COURSE GUIDE

BUS 801
PRODUCTION AND OPERATIONS MANAGEMENT

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INTRODUCTION

BUS 801: Production and Operations Management (POM), is a one semester, two credit unit course. It is available to all M.Sc. Business Administration students in the Faculty of Management Sciences.

The course consists of 15 study units, covering such general areas as introduction to Production and Operations Management, Design of Production Systems, Operating Decisions. The material has been carefully developed to serve as an introductory text for students just coming in contact with POM for the first time.

This Course Guide tells you briefly what the course is about, relevant texts to consult, and how you can work your way through these materials. It also contains some guidelines on your tutor-marked assignments.

WHAT YOU WILL LEARN IN THIS COURSE

The major aim of BUS 801: Production and Operations Management (POM) is to introduce you to the field of production and operations management. The field of POM is dynamic, and very much a part of many of the good things thatare happening in business organizations.

Generally, the subject matter represents a blend of concepts from industrial engineering, cost accounting, general management, marketing, quantitative methods and statistics.

Production and Operations Management activities, such as forecasting, choosing a location for an office or plant, allocating resources, quality, and so on, are core activities of most business organisations.

COURSE AIMS

The course aims to give you a broad frame-work for the management of the operations functions of organizations, and how this is used in planning, coordinating, and executing all the necessary activities that create goods and services.

This will be achieved by aiming to:

- Introduce you to the principles and concepts of POM;
- Demonstrate how to determine an organisation's strategies and competitive priorities;

- Explain how managers make decisions about the type of work to be done in-house, the amount of automation to use, and methods of improving existing process;
- Explain the technologies to pursue and ways to provide leadership in technological change;
- Outline how to structure the organisation, foster teamwork, the degree of specialisation, or enlargement of the jobs created by the process, and methods of making time estimates for work requirement;
- Demonstrate how to coordinate the various parts of the internal and external supply chain, forecast demand, manage inventory and control output and staffing levels over time.

COURSE OBJECTIVES

In order to achieve the aims set out above, the course sets overall objectives. You will also realize that each course unit objectives are always included at the beginning of each unit. It is advisable to read through these specific objectives before studying through the unit.

The following are the broad objectives of the course. By striving to meet these objectives, you should have achieved the aims of the course as a whole.
On successful completion of the course, you should be able to:

1. Describe the nature and scope of POM and how it relates to other parts of the organization.
2. Understand the importance of operations function relative to the goals of a business organization.
3. Appreciate why the entire business community is stressing quality.
4. Discuss the importance of product and service design.
5. Explain the need for management of technology.
6. Formulate a linear programming model from a description of a problem.
7. Explain the importance of work design.
8. Discuss and compare time study methods.
9. Explain the concept of a Learning Curve (LC), use LC to make activity time projections.
10. Evaluate location alternatives.
11. Outline the steps in the forecasting process.
12. Demonstrate an understanding of the management of finished goods, raw materials, purchased parts and retail items.
13. Prepare aggregate plans and compute their costs.

14. Discuss the conditions under which Material Requirements Planning is most appropriate.
15. Outline the consideration important in a traditional mode of production to a Just-In-Time system.
16. Construct simple network diagrams.
17. Explain the importance of maintenance in production systems.

WORKING THROUGH THIS COURSE

It will be very essential that you thoroughly read the study units, consult the suggested texts and other relevant materials at your disposal. Most of the units contain self-assignment, which will be assessed by your tutor.

COURSE MATERIALS

Major components of the course are:

1. Course Guide
2. Study Units
3. Assignment File
4. Presentation Schedule

STUDY UNITS

There are 20 study units in this course, which have been compartmentalized into 4 modules as follows:

Module	**Title**	**Unit**	**Topic**
1	POM: Introduction, Overview and Design	1	POM- An Introduction
		2	Operations Strategy
		3	Forecasting in POM
		4	Process Management
		5	Design of Facilities and Jobs
2	Operating Decisions	1	Management of Technology
		2	Site Selection
		3	Supply-Chain Management
		4	Inventory Management
3	Control Decisions	1	Aggregate Planning
		2	Linear Programming
		3	Materials Requirements Planning

		4	Just-In-Time Systems
4	Project Management and Productivity	1	Project Management
		2	Productivity
		3	Total Quality Management
		4	Maintenance and Reliability

SET TEXTBOOKS

There are no compulsory books for the course. However, you are encouraged to consult some of those listed for further reading at the end of each unit.

ASSESSMENT

Your performance in this course will be based on two major approaches. First are the tutor-marked assignments (TMAs). The second method is through a written examination.

TUTOR-MARKED ASSIGNMENTS (TMAS)

Usually, there are four online tutor-marked assignments in this course. Each assignment will be marked over ten percent. The best three (that is the highest three of the 10 marks) will be counted. This implies that the total mark for the best three assignments will constitute 30% of your total course work. You will be able to complete your online assignments successfully from the information and materials contained in your references, reading and study units.

FINAL EXAMINATION AND GRADING

The final examination for BUS 801 - Production and Operations Management will be two hours duration and have a value of 70% of the total course grade. The examination will consist of multiple choice and fill-in-the-gaps questions which will reflect the practice exercises and tutor-marked assignments you have previously encountered. All areas of the course will be assessed. It is important that you use the adequate time to revise the entire course. You may find it useful to review your tutor-marked assignments before the examination. The final examination covers information from all aspects of the course.

COURSE MARKING SCHEME

The following table lays out how the actual course marking is broken down:

Assessment	**Marks**
Four assignment submitted	Best three marks of the four count @ 10% each = 30% of course marks
Final Examination	70% of overall course marks
Total	100% of course marks

HOW TO GET THE MOST FROM THIS COURSE

The distance learning system of education is quite different from the traditional university system. Here, the study units replace the University lecturer, thus conferring unique advantages to you. For instance, you can read and work through specially designed study materials at your own pace, and at a time and place that suit you best. Hence, instead of listening to a lecturer, all you need to do is reading.

You should understand right from the on-set that the contents of the course are to be worked at, and understood step by step, and not to be read like a novel. The best way is to read a unit quickly in order to see the general run of the content and to re-read it carefully, making sure that the content is understood step by step. You should be prepared at this stage to spend a very long time on some units that may look difficult. A paper and pencil is a piece of equipment in your reading.

TUTORS AND TUTORIALS

Detailed information about the number of tutorial contact hours provided insupport of this course will be communicated to you. You will also be notified of the dates, times, and location of these tutorials, together with the name andphone number of your tutor as soon as you are allocated to a tutorial group.

Your tutor will mark and comment on your assignments. Keep a close watch on your progress and on any difficulties you might encounter, and provideAssistance to you during the course.

Please do not hesitate to contact your tutor by telephone or e-mail if you need help. The following might be circumstances in which you would find helpnecessary:

- You do not understand any part of the study units.
- You have difficulty with the self-test or exercises.
- You have a question or problem with assignment or with the gradingof assignment.

You should endeavour to attend tutorial classes, since this is the only opportunity at your disposal to experience a physical and personal contact with your tutor, and to ask questions which are promptly answered. Before attending tutorial classes, you are advised to thoroughly go through the study units, andthen prepare a question list.

This will afford you the opportunity of participating very actively in the discussions.

SUMMARY

Management of the operations function is the focus of this course. Together with you, we explore the role of operations within the total organization. The explanation of what operations managers do, as well as some of the tools and concepts they use to support key business decisions are given.

At the end of the course, you will appreciate operations management as acompetitive weapon, which is important to:

- Accounting, prepares financial and cost accounting information that aids operations managers in designing and operating production systems.

- Finance, which manages the cash flows and capital investment requirements that are created by the operations function.

- Human. resources, which hired and trains employees to match process needs, location decisions, and planned production levels.

- Management information systems, which develops information systemsand decision support systems for operations managers.

- Marketing, which helps create the demand that operations must satisfy, link customer demand with staffing and production plans, and keep theoperations function focused on satisfying customers' needs.

- Operations, which designs and operates production systems to give thefirm a sustainable competitive advantage.

MAIN COURSE

CONTENTS

MODULE 1 POM: INTRODUCTION, OVERVIEW AND DESIGN

UNIT 1 PRODUCTION AND OPERATIONS MANAGEMENT

Unit Structure

1.1 Introduction

This first unit introduces you to the field of operations management. Generally, it describes the nature and scope of operations management, and how it relatesto the other parts of the organisation.

1.2 Learning Outcomes

By the end of this unit, you will be able to:

- Define the term production/operations management (POM)
- Identify the three major functional areas of organisations and describehow they interrelate
- Compare and contrast service and manufacturing operations
- Briefly describe the historical evolution of POM
- Explain what you understand by Japanese influence on Production Management?
- Relate Growth Technology as a historical evolution of production management

1.3 Introduction to Production and Operations Management

What is operations management all about?
Operations management deals with the production of goods and services thatpeople buy and us every day. It is the function that enables organisations to achieve their goals through efficient acquisition and utilization of resources. Manufacturers of steel, food, vehicles, computer (i.e. physical goods)need operations management. So do health care providers, banks, schools, retailers etc.

Every organisation, whether public or private, manufacturing or service, has an operations function. To many people, the term production conjures up images of factories, machines, and assembly lines. Interestingly enough, the field of production management in the past focused almost exclusively on manufacturing management, with a heavy emphasis on the methods and techniques used in operating a factory. In recent years, the scope of production management has broadened considerably. Production concepts and techniques are now applied to a wide range of activities and situation outside manufacturing; that is in services; such as health care, food service, recreation, banking, hotel management, retail sales, education, transportation and government. This broadened scope has given the field the name production/operations management or more simply operations management – a term that more closely reflects the diverse nature of activities to which itsconcepts and techniques are applied.

Formally stated, therefore, production and operations management (POM) isthe management of an organisation's production system, which converts inputs into the organisation's products and services. (or the direction and control of the processes that transform inputs into finished goods and services). This function is essential to systems producing goods and services in both profit and nonprofit organisations.

1.3.1 Function within Business Organisations

A typical business organisation has three basic functions: finance, marketingand production/operations, (see Figure 1.1).

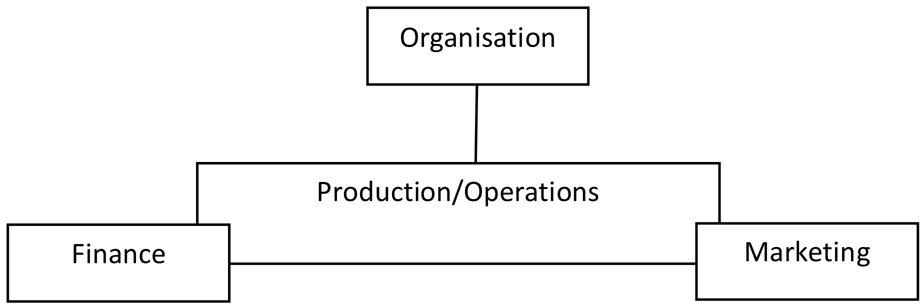

Figure 1.1: The three basic functions of business organizations

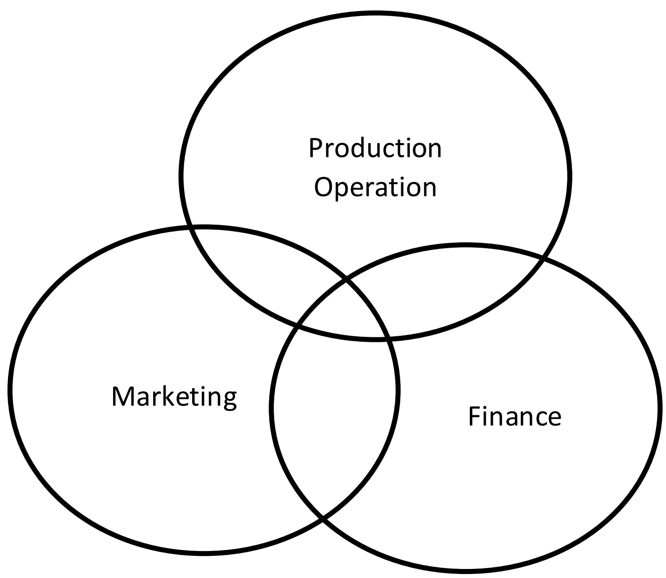

Figure 1.2: The 3 major functions of business organisation overlap

These three functions, and other supporting functions, perform different but related activities necessary for the operation of the organisation. The interdependency of the major functions is depicted by overlapping circles in figure 1.2. These functions must interact to achieve the goals and objectives of the organisation, and each makes an important contribution. Very often, the success of our organization depends not only on how well each area performs but also on how well the areas interface with each other. For instance in manufacturing, it is essential that production and marketing work together. Otherwise, marketing may promote goodsthat production cannot profitably produce,or production may turn out items that have no demand. Similarly, unless finance and production people work closely, funds for expansion or new equipment may not be available when needed in addition to the three primary functions, many organisations have a number of supporting functions, such as personnel, accounting, engineering, purchasing, public relations, distribution etc. the existence of these functions and the emphasis placed on each depend on the type of business a firm is engaged in. We willtake a closer look at these functions:

1.3.2 Operations

The operational function consists of all activities directly related to producinggoods or providing services. Table 1.1 provides illustrations of the diversity of operations management settings.

Table 1.1 Examples of types of operations

Type of operations	Examples
Goods producing	Farming, mining, construction, manufacturing, power generation.
Storage/transportation	Warehousing, trucking, mail service, moving taxis, buses, hotels, airlines.
Exchange	Retailing, wholesaling, banking, renting, or leasing, library loans.
Communications	Newspapers, radio and TV newscasts, telephone, satellites.
Entertainment	Films, radio & television, plays concerts, recording.

The operations function is the core of most business organisations; it is responsible for the creation of an organisation’s goods or services. Inputs are used to obtain finished goods or services using one or more transformation process (e.g. storing, transporting, cutting, and cleaning). To ensure that the desired outputs are obtained, measurements are taken at various points in the transformation process (feedback) and then compared with previously established standards to determine whether corrective action is needed (control). Figure 1.3 shows the conversion process.

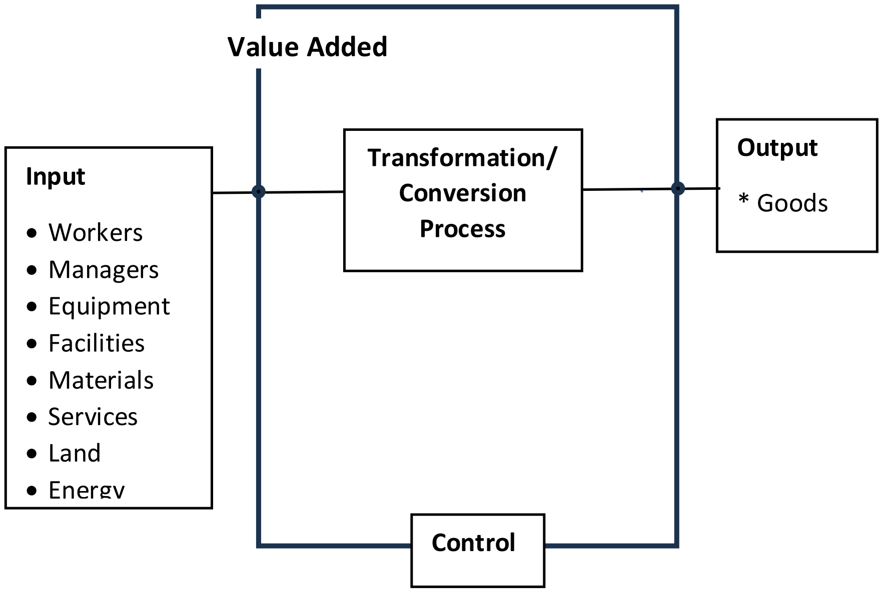

Figure 1.3: The conversion process of the operations function

Table 1.2: Provides some examples of inputs, transformation processes, and outputs

Inputs	Transformation	Outputs
Land Human Physical Intellectual Raw materials Energy Water Chemicals Metals Wood Equipment Machines Computers Trucks Facilities Hospitals Factories Offices Retail stores Information Time Others	Processes Cutting, drilling Transportation Teaching Farming Mixing Packing Canning Consulting Copying, faxing	Goods Houses Automobiles Clothing Computers Machines TV Food products Textbooks Magazines Shoes CD players Services Health care Entertainment Car repair Delivery Crift wrapping Legal Banking Communication

The essence of the operations function is to add value during the transformation process: The term "value added" is used to describe the difference between thecost of inputs and the value or price of outputs. In non-profit organisations, the value of outputs (e.g. highway construction, police and five protection services is their value to society; the greater the value added, the greater the effectiveness of these operations. In the case of profit making organisations, the value of outputs is measured by the prices that customers are willing to pay for these goods or services.

Firms use the money generated by value-added for Research and Development (R&D), investment in new plants and equipment, and profits. Consequently, the greater the value added the greater the amount of funds available for these purposes.

It is obvious that one sure way businesses can attempt to become more productive is to examine critically whether the operations performed by their workers add value. Those operations that do not add value are considered wasteful. By eliminating or improving such operations, firms can reduce the cost of inputs or processing, thereby increasing the value added. Let us use an example to buttress this point: suppose a firm discovers that it is producing an item much earlier than the scheduled delivery dates to a customer. This firm evidently requires the storage of the item without adding to the value of the item. Reducing storage time would reduce the transformation cost and, hence, increase the value – added.

1.3.3 Finance

The finance function is made up of activities related to securing resources at favourable prices and allocating those resources throughout the organisation. Generally, the finance and operations management personnel cooperate by exchanging information and expertise in such activities as budgeting, economic analysis of investment proposals and provision of funds. For instance, budgets must necessarily and periodically prepared for the planning of financial requirements. These budgets must sometimes be adjusted, and performance relative to a budget must be evaluated. In addition, evaluation of alternative investment in plant and equipment requires inputs from both operations and finance people. Furthermore, the necessary funding of operations and the amount and timing of such funding can be important and even critical when funds are tight. Therefore, careful planning can help avoid cash flow problems.

1.3.4 Marketing

Marketing is concerned with sensing, serving, and satisfying the needs and wants of the present and potential customers of the organisation. It consists of selling and/or promoting the goods or services of the firm Advertising andpricing decisions are made by the marketingpeople. It has been said that marketing is responsible for assessing customer needs and wants, and for communicating such to operations people (short-term) and to design people (long term).Hence, operations department needs information about demand over the short to intermediate term so that it can plan accordingly (e.g purchasers raw materials or schedule work). In addition, the design departmentalso needs information that relates to improving current products and servicesand designing new ones.

In essence therefore, departments of marketing, design and production mustwork closely tosuccessfully implement design changes and to develop and produce new products. Marketing usually supplies information on consumer preferences so that the design department will know the kinds of products and features needed Operations department often supplies information about capacities, as well as assess operationally of designs. Operations department will also have advance warming if new equipment or skills will be needed for new products or services.

It is necessary toinclude the finance peoplein these exchanges so as to provide information on what funds might be available (short term), and to learn what funds might be needed for new products or services (intermediate to long term). The marketing department needs information on lead time from the operations department, so that customers can be given realistic estimates of how long it will take to fill their orders.

From our treatment of sections 1.3.1., 1.3.2 and 1.3.3, it is clear that department of marketing, operations and finance must interface on product and processdesign, forecasting, settingrealistic schedules, quality and quantity decisions and keeping each other informed on the other's strengths and weaknesses.

1.3.5 Other Functions

Apart from the three core functions, there are a hostof other supporting functions that interface with these core functional areas of operations, finance, and marketing. These are illustrated in figure 1.4.

Accounting has responsibility for preparing the financial statements, such asincome statement and balance sheet. In addition, it supplies to management costs of labour, materials, and overhead, it may also provide reports on scrap, downtime and inventories. Furthermore, it must keep track of receivables, payables, and insurance costs, as well as prepare tax statements for the firm.

It is the responsibility of the purchasing department to procure materials,suppliers and equipment. The department is usually asked to evaluate vendors for quality, reliability, service, force, and ability to adjust to changing demand.

In addition, the department is responsible for receiving and inspecting thepurchased goods.

The personnel department is concerned with recruitment and training of personnel, labour relations, contract negotiations, wage and salary administration, assisting in manpower projections.
It is the responsibility of public relations department to build and maintain a positioned public image for the organisation. Very often, this might involve sponsoring events in sports, donating to actual events in sports, donating to actual events, and sponsoring community affairs.
Industrial engineering has the responsibility of scheduling, performance standards, work methods, quality control and materials handling.

Distribution is concerned with the movement of goods to warehouses, retailoutlets or to customers.

