - **Earliest Due Date (EDD):** This rule orders the sequence of jobs to be done from the job with the earliest due date to the job with the latest due date. EDD

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finds the optimal schedule that minimises the maximum lateness or tardiness-related measures.

- **Flow shops:** In this arrangement, all jobs visit all machines in the same order. The objective is to determine a job sequence that minimises the makespan. Makespan is the total time taken to completely execute all jobs. This can be done using Johnson's algorithm in case of a 2-machine setup. The principle of Johnson's algorithm is that jobs with smaller processing times on the first machine come earlier in the sequence and the jobs with small processing time on the second machine come later in the sequence. In case of three or more machines, the branch and bound algorithm can be used.
- **Job shops:** In this arrangement, each job visits machines in a specific order. The flow of tasks in a job need not be unidirectional. In addition, each job may use a machine more than once. This scheduling system has two constraints:
- **Precedence:** If there are two consecutive tasks for the same job, then the first task must be completed before the second can be started.
- **No overlap:** A machine cannot work on two tasks simultaneously.

The objective of the job shop scheduling is to minimise the makespan. It is NP-hard problem and employs various analytical techniques for a solution.

Self Assessment Questions

9. Which scheduling systems are the most complex of the following?
   a. Single machine shops
   b. Two-machine shops
   c. Flow shops
   d. Job shops
10. Which method is most effective for solving 2-machine shop scheduling problem?
   a. Linear programming
   b. Johnson's algorithm
   c. Branch and bound
   d. Incremental scheduling

11.6 SUMMARY

- The roots of operations research can be traced back to World War II.
- The theoretical aspects of operations research are founded on the principles of scientific management and specialisation of tasks, while the practical application was due to the development of linear programming, digital revolution, and other computer programming models.
- Operations research is a methodical approach to problem-solving and decision-making through the use of analytical tools.
- The framework of operations research is orientation to problem definition, to data collection, to model formulation and solution, to validation and output analysis, and, finally, to implementation and monitoring.
- Operations research can be applied in any field dealing with human activities and having a problem requiring optimum utilisation of resources.
- Two most widely used techniques for operations research application are dynamic programming and the branch and bound method.

- Dynamic programming divides a large, complex problem into smaller, workable problems. It generates solutions by working backward from the end of a problem to the beginning.
- The branch and bound method divides the feasible solution space into smaller subsets of solutions. These smaller subsets are then determined systematically until the optimal solution is found.
- Another major application of operations research is in scheduling systems, which can be single machine shops, flow shops, or job shops.
- In any scheduling system, operations research is used to find an optimum schedule that minimises the makespan.

11.7 KEY WORDS

- **System:** An organisation of inter-related components that work in tandem to achieve the goal of the system.
- **Scheduling systems:** Systematic procedures employed to promote efficient and methodical scheduling of resources.
- **Constraints:** The linear equations or inequalities arising due to real-world limitations.
- **Decision variables:** Physical quantities whose values represent the solution.
- **Feasible solution:** A solution that satisfies all constraints (including non-negative constraints) in a problem.
- **Feasible region:** A collection of feasible solutions.
- **Unbounded solution:** A solution with infinite objective function.
- **Job:** A combination of tasks to make a product, etc.
- **Machine:** An equipment that is available to execute jobs.
- **Processing time:** The length of time required to process a job.
- **Completion time:** The time in which the processing of a job is completed.
- **Linear programming:** The technique that optimises the objective functions using a series of linear equations, which aim to distribute limited resources among competing demands.
- **Integer programming:** The linear programming technique that uses integer values as some or all of the decision variables.

11.8 CASE STUDY: APPLICATION OF DYNAMIC PROGRAMMING TO AN INVENTORY PROBLEM

This case study illustrates how dynamic programming can be used to solve an inventory problem. Following table displays the product demand during each of the next 4 months:

Period	Demand
Month 1	1 unit
Month 2	2 units
Month 3	3 units
Month 4	4 units

NOTES

At the beginning of each month, the company must determine how many units should be produced during that month. The costs during any month of production are:

- Setup cost: $3
- Variable cost: $1/unit
- Holding cost: 50¢/unit on hand (at the end of each month)
- Maximum capacity per month: 5 units
- Ending inventory size: Maximum 4 units per month

The company wants to determine a production schedule that:

- Meets all demands on time
- Minimises the total costs of production and holding during 4 months

Assumption: At the beginning of month 1, 0 units are on hand.

Now, all demands can be met on time by restricting each month's ending inventory to be positive. To use dynamic programming to solve this problem, the company must identify the appropriate state, stage and decision. The stage should be defined so that when one stage remains, the problem will be trivial to solve. At the beginning of month 4, the company would meet demand at minimum cost by simply producing just enough units to ensure that:

Month 4 production + Month 3 ending inventory = Month 4 demand

Therefore, the stage is represented by time (month). At each stage (month), the company must decide how many units to produce. To make this decision, it must know the inventory level at the beginning of the current month (or the end of the previous month). Therefore, the state at any stage is the beginning inventory level.

To develop the optimal production schedule:

$f_t(i)$ = Minimum cost of meeting demands for months t, t+1,…,4 if i units are on hand at the beginning of month t

$c(x)$ = Cost of producing x units during a period

$c(0) = 0$

For $x > 0$, $c(x) = 3 + x$

$x_t(i)$ = Production level during month t that minimizes the total cost during months, t, t+1,…,4 if i units are on hand at the beginning of month t

Due to limited capacity and for meeting all demands on time, the possible states during each period are 0, 1, 2, 3, and 4.

Solution:

1. **Determine $f_4(0)$, $f_4(1)$, $f_4(2)$, $f_4(3)$, and $f_4(4)$:** During month 4, the company will produce just enough units to meet the month 4 demand of 4 units. Thus:

   $f_4(0)$ = Cost of producing 4 – 0 units = c(4) = 3+4 =$7 and $x_4(0) = 4 - 0 = 4$

   $f_4(1)$ = Cost of producing 4 – 1 units = c(3) = 3+3 =$6 and $x_4(1) = 4 - 1 = 3$

$f_4(2)$ = Cost of producing 4 – 2 units = c(2) = 3+2 =$5 and $x_4(2) = 4 - 2 = 2$

$f_4(3)$ = Cost of producing 4 – 3 units = c(1) = 3+1 =$4 and $x_4(3) = 4 - 3 = 1$