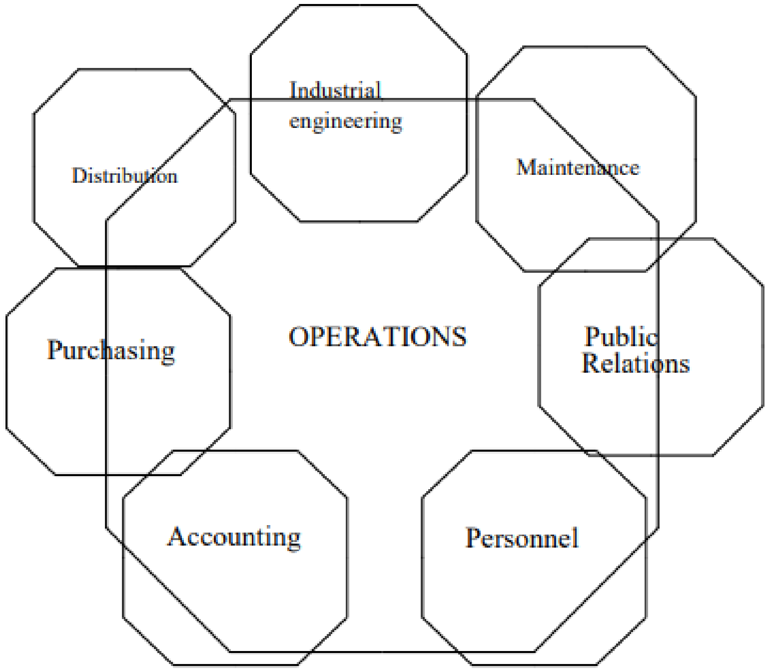

Figure 1.4: Interface of operations with supporting functions.

Last, but by no means the least, the maintenance department is responsible for general upkeep and repair of equipment, building and grounds, heating and air-conditioners removing wastes; parking and, at times security.

Self-Assessment Exercises

1. Explain how the three 3 major functions of business organization overlap

1.4 Manufacturing and Service Operations

Manufacturing implies production of a tangible output (i.e. something that can be seen or touched) such as a car, tyre, bread, knife, etc. Service on the other hand, generally implies an act. Examples here include a doctor's examination, TV and auto repair, lawn care and lodging in a hotel. The majority of service jobs fall into the following categories:

Education (schools, colleges, universities, etc.)

Business services (data processing, delivery, employment agencies, etc.)
Personal services (laundry, dry cleaning, hair/ beauty, gardening etc)
Health care (doctors, dentists, hospital care, etc).

Financial services (banking, stock brokerages, insurance, etc) Wholesale / retail (clothing, food, appliances, stationeries, toys, etc) Government (federal, state, local)

1.4.1 Differences between Manufacturing and Services

The differences between manufacturing and service operations fall into the eight categories show in figure 1.5. You should however note that these distinctions actually represent the ends of a continuum.The first distinction arises from the physical nature of the product: manufactured goods are physical, durable products. Services on the other hand are intangible, perishable product- they are usually ideas, concept, or information.

The second area of difference also relates to the physical nature of the product. For instance, manufactured goods are outputs that can be produced, stored, and transported in anticipation of future demand. This way, creating inventoriesallows manager to cope with fluctuations in demand by smoothing output level.

On the other hand, services can't be pre-produced. To this end, service operations do nothave the luxury of using finished goods inventories as acushion against erratic customer demand.

Customer contract is the third distinction betweenmanufacturing and service operations. Most customers for manufactured products have little or no contact with the production system. The primary customer contract is normally left to distributors and retailers. However, in the case of service firms, the customers themselves are inputs, and thus, are active participant in the process.

Another distinction is response time to customer demand. For instance, manufacturers generally have days or even weeks to meet customer demand. However, many services must be offered within minutes of customer arrival. The purchaser of a generator may be willing to wait for four weeks for delivery. By contrast, a grocery store customer may grow inpatient after waiting fiveminutes in a checkout line. Since customers for services usually arrive at times convenient to them, service operations may have difficulty matching capacity with demand. In addition, arrival patterns may vary daily or hourly, thus creating even more short-term demand uncertainty. There are two distinctions with respect to location andsize of an operation. Manufacturing facilities usually serve regional, national, or even international markets. Therefore, they generally require larger facilities, more automation, and greater capital investments than for service facilities. On the other hand, services cannot be moved to distant locations. Hence, service organisation requiring direct customer contact must locate relatively near the customer

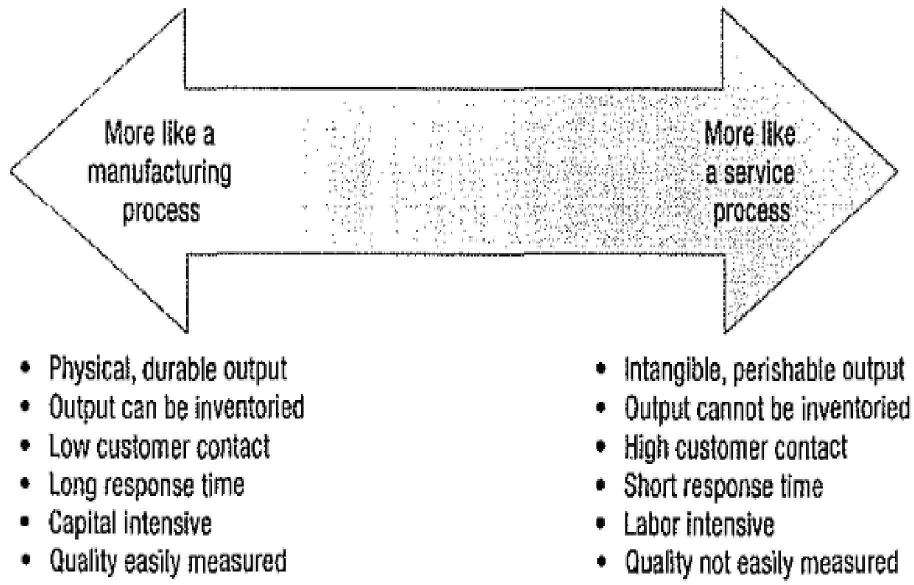

Figure 1.5: Continuum of characteristics of manufacturing and service operations.

The final distinction between manufacturing and service operations relates to the measurement of quality. Since manufacturing systems tend to have tangible products and less customer contact, quality is relatively easy to measure. However, the quality of service systems, which generally produce intangibles, is often very difficult to measure. Coupled with this, the subjective nature of individual preferences further makes the measurement of services difficult.

1.4.2 Similarities between Manufacturing and Service Operations

In spite of the differences already discussed there are compelling similarities between manufacturing and service operation: firstly both have processes that must be designed and managed effectively. Secondly, some type of technology be itmanual or computerized, must be used in each process. Thirdly, both of them are usually concerned about quality, productivity and the timely response to customers. Fourthly they must makechoices about capacity, location, and layout of their facilities. Fifthly, both deal with suppliers of outside servicesand materials, as well as scheduling problems. Sixthly, matching staffing levels and capacities with forecasted demand is a universal problem.

1.5 The Historical Evolution of Production and Operations Management

Systems for production have existed sinceancient times. The Egyptian pyramids, the Greek Parthenon, the Great Wall of China, and the aqua ductsand roads of the Roman Empire provide examples of the human ability to organise for production. But the ways that these ancient peoples produced products were quite different from the production methods of today. The production of goods for sale, atleast inthe modern sense, and the factorysystem had their roots in the industrial revolution.

1.5.1 The Industrial Revolution

The industrial Revolution started in the 1770s in England and spread to the rest of Europe as well to the United States during the nineteenth century. Before this time, product systems were often referred to as the cottage system, because the production of products took place in homes or cottages where craftsmen directed apprentices in performing handwork on products.
Under the cottage system, it was usual for one person to be responsible for making a product, such as a horse drawn wagon or a piece of furniture, for the beginning to the end. Only simple tools were available. Products were made of parts that were custom fitted to other parts. Because of this, the parts were not interchangeable. Generally, production was slow and labour- intensive.

However, the industrial revolution changed the face of production forever with two principal elements: the widespread substitution of machine power forhuman and water power and the establishment of the factory system. The steam engine, invented by James Watt in 1764, provided machine power for factories and stimulated other inventions of the time. For example, the availability of the steam engine and production machines allowed the gathering of workers into factories away from rivers. The large number of workers assembled into factories created the need for organizing them in logical ways to produce products.

It was aroundthis period, that Adam Smith wrote his book, the Wealth of Nationals in 1776, which touted the economic benefits of the division of labour. This meant breaking up a production process unto a series of small tasks, each of which were assigned to different workers.

Another important milestone occurred in 1790 when Eli Whitney, an American inventor, developed the concept of interchangeable parts. Whitney designed rifles to be manufactured for the U.S government on an assembly line such that parts were produced to tolerances allowing every part to fit right the very first time. This method of production ensured that the parts did not have to be custom made, they were standardised.
Consequent upon these various developments, factories began to spring up and grow rapidly, thereby providing jobs for many people who were attracted in large numbers from rural areas. Unfortunately however, working conditions were very poor in those times, and many workers actually suffered injury or death.

In spite of the major changes that took place, management theory and practicehad not progressed much from early days.

1.5.2 Scientific Management

The scientific-management era brought widespread changes to the management of factories. Table 1.3 presents the main characters of the scientific management era. The movement was spearheaded by Frederick Winslow Taylor, who is often referred to as the father of scientific management. Taylor was born in 1856 in Pennsylvania, the son of a prosperous attorney. In 1878, he took a job in philadelphia at the
Midvale Steel Company, whose president believed in experimentation to improve factory work methods. Taylor began as a labourer, but within six years he rose from labourer to clerk, to machinist, to gang boss of mechanist, to foreman, to master mechanic of maintenance, and finally to chief engineer of the works.

Taylor's belief in scientific management was based on observation, measurement, analysis and improvement of work methods, and economicsincentives.

Taylor's shop system, a systematic approach to improving worker efficiency,employed the following steps.

1. Skill, strength and learning ability were determined for each worker so that individuals could be placed in jobs for which they were best suited.
2. Stopwatch studies were used to precisely set standard of output per worker on each task. The expected output on

each job was used for planning and scheduling work and for comparing different methods of performing tasks.

3. Instruction cards, routing sequences, and materials specifications were used to coordinate and organise the shop so that work methods and work flow could be standardised and labour output standard could be met.
4. Supervision was improved through careful selection and training. Taylor frequently pointed out that management was indeed negligent in the performance of its functions. He strongly believed that management had to accept planning, organising, controlling, and methods determination responsibilities, rather than leave these important functions to the workers.
5. Incentive pay systems were initiated to increase efficiency and to
6. relieve foremen of their traditional responsibility or driving workers.

CONTRIBUTOR	**LIFE SPAN**	**CONTRIBUTIONS**
1.Frederick Winslow Taylor	1856 -1915	Scientific management principles, exception principle, time study, method analysis, standard, planning control.
2. Frank B. Gilbreth	1868 – 1924	Motion study, methods, therbligs, construction contracting, consulting.
3. Lillian M. Gilbreth	1878 – 1973	Fatigue studies, human factor in work, employee selection and
4. Henry L. Gantt	1861 – 1919	Gantt charts, incentive pay systems, humanistic approach to labour, and training
5. Carl G. Barth	1860 – 1939	Mathematical analysis, slide rule, feeds and speeds studies, consulting to automobile
6. Harrington Emerson	1885 – 1931	Principles of efficiency, million – dollars-a-day saving in railroads, methods of control
7. Morris L. Cooke	1872 – 960	Scientific management application to education and

Each of the scientific management pioneers listed in Table 1.3 tookactive parts in spreading the gospel of efficiency. All of them contributed valuable techniques and approaches that eventually shaped scientific management into a powerful force to facilitate mass production.

There is no doubt that scientific management hasdramatically affected today's management practices. For instance, the movement's struggle to find the one best way to operate factories leads logically to a questioning attitude on the part of managers in every phase of production systems. This questioning attitude encourages managers to attempt to build factories that operates with clockwork efficiency.

1.5.3 Human Relations and Behaviouralism

During the in industrial Revolution, factory workers were largely uneducated, unskilled, and undisciplined, having come fresh from farms. These workers generally had a basic dislike for factory work. They were however forced by circumstances to take to the jobs, since there was nothing for them to live on.

Factory managers often had to develop stringent controls to force them to work hard. This practice of stringent controls continued into the 1800s and early 1900s. Basic to this management method was the assumption that workers have to be placed in jobs designed to ensure that they would work hard andefficiently.

Table 1.3: Scientific Management: The Players and Their Parts

However, between World War 1 and World War II, there began to emerge in the United States a philosophy among managers that workers were humanbeings and should be treated with dignity while on the job. The human relations movement began in Illinois with the work of Elton Mayo, F.J Roethlisberger, T.N. Whitehead, and W.J Dickson at the Hawthorne, Illinois, plant of the western electric company in the 1927-1932 periods.

These Harwthorne studies were initially started by industrial engineers. The objectives of the studies were to determine the optimal level of lighting to get the most products from workers. The studies produced confusing results about the relationship between physical environment and worker efficiency. The researchers were to later realise that human factor must be affecting Production. This was about the first time that researchers and managers alike recognized that psychological and sociological factors affected not only human motivation and attitude, but production as well. In this regard therefore, operations managers need to create an organisational climate that encourages employees to devote their energy, ingenuity, and skill to the achievement of organisational objectives.

1.5.4 Management Science

With the advent of World War II, military, governmental, and industrial organizations in the United States and Europe grew to immense proportions. The Europe campaign of World War II used enormous quantities of men, supplies, planes, ships, material and other resources that had to be deployed in efficiency ways to accomplish a specific set of objectives in an extremely hectic environment.

Because of the success of its application, quantitative otherwise called management science or operation research, quickly spread to all faces of industry, factory and government today.

The objective usually is to achieve the best or optimum solution. Management science is not a redirection in management but a change in the approach to solving management problems and an addition to the tools that are available for solving management problems.

Although scientific management, human relation and management science (Operations research) have affected the ways that managers in production and operations management manage today, perhaps no other development is as important to these managers as the growing presence of computers in their jobs.

1.5.5 The Information Age

Advances in information and communications technology have had a major impact on the way businesses are done and on the management process. Capabilities such as satellite communication, facsimile transmission, and electronic data interchange have made global operations easier and more common. At the same time these developments, coupled with reduced trade barriers, have made possible competition from all parts of the globe so that management must deal with new challenges.

The improved ability to record, summarize, analyze and communicate data has reduced the need for so many layers have relatively short lives – have increased the pace of business. There have been other changes in the technology available for production.

1.5.6 Growth of Technology

Early production tasks relied on human effort both to control the process and to provide the energy to make it go. Next, machines were used to power the processes, but the processes were still manually controlled. Then automation provided automatic control, so that a machine could sense its output, compare it to some preset target value, and adjust its setting if necessary. Today, computers make it possible to send various instructions to machines and can change the target measurements or the types of items they are making. Computers have changed both the way businesses are run and the way processes are controlled. It perform such functions as keeping accounting records, scheduling work, tracking job progress, and keeping personnel data. Computers are used also in the processes performed by service business-automatic airline ticket reservations and automatic bank teller machines, for example.

Automated production continues to become more flexible and versatile. Today materials-handling systems can move objects to various locations in response to the computer signals they receive. Computer-controlled robots can execute various manipulations of work objects or tools. Production machines can execute various commands without human assistance and can operate as unstaffed machining centers. Combinations of automatic materials-human systems and automatic machines, coordinated under the control of a computer, are being operated as unstaffed factories during part of the day. Designers can use computer graphics and powerful simulation programs to develop and test designs. These designs can then be translated to instructions to operate automatic equipment in the type of factory or industry just described.

SELF-ASSESSMENT EXERCISES

Explain briefly what you understand by Growth of Technology

1.5.7 Japanese Influence on Productions Management

While technology can be used to some extent to improve efficiency and productivity, much can be gained from new management practices and operating methods. The concepts of *just-in-time (JIT)* production, which originally were practiced in Japan, are continuing to be employed more broadly in other parts of the world. These concepts, also called *stockless production or zero-inventory* programs, rely on employing only a minimum of inventories or other resources to make centre products. Companies operating under this philosophy coordinate their operations so that one work centre produces only what are required by subsequent work centers, and this production occurs just when the necessary components are needed. The method characteristically produces items in small lots, which means setup cost must be low and workers must have multiple skills so they can shift back and forth between various items. Successful implementation of JIT production also requires that companies develop reliable supplier networks, sound preventive maintenance programs, and excellent quality control programs to avoid defective components.

SELF ASSESSMENT EXERCISE (SAE)

i. How best will define production and operations management
ii. What was the industrial Revolution? When did it happen?

1.6 Summary

This unit has introduced Operations Management as a function that enables organizations to achieve goals through efficient acquisition and utilization of resources. The unit points out that a typical business organization has three basic functions, including: Finance; production/operations; and marketing. It also point out that, apart from these three core functions, there are other functions, including: distribution, maintenance purchasing, accounting, personnel, public relations, and the like.

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1.8 Possible Answers to Self-Assessment Exercises

1. Production and operations management could be defined as the management of complex of men, machine, money, materials and physical structures whose effective coordination is necessary in the production of a product or service that has economic value to the society.
2. The industrial Revolution started in the 1770s in England and spread to the rest of Europe as well to the United States during the nineteenth century. Before this time, product systems were often referred to as the cottage system, because the production of products took place in homes or cottages where craftsmen directed apprentices in performing handwork on products.

   Under the cottage system, it was usual for one person to be responsible for making a product, such as a horse drawn wagon or a piece of furniture, for the beginning to the end. Only simple tools were available. Products were made ofparts that were custom fitted to other parts. Because of this, the parts were not interchangeable. Generally, production was slow and labour-intensive.

   However, the industrial revolution changed the face of production forever with two principal elements: the widespread substitution of machine power for human and water power and the establishment of the factory system. The steam engine, invented by James Watt in 1764, provided machine power for factories and stimulated other inventions of the time. For example, the availability of the steam engine and production machines allowed the gathering of workers into factories away from rivers. The large number of workers assembled into factories created the need for organizing them in logical ways to produce products.

   It was around this period, that Adam Smith wrote hisbook, the Wealth of Nationals in 1776, which touted the economic benefits of the division of labour. This meant breaking up a production process unto a series of small tasks, each of which were assigned to different workers. There was no economic of scale as a result jobshop production. With the advent of gauge system changes the face of (craftship) craft production to industrialized Revolution.

UNIT 2 OPERATIONS STRATEGY

Unit Structure

2.1 Introduction

There is an increasing recognition that operations should assist the firm achieve a competitive position in the market place. Hence, apart from being a place to make the firm'sproducts and services, operations should also lead to somecompetitive strength to the business as well. This realization is being encouraged by increased foreign competition, the need for improved productivity and increased customer demands for improved quality. Gaining a competitive advantage through improved operations performance requires a strategic response on the part of the operations function. The focus of this unit is therefore on operations strategy, which specifies how operations can help implement the firm's corporate strategy. Here, you will see how operations strategy links long and short operations decision.

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Define the term strategy, and explain why it is important for competitiveness.
- Explain how to link marketing strategy to operations strategy, through the use of competitive priorities.
- Provide example of how firms use competitive priorities for competitive advantage.
- Compare organisation strategy and operations strategy and explain whyit is important to link them

2.3 Operations Strategy

2.3.1 Definition of Operations Strategy

Let us start by giving a working definition of operations strategy as follows:

"O*perations strategy is a vision for the operations function that sets an overall direction or thrust for decision making. This vision should be integrated with the business strategy and is often, but not always, reflected in a formed plan. The operations strategy showed result in a consistent pattern of decision making in operations and a competitive advantage for the company"*

(Shroeder, 1993)

There are many definitions of operations strategy in theliterature, and these help to amplify and expand on the above definition. We will examine three of such definitions: The first, by Shroeder, Anderson, and Cleveland (1986) define operations strategy as consisting of four components: Mission, distinctive competence, objectives and policies. These four components assist us in defining what goals operations should accomplish and how it should achieve those goals. The resulting strategy should then guide decision making in all phases of operations.

The second definition we shall examine is given by Hayes and Wheelwright (1984). They define operations strategy as a consistent pattern in operations decision. The more consistent those decision are, and the greater the degree to which they support the business strategy, the better. They go on to define how major decisions in operations should be made and integrated with each other.

While Hayes and Wheelwright emphasize the result of operations strategy i.e a consistent pattern in decision making, Schroader et al, emphasize operations strategy as an antecedent to decision making. However, both agree that a consistent pattern of decision making must be the result.

In our third definition, Skinner (1985) defines operations strategy in term of the linkage between decision in operations and corporate strategy. He observes that when operations are out of step with the corporate strategy, operationsdecisions are often inconsistent and short range in nature. Consequently, operations are divorced from the business and the linkage with corporate strategy is weak. To remedy this unpleasant situation, Skinner recommends the development of an operations strategy, derived from the corporate strategy, which defines a primary task (i.e. what operations must do well for the business to succeed), and a consistent set of operations policies to guide decision making.

In addition to the three definitions just examined, Hill (1989) has alsodeveloped an innovative approach to defining and developing operations strategy. He shows how to link operations decisions. This is a customer-driven approach to focus operations on what the customer requires.

From this perspective, quality, process, capacity, inventory and work-force decisions then follow from the customer requirement.

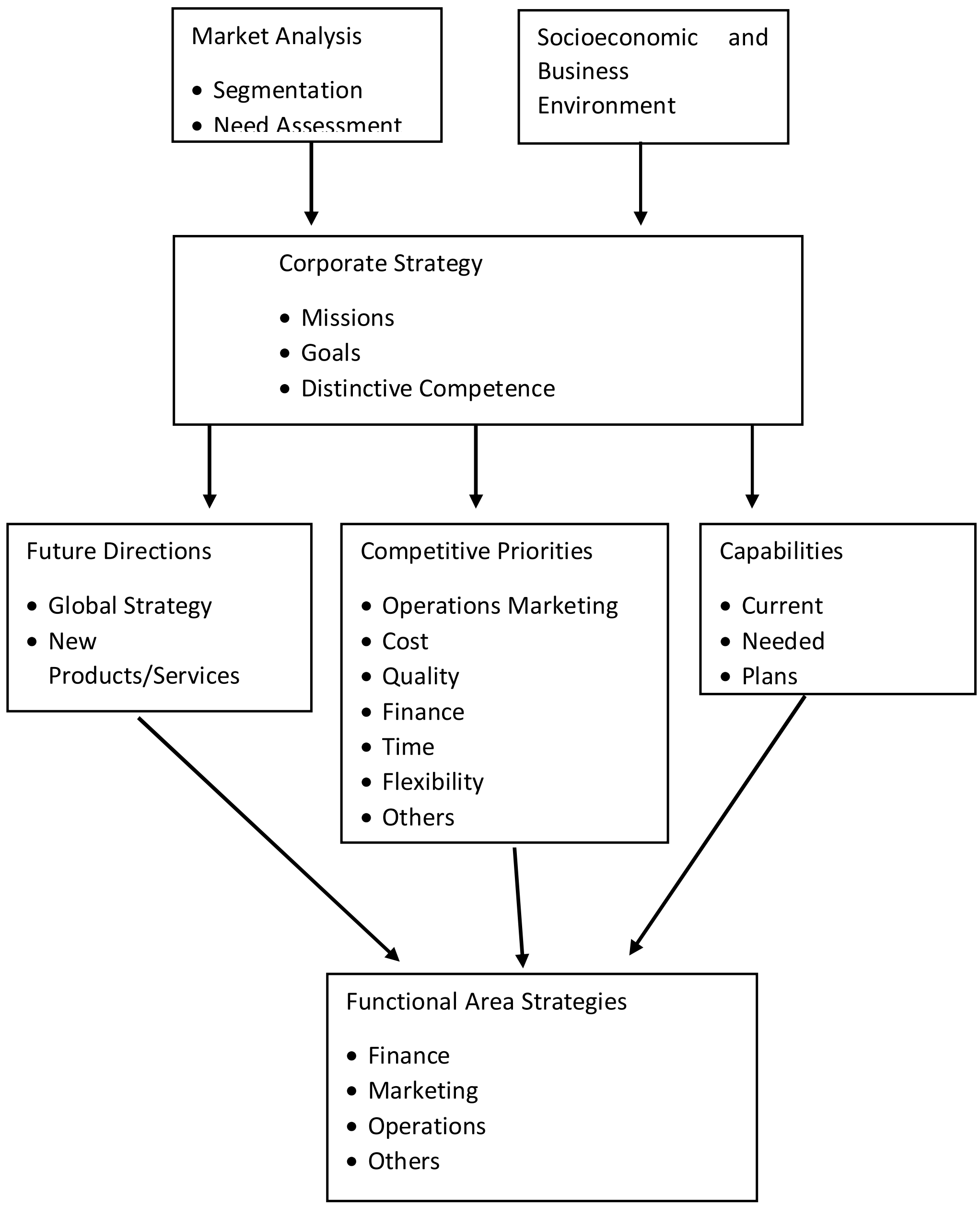
These various approaches we just examined should give us some insight intowhat operations strategy is, and how the strategy can be developed or improved.

2.3.2 Relationship Between Operations Strategy and CorporateStrategy

Developing a customer driven operations strategy begins with market analysis, which categorizes the firm's customers, identifies their needs and assessescompetitors' strength. You should note thatthis analysis accompanies an analysis of the external environment. In the second phase, the firm formulates its corporate strategy, which constitutes the organisation's overall goals. After the firm has determined which customers it wants to serve, it then goes on to develop its competitive priorities, or the capabilities and strength that the firm mustpossess to meet customer demand.

The competitive priorities and the future directions the form will take, such a global strategies, and new products or services, provide input for functional strategies or the goals and long-term plans of each functional area. By making use of its strategies planning process, each functional area is responsible for identifying ways to develop the capabilities it will need to carry out functional strategies and achieve corporate goals. This input, along with the current status and capability of each area, is fedback into the corporate strategic planning process to indicate whether corporate strategy should be modified. (See Figure 2.1).

Figure 2.1: Priorities: Link Between Corporate Strategy and FunctionalArea Strategies



Corporate Strategy

In any business organisation, it is the responsibility of top management to plan the organisation's long-term future. In this regard therefore, corporate strategy defines the businesses that the company will pursue, new threats and opportunities in the environment, and the growth objectives hat it should achieve. Also addressed, is business strategy, i.e how a firm can differentiate itself from the competition. The various alternatives could include producing standardized products instead of customized products or competing on the basis of cost advantage versus responsive delivery. Thus, corporate strategy provides an overall direction that serves as the framework for carrying out all the organisation's functions. In the sections that follow, we shall discuss the basic alternatives involved in corporate strategy and how global markets affect strategic planning.

2.3.2.1 Strategic Alternatives

As you already know, corporate strategy defines the direction of the organisation over the long term and determines the goals that must be achieved for the firm to be successful. Corporate strategy is set by management via three strategic alternatives:

(i) determining the firm's mission;
(ii) monitoring and adjusting to changes in the environment ; and
(iii) identifying and developing the firm's core competenciesLet us try to look into these three alternatives more closely:

(a) Determining the firm's mission

An organisation's mission is the basis of the organisation, i.e the reason for its existence. Note that missions vary from organization to organisation, depending on the nature of their business. It is important that an organization have a clear and simple mission statement, one which answers severalfundamental questions such as:

What business are we in?
Where should we be ten years from now? Who are our customers (or clients)?
What are our basic beliefs?
What are the key performance objectives, such as profits, growth or market share, by which we measure success?

The mission statement should serve to guide formulation of strategies for theorganisation, as well as decision making at all levels. In addition, an understanding of the firm's mission helps managers generate ideas and design new products and services. If its mission is too broadly defined, the firm could enter areas in which it has no expertise. On the other hand, if the mission is too narrowly defined the firm could miss promising growth opportunities. Hence, without a clear mission, an organisation is unlikely to achieve its true potential because there is little direction for formulating strategies.

(b) Monitoring and adjusting to change in the Environment

The external business environment in which a firm competes changes continually for this reason, an organisationneeds to adapt to those changes.Usually, adaptation begins with environmental scanning. Environment scanning is the considering of events and trends that present either threats or opportunities for the organisation. Generally, these include:

Competitor's activities; Changing consumer needs;
Legal, economic, political and environmental issues; The potential for new markets; etc.

Technological changes Social changes (such as attitudes toward work) Availability of vital resources and Collective power of customers or suppliers.

Depending on the nature of an organisation and the locations of its customers,the issues raised above may be looked at on global, national, regional or local basis.

A crucial reason for environmental scanning is to stay ahead of the competition. For instance, competitors may be gaining an edge by broadening product lines, improving quality, or lowering costs. In addition, new entrants into the market or competitors who offer substitutes for the firms product or service may threaten continued profitability.

(c) Identifying and developing the firm's core competencies

Core competencies are those special attributes or abilities possessed by anorganisation that givesit a competitive edge. They reflect the collective learning of the organisation, especially in how to coordinate diverse processes and integrate multiple technologies. In effect core competencies relate to theways that organisations compete.

Competitiveness is an important factor in determining whether a companyprospers, barely gets by, or fails. Business organisations compete with themselves in a variety of ways. Key among them are price, quality, product or service differentiation, flexibility, time to perform certain activities, workforce, facilities, market and financial know-how and systems, and technology.

(i) **Price: Price is the amount a customer must pay for the product or service.**
If all other factors are equal, customers will choose the productor services that has the lower price. Organisations that compete on price may settle for lower profit margins. However, they must focus on lowering production costs

(ii) **Quality: This refers to materials and workmanship as well as design.**
Generally, it relates to the buyer's perceptions of how well the productor service will serve its purpose.

(iii) **Product differentiation:** Product differentiation refers to any special features (.e.g design, cost, quality, case of use, convenient location, warrants etc) that cause a product or service to be perceived by the buyers is more suitable than a competitor's product or service.

(iv) **Flexibility:** This is the ability to respond to changes. The better acompany or department is at responding to changes, the greater its competitive advantage one another company that is not as responsive. The changes might relate to increases or decreases in volume demanded, or to changes in product mix.

(v) **Time:** This refers to a number of different aspects of an organisation's operations. There are at least three examples here: one is how quickly a product or service is delivered to a customer. Two, is how quickly new product or services are developed and brought to the market. Thirdly, is the rate at which improvements in products or services are made.

(vi) **Workforce:** A well-trained and flexible work force is an advantage that allows organisations to respond to market needs in a timely fashion. This competency is particularly important in service organisation where the customer comes in direct contact with the employees**.**

(vii) **Facilities:** Having well-located facilities – offices, stores, and plants –is a primary advantage because of the long lead time needed to build new ones. For instance, expansion into new products or services may be accomplished quickly. Furthermore, facilities that are flexible and can handle a variety of products or services at different levels of volume provide a competitive advantage**.**

(viii) **Market and Financial know-how:** An organization that can easily attract capital from stock sales, market and distribute its products has a competitive edge.

SELF-ASSESSMENT EXERCISES

How would you differentiate Between Operations Strategy and CorporateStrategy

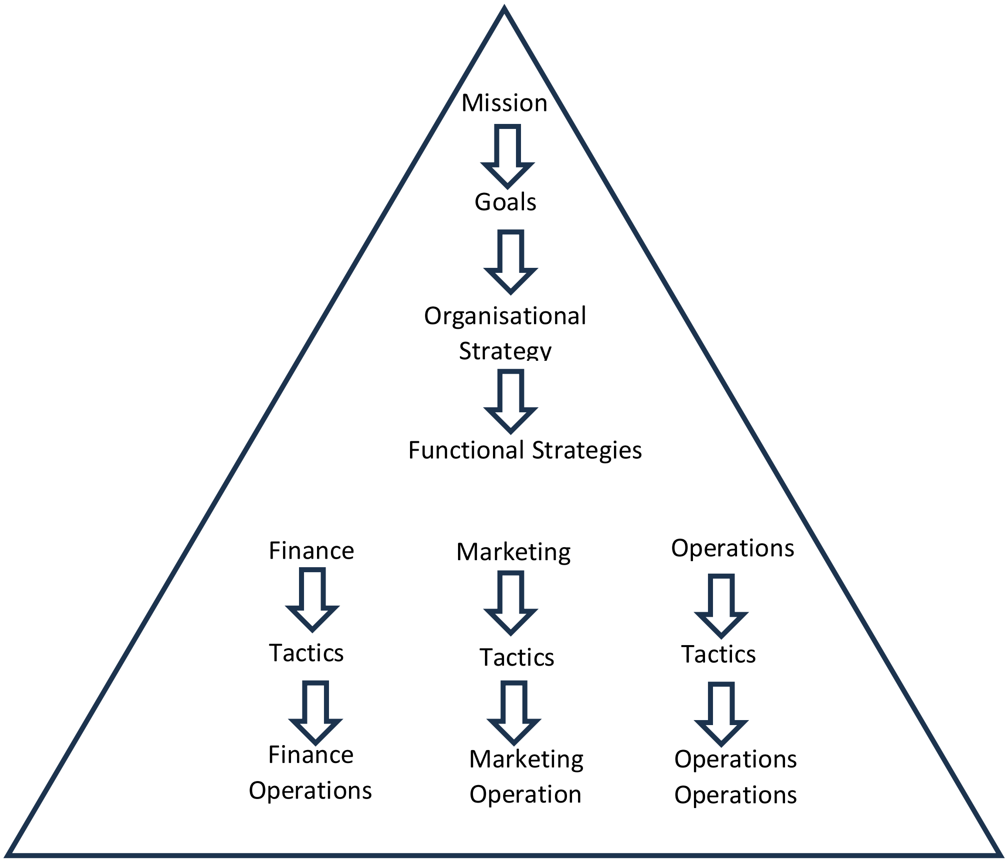
2.3.3 Strategies and Tactics

As you are already aware, a mission statement provides a general direction foran organisation and gives rise to organizational goals, which provide substance to the overall mission. For example, one goal of an organisation may be tocapture a certain percentage of market share for a product; another goal may be to achieve a certain level of profitability.

Taken together, the goals and themission establish a destination for the organisation. Strategies are plans for achieving goals. If we have already likened goals todestinations, then, strategies may be seen as road maps for reaching the destination. Strategies provide focus for decision making. organisations usually have overall strategies referred to as organisation strategies (i.e.Corporate Strategies), which relate to the entire organisation. They also have functionalstrategies, which relate to each of the functional areas of the organisation.

Tactics are the methodsand actions used to accomplish strategies. They are more specific in nature than strategies, and they provide guidance and direction for carrying outactual operations, which need the most specific and detailed plans and decision making in an organisation. One may think of tactics as the "how to" part of the process (e.g. how to reach the destination, following the strategy road map) and operation as the actual "doing: part of the process. Please note that the overall relationship that exists from the mission down to actual operations is hierarchical in nature. This is illustrated in Figure 2.2.

Figure 2.2: Planning and Decision Making in Hierarchical Organizations



2.3.4 Operations Strategy

You have seen that corporate strategy provides the overall direction for the organisation. It is broad in scope, covering the entire organisation. Operations strategy on the other hand is narrower in scope, dealing primarily with the operations aspect of the organisation. It relates to products, processes, methods, operating resources, quality, costs, lead times and scheduling.

It is often very important to link operations strategy to corporate strategy, so as to make it truly effective. This means that the two should not be formulated independently. In this regard, therefore, formulation of corporate strategy should always consider the realities of operations' strengths and weaknesses what is normally done is to capitalize on strengths and dealsquarely with weaknesses. Similarly, operations strategy must be consistent with the overall strategy of the organisation, and formulated to support the goals of the organisation.

In conformity with the principles above, Figure 2.3 shows that operations strategies are derived directly form the corporate mission and business strategy.

Operations strategy can have a major influence on the competitiveness of anorganisation. For instance, if it is well formulated and well executed, there is a strong possibility that the organisation will be successful. Conversely, if it is poorly designed or excited, the chances are much less that the organisation willbe successful.

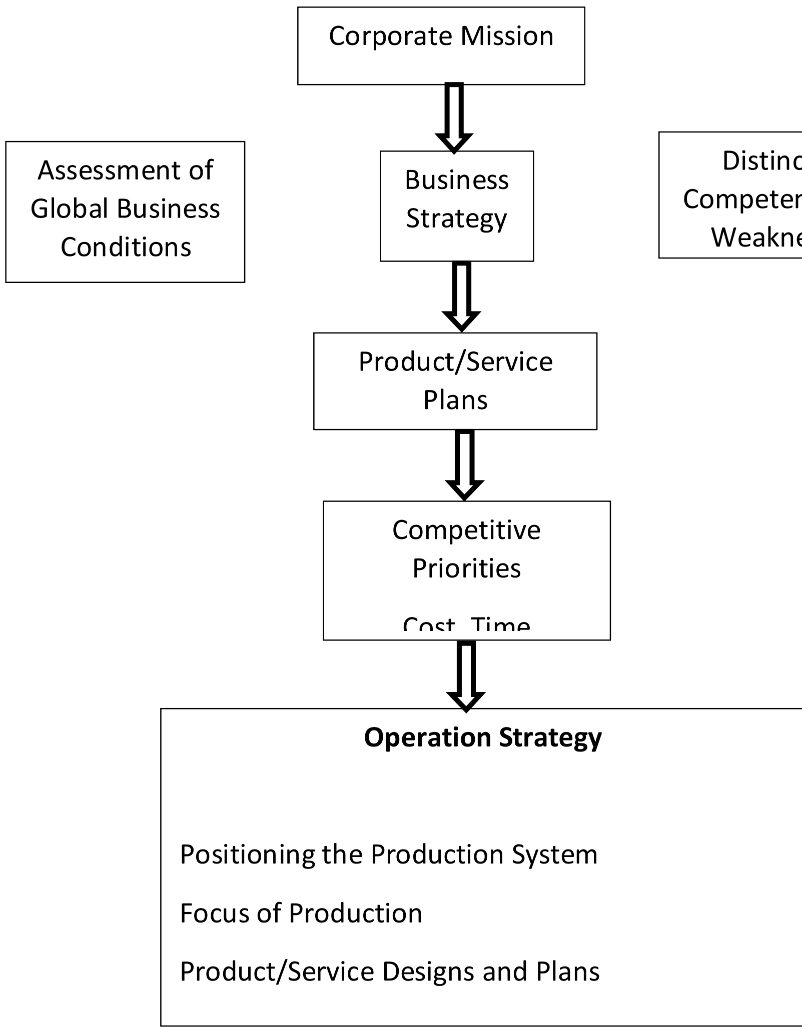


Figure 2.3: Developing Operations Strategy

2.4 Elements of Operations Strategy

We shall break our discussion on operation strategy under the following units:
(1) positioning the production system, (2) focus of production (3) product/ service plans, (4) production process and technology

plans, (5) allocation of resources to strategic alternatives, and (6) facility plans: capacity, location and layout.

Positioning the Production System

Positioning the production system in manufacturing generally means selecting the type of product design, type of production processing system,and type of finished–goods inventory policy for each product group in the business strategy.

With regard to product design, there are usually two basic types: custom and standard. Custom products are designed according to the need of individual customers. The consequence of choosing this type of product is that there will be many products, each being produced in small batches. It should be clear to you that flexibility and on-time delivery are the competitive prioritiesneeded for this type of product. In case of standard products, only a few product models are produced, either continuously or in very large batches. Fast delivery and low production cost are usually needed for this type of product.

There are also two basic types of production process: product-focused and process-focused. Product- focused production is also called line flow production, production lines and assembly lives. Here, both the machines and workers needed to produce a product are grouped together. This type of product is appropriate where there are only a few standard products, each with a high volume. Since such systems are usually difficult and expensive to change to other product designs and production volumes, they are not very flexible. Process-focused production is usually best when producing many unique products, eachwith a relatively low volume. Each production department ordinarily performs only one type of process, such as painting. All products that need such services are then transported to that particular department. Custom products usually require this form of production because process-focused systems are relatively easy and inexpensive to change to other products and volumes, thereby offering great flexibility. Hence, if a business strategy calls for custom products whose market strategy requires the competitive priorities of flexibility and on-time delivery, then process-focused production is usually preferred.

Again, there are two types of finished – goods inventory policies: produce to – stock and produce to order. In the case of the produce-to-stock policy, products are produced ahead of time and then placed in inventory. Later, when orders for the products are received, the products are then shipped immediately from inventory. For the produce-to-order policy, operations managers usually wait until they have the customer's order in hand before they produce the products.

With the proper selection of an appropriate product design, production process and finished –goods inventory policy for a product, much of the structure required of a factory may have been established.

SELF-ASSESSMENT EXERCISES

i. Why should a firm not attempt to excel in all the areas of competitive priorities?
ii. What determines the choice of the competitive priorities that a companyshould emphasize?

2.4.1 Focus of Production

Another important element of operations strategy is the plan for eachproduction facility to be specialized in some way. This idea of the specialized factory has been labeled "focused factory" by Skinner (1974). According to him "afactory that focuses on a narrow product mix for a particular market niche will outperform the conventional plant which attempts a broader mission.

Because its equipment supporting system and procedures can concentrate on a limited task for one set of customers, its costs and especially its overheads are likely to be lower than those of the conventional plant. But, more important,such a plant can become a competitive weapon because its entire apparatus is focused to accompany the particular manufacturing task demanded by the company's overall strategy and marking objective.

How can factories and service facilities become more focused? This can be done in two major ways: specializingin only a few product models or a few production processes. Graither (1996) submits that it is desirable for factories and service facilities to be specialised in some way, so that they willnot be vulnerable to smaller and more specialized competitors that can provide a particular set of customers with a better set of cost, delivery, quality and customer service performance. However, this is not to say that smaller facilities are always better. Actually, economies of scale have to be considered whilechoosing the size of production facilities.

2.4.1.1 Product/Service Plans

Plans for new products and services to be designed, developed and introduced are also an important part of business strategy. Operations strategy is directly influenced by product/service plans because:

(i) As products are designed, all the detailed characteristics of each productare established;
(ii) Each product characteristics directly affects how the product can bemade or produced; and
(iii) How the product is made determines the design of the productionsystem, which is the heart of operations strategy.

2.4.1.2 Production Process and Technology Plans

Another important part of operations strategy is the determination of how products will be produced. This entails planning every detail of production process and facilities. You should note here, that the range of production technologies available to produce both products and service is great and is continuously increasing. For instance, combining high-technology production equipment with conventional equipment, and devising effective overall production schemes are indeed challenging.

2.4.1.3 Allocation of Resources to Strategic Alternative

Allocation of resources constitutes a common type of strategic decision to be made by operations managers.

For example, almost all companies today have limited resources available for production. For instance, cash and capital funds, capacity, research laboratories, workers, engineers, machines, materials and other resources are scarce in varying degrees to each firm. Shortages of these resources generally have serious impacts on production systems. These resources must be divided among, or allocated to product, business units, projects, or profit opportunities in ways that maximize the achievement of the objectives of operations.