$f_4(4)$ = Cost of producing 4 – 4 units = c(0) = $0 and $x_4(4) = 4 - 4 = 4$

2. **Determine $f_3(0)$, $f_3(1)$, $f_3(2)$, $f_3(3)$, and $f_3(4)$:** The cost $f_3(i)$ is the minimum cost incurred during months 3 and 4 if the inventory at the beginning of month 3 is i. For each possible production level x during month 3, the total cost during months 3 and 4 is:

$$\left(\frac{1}{2}\right)(i + x - 2) + c(x) + f_4(i + x - 2) \quad (1)$$

The above equation states that if x units are produced during month 3, the ending inventory for that month will be $i + x - 2$. Then the holding cost for month 3 will be $\left(\frac{1}{2}\right)(i + x - 2)$, and the production cost will be c(x). Then, month 4 is entered with i + x – 2 units on hand. Considering the principle of optimality, the cost for month 4 will be $f_4(i + x - 2)$. The month 3 production level will be selected to minimise the cost in equation 1. Therefore,

$$f_3(i) = \min_x \left\{\left(\frac{1}{2}\right)(i + x - 2) + c(x) + f_4(i + x - 2)\right\} \quad (2)$$

In equation 2 above, x must be a member of {0, 1, 2, 3, 4, 5}, and must satisfy $4 \geq i + x - 2 \geq 0$. This shows that the demand of month 3 must be met ($i + x - 2 \geq 0$), and ending inventory must not be more than $4(i + x - 2 \leq 4)$. The following table displays the computations for $f_3(i)$:

Computations for $f_3(i)$

i	x	$(\frac{1}{2})(i + x - 2) + c(x)$	$f_4(i + x - 2)$	Total Cost Months 3, 4	$f_3(i)$ $x_3(i)$
0	2	$0 + 5 = 5$	7	$5 + 7 = 12$*	$f_3(0) = 12$
0	3	$\frac{1}{2} + 6 = \frac{13}{2}$	6	$\frac{13}{2} + 6 = \frac{25}{2}$	$x_3(0) = 2$
0	4	$1 + 7 = 8$	5	$8 + 5 = 13$	
0	5	$\frac{3}{2} + 8 = \frac{19}{2}$	4	$\frac{19}{2} + 4 = \frac{27}{2}$	
1	1	$0 + 4 = 4$	7	$4 + 7 = 11$	$f_3(1) = 10$
1	2	$\frac{1}{2} + 5 = \frac{11}{2}$	6	$\frac{11}{2} + 6 = \frac{23}{2}$	$x_3(1) = 5$
1	3	$1 + 6 = 7$	5	$7 + 5 = 12$	
1	4	$\frac{3}{2} + 7 = \frac{17}{2}$	4	$\frac{17}{2} + 4 = \frac{25}{2}$	
1	5	$2 + 8 = 10$	0	$10 + 0 = 10$*	
2	0	$0 + 0 = 0$	7	$0 + 7 = 7$*	$f_3(2) = 7$
2	1	$\frac{1}{2} + 4 = \frac{9}{2}$	6	$\frac{9}{2} + 6 = \frac{21}{2}$	$x_3(2) = 0$
2	2	$1 + 5 = 6$	5	$6 + 5 = 11$	
2	3	$\frac{3}{2} + 6 = \frac{15}{2}$	4	$\frac{15}{2} + 4 = \frac{23}{2}$	
2	4	$2 + 7 = 9$	0	$9 + 0 = 9$	
3	0	$\frac{1}{2} + 0 = \frac{1}{2}$	6	$\frac{1}{2} + 6 = \frac{13}{2}$*	$f_3(3) = \frac{13}{2}$
3	1	$1 + 4 = 5$	5	$5 + 5 = 10$	$x_3(3) = 0$
3	2	$\frac{3}{2} + 5 = \frac{13}{2}$	4	$\frac{13}{2} + 4 = \frac{21}{2}$	
3	3	$2 + 6 = 8$	0	$8 + 0 = 8$	
4	0	$1 + 0 = 1$	5	$1 + 5 = 6$*	$f_3(4) = 6$
4	1	$\frac{3}{2} + 4 = \frac{11}{2}$	4	$\frac{11}{2} + 4 = \frac{19}{2}$	$x_3(4) = 0$
4	2	$2 + 5 = 7$	0	$7 + 0 = 7$	

Source: *https://fac.ksu.edu.sa/sites/default/files/books_3337_0.pdf*

Notes

3. **Determine $f_2(0)$, $f_2(1)$, $f_2(2)$, $f_2(3)$, and $f_2(4)$.** Suppose month 2 production = x. Since month 2 demand is 3 units, a holding cost of $\left(\frac{1}{2}\right)$(i + x – 3) is incurred at the end of month 2. Thus, the total cost incurred during month 2 is $\left(\frac{1}{2}\right)$(i + x – 3) + c(x). During months 3 and 4, an optimal policy is followed. Since month 3 begins with an inventory of i + x – 3, the cost incurred during months 3 and 4 is f_3(i + x – 3). Similar to equation 2, the new recursive relation will be:

$$f_2(i) = \min_x \left\{ \left(\frac{1}{2}\right)(i + x - 3) + c(x) + f_3(i + x - 3) \right\} \qquad (3)$$

Where x must be a member of {0, 1, 2, 3, 4, 5}, and must also satisfy 0 ≤ i + x – 3 ≤ 4. Following table displays the computations for $f_2(i)$:

Computations for $f_2(i)$

i	x	$(\frac{1}{2})(i + x - 3) + c(x)$	$f_3(i + x - 3)$	Total Cost Months 2–4	$f_2(i)$ $x_2(i)$
0	3	$0 + 6 = 6$	12	$6 + 12 = 18$	$f_2(0) = 16$
0	4	$\frac{1}{2} + 7 = \frac{15}{2}$	10	$\frac{15}{2} + 10 = \frac{35}{2}$	$x_2(0) = 5$
0	5	$1 + 8 = 9$	7	$9 + 7 = 16$*	
1	2	$0 + 5 = 5$	12	$5 + 12 = 17$	$f_2(1) = 15$
1	3	$\frac{1}{2} + 6 = \frac{13}{2}$	10	$\frac{13}{2} + 10 = \frac{33}{2}$	$x_2(1) = 4$
1	4	$1 + 7 = 8$	7	$8 + 7 = 15$*	
1	5	$\frac{3}{2} + 8 = \frac{19}{2}$	$\frac{13}{2}$	$\frac{19}{2} + \frac{13}{2} = 16$	
2	1	$0 + 4 = 4$	12	$4 + 12 = 16$	$f_2(2) = 14$
2	2	$\frac{1}{2} + 5 = \frac{11}{2}$	10	$\frac{11}{2} + 10 = \frac{31}{2}$*	$x_2(2) = 3$
2	3	$1 + 6 = 7$	7	$7 + 7 = 14$*	
2	4	$\frac{3}{2} + 7 = \frac{17}{2}$	$\frac{13}{2}$	$\frac{17}{2} + \frac{13}{2} = 15$	
2	5	$2 + 8 = 10$	6	$10 + 6 = 16$	
3	0	$0 + 0 = 0$	12	$0 + 12 = 12$*	$f_2(3) = 12$
3	1	$\frac{1}{2} + 4 = \frac{9}{2}$	10	$\frac{9}{2} + 10 = \frac{29}{2}$	$x_2(3) = 0$
3	2	$1 + 5 = 6$	7	$6 + 7 = 13$	
3	3	$\frac{3}{2} + 6 = \frac{15}{2}$	$\frac{13}{2}$	$\frac{15}{2} + \frac{13}{2} = 14$	
3	4	$2 + 7 = 9$	6	$9 + 6 = 15$	
4	0	$\frac{1}{2} + 0 = \frac{1}{2}$	10	$\frac{1}{2} + 10 = \frac{21}{2}$*	$f_2(4) = \frac{21}{2}$
4	1	$1 + 4 = 5$	7	$5 + 7 = 12$	$x_2(4) = 0$
4	2	$\frac{3}{2} + 5 = \frac{13}{2}$	$\frac{13}{2}$	$\frac{13}{2} + \frac{13}{2} = 13$	
4	3	$2 + 6 = 8$	6	$8 + 6 = 14$	

Source: *https://fac.ksu.edu.sa/sites/default/files/books_3337_0.pdf*

4. **Determine $f_1(0)$.** Similarly, f_1(i) can be determined by the following recursive relation:

$$f_1(i) = \min_x \left\{ \left(\frac{1}{2}\right)(i + x - 1) + c(x) + f_3(i + x - 1) \right\} \qquad (4)$$

Where x must be a member of {0, 1, 2, 3, 4, 5}, and must also satisfy $0 \le i + x - 1 \le 4$. Since the inventory at the beginning of month 1 is 0 units, only $f_1(0)$ and $x_1(0)$ need to be determined. However, following table displays the computations for all $f_1(i)$s:

Computations for $f_1(i)$

i	x	$(\frac{1}{2})(i + x - 1) + c(x)$	$f_2(i + x - 1)$	Total Cost	$f_1(i)$ / $x_1(i)$
0	1	$0 + 4 = 4$	16	$4 + 16 = 20$*	$f_1(0) = 20$
0	2	$\frac{1}{2} + 5 = \frac{11}{2}$	15	$\frac{11}{2} + 15 = \frac{41}{2}$	$x_1(0) = 1$
0	3	$1 + 6 = 7$	14	$7 + 14 = 21$	
0	4	$\frac{3}{2} + 7 = \frac{17}{2}$	12	$\frac{17}{2} + 12 = \frac{41}{2}$	
0	5	$2 + 8 = 10$	$\frac{21}{2}$	$10 + \frac{21}{2} = \frac{41}{2}$	
1	0	$0 + 0 = 0$	16	$0 + 16 = 16$*	$f_1(1) = 16$
1	1	$\frac{1}{2} + 4 = \frac{9}{2}$	15	$\frac{9}{2} + 15 = \frac{39}{2}$	$x_1(1) = 0$
1	2	$1 + 5 = 6$	14	20	
1	3	$\frac{3}{2} + 6 = \frac{15}{2}$	12	$\frac{15}{2} + 12 = \frac{39}{2}$	
1	4	$2 + 7 = 9$	$\frac{21}{2}$	$9 + \frac{21}{2} = \frac{39}{2}$	
2	0	$\frac{1}{2} + 0 = \frac{1}{2}$	15	$\frac{1}{2} + 15 = \frac{31}{2}$*	$f_1(2) = \frac{31}{2}$
2	1	$1 + 4 = 5$	14	$5 + 14 = 19$	$x_1(2) = 0$
2	2	$\frac{3}{2} + 5 = \frac{13}{2}$	12	$\frac{13}{2} + 12 = \frac{37}{2}$	
2	3	$2 + 6 = 8$	$\frac{21}{2}$	$8 + \frac{21}{2} = \frac{37}{2}$	
3	0	$1 + 0 = 1$	14	$1 + 14 = 15$*	$f_1(3) = 15$
3	1	$\frac{3}{2} + 4 = \frac{11}{2}$	12	$\frac{11}{2} + 12 = \frac{35}{2}$	$x_1(3) = 0$
3	2	$2 + 5 = 7$	$\frac{21}{2}$	$7 + \frac{21}{2} = \frac{35}{2}$	
4	0	$\frac{3}{2} + 0 = \frac{3}{2}$	12	$\frac{3}{2} + 12 = \frac{27}{2}$*	$f_1(4) = \frac{27}{2}$
4	1	$2 + 4 = 6$	$\frac{21}{2}$	$6 + \frac{21}{2} = \frac{33}{2}$	$x_1(4) = 0$

Source: *https://fac.ksu.edu.sa/sites/default/files/books_3337_0.pdf*

5. **Determine the optimal production level for each month:** Since the initial inventory is 0 unit, the minimum cost for 4 months will be $f_1(0) = \$20$.

   To achieve $f_1(0)$, the production level during month 1 should be $x_1(0) = 1$.

   Then the inventory at the beginning of month 2 will be $0 + 1 - 1 = 0$

   Thus, in month 2, the company should produce $x_2(0) = 5$ units.

   Then the inventory at the beginning of month 3 will be $0 + 5 - 3 = 2$.

   Thus, during month 3, the company should produce $x_3(2) = 0$ units.

   Then the inventory at the beginning of month 4 will be $2 - 2 + 0 = 0$.

   Thus, during month 4, the company should produce $x_4(0) = 4$ units.

   The optimal production schedule incurs a total cost of \$20 and produces 1 unit during month 1, 5 units during month 2, 0 units during month 3, and 4 units during month 4.