2.4.1.4 Facility Plans: Capacity, Location and Layout

Another critical part of setting operations strategy is how to provide the long- range production capacity to produce the products/services for a firm. Huge capital investment is required to make production capacity available. For instance, land and production equipment may need to be bought, and specialized production technologies may have to be developed. In addition, new production equipment may need to be made or purchased and installed, and new factories may need to be located and built.

It is obvious that the decisions involved here have long-lasting effects and are subject to great risk. For example, if poor decisions are made or if circumstances change after the company has commuted to a choice of alternatives, it has to live with the results of such decision for quite sometime.

Relevant decisions in these areas are therefore treated under long-range planning and Facility Location.

2.4.2 Market Analysis

One important key to success in formulating a customer-driven operationsstrategy is understanding what the customer wants and how to provide it better than the competitor does. This clearly means that the market must be analyzed.

Market analysis first divides the firm's customers into market segments and then identifies the need of each segment. In the sections that follow, we shall define and discuss the concept of market segmentation and needs assessment.

2.4.2.1Market Segmentation.

This is the process of identifying groups of customers with similar characteristics to warrant the design and provision of products or services that the larger group wants and needs. In general, in order to identify market segments, the analyst must determine the characteristics that clearly differentiate each segment. After this, a sound marketing programme can be devised and an effective operating system developed to support the marketingplan.

Having identified a market segment, the firm can then incorporate the needs of customers into the design of the product or service as well as the operations systems for its production. The following characteristics are among those that can be used to determine market segments:

(i) Demographic factors: age, income, educational level, occupation and geographical locations are examples of factors that can differentiatemarkets.

(ii) Psychological factors: factors such as pleasure, fear, innovativeness, and boredom can be said to segment markets. For example, people with a fear of crime constitute a market segment that has led to the creation of new products and services for protection.

(iii) Industry factors: Customers may make use of specific technologies (e.g. electronics, robotics, or microwave telecommunications), use certain materials (e.g. rubber, oil or wool) or participate in a particular industry (e.g. banking health, care or automotive). These factors are used for market segmentation when the firm's customers use its goods or services to produce other goods or services for sale.

2.4.3 Needs Assessment

The second step in market analysis is to make a needs assessment. Needs assessment seeks to identify the needs of each segment, and assess how well competitors are addressing those needs. One important advantage of the needs assessment is that it allows the firm to differentiate itself from its competitors.

Usually, the needs assessment include both the tangible and the intangible product attributes and features a customer desires. The attributes and features are commonly referred to as the customer benefit package, and they consist of a core product or service and a set of peripheral products or services. Note that the customer often views the customer benefit package as a whole. For example, when you buy a personal computer (PC), the core product is the PC itself i.e. its features and qualities. However, the peripheral services offered by the dealer play an important role in your decision to purchase the PC. These include the manner in which you are treated by the sales person, the availability of credit facility, and the quality of after-sales services at the dealership. Hence, the customer benefit package is the PC together with the services provided by the dealership. Generally, customers will not be completely satisfied unless they receive the entire customer benefit package.

By understanding the customer benefit package for a market segment, management is able to identify ways of gaining competitive advantage in themarket. Each market segment has market needs that can be related to product/service process or demand attributes. Market needs has been groupedas follows:

(a) Product/Service needs i.e. attributes of the product or service, such asprice, quality and degree of customization desired.

(b) Delivery system needs i.e. attributes of the process and the supportingsystems and resources needed to deliver the product or service, such as availability, convenience, courtesy, safety, delivery speed and delivery dependability

(c) Volume needs i.e attributes of the demand for the product or service, such as high or low volume, degree of variability in volume and degree of predictability in volume.

(d) Other need i.e other attributes not directly relating to operations, such as reputation and number of years in business, technical after sales support, accurate and reliable billing and accounting systems, ability to invest in international financial markets, competent legal services and product/services design capability.

SELF-ASSESSMENT EXERCISE (SAE)

Understanding the customer benefit package enables management to identify ways to gain competitive advantage in the marketplace. What do you consider
to be the components of the customers benefit package in the provision of:

(a) a car
(b) an airline flight

Suppose that you were conducting a market analysis for a new textbook about Business management. What factors would you consider in order to identify amarket segment? How would you make a need assessment?

2.5 Summary

In this unit, you have learnt that strategies are the basic approaches used by an organisation to achieve its goals. Strategies provide focus for planning and decision making. Organisations typically have overall strategies that pertain to the entire organisation, and strategies for each of the functional areas. The unit also discussed functional strategies as being narrower in scope, and therefore should be linked to overall strategies.

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2.7 Possible Answers to Self-Assessment Exercises

1. By understanding the customer benefit package for a market segment, management is able to identify ways of gaining competitive advantage in the market. Each market segment has market needs that can be related to product/service process or demand attributes. Market needs has been grouped as follows:

a. Product/Service needs i.e. attributes of the product or service, such as price, quality and degree of customization desired.

b. Delivery system needs i.e. attributes of the process and the supporting systems and resources needed to deliver the product or service, such as availability, convenience, courtesy, safety, delivery speed and delivery dependability

c. Volume needs i.e attributes of the demand for the product or service, such as high or low volume, degree of variability in volume and degree of predictability in volume.

d. Other need i.e other attributes not directly relating to operations, such as reputation and number of years in business, technical after sales support, accurate and reliable billing and accounting systems, ability to invest in international financial markets, competent legal services and product/services design capability.

UNIT 3 FORECASTING IN POM

Unit Structure

3.1 Introduction

This unit introduces you to forecasting in production and operations management (POM). Planning is an integral part of a manager's job, and if uncertainties becloud the planning horizon, managers will find it difficult to plan effectively. Forecasts help managers by reducing some of the uncertainties, thereby enabling them to develop more meaningful plans. In a nutshell, a forecast is statement about the future.

3.2 Learning Outcomes

By the end of this unit, you should be able to:

- Describe at least four qualitative forecasting techniques and the advantages and limitations of each.
- Compare and contrast qualitative and quantitative approaches to forecasting.

- Identify the five basic demand patterns that combine to produce someseries.
- Choose an appropriate forecasting technique for a given decisionproblem.

3.3 Forecasting in POM

3.3.1 Introduction to Forecasting in POM

Customer demand is thebackbone of all enterprises. Occasionally, however,customers appear unexpectedly, without prior notice. This sudden situation very often throws organisations off balance to the extent that the quality of their products, response time and customer service are badly affected. But this shouldn't be allowed to happen. A well-managed enterprise will make efforts toforecast demand, which normally allows it to be reasonably prepared when the demand actually occurs. Broadly speaking, well-managed businesses strive to manage demand, and this normally includes:

- Planning for demand
- Recognizing and accounting for all sources of demand
- Pre-processing of demand.

From the foregoing therefore, it is important that organisations have effective approaches to forecasting. In addition, forecasting should be an integral part of their business planning. Figure 3.1 is an illustration that forecasting is anintegral part of business planning. The figure shows that the major inputs from various market conditions, economic outlook and other factors such as legal, political, sociological and cultural forces are processed through forecasting models or methods to develop demand estimates. You must however note that these demand estimates are not the sales forecasts. They are just the starting point for management teams to Develop sales forecast. The sales forecasts in turn become inputs to both business strategy and production resource forecasts.

Actually, when managers plan, they are merely trying to determine in the present, what causes of action they will take in the future. The first step in planning is therefore forecasting or better still, estimating the future demand for products and services and the resources necessary to produce these outputs. Estimates of the future demand for products are usually referred to as sales forecasts. These are the starting point for all the other forecasts in POM. Can you now guess why forecasting is so essential to POM? Anyway, let us look at this together: Operations managers need long-range forecasts to make strategic decisions about products, process, and facilities. They will also need short- range forecasts to assist them in making decisions about product issues thatspan only the next few weeks.

INPUTS

Market Conditions

Competitor Actions

Products' Life Cycles

Season

Customers' Plans

Economy Outlook

Business Cycle Status

Leading Indicators-Stock

Prices, Bond Yields, Material

Prices, Business Failures, Money

Supply, Unemployment

Other Factors

Legal

Political

Forecasting

Method(s)

Or Model(s)

Estimated Demand For Each Product in Each Time Period

Other

SALES FORECAST

Forecast of demand for each product in each time

Management Team

Production

Capacity

Available

Resources

Risk Aversion

Experience

Personal Values

Forecast Errors

Forecast Errors

Procedure for Translating Sales Forecast in Production

Resource Forecasts

Business Strategy

Marketing Plan – Advertising, Sales Efforts, Price, Past Sales

Production Plan – Quality Levels, Customer Service, Capacity, Costs

Credit Policies, Billing Policies

Long-Range	Medium-Range	Short-Range
Factory Capacities	Work Force	Labour by Skill Class
Capital Funds	Department Capacities	Machine Capacities
Facility Needs	Purchased Materials	Cash
Other	Inventories	Inventories

Figure 3.1 Forecasting as an Integral Part of Business Planning
Source: Adapted From Gaither, N. (1996), Belmont, Duxury Press, p.64.

3.3.2 Importance of Forecasting in POM.

Some of the reasons why forecasting is very essential in POM are given below:

1. **New Facility Planning: It usually takes as long as five years to design**
   and build a new factory or design and implement a new production process. Such strategic activities in POM require long-range forecasts of demand for existing and new products so that operations managers can have the necessary lead time to build factories and install processes to produce the products and services when needed.
2. **Production Planning: Usually, demands from products continue to**
   vary from month to month and from one season to the other. Hence production rates need to be scaled up or down to meet these varying demands. We should also note that it can take some months to alter the capacities of production processes. Therefore, operations managers need medium-range forecasts so that they can have the lead time necessary to provide the production capacity to produce there variable monthly demands.
3. **Work Force Scheduling: Demands for products and services may** actually vary from week to week. In order to remain on an efficient or profitable level of operation, the work force must, out of necessity bescaled up or down to meet these demands by using various methods, such as reassignment, overtime, layoffs, or hiring. In this regards, operations managers need short-range forecasts so that they can have the lead time necessary to provide work force changes for the production ofweekly demands.

3.3.3 An Overview of Demand Measurement:

We need to realize right from here, that demand management is a sharedresponsibility.Usually, a master planning team, composed of experts in Marketing, Finance and Operations is responsible for taking care of, and coordinating demand management activities. This team has at least three important roles to play. These are to:

* Account for all sources of demand: historical demand patterns, sales force estimates, actual orders and direct selling, within – company (i.e. division-to-division) demands, and economic influences.
* Influence demand, e.g. through special promotions

* Evaluate the impact of any demand management plan on capacity andcash flow.

3.3.4 Time Horizon in Forecasting

From our previous discussion, you will have observed that forecasts can be made over any time horizon. However, the shorter the period being considered, the more accurate is the forecasts, since one is more certain of the variables involved. Descriptions of forecast elements over three time horizon include short-range, medium-range and long-range. Each time frame is discussed below with examples of some of the things usually forecasted:

3.3.4.1Short Range

A short-range forecast is one for a time span of a few weeks, up to say aboutthree months. It would include forecasting such items as:

- purchase transactions;
- cash requirements;
- work scheduling;
- workforce levels;
- job assignments; and
- production levels.

3.3.4.2Medium Range

The medium-range forecast covers between about three months and up to oneyear. Items usually included here are:

- capacity plan;
- operating cash budgets;
- production plans;
- sales plans; and
- Subcontractor needs.

3.3.4.3Long Range

A long-range forecast usually spans a year up to about five years, and wouldinclude:

- new investments;
- capital expansion plans;
- facility location;
- new product development
- strategic plans;
- acquisition;
- implementing new technology; and
- research and development programmes.

SELF-ASSESSMENT EXERCISES

Identify the various time horizons in forecasting.

3.4 Importance of Sales Forecast

What we have been stressing all along is that an estimate of demand, typically in the form of a sales forecast, is critical to the successful functioning of most businesses. It is one of the most important pieces of data used by management and takes a central stage in most companies' planning efforts. Its importance spreads across the following areas: as shown in Table 3.1.

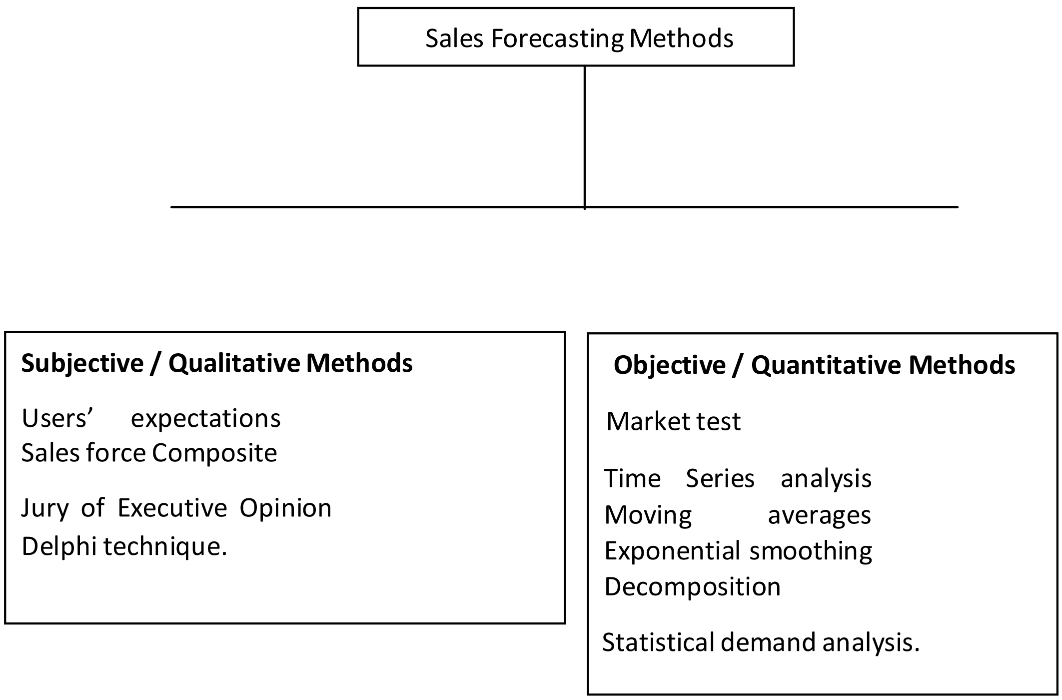
Table 3.1: Different Areas of Application of Sales forecasts within an organization

User within the Organization	Areas of application
Top management	* Allocating resources among functional areas * Control of operations of the firm
Finance Department	* Projection of cash flows Deciding capital appropriations Establishing operating budgets
Production Department	*Determination of production quantities Determination of production schedules Control of inventory.
Personnel Department	*Planning manpower requirements * As an input in collective bargaining
Purchasing Department	*Planning the firm's overall material requirements * Scheduling materials' arrival.
Marketing Department	*Planning marketing strategies and soles programmes * Allocation of resources among various marketingactivities * Planning and evaluating the personal sellingefforts Setting sales quota As an input into compensation plan Evaluating the field sales force.

3.5 Sales Forecasting Methods.

There are two main classes of forecasting methods: Qualitative (or subjective) and Quantitative (or objective). The qualitative or subjective methods rely primarily on judgment to produce sales forecasts. The quantitative or objective methods, in contrast, involve the application of statistical techniques of varying degrees of sophistication. The different techniques under each main class are shown in Figure 3.2. We will consider these methods at some length in the sections that follow.

Figure 3.2: Classification of Sales Forecasting Methods



3.5.1 Subjective or Qualitative Methods

The subjective methods are based on assumptions, or intuitive estimates of those in the firm that are familiar with the market. This may include salespersonnel, purchasing representatives or management people who all have close contact with customers. Some of there techniques may involve several levels of sophistication. An example here is an opinion survey that has beenscientifically conducted. Others are merely intuitive hunches about future events. The accuracy of a particular subjective approach depends on the good judgment, honesty and philosophy of the individuals concerned. We shall attempt to examine each of the subjective techniques indicated in Figure 3.2

3.5.1.1 Users' Expectations

The users' expectations method is also known as the buyers' intentions methods since it relies on responses from customers with regard to their expected consumption or purchase of a product. The customers may be surveyed in person, over the telephone, or by mail. In some particular situations, the respondents in a users' expectations survey do not necessarily have to be the ultimate consumers. Rather, the firm may find it advantageous to secure the reactions of wholesalers and retailers that serve the channel.

Advantages

The users' expectations method offers several advantages.

These include the following:

(i) The forecast is based on estimates obtained directly from firms whose buying actions will actually determine the sales of the product.
(ii) The way through which the information was obtained i.e. projected product use by customers, allows preparation of forecasts in great detail e.g. by product, by customer, or by sales territory.
(iii) The method may often provide some insight into the buyer's thinking and plan. Therefore, it could be helpful in planning the marketing strategy.
(iv) It is particularly useful to solicit opinions from prospective buyers about a new product that is just coming to the market.

Disadvantages of Users' expectations are as enumerated below:

(i) The method is limited to situations in which the potential customers for the product are few and well defined. The method could be difficult to adopt and can actually result in grave errors when there are many customers that cannot be easily identified.
(ii) The method also depends on the sophistication of the potential customers in appreciating their needs. Here, we should remember that buyer intentions are subject to change, thus the method does not work particularly well for consumer goods.
(iii) It is often difficult to determine the firmness of intentions to purchase, particularly when the person being interviewed is not literate or uncooperative.
(iv) The method requires a considerable expenditure of money, time and manpower.

3.5.1.2 Sales Force Composite

The sales force composite is a specific judgmental forecast for which opinions are solicited from line sales personnel and sales managers. Each person states how much he or she expects to sell during the forecast period. The usual technique is to ask sales people to forecast sales for their districts and have these estimates reviewed by the regional sales manager and then by the head office sales manager. This method is based on the belief that those closest tothe sales people have the best knowledge of the market.

Advantages

(i) A primary advantage of the sales force composite method is that it usesthe specialised knowledge of the people closest to the market.
(ii) It has also been argued that the size of the sample used to develop the forecast tends to produce estimates that are fairly accurate.
(iii) The method lends itself to the easy development of customer; product, territory, or sales force breakdowns. These are particularly important in controlling the sales effort.

Disadvantages

(i) Sales representatives are often seen to be notoriously poor estimates. For instance, they tend to be overly optimistic when the economy is booming and overly pessimistic when things are not so good.
(ii) Salesmen usually are not trained forecasters and are ill-informed on thefactors influencing sale.
(iii) The approach makes no provisionfor bringing the systematicconsideration of uncontrollables into the analysis.
(iv) The approach does not provide for discovery of important facts throughstatistical analysis of historical data.

3.5.1.3 Jury of Executive Opinion

The jury of executive opinion method is about the oldest and simplest method of making sales forecast. The method either formally or informally polls the top executives of the company for their assessment of sales possibilities.The separate assessments are then combined into a sales forecast for the company.

This is sometimes often done by simply averaging the individual judgments.Disparate views are resolved through group discussions. In some cases, the process amounts to little more than group guessing. In other cases however, it involves the careful judgment of experienced executives who have studied the underlying factors influencing their company's sales.

Advantages

(i) Ease and quickness with which it can be made.
(ii) Does not require elaborate statistics.
(iii) The method brings together a variety of specialized viewpoints. The resulting "collective wisdom" reflects the thinking of the top people in the company.
(iv) When there is an absence of adequate data or experience, such as with innovative products, the jury of executive opinion method may be the only means of sales forecasting available to the company.

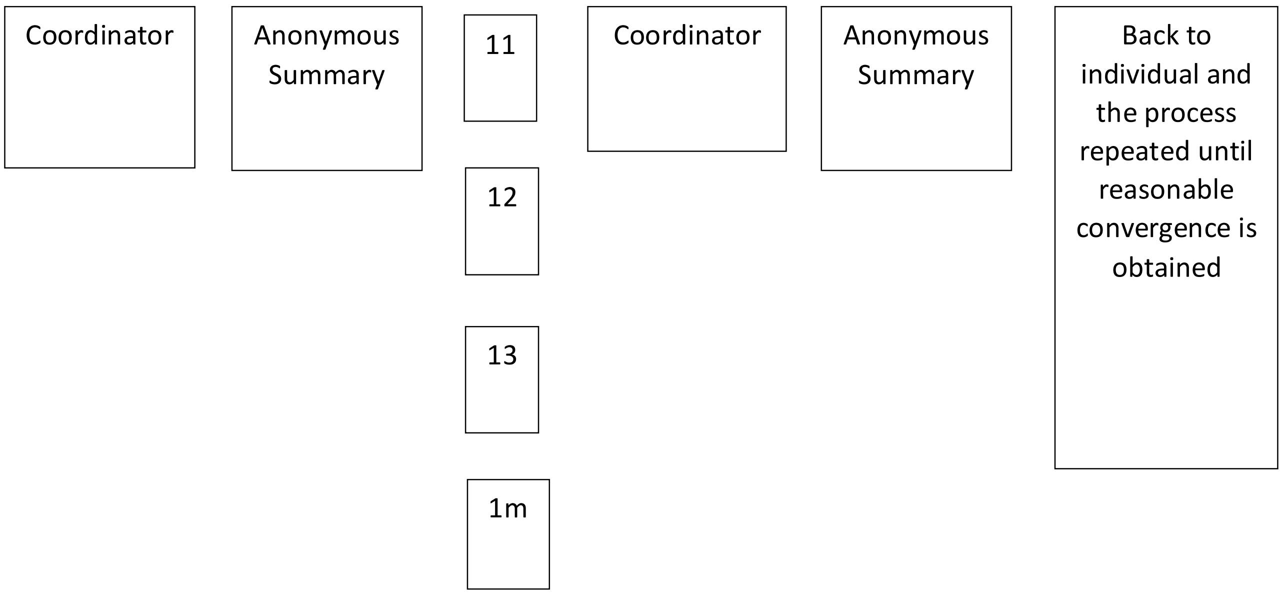
Disadvantages

(i) The forecasts are based on opinions rather than on facts and analysis.
(ii) Averaging opinions reduces responsibility for accurate forecasting.
(iii) The method is expensive because of the large amounts of highly paid executives' time it consumes.
(iv) The forecast may not properly weight the expertise of those most informed.