Notes

6. **Network representation of inventory problem:** Finding this solution to inventory problem is the same as finding the shortest route joining the node (1, 0) to the node (5, 0) in the following figure:

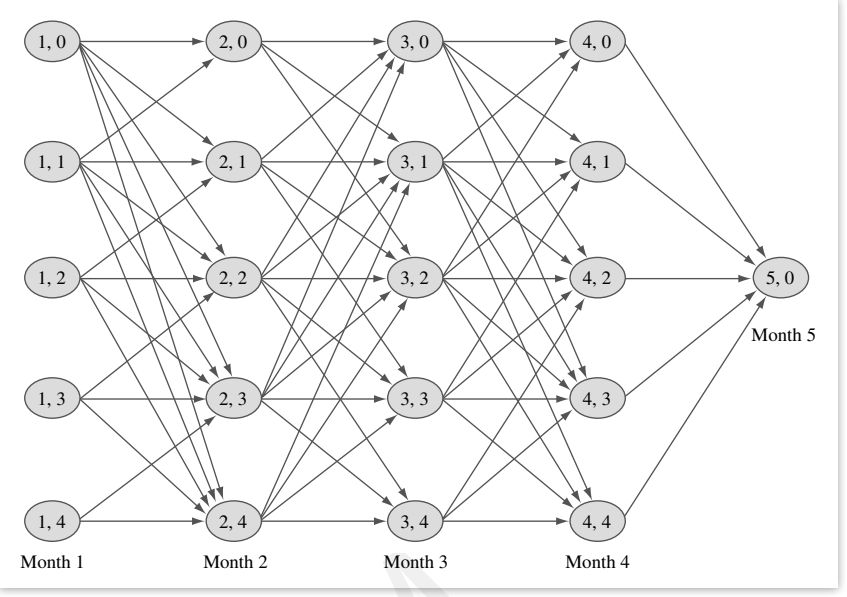

Figure: Network Representation of Inventory Problem

Source: *https://fac.ksu.edu.sa/sites/default/files/books_3337_0.pdf*

- Each node corresponds to a state. Each column of nodes corresponds to all the possible states of a given stage. For example, at node (2, 3), we are at the beginning of month 2, and the inventory at the beginning of this month is 3 units.
- Each arc represents the way in which a decision (how much to produce during the current month) transforms the current state into next month's state. For example, the arc 1 joining nodes (1,0) and (2,2) is related to producing 3 units during month 1. If 3 units are produced during month 1, then month 2 starts with 0 + 3 – 1 = 2 units.
- The length of each arc is the sum of production and inventory costs during the current period. For example, the cost associated with arc 1 would be $6 + \left(\frac{1}{2}\right) \times 2$ = 7.
- Some nodes in adjacent stages are not joined by an arc. For example, node (2,4) is not joined to node (3,0). This is because if month 2 begins with 4 units, then at the beginning of month 3, the company will have at least 4 – 3 = 1 unit on hand.
- At node (5,0) will be the arcs joining all month 4 states because having a positive inventory at the end of month 4 is suboptimal.

Result

The minimum-cost production schedule corresponds to the shortest path joining (1,0) and (5,0). This would be the path corresponding to production levels of 1, 5, 0, and 4. This means the path begins at (1,0), then goes to (2, 0 + 1 – 1) = (2, 0), then to (3, 0 + 5 – 3) = (3,2), then to (4, 2 + 0 – 2) = (4, 0), and, finally, to (5, 0 + 4 – 4) = (5, 0).

Thus, the optimal production schedule corresponds to the path (1, 0) – (2, 0) – (3, 2) – (4, 0) – (5, 0) in the above figure.

Conclusion

Dynamic programming solves a complex problem by dividing the problem into a series of simpler problems. It first solves a one-stage problem, then a two-stage problem, and finally a T-stage problem (T = total number of stages in the problem). In most applications, a decision is made at each stage (t = current stage), a cost is incurred (or a reward is earned) at each stage, and then the stage t + 1 state is reached.

Source: *https://fac.ksu.edu.sa/sites/default/files/books_3337_0.pdf*

QUESTIONS

1. In dynamic programming, what is the difference between a stage and a state?

   (**Hint:** A stage is the mechanism by which a problem is developed. The state at any stage provides the required information to make the correct decision at the current stage.)

2. Apart from inventory scheduling, what other problems can be solved by using dynamic programming?

   (**Hint:** Resource allocation, travelling salesperson, equipment replacement, etc.)

11.9 EXERCISE

1. How did operations research start? List some important developments that contributed significantly to its development.
2. What is the difference between operations research and operations management?
3. Explain the operations research framework, using a generic example.
4. Mention the applications of operations research in agriculture, national development, education and manufacturing.
5. What is dynamic programming? What are its most common features?
6. Explain the branch and bound method with an example.
7. What is a scheduling system? What are its different types?

11.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Origin of Operations Research and Operations Management	1.	d. 1937
	2.	c. Charles Babbage
Operations Research	3.	b. It is used to objectively analyse problems.
	4.	model
	5.	False

Notes

Topic	Q. No.	Answer
	6.	a. Heuristics
Operational Research Applications	7.	c. Dynamic programming
	8.	integer programming
Scheduling Systems	9.	d. Job shops
	10.	b. Johnson's algorithm

11.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

- Kwak, N., & Schniederjans, M. (1982). *Managerial Applications of Operations Research*. Washington, D.C.: University Press of America.
- Kumar, S., & Suresh, N. (2009). *Operations Management*. New Delhi: New Age International.
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CHAPTER 12

Risk Management in Operations

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NOTES

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

- Explain the concept of risk in operations management
- Discuss risk mitigation strategies
- Describe the concept of managing uncertainty and resilience
- Discuss how to implement a risk management framework

12.1 INTRODUCTION

In the previous chapter, you studied about the concept of operations research. You also studied how some operations research techniques are applied in the field of operations management.

Risk management in operations involves identifying, assessing and addressing potential threats and uncertainties that could impact an organisation's ability to achieve its objectives. This discipline ensures that risks are systematically managed and mitigated, enhancing operational resilience and efficiency. By integrating risk management into operational processes, organisations can anticipate disruptions, minimise adverse effects and maintain continuity.

In this chapter, you will study the concept of risk in operations management and risk mitigation strategies. You will also study about managing uncertainty and resilience and implementing a risk management framework.

12.2 UNDERSTANDING RISK IN OPERATIONS MANAGEMENT

Risk in operations management refers to the potential for unforeseen events or conditions that can adversely affect the efficiency, effectiveness and profitability of an organisation's operational processes. This encompasses a wide range of uncertainties, including fluctuations in customer demand, technological changes, regulatory shifts and unexpected crises like natural disasters or pandemics.

For effective risk management, organisations utilise various strategies such as robust forecasting, inventory management, flexible manufacturing systems and strong supplier relationships to manage these uncertainties. Additionally, integrating risk management with the overall operations strategy ensures that risk considerations are embedded in decision-making processes, enhancing the organisation's ability to adapt and thrive amidst challenges. Leveraging advanced technologies like AI, IoT and blockchain further strengthens an organisation's capacity to predict, monitor and respond to risks, ultimately safeguarding operational continuity and achieving long-term success.

12.2.1 TYPES OF RISKS IN OPERATIONS

Risks in operations can be categorised into several types, each with unique characteristics and potential impacts on the organisation. Understanding these types is the first step in effective risk management.

- **Operational risks:** Operational risks are internal risks that arise from day-to-day activities within the organisation. These risks can result from:
  - **Process failures:** Inefficiencies, errors or breakdowns in production processes can lead to delays, defects and increased costs.
  - **Human error:** Mistakes made by employees, such as incorrect data entry or miscommunication, can disrupt operations.
  - **Technology failures:** Malfunctions in machinery, equipment or IT systems can halt production and cause significant delays.
  - **Health and safety issues:** Accidents and injuries in the workplace can lead to operational disruptions and legal liabilities.
- **Financial risks:** Financial risks pertain to uncertainties related to the financial health of the organisation. These risks include:
  - **Currency fluctuations:** Fluctuations in exchange rates can impact the expense of imported materials and the marketability of exported goods.
  - **Interest rate changes:** Variations in interest rates can impact borrowing costs and financial planning.
  - **Credit risk:** The possibility that customers or suppliers may default on their financial obligations can affect cash flow and profitability.
  - **Market volatility:** Changes in market demand and prices can lead to revenue fluctuations and affect profitability.
- **Compliance and legal risks:** Compliance and legal risks involve the potential for legal action or regulatory penalties due to non-compliance with laws and regulations. These risks can arise from:
  - **Regulatory changes:** New laws or changes in existing regulations can require significant adjustments in operations and increase costs.
  - **Contractual disputes:** Disagreements with suppliers, customers or partners over contract terms can lead to legal battles and financial losses.
  - **Intellectual property infringement:** Unauthorised use of intellectual property can result in legal disputes and reputational damage.
  - **Environmental regulations:** Non-compliance with environmental laws can lead to fines, sanctions and damage to the organisation's reputation.
- **Reputational risks:** Reputational risks relate to potential damage to the organisation's image and brand. These risks can result from:
  - **Product recalls:** Recalling defective products can harm the organisation's reputation and lead to financial losses.
  - **Negative publicity:** Media coverage of scandals, accidents or unethical practices can damage the organisation's reputation.
  - **Customer dissatisfaction:** Poor customer service or product quality can lead to negative reviews and loss of customer trust.

- **Social media backlash:** Negative comments and campaigns on social media can spread rapidly, causing significant reputational harm.

12.2.2 RISK ASSESSMENT AND ANALYSIS

Risk assessment and analysis involve identifying potential risks, evaluating their impact and developing strategies to manage them effectively. This approach enables organisations to rank risks and allocate resources effectively to manage them.

The following steps outline a comprehensive approach to risk assessment and analysis.

1. **Risk identification:** Risk identification is the process of recognising potential risks that could affect the organisation. This step involves:
   - **Brainstorming sessions:** Engaging stakeholders from various departments to identify risks based on their experiences and insights.
   - **Historical data analysis:** Reviewing past incidents and disruptions to identify recurring risks and patterns.
   - **Industry benchmarking:** Comparing the organisation's risk profile with industry standards and best practices.
   - **Scenario analysis:** Considering different hypothetical situations to identify potential risks and their impacts.
2. **Risk evaluation:** Once risks are identified, the next step is to evaluate their potential impact and likelihood. This involves:
   - **Risk matrix:** Creating a risk matrix to plot risks based on their likelihood of occurrence and potential impact. This visual tool helps prioritise risks for further analysis.
   - **Quantitative analysis:** Using statistical methods and models to estimate the financial impact of risks. This may include techniques like Monte Carlo simulations and Value at Risk (VaR) analysis.
   - **Qualitative analysis:** Assessing risks based on expert judgment and qualitative criteria, such as severity, frequency and detectability.
3. **Risk prioritisation:** Risk prioritisation involves ranking risks based on their potential impact and likelihood. This helps organisations focus on the most critical risks and allocate resources accordingly. Key considerations include:
   - **Risk appetite:** Understanding the organisation's tolerance for risk and aligning risk management efforts with strategic objectives.
   - **Risk mitigation strategies:** Identifying and implementing measures to reduce the likelihood or impact of high-priority risks. This may include process improvements, technology upgrades and employee training.
   - **Contingency planning:** Developing plans to respond to and recover from high-priority risks. This may involve creating backup systems, establishing communication protocols and identifying alternative suppliers.

4. **Risk mitigation:** Risk mitigation involves implementing strategies to reduce the impact and likelihood of identified risks. Common risk mitigation strategies include:
   - **Avoidance:** Eliminating activities or processes that expose the organisation to risk.
   - **Reduction:** Implementing measures to reduce the likelihood or impact of risks. This may include investing in technology, improving processes and enhancing training programs.
   - **Transfer:** Shifting the risk to another party, such as through insurance policies or outsourcing arrangements.
   - **Acceptance:** Acknowledging the risk and preparing to manage its consequences if it occurs. This approach is often used for low-impact, low-likelihood risks.
5. **Risk monitoring and review:** Risk monitoring and review involve continuously tracking identified risks and evaluating the effectiveness of risk management strategies. This process ensures that risks are managed proactively and adjustments are made as needed. Key activities include:
   - **Key Risk Indicators (KRIs):** Establishing metrics to monitor risk levels and detect early warning signs of potential issues.
   - **Regular reviews:** Conducting periodic reviews of the risk management process to assess its effectiveness and identify areas for improvement.
   - **Incident reporting:** Implementing a system for reporting and analysing incidents to learn from past experiences and prevent future occurrences.
   - **Stakeholder engagement:** Engaging stakeholders in the risk management process to ensure that risks are identified, assessed and managed collaboratively.

Self Assessment Questions

1. _____ pertain to uncertainties related to the financial health of the organisation, including currency fluctuations, interest rate changes and credit risk.
2. Human error is categorised under financial risks in operations management. (True/False)

12.3 RISK MITIGATION STRATEGIES

Risk mitigation is a critical component of operations management. It involves identifying, assessing and prioritising risks followed by the application of resources to minimise, control and monitor the probability and/or impact of unfortunate events. Effective risk mitigation strategies ensure that organisations can continue their operations smoothly, even in the face of potential threats. There are three fundamental risk mitigation strategies: risk avoidance, risk reduction and risk sharing.

Notes

12.3.1 RISK AVOIDANCE

Risk avoidance involves taking proactive steps to eliminate the potential for risk entirely. This strategy is about deciding not to engage in activities or actions that carry inherent risks. By not participating in the risky activity, the organisation ensures that there is no exposure to the risk and, therefore, no impact.

Risk avoidance can be implemented in several ways:

1. **Eliminating hazardous activities:** Organisations can choose to stop or never start activities that are deemed too risky. For instance, a company may decide not to enter a market known for political instability or high levels of corruption.
2. **Strict policy enforcement:** Developing and enforcing stringent policies and procedures can help avoid risks. For example, implementing strict safety protocols can avoid workplace accidents.
3. **Alternative approaches:** Opting for alternative approaches that carry less risk can be another form of avoidance. For instance, a company might use more secure methods of data storage to avoid the risk of data breaches.