3.5.1.4 Delphi Technique

This method is used to achieve consensus within a committee. The Delphi technique uses repeated measurements and controlled feedback instead of direct confrontation and debate among the experts preparing the forecast. The way this method is employed is illustrated by Figure 3.3. The following steps are involved. First, each individual prepares a forecast using whatever facts, figures and general knowledge of the environment he or she has at his or her disposal. Second, the forecasts made are collected, and the person supervising the process prepares an anonymous summary. Third, the summary is distributed to each person who participated in the initial phase. Usually, the summary indicates each forecast figure, the average and some other summary measure of the spread of the estimates. Those whose initial estimates fell outside the mid-range of responses are asked to express their reasons for these extreme positions. The explanations offered are then incorporated into the summary. Those participating in the exercise are asked to study the summary and submit a revised forecast. The process is then repeated.

3.2: Operation of Delphi Process



The method is based on the following two Premises

$$Q_{t+1} = \alpha Q_t = \alpha Q_t + (1-\alpha)\, Q_{t-1}$$

(a) The range of responses will decrease, and the estimates will converge with repeated measurements

b) The total group response or median will move successively toward the "correct" or "true" answer.

Advantages

(i) The strategy of forcing those whose forecasts lie at the ends of thedistribution to justify their estimates seems to have benefits in that"informed" experts have greater opportunity to influence the final forecast.

(ii) Those who might have a deviant opinion, but with good reason, can defend that position, rather than going in to group pressure.

(iii) The method can result in forecasts that most participants have ultimatelyagreed to in spite of their initial disagreement.

Disadvantages

(i) The process of iteration and feedback in the Delphi often takes a long time
(ii) The method can also be very expensive.

3.5.2 Objective of Quantitative Methods

As we have already noted, the objectives or quantitative methods of forecasting are statistical in nature. They range in complexity from relatively simple trend extrapolations to the use of sophisticated mathematical models. A lot of organisations are tending toward the use of advanced methods in which the computer correlates a host of relationships. Let us now go into the treatment of the quantitative techniques earlier shown in Figure 3.

3.5.2.1 Market Test

Market testing is a relatively recent phenomenon in demand estimation and ismostly used to assess the demand for new products. The essential feature of a market test is that it is a controlled experiment, done in a limited but carefully selected part ofthe marketplace, whose aim is to predict the sales or profitconsequences, either in absolute or relative terms, of one or more proposed marketing actions. It therefore goes beyond estimating the potential sales of a new product.

It is necessary for us to note that market testing methods differ in the testing of consumer and industrial products. For instance, when testingconsumer products, the company wants to estimate the major determinants of sales, such as trial, first repeat, adoption, and purchase frequency. The major methods of consumer goods market testing include sales-wave research, simulates store technique, controlled test marketing and test markets. However, we are notgoing into their details here. You will learn more about them under Marketing Research.

Test marketing is not typically used in the case of industrial products.For instance, it will be too expensive to produce a sample of airplanes; ships etc, let alone put them up for sale in a select market to see how well they will sell.

Marketing research firms have actually not built the test-market systems that are found in consumer markets. Therefore, goods industrial manufacturers have to resort to other methods to research the market's interest in a new industrial product. The most common method adopted is product-use test. A second common market test is to introduce the new industrial product at trade shows. A new industrial product can also be tested in a distributor and dealer displayrooms. The details of these methods are under Marketing Research.

Advantages

(i) Market testing can indicate the product's performance under actualoperating conditions.
(ii) It can also show the key buying influences and the best market segment
(iii) It provides ultimate test of consumers' reactions to the product
(iv) It allows the assessment of the effectiveness of the total marketingprogramme
(v) It is very useful for new and innovative products.

Disadvantages

(i) It allows competitors know what the firm is doing; hence theymay jam the experiment by creating artificial situations so that the results of the test may not be meaningful.
(ii) It invites competitive reaction
(iii) It is expensive and time consuming.
(iv) Often takes a long time to accurately assess level of initial and repeat demand.

3.5.2.2Time Series

This approach to sales forecasting rely on the analysis of historical data to develop a prediction for the future. The depth and sophistication of these analyses often vary widely. At one extreme, the forecaster might just forecast next year's sales to be equal this year's sales. This forecast might be reasonably accurate for amature industry that is experiencing little growth. However, if there is some growth, the forecaster might allow for it by predicting the same percentage increase for next year that the company experience this year. Stillfurther along the continuum, the forecaster might attempt to break historical sales into basic components by isolating that portion due to trend, cyclical, seasonal and irregular influences.

The first component, trend (T), is the result of basic developments in population, capital formation, and technology. It is found by fitting a straight or curved line through pass sales. The second component, cycle (C), captures the wavelike movement of sales.

Many sales are affected by swings in general economic activity, which tends to be somewhat periodic. The cyclical component can be useful in medium-range forecasting. The third component, season (S), refers to a consistent pattern of sales movement within the year.

The term season, describes any recurrent hourly, weekly, monthly, or quarterly sales pattern. The seasonal component may be related to weather factors,holidays, and trade customs.
The seasonal pattern provides a norm for forecasting short-range sales. The fourth component, erratic events (E), includes strikes, blizzards, fads, riots, fires, war scares, and other disturbances. These erratic components are by definition unpredictable, and should be removed from past data to see the more normal behaviour of sales.

Time series analysis consists of decomposing the original sales series, Y, into the components, T, C, S, and E. Then these components are recombined to produce the sales forecast. The following is an example.

A company sold 12,000 units of its main product this year. It now wants topredict next year's December sales. The long-term trend shows a 5% sales growth rate per year. This alone suggests sales next year of 12,600. (i.e. 12,000 x 1.05). However, a business recession is expected next year and will probably result in total sales achieving only 90% of the expected trend-adjusted sales.Therefore, sales next year will more likely be 11,340(i.e. 12, 600 x 0.90). If sales were the same each year, monthly sales would be 945 (i.e. 11,340 – 12).

However, December is an above-average month for that particular product, with a seasonal index of 1.30. Therefore, December sales may be as high as 1,228.5 (i.e. 945 x 1.30). No erratic events such as strikes or new product regulations are. Therefore, the best estimate of new product sales next December is 1,228.5.

A newer time-series technique called exponential smoothing is now available. This is being used by a firm withhundreds of items in its product line, and wants to produce efficient and economical short-run forecasts. In its simplest form, exponential smoothing requires only three pieces of information: this period's actual sales, Qt; this periods smoothed sales, Qt; and a smoothing parameter, a . The sales forecast for next period's sales is then given by:
$Q_{t+1} = \alpha Q_t + (1- \alpha)\, Q_{t-1}$

Where:

Q_{t+1} = sales forecast for next period
α = the smoothing constant, where 0 = α = 1
Qt = current sales in period t
Q t = smoothed sales in period t.

Example:

Suppose the smoothing constant is 0.3, current sales are N600, 000, andsmoothed sales are N500, 000.

Then sales forecast is:

Q_{t+1} = 0.3 (N600,000) + 0.7 (N500,000)
= N180,000 + N350, 000
= N530, 000.

You will observe that the sales forecast is always between (or at an extreme of)current sales and smoothed sales.

Another technique under time series analysis is the method of moving averages. This is conceptually simple.
Let us consider the forecastthat next year's sales will be equal to this year's sales. Such a forecast might be subject to large error, if there is a great deal of fluctuation in sales from one year to the next. To allow for such randomness, we might want to consider making use of some kind of recent values. For example, we might average the last two yearssales, the last three years' sales, etc. The forecast would simply be the average
that resulted. The term moving average is usedbecause a new average can becomputed and used as a forecast as each new observation becomes available.

Table 3.2 presents 15 years of historical data for a manufacturer of shirts,together with the resulting forecast for a number of years using two-year and four-year moving averages.

Table 3.2: Annual and Forecasted sales for a manufacturer of shirts

Forecasted Sales

Year	Actual Sales	Two-Year Moving Average	Four-Year Moving Average
1974	4,200		
1975	4,410		
1976	4,322	4,305	
1977	4,106	4,366	
1978	4,311	4,214	4,260
1979	4,742	4,209	4,287
1980	4,837	4,527	4,370

1981	5,030	4,790	4,730
1982	4,779	4,934	4,847
1983	4,970	4,905	4,904
1984	5,716	4,875	5,128
1985	6,116	5,343	5,395
1986	5,932	5,916	5,684
1987	5,576	6,024	5,835
1988	5,465	5,754	5,772
1989		5,520	

As earlier explained, the calculation of moving average is relatively simple. For instance, the entry 4305 for 1976 under the two-year moving average method, for example, is the average of the sales of 4,200units in 1974 and4,410 units in 1975. In the same vein, the forecasts of 5520 units in 1989 represent the average of the number of units sold in 1987 and 1988. You may attempt to verify other forecast in the table.

Advantages

(i) The time series approach to sales forecasting provides a systematic means for making quantitative projections of sales.
(ii) The method is objective in the sense that two analysts working on thesame data series using the same forecasting technique and the same model should produce the same forecast.

Disadvantages

(i) It is not useful for new or innovative products
(ii) Factors for trend, cyclical, seasonal, or product life-cycle phase must beaccurately assessed and included
(iii) Technical skill and good judgement required.
(iv) Final forecast may be difficult to break down into individual territoryestimates.

3.5.2.3 Statistical Demand Analysis

Statistical demand analysis is a set of statistical procedures designed to discover the most important real factors affecting sales and their relative influence. The factors most commonly analysed are price, income, population and promotion.
The method consists of expressing sales (Q) as a dependent variable and trying to explain sales as a function of a number of independent demand variables X1,X2, …, Xn; that is:

Q = f (X1, X2, …, Xn)

By making use of multiple regression analysis, various equation forms can be statistically fitted to the data in the search for the best predicting factors andequation.

Let us make use of the work of Palda (1964), who tried to measure cumulate advertising effects of a vegetable product. He found that the following demand equation gave a fairly good fit to the historical sales of the product in question between the years 1908 and 1960:

$$Y = - 3649 + 0.665X1 + 1180 \log X2 + 774 X3 + 32X4 – 2.83X5$$

Where:

Y = Yearly sales in thousands of dollars
X1 = yearly sales (lagged one year) in thousands of dollars X2 = yearly advertising expenditures in thousands of dollars
X3 = a dummy variable, taking on the value 1 between 1908 and 1925 and 0
from 1926 on
X4 = year (1908 = 0, 1909 = 1, etc)
X5 = disposable personal income in billions of current dollars.

It was found that all the five independent variables accounted for 94% of the yearly variation in the sale of the commodity under investigation between 1908
and 1960. How can we use this demand equation as a sales forecasting equationfor the five independent variables? It follows thus:

- Sales in 1960 should be put in X1;
- The log of the company's planned expenditures for 1961 should be put in X2;
- 0 should be put in X3;
- The numbered year corresponding to 1961 should be put in X4;
- andEstimated 1961 disposable personnel income should be put in X5.

The result of multiplying these numbers by the respective coefficients andsumming them gives a sales forecast (Y) for 1961.

Advantages

(i) It has great intuitive appeal
(ii) Requires quantification of assumptions underlying the estimates. This makes it easier for management to check the results
(iii) It provides a means of discovering factors affecting sales which intuitivereasoning may not uncover.
(iv) The method is objective in the resultscan be reproduced by differentanalysts using the same model and variables.

Disadvantages

(i) It presumes that historical relationships will continue into the future, hence the analysts may have a false sense of security in this regard.
(ii) It requires technical skill and expertise
(iii) Some managers are reluctant to use the method due to its sophistication.

SELF-ASSESSMENT EXERCISES

Outline some of the advantages and disadvantages of Market test in forecasting

3.6 Summary

Forecasts are vital inputs for the design and the operation ofthe productivesystems because they help managers to anticipate the future. Forecasting techniques are generally classified as qualitative or quantitative. Qualitative techniques rely on judgement, experience, and expertise to formulate forecasts; quantitative techniques rely on the use of historical data, or associations among variables to develop forecasts. Some of the techniques are simple, while others are complex. Some work better than others, but no technique works all the time.

3.7 References/Further Readings/Web Resources

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3.8 Possible Answers to Self-Assessment Exercises

1. Outline some of the advantages and disadvantages of Market test in forecasting

Advantages

(i) Market testing can indicate the product's performance under actualoperating conditions.
(ii) It can also show the key buying influences and the best market segment
(iii) It provides ultimate test of consumers' reactions to the product
(iv) It allows the assessment of the effectiveness of the total marketingprogramme
(v) It is very useful for new and innovative products.

Disadvantages

(i) It allows competitors know what the firm is doing; hence they may jam the experiment by creating artificial situations so that the results of the test may not be meaningful.
(ii) It invites competitive reaction
(iii) It is expensive and time consuming.
(iv) Often takes a long time to accurately assess level of initial and repeat demand.

UNIT 4 PROCESS MANAGEMENT

Unit Structure

4.1 Introduction

This unit discusses process management, which is very essential in the design of a production system. Deciding on process involves many different choices in selecting human resources, equipment, as well as materials. Processes are involved inhow the marketing department prepares a market analysis; how a retail store provides services on the sales floor; and how a manufacturing plant performs its assembly operations.

4.2 Learning Outcomes

By the end of this unit, you should be able to: Describe each of the main process decisions and how they must relate to volume.

(i) Discuss how process choice implements flow strategy and how the fivechoices differ.
(ii) Explain when less vertical integration and more outsourcing areappropriate and how resource flexibility supports competitive priorities.
(iii) Describe the different ways that customer contact can affect a process.

4.3 Process Management

4.3.1 The Meaning of Process Management

Let us start by first defining what a process is: A process involves the use of an organisation's resources to provide something of value. You should understand that no product can be made and no service can be provided without a process. On the other hand too, no process can exist without a product or service.

Two implications of this definition come out very clearly:

(i) Processes underline all work activity and are found in all organisations,as well as all functions of an organisation.
(ii) Processes are nested within other processes along an organisation's supply chain. A firm's supply chain (also called the value chain) is aninterconnected set of linkages among suppliers of materials and services that spans the transformation process that convert ideas and rawmaterials into finished goods and services for a firm's customers.

We can now go ahead to define process management as the selection of the inputs, operations, work flows, and methods that transforms input into outputs. Usually input selection begins by deciding which processes are to be done in-house, and which processes are to be done outside, as well as purchasedmaterials and services. Process decisions also deal with the proper mix of human skills and equipment and which parts of the processes are to be performed by each. You should also note that decisions about processes must be consistent with the organisation's flow strategy, and the organisation's ability to obtain the resources necessary to support that strategy.

When should process decisions be made? It is always better to take the necessary decisions whenever:

(i) A new or substantially modified product or service is being offered.
(ii) Quality must be improved;
(iii) Competitive priorities have changed;
(iv) Demand for a product or service is changing;
(v) Current performance is inadequate;
(vi) Competitors are gaining by using a new process or technology, or
(vii) The cost or availability of inputs has changed.

However, not all these situations will result to changes in current processes.
Very often, process decisions must recognize costs, and sometimes the cost of change outweighs its benefits.

In addition, process decisions must take other choices into account, especially those concerning quality, capacity, layout, and inventory. Furthermore, process decisions depend on competitive priorities and on flow strategy. Ethics and the environment are similarly considered.

4.3.2 Major Types of Process Decisions

Operations managers usually consider five common process decisions. These are discussed in the sections that follow:

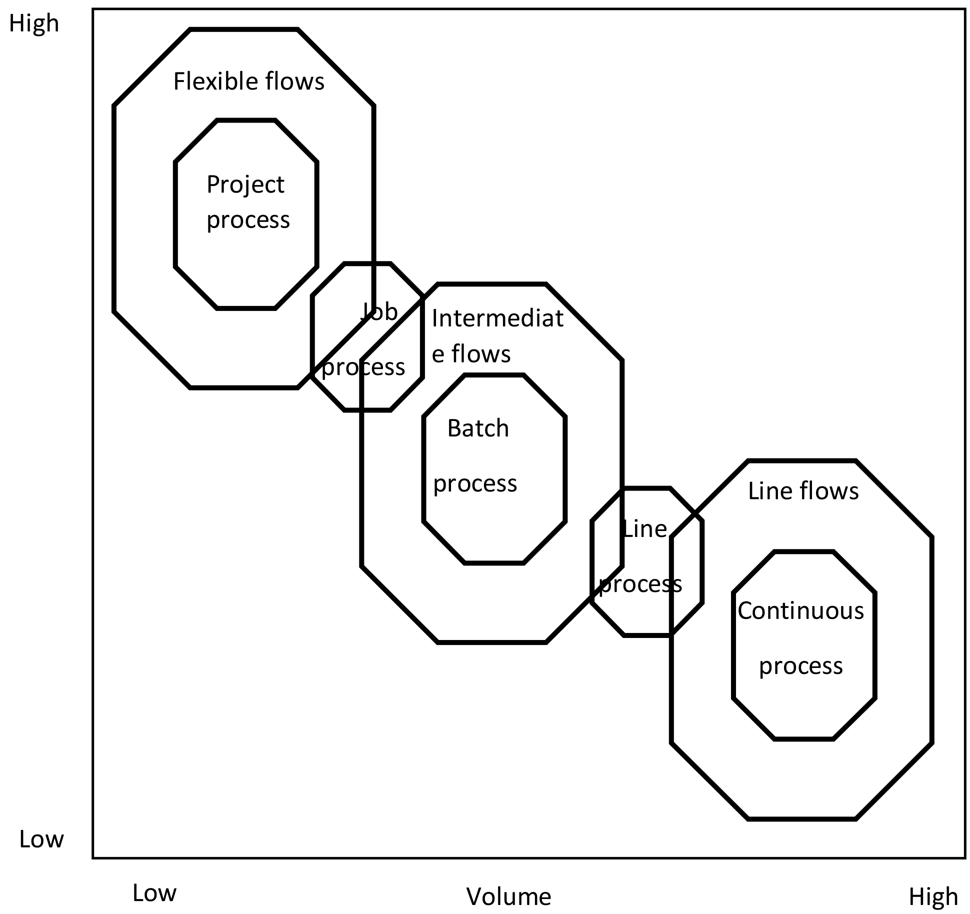
4.3.3 Process Choice

Choosing a process that best supports an organisation's flow strategy is one of the first decisions a manager makes in order to design a well-functioning operation. There are five process types, which form a continuum, and from which the manager can choose:

(a) Project,
(b) Job,
(c) Batch,
(d) Line, and
(e) Continuous process.

A close look at Figure 4.1 should reveal to you that the best choice depends on the volume and degree of customisation. It is important to note that a process choice might apply to an entire facility or just one segment of its overall process. For example, a process segment might best be characterised as a job process and another segment as a line process.

Figure 4.1:



3.2.1.1 Project Process

A project process is characterized by a high degree of job customisation, the large scope of each project, and the release of substantial resources once a project is completed. A project process lies at the high – customisation, low- volume end of the process choice continuum. The sequence of operations and the process involved in each one are unique to each project, thereby creating one-of-a-kind products or services made specifically to customer order.

Very often, firms with project processes sell themselves on the basis of their capabilities rather than on specific products or services. One attribute of project is that they tend to be complex, take a long time, and be large. Also, many interrelated tasks must be completed, and these usually require close coordination. Projects usually make heavy use of certain skills and resources at particular stages, and then have little use for them till the end of the time. A project process is based on a flexible flow strategy, with work flows re-defined with each new project.

Examples of a project process: Building a shopping centre, forming a project team to do a task, running a political campaign, doing management consultancy work, or developing a new technology or product.

4.3.3.1 Job Process

A job process creates the flexibility needed to produce a variety of products or services in significant quantities. Very often, customization is relatively high and volume for any one product or service is low. However, the volume here is larger than in the case of project process. Note that by definition, a project process does not produce in quantity. The work force andequipment are flexible and can handle various tasks.

Organisations choosing the job process usually bid for work. Since the specific needs of the next customer is unknown, and the timing of repeat orders from the same customer is unpredictable, products are made to order and neverahead of time.

Thus, each new job is handled as a single unit, i.e. as a job. A job process primarily involves the use of a flexible flow strategy, with resource organized around the process.