Examples

1. A pharmaceutical company may decide not to develop a new drug if the clinical trials reveal significant adverse effects, thus avoiding potential legal liabilities and damage to reputation.
2. A business may avoid entering a new geographic market if there is a high risk of economic sanctions or political unrest, thus preventing potential financial losses and operational disruptions.

The advantages of risk avoidance are as follows:

- **Elimination of risk:** The primary advantage is that the risk is completely avoided, leading to zero exposure.
- **Simplicity:** Avoidance is often simpler than managing and mitigating risks.

The disadvantages of risk avoidance are as follows:

- **Missed opportunities:** Avoiding risks can also mean missing out on potential opportunities for growth, innovation and profits.
- **Feasibility:** Not all risks can be avoided without significantly altering business operations.

12.3.2 RISK REDUCTION

Risk reduction involves taking steps to lessen the probability or impact of a risk. Unlike risk avoidance, which seeks to eliminate risk entirely, risk reduction aims to manage and minimise the adverse effects of risk to an acceptable level. This strategy is about implementing measures that make the risky activity safer or less impactful.

Risk reduction can be implemented through various methods, including:

1. **Process improvements:** Streamlining processes and improving operational efficiency can reduce risks. For example, adopting lean manufacturing techniques can minimise production errors and defects.
2. **Safety enhancements:** Implementing better safety measures and protocols can reduce the risk of accidents and injuries in the workplace. This could include regular safety training and investing in high-quality safety equipment.
3. **Technological upgrades:** Utilising advanced technologies can help reduce risks. For instance, using sophisticated software for data security can mitigate the risk of cyber-attacks.
4. **Preventive maintenance:** Regular maintenance of equipment and infrastructure can prevent breakdowns and failures, thus reducing the risk of operational disruptions.

Examples

1. A manufacturing company might implement stringent quality control measures to reduce the risk of producing defective products. This could involve regular inspections and testing at various stages of production.
2. A financial institution could invest in robust cybersecurity systems to protect against data breaches and cyber-attacks, reducing the risk of financial loss and reputational damage.

The advantages of risk reduction are as follows:

- **Enhanced safety:** Reduces the likelihood and impact of adverse events, enhancing overall safety and security.
- **Continued operations:** Allows organisations to continue operations while managing risks, rather than avoiding them altogether.

The disadvantages of risk reduction are as follows:

- **Cost:** Implementing risk reduction measures can be costly, requiring significant investment in resources, technology and training.
- **Complexity:** Reducing risk often involves complex processes and ongoing monitoring and evaluation.

12.3.3 RISK SHARING

Risk sharing involves distributing the risk among multiple parties. This strategy does not eliminate the risk but spreads its impact across several entities, reducing the burden on any single party. Risk sharing is often achieved through partnerships, contracts, insurance or outsourcing.

NOTES

Risk sharing can be implemented through various mechanisms, such as:

1. **Insurance:** Purchasing insurance policies to transfer the financial impact of certain risks to an insurance company. For example, a company might buy property insurance to protect against losses from fire or natural disasters.
2. **Partnerships and joint ventures:** Forming partnerships or joint ventures where the risks and rewards are shared. For instance, two companies might collaborate on a project, sharing both the potential profits and the associated risks.
3. **Outsourcing:** Outsourcing certain operations or functions to third-party providers can share the risk. For example, a company might outsource its IT services to a specialised firm, transferring the risk of IT failures to the provider.
4. **Contracts and agreements:** Using contracts to specify how risks will be shared among parties. For example, a construction company might include clauses in its contracts with suppliers and subcontractors that outline their responsibilities for managing specific risks.

EXAMPLES

1. A logistics company may buy cargo insurance to safeguard against the possibility of goods being damaged or lost during transit. The insurance company assumes the financial risk in exchange for a premium.
2. A technology firm might enter into a strategic alliance with a research institution to develop new products. The risks associated with research and development are shared between the parties, reducing the burden on each.

The advantages of risk sharing are as follows:

- **Reduced individual burden:** Spreads the risk, reducing the impact on any single entity.
- **Access to expertise:** Partnerships and outsourcing can provide access to specialised expertise and resources.

The disadvantages of risk sharing are as follows:

- **Dependence on others:** Sharing risks also means depending on other parties to manage their share of the risk effectively.
- **Complexity in management:** Managing relationships and agreements with multiple parties can be complex and time-consuming.

SELF ASSESSMENT QUESTIONS

3. Which risk mitigation strategy involves distributing the risk among multiple parties, often achieved through partnerships, contracts, insurance or outsourcing?

   a. Risk avoidance b. Risk reduction

   c. Risk sharing d. Risk assessment

4. _____ involves taking steps to lessen the probability or impact of a risk, making the risky activity safer or less impactful.

12.4 MANAGING UNCERTAINTY AND RESILIENCE

Uncertainty and resilience are critical concepts in operations management, essential for maintaining smooth operations and achieving organisational goals. Uncertainty refers to the lack of predictability in external and internal factors that can impact operations, while resilience is the ability of an organisation to anticipate, prepare for, respond to and recover from such uncertainties. Effective management of these elements can lead to improved performance, competitive advantage and sustainability.

Uncertainty in operations management can arise from various sources, including market volatility, supply chain disruptions, technological changes, regulatory changes and unexpected events such as natural disasters or pandemics. It can be categorised into four main types:

- **Demand uncertainty:** Fluctuations in customer demand can lead to overproduction or stockouts. For example, seasonal variations or changes in consumer preferences can affect demand.
- **Supply uncertainty:** Variations in the supply of raw materials or components can disrupt production schedules. This includes supplier reliability, lead times and quality issues.
- **Process uncertainty:** Variability in production processes can lead to inefficiencies. Factors such as equipment breakdowns, labor variability and process defects contribute to this type.
- **Environmental uncertainty:** External factors like economic conditions, political instability and natural disasters can impact operations.

Following are the strategies for managing uncertainty:

- **Forecasting and demand planning:** Accurate forecasting techniques, including time series analysis, regression models and machine learning algorithms, help predict future demand and plan accordingly. Demand planning aligns production schedules with expected sales, minimising the risk of overproduction or stockouts.
- **Inventory management:** Maintaining optimal inventory levels through techniques like Just-In-Time (JIT), Economic Order Quantity (EOQ) and safety stock calculations helps buffer against supply chain disruptions and demand fluctuations. Inventory management ensures that there are enough raw materials and finished goods to meet customer demands without excessive holding costs.
- **Supplier management:** Building strong relationships with suppliers, diversifying the supplier base and establishing backup suppliers can mitigate supply chain risks. Long-term contracts, supplier audits and collaboration on quality improvements enhance reliability.
- **Flexible manufacturing systems:** Implementing flexible manufacturing systems allows quick adjustments to production processes in response to changes in demand or supply. Modular equipment, cross-trained employees and adaptable process layouts contribute to this flexibility.

Notes

- **Risk management:** Identifying, assessing and mitigating risks through risk management frameworks is essential. Techniques such as Failure Mode and Effects Analysis (FMEA), risk heat maps and scenario planning help anticipate potential disruptions and develop contingency plans.

Resilience in operations management involves creating systems and processes that can withstand and quickly recover from disruptions. It encompasses several key elements:

- **Robustness:** Designing systems to endure stress without significant performance degradation. This includes using high-quality materials, maintaining equipment and ensuring redundancy in critical components.
- **Redundancy:** Having backup systems, suppliers and processes to take over in case of failure. Redundancy ensures continuity of operations even if one part of the system fails.
- **Flexibility:** The ability to adapt to changing circumstances. Flexible manufacturing systems, versatile workforce and agile supply chains contribute to resilience.
- **Visibility:** Real-time monitoring and data analytics provide visibility into operations, enabling quick detection and response to issues. IoT devices, sensors and advanced analytics tools enhance situational awareness.
- **Collaboration:** Strong relationships with suppliers, customers and other stakeholders facilitate coordinated responses to disruptions. Collaboration includes information sharing, joint problem-solving and collective risk management.

Self Assessment Questions

5. _____ refers to the ability of an organisation to anticipate, prepare for, respond to and recover from uncertainties in operations management.
6. Environmental uncertainty includes factors such as economic conditions, political instability and natural disasters. (True/False)

12.5 IMPLEMENTING A RISK MANAGEMENT FRAMEWORK

Implementing a risk management framework involves establishing a structured approach to identify, assess and manage risks throughout an organisation. It integrates risk management principles into all aspects of operations, ensuring that risks are systematically addressed and mitigated. The framework provides a foundation for decision-making, enhances organisational resilience and supports strategic goals by embedding risk management practices into daily activities. It ensures consistency and accountability in handling potential threats and opportunities, fostering a proactive risk-aware culture. By doing so, it helps safeguard assets, maintain operational stability and drive sustainable performance.

12.5.1 RISK MONITORING AND CONTROL

Risk monitoring and control involves continuously tracking identified risks, detecting new risks and evaluating risk mitigation efforts. This dynamic process

ensures that risks are managed effectively throughout the operational lifecycle. Key elements include:

- **Risk identification and assessment:**
  - **Identification:** Continually identifying potential risks that could impact operations. This involves regular risk assessments, brainstorming sessions and using tools like SWOT analysis (Strengths, Weaknesses, Opportunities, Threats).
  - **Assessment:** Evaluating the likelihood and potential impact of identified risks. This can be done using qualitative methods (risk matrices) or quantitative methods (probability distributions, statistical analysis).
- **Risk tracking:**
  - **Risk register:** Maintaining a risk register that documents all identified risks, their assessments, mitigation strategies and monitoring plans. This register is regularly updated as new risks emerge or existing risks change.
  - **Key Risk Indicators (KRIs):** Developing KRIs to monitor risk levels. KRIs are metrics that provide early warning signs of potential risk events. For instance, a significant increase in supplier lead times might indicate a rising supply chain risk.
- **Risk control:**
  - **Mitigation strategies:** Implementing and adjusting mitigation strategies based on the current risk environment. This includes revising contingency plans, updating safety stock levels and enhancing supplier relationships.
  - **Action plans:** Developing specific action plans for risk response. These plans outline steps to be taken when a risk materialises, including assigning responsibilities, resources and timelines for implementation.
- **Communication and reporting:**
  - **Regular reporting:** Providing regular risk reports to stakeholders, including senior management, to ensure transparency and facilitate informed decision-making. Reports should include the status of key risks, mitigation efforts and any changes in the risk landscape.
  - **Stakeholder engagement:** Engaging stakeholders in the risk management process. This includes conducting regular meetings, risk review sessions and workshops to keep everyone informed and aligned.
- **Continuous improvement:**
  - **Feedback loops:** Establishing feedback loops to learn from past risk events and improve future risk management practices. Analysing the effectiveness of risk responses and incorporating lessons learned into the risk management framework.
  - **Training and development:** Offering continuous training and development programs for employees to improve their risk awareness and management skills. This includes workshops, seminars and scenario-based training exercises.

Notes

12.5.2 INTEGRATING RISK MANAGEMENT WITH OPERATIONS STRATEGY

Integrating risk management with operations strategy ensures that risk considerations are embedded in strategic planning and decision-making processes. This alignment enhances organisational resilience and ensures that risk management supports overall business objectives. Key aspects include:

- **Strategic alignment:**
  - **Vision and goals:** Ensuring that risk management aligns with the organisation's vision, goals and strategic objectives. Risk management should support the achievement of these goals by protecting against potential disruptions.
  - **Strategic planning:** Incorporating risk management into strategic planning processes. This involves identifying strategic risks, evaluating their potential impact on strategic objectives and developing strategies to mitigate these risks.
- **Risk-informed decision making:**
  - **Scenario analysis:** Using scenario analysis to evaluate the impact of different risk events on strategic plans. This helps in understanding potential outcomes and making informed decisions.
  - **Decision support systems:** Implementing decision support systems that integrate risk data and analytics. These systems provide real-time insights into risk levels and support strategic decision-making.
- **Operational resilience:**
  - **Resilience strategies:** Developing resilience strategies that align with the organisation's operations strategy. This includes building redundancy, enhancing flexibility and ensuring robustness in operations.
  - **Resource allocation:** Allocating resources to support risk management initiatives. This includes investing in technology, infrastructure and training to enhance operational resilience.
- **Performance measurement:**
  - **Key Performance Indicators (KPIs):** Developing KPIs that measure the effectiveness of risk management efforts. These KPIs should be aligned with strategic objectives and provide insights into the organisation's risk posture.
  - **Balanced scorecard:** Using a balanced scorecard approach to integrate risk management into performance measurement. This ensures that risk considerations are included in evaluating organisational performance.
- **Cultural integration:**
  - **Risk culture:** Fostering a risk-aware culture where employees at all levels understand the importance of risk management and are actively engaged in identifying and mitigating risks.
  - **Leadership commitment:** Ensuring strong commitment from leadership to prioritise risk management. Leaders should communicate the importance of risk management and allocate necessary resources to support it.