Examples of a job process: Providing emergency room care, courier services, making customised cabinets etc.

4.3.3.2 Batch Process

A batch process differs from the job process with respect to volume, varietyand quantity. For instance, volumes are higher in the case of batch process since the same or similar products or services are provided repeatedly.

However, a narrower range of products and services is provided with respect to quantity, production lots, or customer groups are handled in larger quantities (or batches) then they are with job processes. A batch of one product or customer grouping is processed, and production is later switched to the next one. Invariably, the first product or service is produced again.

Examples of a batch process: Scheduling air travel for a group (pilgrims, students, holiday makers), making components that feed an assembly line, andmanufacturing capital equipment.

4.3.3.3 Line Process

A line process lies between the batch and continuous process on the continuum, volumes are high, and products or services are standardised, thus allowingresources to be organised around a product or service. In this process, materials move linearly from one operation to the next according to a fixed order, and little inventory being held between operations.

Unlike project and job processes, production orders are not directly linked tocustomer orders. Manufacturers with line processes usually follow a make-to-stock strategy, with standard products held in inventory so that they are ready when a customer places an order. Note that the use of a line process is alsoreferred to as mass production. It is possible to have product variety by carefully controlling the addition of standard options to the main product or service. Very often, a line process fits primarily with the line flow strategy, although it can overlap into the intermediate flow strategy when mass customisation or assemble-to-order strategies are pursued.

Examples of a line process: Vehicle assembly plants, Electrical and electronic manufacturing companies, garment factories etc.

4.3.3.4 Continuous Process

A continuous process is the extreme and of high-volume, standardised production with rigid line flows. Usually, one primary material, such as aliquid, gas, or powder, moves without stopping through the facility. Typically this process is capital intensive and operated round the ch to maximizeutilization and to wid expensive shutdowns and start-ups. They are used almost exclusively in manufacturing and fit perfectly a line flow strategy.

4.3.4 Degree of Vertical Integration

Another important issue to resolve when developing production process designs is the determination of how much of the production of products orservices a company should bring under its own roof. Vertical integration is the amount of the production and distribution chain, from suppliers of components to the delivery of products and services to customers that is brought under the ownership of a company.

Usually, management decides the level of vertical integration by looking at all the activities performed between acquisition of raw materials or outside services and delivery of finished productsor services. The more processes in the supply chain that the organisation performs itself, the more verticallyintegrated it is. If the organisation does not perform some processes itself, then it must rely on outsourcing.

Decisions such as these are often called make-or-buy decisions. A make decision translates to more integration, while a buy decision essentially means more outsourcing.

The make-or-buy decisions are not always simple. But the starting point is to determine whether the cost of making components is less than that of buying them from suppliers. Unless there are clear cost advantages to making components in-house, such issues as the following are not likely to be as important. Is enough investment capital available to expand production capacity to make the components?. Does the company have the technological capability to make the components? Are there high-quality suppliers available? Is there a risk that suppliers will become competitors?

Whatever decision is taken, management must find ways to coordinate and integrate the various processes and suppliers involved.

Because of shortages of both capital and production capacity, small firms and start-up ventures ordinarily choose to have a very low degree of vertical integration.

4.3.5 Resource Flexibility

Usually, the choices that management makes with respect to competitive priorities determine the degree of flexibility required of a company's resources (i.e. its employees, facilities, and equipment).

With respect to human resources, operations managers must decide whether to have a flexible work force or an inflexible one. Members of a flexible workforce are capable of doing many tasks. However this flexibility has its costs. For example, it requires greater skills and thus more training and education. On the other hand, worker flexibility provides an opportunity to achieve reliable customer service and alleviate capacity bottlenecks.

When a firm's product or service has a short life cycle and a high degree of customisation, low production volumes suggest that the firm should select flexible, general-purchase equipment.

4.3.6 Customer Involvement

The extent to which customers interact with the process is another important process decision to consider. The amount of customer involvement ranges from self-service to customisation of product, to deciding the time and place that theservice is to be provided.

4.3.7 Degree of Automation

A key issue in designing production processes is determining how muchautomation to integrate into the production system. Usually, automation projects are not under-taken lightly since the equipment is very expensive and managing the integration of automation into existing or new operation is difficult.

Automation can reduce labour and related costs. In many applications however, the huge capital investment required by automation projects cannot be justified on labour savings alone.

It is the goals of improving product quality and product flexibility that motivate companies to make the huge investments in automation projects. Apart from anything else, the degree of automation appropriate for producing a product or service must be driven by the operations strategy of the firm. For instance, if those strategies call for high product quality and product flexibility, automation can be an important element ofoperations strategy.

4.4 Designing Processes

Having broadly examined the five main process decisions, the manager should determine exactly how each process will be performed. There are two different, but complementary approaches for designing process: process re-engineeringand process improvement.

4.4.1 Process Re-engineering

Re-engineering is the fundamental rethinking and radical redesign of processes to improve performance dramatically in terms of cost, quality, service, and speed. It is all about re-invention, rather than an incremental improvement.

Though re-engineering can make a company more competitive, its side effects, especially on employees are often very harsh. For example, it usually leads to massive lay-offs. The company also coughs out large cash outflows for investment in information technology. The following points are useful guidelines for reengineering:

4.4.1.1Critical Processes

Normally, a process selected for reengineering should be a core process, rather than functional departments (such as purchasing or marketing). By focusing on processes, managers may discover opportunities to eliminate unnecessary work and supervisory activities. Hence, reengineeringshouldbe reserved for essential processes, such as new-product developmentor customer services,because of the time and energy involved.

4.4.1.2Strong Leadership

It has also been suggested that senior executives must provide strong leadership for reengineering to be successful. If this is not effectively and efficiently done, cynicism, resistance and boundaries between functional areas can block such a radicalchange. Resistance can be over-come by providing the clout necessary to ensure that the project proceeds within a strategic choice.

4.4.1.3Cross-Functional Teams

Usually, a team, made up of members from each functional area affected by the process change should be charged with carrying out a reengineering project.

4.4.1.4 Information Technology

Information technology is absolutely necessary for a successful reengineering. This is because most reengineering projects design processes around information flows such as customer order fulfillment.

4.4.1.5 Clean Slate Philosophy

A “clean slate” philosophy means starting with the way the customer wants to deal with the company. A customer-driven orientation necessitates that the cross-functional teams start with internal and external customer objectives for the process. What the teams usually do is to first establish a price target for the product or service, subtractthe desired profit, and then find an appropriateprocess that will provide what the customer wishes to pay. It is thus a common practice for Reengineers to start from the future and work backward, usually unconstrained by current approaches.

4.4.1.6 Process Analysis

In spite of the clean slate philosophy discussed above re-engineering team must understand things about the current process. For instance, what it does, how well it performs, and what factors affect it. A critical analysis of such details can highlight areas in which new thinking will provide the biggest payoff. It is therefore necessary for the team toexamine every procedure involved in the process throughout the organisation, recording each step, questioning why it is done, and then eliminating it, if it is not necessary.

4.4.2 Process Improvement

This is the systematic study of the activities and flows of each process toimprove it. The major objective of process improvement is to "learn the number", understand the process, and dig out the details. The idea here is that once a process is really understood, it can be improved. Please note that process improvement goes on, whether or not a process is reengineered. In actual fact, the relentless pressure to provide better quality at a lower pricemeans firms must always review all aspects of their operations.

There are two basic techniques for analyzing processes: flow diagrams and process charts. These are already treated. As discussed in that unit, these techniques involve the systematic observation and recording of process details to allow better understanding of it. Thereafter, the analysis can highlight tasks to be simplified, or where productivity can otherwise be improved.

SELF-ASSESSMENT EXERCISE (SAE)

Question: An automobile service station is having difficulty providing oil changes in the 29 minutes or less mentioned in its advertisement.The process chart is given in Figure 4.2.

Process: Changing engine oil
Subject: Mechanic
Beginning: Direct customer arrival
Ending: Total charges, receive payment

Insert Step
Append Step
Remove Step

Summary

Activity	Number of Steps	Time (min)	Distance (ft)
Operation ●	7	16.50	
Transport ➡	8	5.50	420
Inspect ■	4	5.00	
Delay ◗	1	0.70	
Store ▼	1	0.30	

Step No.	Time (min)	Distance (ft)	●	➡	■	◗	▼	Step Description
1	0.80	50.0		X				Direct customer into service bay
2	1.80		X					Record name and desired service
3	2.30				X			Open hood, verify engine type, inspect hoses, check fluids
4	0.80	30.0		X				Walk to customer in waiting area
5	0.60		X					Recommend additional services
6	0.70					X		Wait for customer decision
7	0.90	70.0		X				Walk to storeroom
8	1.90		X					Look up filter number(s), find filter(s)
9	0.40				X			Check filter number(s)
10	0.60	50.0		X				Carry filter(s) to service pit
11	4.20		X					Perform under-car services
12	0.70	40.0		X				Climb from pit, walk to automobile
13	2.70		X					Fill engine with oil, start engine
14	1.30				X			Inspect for leaks
15	0.50	40.0		X				Walk to pit
16	1.00				X			Inspect for leaks
17	3.00		X					Clean and organize work area
18	0.70	80.0		X				Return to auto, drive from bay
19	0.30						X	Park the car
20	0.50	60.0		X				Walk to customer waiting area
21	2.30		X					Total charges, receive payment

Solution

The process is broken into 21 steps. A summary of the number of steps times and distances traveled is presented below:

Summary

Activity	**Number of Steps**	**Time (min.)**	**Distance (ft)**
Operation	7	16.5	-
Transport	8	5.5	420
Inspection	4	5.0	-
Delay	1	0.7	-
Store	1	0.3	-
TOTAL	**21**	**28.0**	**420**

Source: Figure 4 .2

The times add up to 28 minutes, which does not allow much room for error if the 29 minutes guarantee is to be met, and the mechanic travels a total of 420feet.

SELF-ASSESSMENT EXERCISE (SAE)

Outline the necessary conditions before process decisions are made?

4.5 Summary

This unit has demonstrated that process decisions are strategic and can affect an organisation's ability to compete over the long-run. We started by defining five basic process decisions: process choice, degree of vertical integration, resource flexibility, customer involvement, and degree of automation. We also discussed how each process will be performed.

4.6 References /Further Readings/Web Resources

Harmer, M. (1996): Beyond Reengineering. New York: Harper Business

Hill, T (1989): Manufacturing strategy: Text and cases. Homewood, Ill.: Irwin.

Krajewski; L.J and L.P.Ritzman (1999): Operations Management:Strategy and Analysis. 5th ed. Reading, Massachusetts, Addison – Wesley.

4.7 Possible Answers to Self-Assessment Exercises

When should process decisions be made? It is always better to take the necessary decisions whenever:

i). A new or substantially modified product or service is being offered.

ii). Quality must be improved;

iii). Competitive priorities have changed;

iv). Demand for a product or service is changing;

v). Current performance is inadequate;

vi). Competitors are gaining by using a new process or technology, or

vii). The cost or availability of inputs has changed.

Unit 5 Design of Facilities and Jobs

Unit Structure

5.1 Introduction

Design of facilities and Jobs are those basic components that make organisations competitive. Design of the production system involves planning for the inputs, Conversion process and outputs of production operation. The effective management of capacity is the most important responsibility of production management. It involves job design, work measurement, allowances, work sampling and predetermined motion time analysis. Understanding of these concepts is essential for effective operation Management.

5.2 Learning Outcomes

By the end of this unit, you will be able to:

- Explain the various aspects of Job design
- Describe the concept of work measurement
- Enumerate the objectives of work measurement
- Briefly explain different types of allowances
- Mention the procedure for conducting a work sampling study.

5.3 Design of Facilities and Jobs

5.3.1 Job Design

Job design may be defined as the function of specifying the work activities of an individual or group in an organisational setting.

The objective of the job design is to develop job structure that meet the requirements of the organization and its technology and that satisfies the individual requirements. The various decisions involved in job design are represented in the fig 10.1

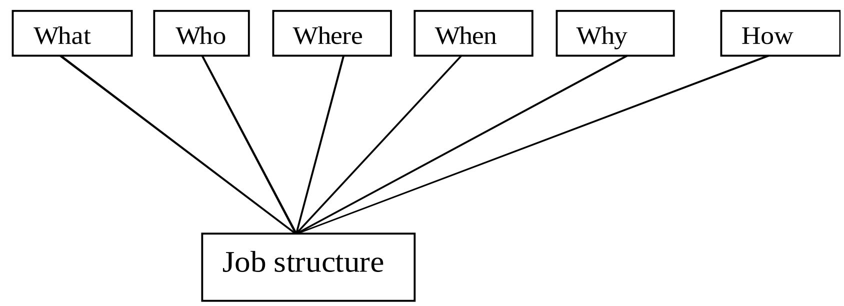


Figure 3.1 **Various Decisions involved in Job design**

The following trends are going to influence the job design.

* Workers concern and responsibility for quality – concept of quality at source or self-certification concept
* Multi-skilling of workers.
* Workers involvement in designing and organizing labour
* Extensive use of temporary or contract labours
* Education of work force and ability to take challenges
* Automation of heavy and hazardous work.

5.3.2 Various Aspects of Job Design

A. Socio – Technical approach

This approach attempts to develop job that adjust the needs of the production process technology to the need of worker and workgroup. It emphasis on both technical and social variables in relation to Job design. This approach helps in designing the job that takes into account the possible costs of turnover, absenteeism and boredom in relations to technology.

The job design is divided into work groups that require a logically integrated pattern of work activities that incorporate the following job design principles.

1. Task variety

Try to provide an optimal variety of tasks within each Job. Too much variety is frustrating and too little leads to monotony and boredom. Optimal level is one, which allows the employee to take a rest from high level of attention or effort, while working on another job.

2. Skill Variety

Employees derive satisfaction from applying number of skill levels.

3. Feed Back

A means for informing employees regarding their achievement. Fast feedback aids in learning process.

4. Task Identify

A particular set of tasks should be separated from other tasks by some clear boundary. A group or individual should have responsibility for some set of tasks that can be clearly defined, visible and meaningful.

5. Task Anatomy

Employees should be able to exercise some control over their work i.e. they should be involved in decision – making.

B. Degree of labour specialization

Specicalization of labour on one side results in high speed, low cost production and on other side it has some serious adverse effects on worker as well as on production system. The problem is to determine how much specialization is to be accounted for?

The advantages of specialization include

Rapid training of workforce, ease in recruiting new work force, lower wages to ease of substitutability and higher out- puts.

The main limitations are limited perspective of workers, limited flexibility in workforce, and repetitive nature of jobs and higher and boredom

C. Job enrichment Approach

Job enrichment generally entails adjusting a specialized job to make it more interesting to the job holder. A job is said to enlarged horizontally, if the worker performs a greater number of variety of tasks and it is said to be enlarged vertically if the worker involves in planning organizing and inspecting his own work.

Vertically enlargement referred to as job enrichment attempts to broaden workers influence in the transformation process by giving them certain managerial powers over their own activities. Thus, job enrichment is an approach to job design, which stresses the motivating potential in the work itself.

The organizational benefits of job enrichment occur both in quality and productivity.

Quality in particular in proves drastically because when individuals are responsible for their work output, they take ownership of it and supply do a better job. Productivity improvement also occurs from job enrichment

D. Physical consideration in job Design

The work physiology – incorporates the cost of moderate to heavy work in job design work physiology sets, work rest cycles according to energy expended in various part of the job.

Ergonomics: Is the term used to describe the study of physical arrangement of the work space together with the tools used to perform a task. In ergonomics, attempt is made to fit the work to the body rather than forcing the body to conform to the work.

Work method: The principal approach to the study of work methods is the construction of charts such as operation process chart, flow process chart, man machine charts and multiple activity charts with time study or standard time date. The choice of charting method depends on tasks activity level i.e. whether focus is on production process, worker at fixed place a work or interacting with equipment and worker interacting with other workers.

Self-Assessment Exercises

Assess the relevance of Job design to operations Management

5.4 Work measurement

5.4.1 Definition: work measurement is also called by the name "**Time study**". Work measurement is absolutely essential for both the planning and control of operations. Without measurement data, we cannot determine the capacity of facilities or it is not possible to quote delivery dates or costs. We are not in a position to determine the rate of production and also labour utilization and efficiency. It may not be possible to introduce inactive schemes and standard costs for budget control.

Time study has been defined by British standard institutions as "The application of techniques designed to establish the time for a qualified worker to carryout a specified job at a defined level of performance".

5.4.2 Objectives at work measurement

The use work measurement at basis for inactive only a small part of its total application.

The objectives of work measurement are to provide a sound basis for:

a. Comparing alternative methods
b. Assessing the correct initial manning (Man power requirement planning).
c. Planning and control
d. Realistic costing
e. Financial incentive scheme
f. Delivery date of goods
g. Cost reduction and cost control
h. Identifying substandard workers
i. Training new employees.

5.4.3 Techniques of work measurement

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

❖ Repetitive Work – The type of work in which the main operation or group of operations repeat continuously during the time spent at the job. These apply to work cycles of extremely short duration.

* **Non repetitive work**. It includes some type of maintenance and construction work, where the work cycle itself is hardly ever repeated identically

Various Techniques of Work Measurement are

❖ Time study (stop watch technique)
❖ Synthesis
❖ Work sampling
❖ Predetermined motive and time study.

Time study and work sampling involved direct observation and the remaining are data based and analytical in nature.

Time study. A work measurement techniques for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analyzing the data so as to determine the time necessary from carrying out the job at the defined level of performance.

Synthetic Data - A work measurement techniques for holding up the time for a job or parts of the job at a defined level of performance by totaling element times obtained previously from time studies other jobs containing the elements concerned or from synthetic data.

Work Sampling - A technique in which a large number of observations are made over a period of time of one or group of machines, processes or workers. Each observations records what is happening at that instant and the percentage of observations recorded for a particular activity, or delay is a measure of the percentage of time during which that activities delay occurs.

Predetermined Motion Time Study (PMTS) - A work measurement techniques whereby times established for basic human motions (classified according to the nature of the motion and conditions under which it in made) are used to build up the time for a job at the defined level of performance.

The most commonly used PMTS is known as methods time measurement (MTM).

Analytical Estimating

A work measurement technique, being a development of estimating, whereby the time required to carry out elements of a job at a defined level of performance is estimated partly from knowledge and practical experience of the elements concerned and partly from synthetic data.

The work measurement techniques and their application is shown in table 10.1

Table 3.2 work measurement and techniques and their application

	Techniques	Application	Unit of measurement
1	Time study	Short cycle repetitive jobs wisely use for direct work	Centi minutes 0.0 min
2	Working sampling	Long cycle jobs/heterogeneous	Centi minutes

		operations	
3	Synthetic data	Short cycle repetitive jobs	Centi minutes
4	MTM	Manual operations confirmed to one work centre	TMU (1 TUM = 0.006 min)
5.	Analytical estimating	Short cycle non-repetitive job	Minutes.

5.4.4 Step in Making Time Study

Stop watch time is the basic techniques for determining accurate time standards. They are economical for repetitive types of work steps in taking the time study are

1. Select the work to the studied

2. Obtain and record all the information available about the job, the operator and the working conditions likely to affect the time study work.

3. Breakdown the operation into demands. An element in a distinct part of a specified actively composed of one or more fundamental motions selected for convenience of observation and timing.

4. At the same time assess the operator effective speed of work relation to the observed concept of "Normal" speed. This is called performance rating.

5. Adjust the observed time by rating factor to obtain Normal time for each element

$$\text{Normal time} = \frac{\text{Observed x Rating}}{100}$$

6. Add the suitable allowances to compensate for fatigue, personal needs contingencies so on to give standard time for each element.

7. Compute allowed time for the entire job by adding elemental standard time considering frequency of occurrence of each element.

8. Make a detailed job description describing the method for which the standard time is established

9. Test and review standards where necessary. The basic steps in time study are represented by a block diagram in fig. 10.2

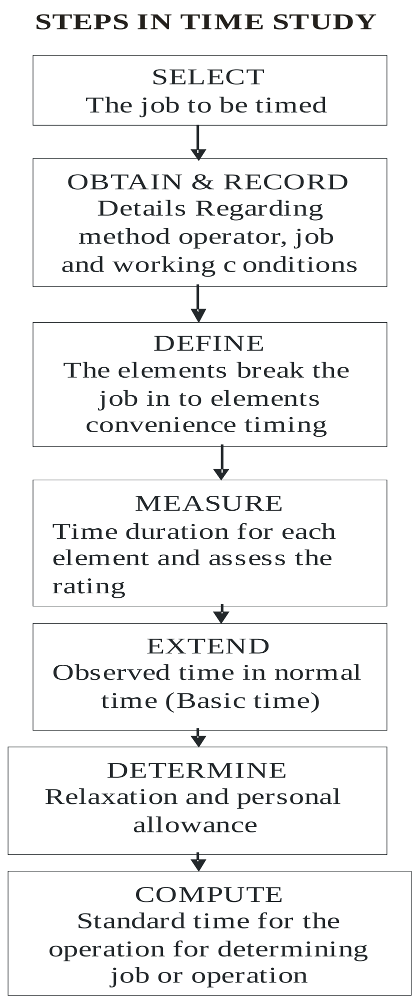


Figure 3.3 **Steps in Time Study**

5.4.5 Allowances

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

The allowances are categorized as:
1. Relaxation allowance
2. Interference allowance
3. Contingency Allowance

Relaxation Allowance

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

Relaxation allowances are of two types – fixed allowances and variable allowances.