- **Collaboration and coordination:**
  - **Cross-functional collaboration:** Promoting collaboration between different functions (e.g., operations, finance, supply chain) to ensure a holistic approach to risk management. Cross-functional teams can provide diverse perspectives and enhance risk identification and mitigation efforts.
  - **External partnerships:** Building partnerships with external stakeholders (e.g., suppliers, customers, industry associations) to enhance risk management capabilities. Collaboration with external partners can provide additional resources and insights for managing risks.
- **Technology and innovation:**
  - **Digital transformation:** Leveraging digital technologies to enhance risk management. This includes using data analytics, artificial intelligence and blockchain to improve risk identification, assessment and mitigation.
  - **Innovation management:** Encouraging innovation in risk management practices. This involves exploring new methods and tools for managing risks and continuously improving the risk management framework.

Self Assessment Questions

7. Which of the following is NOT a key element of risk monitoring and control in operations management?
   a. Risk identification and assessment
   b. Risk avoidance
   c. Risk tracking
   d. Communication and reporting
8. Developing Key Risk Indicators (KRIs) is a part of the risk control process in risk monitoring and control. (True/False)

12.6 SUMMARY

- Risk in operations management refers to the potential for unforeseen events or conditions that can adversely affect the efficiency, effectiveness and profitability of an organisation's operational processes.
- Effective risk management involves identifying, assessing and mitigating these risks to ensure smooth and resilient operations.
- Risk mitigation is a critical component of operations management. It involves identifying, assessing and prioritising risks followed by the application of resources to minimise, control and monitor the probability and/or impact of unfortunate events.
- Effective risk mitigation strategies ensure that organisations can continue their operations smoothly, even in the face of potential threats.

Notes

- Risk avoidance involves taking proactive steps to eliminate the potential for risk entirely. This strategy is about deciding not to engage in activities or actions that carry inherent risks.
- Risk reduction involves taking steps to lessen the probability or impact of a risk. Unlike risk avoidance, which seeks to eliminate risk entirely, risk reduction aims to manage and minimise the adverse effects of risk to an acceptable level.
- Risk sharing involves distributing the risk among multiple parties. This strategy does not eliminate the risk but spreads its impact across several entities, reducing the burden on any single party. Risk sharing is often achieved through partnerships, contracts, insurance or outsourcing.
- Uncertainty in operations management can arise from various sources, including market volatility, supply chain disruptions, technological changes, regulatory changes and unexpected events such as natural disasters or pandemics.
- Resilience in operations management involves creating systems and processes that can withstand and quickly recover from disruptions.
- Implementing a risk management framework involves establishing a structured approach to identify, assess and manage risks throughout an organisation.

12.7 KEY WORDS

- **KRIs (Key Risk Indicators):** KRIs are metrics used to monitor risk levels and provide early warning signs of potential risk events, enabling proactive management and response to emerging risks.
- **FMEA (Failure Mode and Effects Analysis):** FMEA is a systematic method for evaluating potential failure modes in a process or product, assessing their effects and prioritising actions to mitigate risks and enhance reliability.
- **JIT (Just-In-Time):** JIT is an inventory management strategy that aims to reduce waste and increase efficiency by receiving goods only as they are needed in the production process, minimising holding costs.
- **EOQ (Economic Order Quantity):** The EOQ formula helps determine the optimal order quantity that reduces overall inventory costs, such as holding, ordering and stockout expenses, enhancing the efficiency of inventory management.
- **VaR (Value at Risk):** VaR is a statistical measure used to assess the potential loss in value of a portfolio over a specified period, under normal market conditions, at a given confidence level.

12.8 CASE STUDY: GLOBAL FINANCIAL CORP RISK MANAGEMENT

Global Financial Corp, a multinational financial services company, operates in various markets worldwide, including emerging and developed economies. Recently, the company faced significant challenges due to fluctuating market conditions, regulatory changes and cyber threats. In response, Global Financial Corp implemented a comprehensive risk management strategy to address these uncertainties and safeguard its operations.

The company's risk management strategy included the following components:

1. **Risk identification and assessment:** The company used a combination of quantitative models and qualitative assessments to identify potential risks, including market volatility, regulatory changes and cybersecurity threats.
2. **Risk tracking:** Global Financial Corp maintained a risk register to document and track identified risks, using Key Risk Indicators (KRIs) to monitor risk levels continuously.
3. **Risk control:** The company implemented various risk control measures, such as investing in advanced cybersecurity technologies, diversifying its investment portfolio and establishing robust compliance frameworks to address regulatory changes.
4. **Communication and reporting:** Regular risk reports were provided to senior management and stakeholders, detailing the status of key risks, mitigation efforts and any changes in the risk landscape.
5. **Continuous improvement:** The company established feedback loops to learn from past risk events, updated its risk management practices accordingly and provided ongoing training for employees to enhance risk awareness.

Global Financial Corp's comprehensive risk management strategy proved effective in managing and mitigating various uncertainties. By integrating risk management with its overall operations strategy, the company enhanced its ability to anticipate, prepare for and respond to potential disruptions. The use of KRIs provided early warning signs, allowing for timely interventions and adjustments. The diversified risk control measures and robust communication practices ensured that risks were managed proactively, supporting operational continuity and organisational resilience. Overall, Global Financial Corp's approach resulted in improved performance, greater strategic alignment and enhanced capacity to navigate complex risk landscapes, ultimately strengthening its competitive advantage in the financial services sector.

QUESTIONS

1. How did Global Financial Corp use Key Risk Indicators (KRIs) in its risk management strategy and what role did they play in monitoring risks?

   (**Hint:** Consider the purpose of KRIs and how they contribute to tracking and managing risks within an organisation.)

2. What are the advantages of integrating risk management with the overall operations strategy, as demonstrated by Global Financial Corp's approach?

   (**Hint:** Reflect on how aligning risk management with strategic planning and decision-making can benefit an organisation in terms of resilience and operational effectiveness.)

Notes

12.9 EXERCISE

1. What are the key components of risk in operations management and how can organisations identify them?
2. Explain the difference between risk avoidance, risk reduction and risk sharing as risk mitigation strategies.
3. How can organisations manage uncertainty and build resilience in their operations?
4. What is a risk management framework and what are its essential elements?
5. Describe how an organisation can implement a risk management framework effectively.

12.10 ANSWERS FOR SELF ASSESSMENT QUESTIONS

Topic	Q. No.	Answer
Understanding Risk in Operations Management	1.	Financial risks
	2.	False
Risk Mitigation Strategies	3.	c. Risk sharing
	4.	Risk reduction
Managing Uncertainty and Resilience	5.	Resilience
	6.	True
Implementing a Risk Management Framework	7.	b. Risk avoidance
	8.	False

12.11 SUGGESTED BOOKS AND E-REFERENCES

SUGGESTED BOOKS

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