Fixed allowances constitute:

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

(b) Allowances for basic fatigue. This allowance is given to compensate for energy expended during working. A common figure considered as allowance is 4% of the basic time.

Variable Allowance

Variable allowance is allowed to an operator who is working under poor environmental conditions that cannot be improved, added stress and strain in performing the job.

The variable fatigue allowance is added to the fixed allowance to an operator who is engaged on medium and heavy work and working under abnormal conditions. The amount of variable fatigue allowance varies from organization to organization.

Interference Allowance

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

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

Contingency Allowance

A contingency allowance is a small allowance of time which may be included in a standard time to meet legitimate and expected items of

work or delays, the precise measurement of which is uneconomical because of their in frequent or irregular occurrence.
This allowance provides for small unavoidable delays as well as for occasional minor, extra work.

Some of the examples calling for contingency allowance are:

- Tool breakage involving removal of tool from the holder and all other activities to insert new tool in to the tool holder.
- Power families of small demotion.
- Obtaining the necessary tools and gauges from central tool store. Contingency allowance should not exceed 5%.

Policy Allowance
Policy allowances are not the genuine part of the time study and should be used with utmost care and only in clearly defined circumstances.

The usual reason for making the policy allowance is to line up standard times with requirements of wage agreement between employers and trade unions.

A policy allowance is an increment, other than bonus increment, applied to a standard time (or to some constituent part of it, e.g. work content) to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstances. Policy allowances are some time made as imperfect functioning of a division or part of a plant.

Various the allowances used to build the standard time are shown in fig. 10.2.

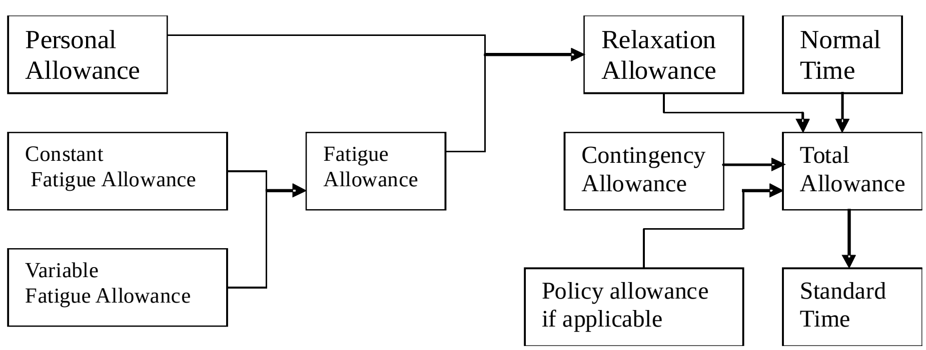
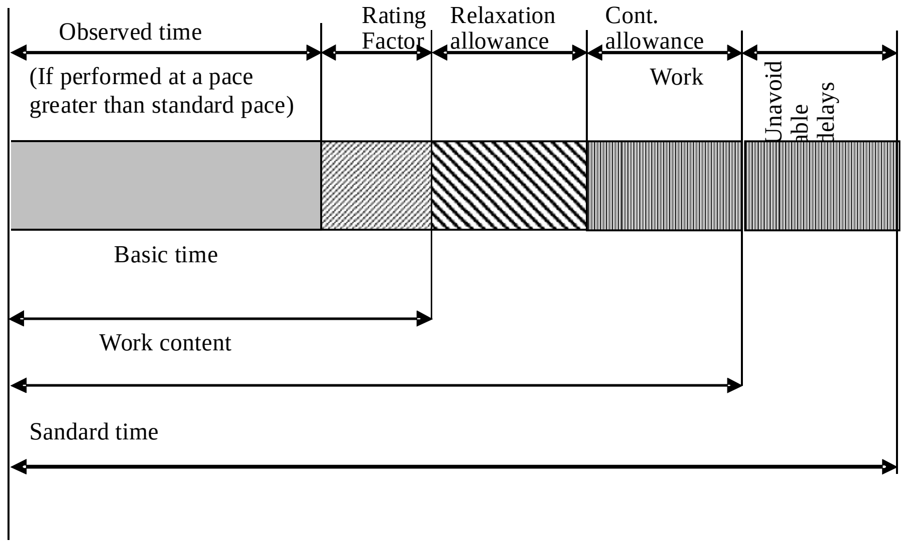


Fig. 3.3 **Various Allowances to Build Standard Time**

5.4.6 Computation of Standard Time

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



Fi **5.4.6.1 How the standard time for a simple manual job is made up**

The basic constituents of standard time are as shown in fig. 3.4.

Problem 3.1. The elemental times (in minutes) for 4 cycles of an operation using a stop watch are presented below.

Elements	Cycle time in minutes			
1	1	2	3	4
2	1.5	1.5	1.3	1.4
3	2.6	2.7	2.4	2.6
4	3.3	3.2	3.4	3.4
5	1.2	1.2	1.1	1.2
	0.51	0.51	0.52	0.59

Calculate standard time for the operation if

(i) Elements 2 and 4 are machine elements

(ii) For other elements, the operator is rated at 110%

(iii) Total allowances are 15% of the normal shown in time

Solution

The normal times are shown in table 3.1 below:

Element No	Cycle Time (min)	Avg. Cycle Time (3)	Rating	Normal Time = Avg. Time x Rating (4)
	1 2 3 4			
1	1.5 1.5 1.3 1.4	1.425%	110%	1.425 x 1.1 = 1.568
2	2.6 2.7 2.4 2.6	2.575	m/c elem	= 2.575
3	3.3 3.2 3.4 3.4	3.325	110%	3.325 x 1.1 = 3.658
4	1.2 1.2 1.1 1.2	1.175	m/c elem.	= 1.175
5	0.51 0.51 0.52 0.4	0.505	110%	0.505 x 1.1 = 0.555

Normal time for the cycle = 1.568 + 2.575 + 3.658 + 1.175 + 0.555

= 9.531

Standard time = (9.531 _ (0.15 x 9.531)

= 10.484 minutes

Problem 3.2. The following table shows a time study data. The times shown are continuous watch readings in minute. Initial setting of stop watch is at 0.00.

S. No.	Element	Cycle Time			Performance rating
		1	2	3	
1	Get two cases	0.5	4.2	8.6	1.05
2	Put parts into cases	1.5	5.7	9.9	1.15
3	Clamp two parts in position	3.8	8.1	12.6	0.95

Take relaxation allowance as 15% and find the standard time

Solution

This is a cumulative timing method the cycle times are tabulated as shown in table

S. No.	Element Cycle Time	Avg. time	Rating	Normal time
	1 2 3			
1	Get two cases 0.5	0.466	1.05	0.49

	0.4 0.5			
2	Put parts in to cases 1.0 1.5 1.3	1.266	1.15	1.456
3	Clamp two parts in position 2.3 2.4 2.7	2.466	0.95	2.343

Standard time = Normal time (1 + 0.15)

= 0.49 + 1.456 + 2.343 (1.15)

Normal time for the cycle = observed time /cycle X rating

= 13.005 x 1.2

= 15.606 min

Total Allowance = Fatigue allowance + contingency allowance

(∴ Personal allowance per shift is given)

Standard time = 15.606 (1 + 0.15 + 0.2)

= 18.259 minutes

(ii) **Production rate Per Shift**

Total time per shift of 8 hrs. = 8 x 60 = 480 min

Less personal allowance = 30 min

Effective production time = 450 min

Production in 8 hrs. shift

$$\frac{Time\ available\ for\ production}{S\tan dard\ Time} = \frac{450}{18.259}$$

Problem 3.3 A time study was conducted on a job consisting of three elements. Stop watch readings in hundredth of a minute are given. Using cumulative timing method along with rating factors.

Calculate the standard time if allowance is 12%.

Element	**Stop watch readings**					**Rating**
	1	2	3	4	5	
A	10	73	139	203	266	80
B	25	88	155	218	280	100
C	64	128	193	257	320	110

Solution

This stop watch readings are cumulative. The individual timings for elements are computed by subtracting proceeding reading from successive figure as shown in table below.

Example 25 – 10 = 15 for element B, 1st observation

Element	**Individual Element timings**	**Avg. time (min)**	**Rating**	**Normal time**
	1 2 3 4 5			
A	10 09 11 10 09	0.098	80	0.0784
B	15 15 16 15 14	0.150	100	0.1500
C	39 40 38			
	39 40			
	Total		0.6596	

Standard time = 0.6596 (+ 0.12)
= 0.7387 minutes.

Problem 3.4. Continuous stop watch study observations for a job are given. Compute the standard time for the job, if the total allowances are 15%.

Ele. No.	**Desc**	**Cycle time (min)**										**P.R**	
		1	2	3	4	5	6	7	8	9	10		1
A	Loosen vice	0.09	0.49	0.89	1.31	1.70	2.09	2.50	2.88	3.29	3.71	90	0.09
B	Set bar length	0.16	0.056	1.38	1,38	1.76	2.16	2.57	2.95	3.36	3.78	110	0.16
C	Switch m/c	0.28	0.67	.149	1.49	1.88	2.28	2.68	3.07	3.40	3.90	120	0.28
D	Unlock arm & set saw	0.41	0.80	1.61	1.61	2.00	2.41	2.80	3.20	3.62	4.03	100	0.41

Ele. No.	**Cycle time (min)**											avg.
	1	2	3	4	5	6	7	8	9	10	Time	Time
A	0.09	0.08	0.10	0.09	0.09	0.09	2.09	0.08	0.09	0.09	0.089	0.080
B	0.07	0.07	0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.068	0.075
C	0.12	0.11	0.12	0.11	0.12	0.12	0.11	0.12	0.13	0.12	0.118	0.142
D	0.13	0.13	0.14	0.12	0.12	0.13	0.12	0.13	0.13	0.13	0.128 Total	0.128 0.425

Solution: The individual element cycle timing is computer from the cumulative cycle times as shown in table below.

5.5 Work Sampling

Work sampling was originally developed by L.H.C. Tippett in Britain in 1934 for the British Cotton Industry Research Board. Work sampling is a fact finding tool.

Work sampling is defined as:
"A technique in which a statistically competent number of instantaneous observations are taken, over a period of time, of a group of machines, processes or workers. Each observations recorded for a particular activity or delay is a measure of the percentage of time observed by the occurrence."
Work sampling has three main application.

1. ***Activity and delay Sampling:*** to measure the activities and delays of workers or machine. E.g. the percentage of time in a day, a person is working and the percentage that a person is not working.
2. ***Performance Sampling:*** to measure working time and non-working time of a person on a manual work, and to establish a performance index or performance level for a person during his working time.
3. ***Work Measurement:*** under certain circumstances, to measure a manual task, that is, to establish a time standard for an operation.

Procedure for conducting a work sampling study
The following steps are involved in making sampling study:

1. ***Decide on the objective of the study:*** It is very important to first set the objectives of study as the duration of the study, number of observations, the design study sheet and elemental breakdown depends upon the objective.
2. ***Obtain the approval of the supervisor of the department in which work study is to be conducted***. Make sure that the operators to be studied and the other people in the department understand the purpose of the study. Obtain their co-operation.
3. ***Decide upon work and delay elements:*** Work and delay elements represent the heading under which the observations are to be recorded. The nature of the work and delay elements differs from company to company depending upon the objective of the study and the work.
4. ***Decide upon the duration of the study:*** The duration of study depends upon the objective, number of observations, the accuracy desired and the frequency of occurrence of the activity.
5. ***Determine the desired accuracy of results:*** This may be stated as the standard error of a percentage or desired accuracy. The confidence level is also to be stated.

6. Make a preliminary estimate of the percentage occurrence of the activity or delay to be measured.

7. Design the study:

(a) Determine number of observations to be made

(b) Determine number of observations needed

(c) Determine the number of days or shifts needed for the study

(d) Make the detailed plans for taking observations.

(e) Design the observation form

8. Make the observations according to the plan, analyse and summarize the data.

9. Check the accuracy or precision of the data at the end of the study.

10. Prepare the report and state conclusions.

Advantages of work sampling compared to time study

1. Many operations or activities which are impractical or costly to measure by time study can be measured by work sampling.
2. A simultaneous work sampling study of several operators or machines may be made by a single observer.
3. It usually requires lesser man-=hours and costs less to make a work sampling study instead of making a continuous time study.
4. Observations may be taken over a period of days or weeks thus reducing the chances of day-to-day variations affecting results.
5. Work sampling measurements may be made with a pre assigned degree of reliability.
6. Work sampling studies are preferred to continuous time studies by the operators being studied.
7. A stop watch is not needed for work sampling studies.
8. Work sampling studies are cause less fatigue and are less tedious.

Disadvantages of work sampling

1. Work sampling is uneconomical for short cycle jobs.
2. It is also uneconomical for studying a single workman or even shall group of workmen or machine.
3. Time study permits a finer break down of activities and delays than is possible with work sampling study.
4. Workman may change their normal pattern of working on seeing the observer, making the sampling study of very little value.
5. Insufficient observations are likely to produce inaccurate results.
6. It does not normally account for speed of the operator.

Problem 3.5 A work sampling study was conducted to establish the standard time for operation. The observations of the study conducted are given below.

Total number of observations	=	160
Manual (hand controlled work)	=	14
Machine controlled work	=	106
Machine idle time	=	40
Average performance rating	=	80%
No. of parts produced	=	36
Allowance for personal needs & fatigue	=	10%
Study conducted for 3 days		
Available working hours/day	=	8hrs

Calculate the standard time per piece.

Solution

Total number of observations (N)	=	160
No. of observations of production activity (Np)	=	120
Observations of machine controlled work (Nm)	=	106
Observations of land controlled work (manual) Nlt		14
Average performance rating R	=	80%

Duration of study = 3 days = 1440 minutes.
(Each day 8 hour)
No of parts produced/day = 36

(i) Overall time per unit (T_0)

$$= \frac{\text{Duration of study}}{\text{No of pieces produced/days}}$$

$$= \frac{1440}{36}$$

$$= 40 \text{ minutes}$$

(ii) Effective time per piece (Te)

Te = Overall time/piece x % of time spent on productive activity.

$$Te = To \times \frac{NP}{N} = To \times \frac{NP + Nm}{N}$$

$$= 40 \times \frac{(106 + 14)}{106}$$

$$= 30 \text{ minutes}$$

(iii) Break down of effective time per piece into machine controlled portion and hand controlled portion.

Tm = machine controlled portion of the effective time per piece

$$Tm = Te \times \frac{Nm}{Np} = Te \times \frac{Nm}{Nm + Nn}$$

$$= 30 \times \frac{106}{(106 + 14)}$$

$$= 26.5 \min utes$$

Hand controlled portion of effect time per piece (Tn)

$$Tn = Te \times \frac{Nn}{Nm + Nh} = 30 \times \frac{14}{120}$$

$$= 3.5 \min utes$$

$$\frac{\text{Normal time per piece}}{\text{Normal time per piece}} = \text{Machine controlled portion} + \text{Normal time of hand}$$

Controlled of effect time per piece portion of effective time/piece

=Tm +(Tn $\times$XR) = 29.3 minutes

Standard time per piece = Normal time + allowances

= 29.3 (1-0.1)

= 32.23 min.

Problem 3.6

A work study was conducted in a machine shop. The data has been recorded.

Total number of observations	=	2000
No activity	=	500
The ratio between manual to machine Portion of the activities	=	3:1
Average performance rating	=	85%
Total number of pieces produced during study	=	120
Duration of the study	=	60hrs.

Calculate the standard time/piece assuming 15% relaxation allowance.

(iv) Overall time per unit (To)

$$\text{To} = \frac{\text{During of study}}{\text{No of pieces produced during study}}$$

$$= \frac{60 \times 60}{120} = 30 \text{ minutes}$$

(v) Effective time per piece (Te)

T_e = Overall time per piece x production of productive observations to total observations.

$$\text{Te} = \text{To} \times \frac{\text{Np}}{\text{N}} = 3 \times \frac{2000}{2500} = 24 \text{ minutes}$$

As the rating is to be applied to only human controlled activities break the effective time in to machine controlled & human controlled.

$\therefore$ Machine controlled time per piece

$\text{Tm} = 2 \times \frac{1}{2} = 6\text{minutes} \; = \text{Th} = 24\text{X}\, \frac{3}{4}$

$= \text{Normal time/per} \; = \text{Tm} + \text{Th} \times \text{R}$

= 6 + 18 x 0.85

= 21.3 min.

Standard time per piece (Ts) = Normal time + allowances

$$21.3 + \left(\frac{100 + 15}{15} \right) = 24.50 \text{minutes}$$

Problem 3.7

The following data refers to a sampling study of production of one component.

1. Duration of data collection 5 days @ 8 hours per day
2. Number of operators – 10
3. Allowances given for the process 15%
4. Production quantity in 5 days – 6000 components
5. sampling data collected

Days	1	2	3	4	5
No. of observations	230	240	200	180	225
Occurrence of activity	200	190	170	150	210

Calculate standard time of production of the component if average performance rating of the operator is 120% and the entire operation is manual.

Solution

No. of observations (N) = 1075
No. of observations (NP) = 920
(Working)

Overall time piece = $\frac{\text{Total time worked}}{\text{No of units produced}} = \frac{5 \times 8 \times 10 \times 60}{600}$

=
= 40min.

Normal time = observed time X rating
= 34.23 x 1.2
= 41.07 min.

Standard time = Normal time (1 + allowances)
= 41.07 (1 + 0.15)
= 47.24 min.

Problem 3.8

The following information is available for a factory:

Daily working hours	8
No. of working days in a week	6
No. of operators	20
Std. hours per unit of production	4

Duration a particular week

Number of units produced	48
Absentee man days	40
Idle time due to load shedding	30 Mondays

Find

(i) Absenteeism percentage
(ii) Labour utilization percentage
(iii) Productive efficiency of labour
(iv) Overall productivity of labour in terms of unit's produced/week/employee.

Solution

(i) Absenteeism percentage = $\frac{\text{Absentee man days/week}}{\text{Total operator man days/week}}$

$\frac{40}{20 \times 6} \times 100 = 33.33\%$

(ii) Labour utilization percentage = $\frac{\text{working man days/week}}{\text{Attended man days/week}}$

$\frac{(20 \times 6) - 40 - 30}{(20 \times 6) - 40} \times 100$

= 62.50%

(iii) Productive efficiency of labour =

(iv) Overall productivity of labour

$$= \frac{\text{Total produced / week}}{\text{Total operators}} = \frac{48}{20} = 204 \text{unit / week / operator}$$

Problem 3.9

A factory can manufacture two products A and B by using either of two materials P or Q. A is expected to sell at ₦70 per unit and product B at ₦30 per unit. The operating data are as follows:

		Material P	Material Q
Output	A	200 units	400 units
	B	300 units	200 units
Quantity of raw material usage		1,000 Kg	1,000 Kg
Labour usage		300 man hrs.	250 man hrs.
Electric energy consumption		1000 KWhr	1500 KWhr
Cost of raw material/Kg		₦20	₦30
Labour per manhour		₦5	₦5
Electrical energy/KEhr		₦1.5	₦1.5

Compare the productivity of material, labour and electrical energy in using materials P and Q. Comment on the relative advantage of using either of the materials.

Solution

Productivity $\frac{\text{Value of output}}{\text{Value of input}}$

Sales value of output with material P

= Output of product A in units x Rate/unit of A + output of product B x Rate/unit of B

= 200 x 70 + 300 x 30 = ₦23,000

Sales value of output with material Q

= 400 x 70 + 200 x 30 = ₦34,000

The partial productivity of different factors of production are computed as follows

= 4.86 min.

Standard time per piece = 8.46 (1+0.17) = 9.9 minutes.

3.4.2 Comparison of Various Techniques

Sr. No.	Criteria	Work Sampling	Predetermined Time Standards	Stop Watch Timing
1	Speed, time required to measure and establish standard.	Average to fast	Slow to average	Average
2	Training and skill required, supervision	Low to moderate	High	Moderate to high
3	Cost employee time, equipment etc.	Average	Fairly high	Average
4	Assistance in methods improvement	Low to moderate	High	Good to high
5	Accuracy, subjective, objective, degree or distortion	Fair to good	Very high	Good to high
6	Acceptability Employee, Supervisor	Fair	Good	Fair to good
7	Interruption of work operations	Moderate	Low	Fairly high
8	Applicability: for physical, clerical, professional work	Very good	Average	Average
9	Savings: How quickly how much	Average to high	High	Average to high
10	Usability: in Scheduling production, evaluating performance	Average to high	High	High
11	Reporting requirements difficulty of furnishing data	Average	Average	Average

5.6 Predetermined Motion Time analysis (PMTS)

A standard time for a job or an operation may be established by time study, by work sampling or by the use of predetermined times.

A predetermined time system consists of a set of time data and a systematic procedure which analyses and subdivides any manual operation of human task in to body motions, or other elements of human performance, and assigns to each the appropriate time value. This system of time data was originally developed from extensive studies of all aspects of human performance through measurement, evaluation and validation procedures.

Predetermined times are the tabulated values of normal times required to perform individual movements such as moving an arm from one position to another etc. The total times needed to perform the operation are the sum of the times needed for basic motions. By arranging the basic motions and aggregating associated times, an existing task can be analysed or a proposed operation can be timed without actually performing it.

Factors to be considered which using PMTS

- Application of PMTS requires that an operation which is to be measured is divided in to basic motions as per the system selected. Each system has its own specific rules and procedures which must be followed exactly.
- Most PMTS do not include allowances, so these are added as in stop watch study.
- At the time of application of PMTS for the first time in a company the adjustment should be made if necessary, in order to match company's performance level which is onetime activity PMTS can be classified as to accuracy level, time required for application and the extent of method description.

1. **Methods time analysis (MTA)**
   A. B. Segur of Oak Park Illinois was one of the first to establish the relationship between the time element and the motion itself as quoted by Telsang M.T. (2007). Segur stated that the method must be well defined before an attempt is made to time-analyze the motions involved. He developed a table of improvement principles involving many of his basic motions such as hold, grasp, pre-position, position, avoidable delay and balance delay. The improvement principle involved here is in the elimination of the left hand as a holding device, in MTA, motion values are given up to fifth decimal.

2. Work Factor System (EF)

His is first system of PMTS to have a general use with the work factor system it is possible to determine the work factor time for manual tasks by the use of predetermined data. A detailed analysis of each of the task is made based upon the identification of major variable of work and the use of work factor as a unit of measure. Then the standard time from the table of motion values is applied to each motion.

Four major variables of work factor system are:

3. Body member
4. Distance
5. Manual control
6. Weight or resistance

This system is applicable to highly repetitive system.

Basic Motion Time study (BMT)

Basic motion time study was developed and is thought by J. P. Woods and Gordon, Limited, Toronto, Canada. Like other predetermined motion time system, all manual activity has been divided into basic motions.

A basic motion, according to Woods and Gordon, is defined as "Any motion which starts from rest, moves through space, and ends at rest.

(Type 1) Reach
(Type 2) Move
(Type 3) Turn

The body motion and symbols are very similar to the body motions employed by MTM. The only difference lies in the step, where the distance measured is the distance the foot travels.

Advantages of PMTS

1. Short cycle jobs can be timed accurately.
2. Rating, the most difficult part of time study is not necessary.
3. The results obtained are consistent.
4. A reasonable estimate of work content can be obtained before the task is actually carried out.

Method Time Measurement (MTM)

The objective of MTM is the establishment of tangible, understandable and acceptable data for the scientific measurement of human effort.

Methods TIME Measurement is defined as:

A procedure which analysis any manual operation or method in to the basic motions required to perform it and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made.

The primary objective of MTM is to improve methods of operation and it establishes methods accurately before production starts by determining correct times and operations.

Uses of MTM

1. Developing effective methods and plans in advance of beginning production.
2. Improving existing methods.
3. Establishing time standards.
4. Cost estimating.
5. Training supervisors to become method conscious.
6. Research in the areas like operating methods, performance rating.

MTM procedure recognizes:

- Eight manual movements.
- Nine pedal and trunk movements.
- Two ocular movements.

Thus, there are nineteen fundamental motions to be considered in the establishment of any motion Patten. The time for each of these motions is determined not only by the physical conditions involved in the motions performance but also by the nature of the conditions under which it is made. Thus, the time for a given motion is affected by a combination of physical and mental conditions.

Self-Assessment Exercise

Unit of MTM is TMU, One TMU = 0.0006 minutes.

5.7 Summary

In this unit, you have learned about the job design, work measurement, allowances, work sampling and predetermined motion time analysis. Work study is critical to the effective functioning of many production system. It helps in unveiling faulty work procedures and bottlenecks. Work study effort comprises method study and work measurement. Work measurement aims at determining work or performance standards. Whereas, allowances must be made to enable the worker attend to his personal needs and be focus to the work(productivity).

5.7 References/Further Readings/Web Resources

Densiotis Kostas N – "Operation Management", McGraw Hill, New York (1981)

Monks Joseph – "Operation Management," McGraw Hill New York (1984) Rinath L S – PERT & CPM"

K G Lockyer, Factory and production Management (Chatham; W & J Mackay, Limited, 1974)

British Standard 3138, Glossary to terms in work study

5.8 Possible Answers to Self-Assessment Exercises

The followings are the advantages of work sampling over time study
Advantages of work sampling compared to time study

1. Many operations or activities which are impractical or costly to measure by time study can be measured by work sampling.
9. A simultaneous work sampling study of several operators or machines may be made by a single observer.
10. It usually requires lesser man-=hours and costs less to make a work sampling study instead of making a continuous time study.
11. Observations may be taken over a period of days or weeks thus reducing the chances of day-to-day variations affecting results.
12. Work sampling measurements may be made with a pre assigned degree of reliability.
13. Work sampling studies are preferred to continuous time studies by the operators being studied.
14. A stop watch is not needed for work sampling studies.
15. Work sampling studies are cause less fatigue and are less tedious.

MODULE 2 OPERATING DECISIONS

UNIT 1 MANAGEMENT OF TECHNOLOGY

Unit Structure

1.1 Introduction

In this unit, you will learn that technological change is a major factor in gaining competitive advantage. It can create whole new industries and dramatically alter the landscape in existing industries. You will also realise in this unit that the development and innovative use of technology can give a firm a distinctive competence that might be difficult to match. The scope of what the unit comprises is given in the objectives.

1.2 Learning Outcomes

By the end of this unit, you will be able to:

(i) define the meaning of technology and describe how best to manage it.
(ii) demonstrate the importance of technology to the firm's supply chain and within each functional area.
(iii) describe the fundamental role of the computer and information technology in reshaping an organisation's processes.
(iv) discuss the stages of the research and development (R&D) and how firms use R & D to create and apply new technology.

1.3 The Meaning and Role of Technology

Technology may be defined as the know-how, physical things, and procedures used in the production of products and services. The "know-how" component of this definition is the knowledge and judgement of how, when, and why to employ equipment and procedures. Craftmanship and experience are naturally embodied in this knowledge, but unfortunately, cannot be written into manuals or routines. The second component, physical things, are the equipment and tools. The last component, procedures, is the rules and techniques for operating the equipment and performing the work.

Let us use the air travel technology to illustrate how the three components in our definition of technology work together: knowledge is reflected in scheduling, routing, and pricing decisions. The airplane is the equipment, consisting of many components and assemblies. The procedures are rules and manuals on aircraft maintenance and how to operate the airplane under many different conditions.

You need to understand that technologies don't occur in a vacuum, rather, they are embedded in support networks. A support network comprises the physical, informational, and organizational relationships that make a technology complete and allow it to function as intended.

Using our air travel technology example, its support network will include the infrastructure of airports, baggage handling facilities, travel agencies, air traffic control operations, and the communication systems connecting them.

1.3.1 The Three Primary Aspects of Technology

Within any organization, technologies often reflect what people are working on, and what they are using to do that work. Three general aspects of technology have been identified. The first, and most widespread is product technology, which is what a firm's engineering and research groups develop when creating new products and services. The second aspect is that of process technology, which a firm's employees use to do their work. The third is information technology, which a firm's employees use to acquire, process, and communicate information. Note that information technology is becoming increasingly important in this modern day. The particular way in which a specific technology is classified depends on its application. For instance, a product technology to one firm may be part of the process technology.

Why should operations managers be interested in these three aspects of technology? Let us look at the reasons: product technology# is important because the production system must be designed to produce products and services generated by technological advances. Similarly, process technology is important because it can improve the methods currently used in the production system. Lastly, information technology is important because it can improve how information is used to operate the production system. We shall briefly examine these three areas of technology.

1.3.1.1Product Technology

Product technology is developed within the organisation, whereby it translates ideas into new products and services for the firm's# customers. Production technology is often developed primarily by engineers and researchers. This group of workers develops new knowledge and ways of doing things, merge them with and extend conventional capabilities, and then translate them into specific products and services with features that customers value. Wherever new product technologies are being developed, it is usually necessary to seek close cooperation with the marketing personnel in order to find out what customers actually want. The operations department can then determine how the goods and services can be produced effectively. Product technology also requires the design systems to support field installation and maintenance.

1.3.1.2Process Technology

The methods by which an organization does things usually rely on the application of technology. At times, some of the large number of process technologies used by an organization is unique to a particular functional area, while others are used more universally. Figure 6.1 illustrates how technologies support the processes in the supply chain for both manufacturers and service providers. Each of the technologies shown in the Figure can be further broken into more technologies. Process technologies commonly used in other functional areas are shown in Figure 6.2.

Figure 6.1 Process Technologies

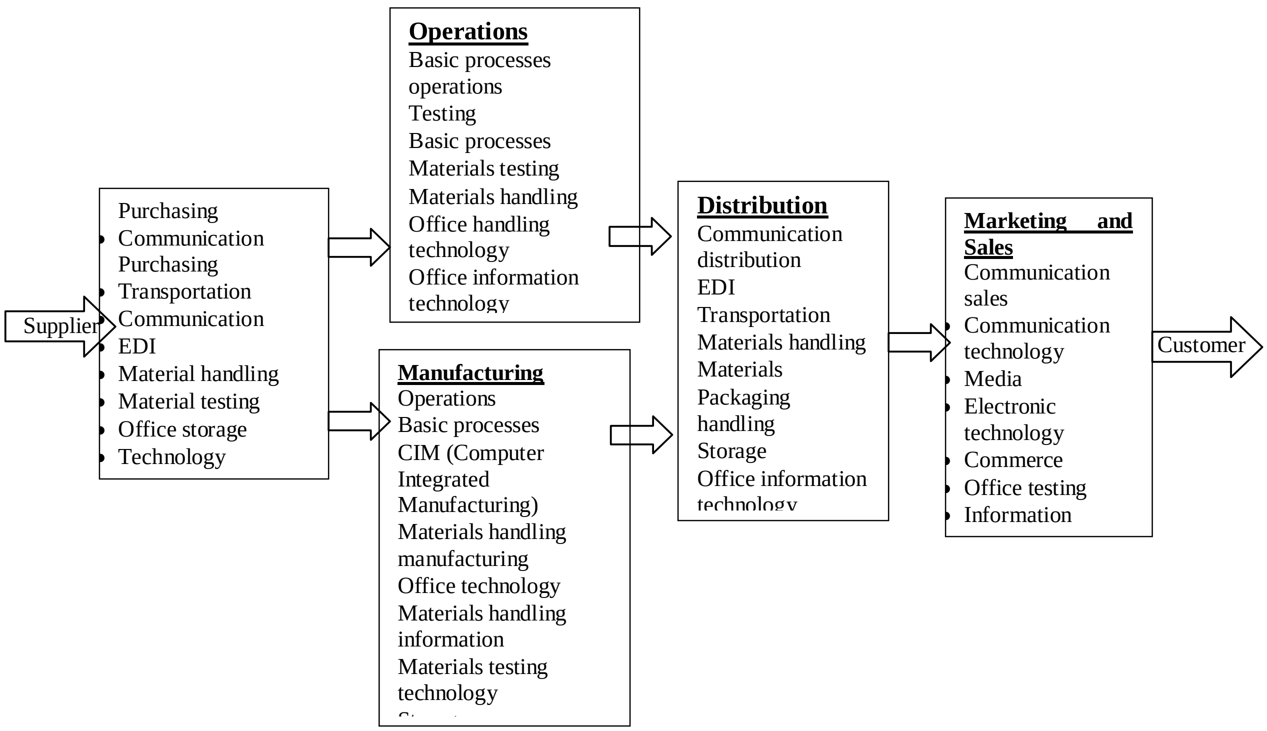
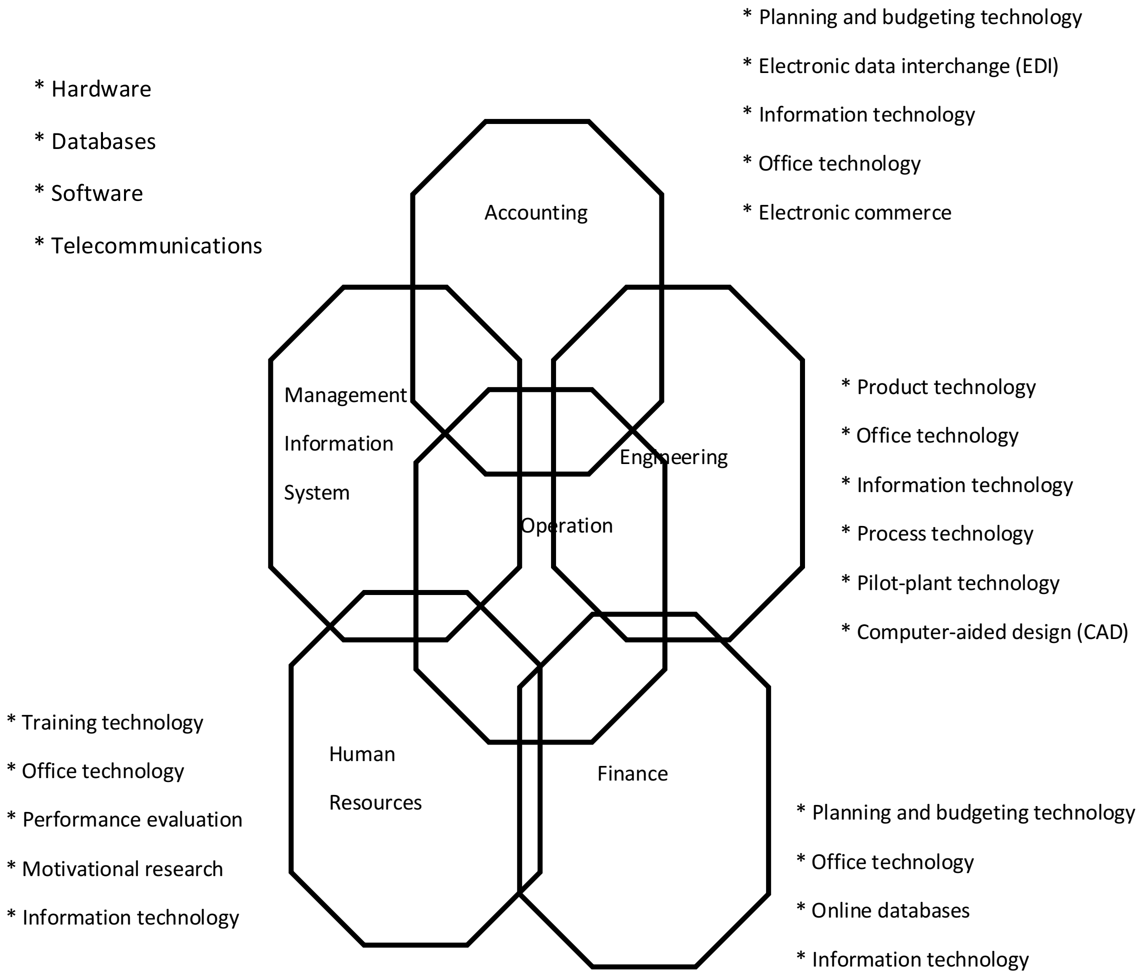


Figure 6.2: Process Technologies – Technologies for other Functional Areas



There continue to be great developments in process technology of almost allfunctional areas of an organisation. Imagine the sales processes in the service section that use vending machines to distribute products. This process technology is now shedding its low-tech image. New electronic vending machines are loaded with circuit boards and microprocessors, instead of the gears and chains of previous versions. With this improved technology, these vending machines can count how much product is left, check the coin boxes, and make sure that the mechanisms work properly. Of course, this capabilities demonstrated by the machines simplify product ordering and inventory control processes.

1.3.1.3 Information Technology

Information Technology (IT) is increasingly being used by managers to acquire, process and transmit information so that they can make more effective decisions. As Figure 6.1 illustrates, IT pervades every functional area in the workplace. It is particularly more revolutionary in offices. Office technologies include various types of telecommunication systems, word processing, computer spreadsheets, computer graphics, e-mail, on-line databases, the internet and the intranet.

SELF-ASSESMENT EXERCISE 1

Describe the three primary aspects of technology.

1.3.1 Management of Technology

Management of technology, links R & D, engineering, and management to plan, develop and implement new technological capabilities that can accomplish corporate and operations strategies. This in essence, means identifying technological possibilities that should be pursued through R&D, choosing from both internal and external sources the technologies to implement, and then following through their successful implementation as products, processes, and services. There is quite a large array of technologies, and yet managers need to be knowledgeable about the technologies used in their operations. What in fact, does a manager need to know about technology?

There are two sides to this question. One is that the manager just needs to understand what a technology can do, including its costs and performance possibilities. The second is that such understanding is not enough. Rather, the effective manager must also understand how the technology works and what goes on in the technology "black box". The better answer is that managers must invest the time to learn more about these technologies, and at the same time develop good sources of technical advice within the organisation.

1.3.2 The Role of Technology in Business Performance

In this modern time, technology is about the most important force during the increase in global competition. It also plays a pivotal role in creating new products and improving processes. It has been shown by many empirical studies that firms that invest in, and apply new technologies often tend to have stronger financial positions than those that think otherwise. A study by Steele (1988) on large U.S. firms showed that, as the investment in R &D for technology increases, so does profitability and new product introductions. Another study by Roth (1996) of over 1,300 manufacturers in Europe, Japan, and North America focused more on process technologies, and reported a strong relationship between financial performance and technological innovation. The benefits of the application of technology to business are not limited to large firms. For example, small firms that have more technical know-how and use computer based information and manufacturing technologies more intensively enjoy stronger competitive positions (Lefebvre, Harrey, and Lefenbvre, 1992).

It is necessary to point out that high technology and technological change for its own sake might not create a competitive advantage, be economically justifiable, fit with the desired profile of competitive priorities, or adds to the firm's core competencies. To be worthwhile, technology must be appropriately applied to the operations of the business. In many jobs, for instance, a simple handsaw might be a better choice than a computer-controlled laser.

SELF-ASSESSMENT EXERCISE (SAE) 2

1. How do you understand the term technology?
2. IT comprises computing and telecommunications technologies. Explainits basic partitions.

1.4 Information Technology

As you already learned in section 3.1.1.3 IT is very crucial to operations everywhere along the supply chain and to every functional area. This fact has been vividly illustrated by Figure 6.1 and 6.2. It is commonly seen that computers are spawning a huge proportion of current technological changesand innovations, either directly on indirectly. For example, computer-based information has greatly influenced how operations are managed and how offices work. Today, office workers are able to do things that were not possible a short time ago, such as accessing information simultaneously from several locations and diverse functional areas. In fact IT makes cr functional coordination easier and links a firm's basic processes. For instance, in a manufacturing plant, IT can link people with the work centres, databases, and computers. Computer literacy is now rapidly becoming a critical factor inthe success of an organisation.

1.4.1 Components of Information Technology

IT comprises computing and telecommunications technologies. It is the merging of the above two technologies, and the organizational and management technologies that help in fashioning it for organizational use. On the whole, IT can be partitioned into four sub technologies:
(1) Hardware (2) Software (3) databases, and (4) telecommunications

1.4.1.1Hardware

The hardware sub technology is made up of a computer and the devices connected to it. Improved hardware memory, processing capability, and speed have greatly taken technological changes to higher levels.

1.4.1.2 Software

Software refers to the computer programmes written to make the hardware work, and to carry out different application tasks. Application software is what computer users' work with. Generally, it allows information to be recorded, manipulated, and presented as output that is invaluable in performing work and managing operations. For instance, software is available for use with almost all the decision tools such as flow diagramming, statistical process control techniques, learning curves, simulation, queuing models, location, and layout techniques, forecasting models, linear programming, production and inventory control systems, and scheduling techniques. Furthermore, software is essential to numerous manufacturing capabilities, such as computer-aided design and manufacturing, robots, automated guided vehicles, and flexible manufacturing system. Again, software provides various executive support systems, including management information systems, as well as decision support systems. The advantages inherent in this software are that it allows managers to quickly and effectively evaluate business issues.

1.4.1.3 Databases

The third component of IT is databases. A database is a collection of interrelated data or information stored on a data storage device such as a computer hard drive, a floppy disk, or tape. For instance, a database can be a firm's inventory records, time standards for different kinds of processes, cost data, or customer demand information. Databases have been put to numerous uses. For example, the police use it to launch assault on neighbourhood drug trafficking by keeping track of drug-selling locations and activity. Some business organisations also employ it to offer innovative marketing programmes. The marketing information in such firms contains customers' bio-data, location, purchase records, and other information. By using proprietarysoftware with this database, firms can add personalised offers and messages to the invoices of selected customers. The database then tracks customer reactions to the messages forwarded. This person-to-person marketingprocess is based on the philosophy that different customers should be treated differently, and that the best customers should get the most attention. This information management system just described has appeals in airlines, grocery delivery businesses, mass-customisation manufacturers, etc.

1.4.1.4 Telecommunications

Telecommunications is the fourth and final component of IT. In order for one computer to communicate data with another computer, it has to do so through the telecommunication technology. Telecommunication's main purpose is to enable thetransmission of signals representing voice data, physical data,and images between remote locations.

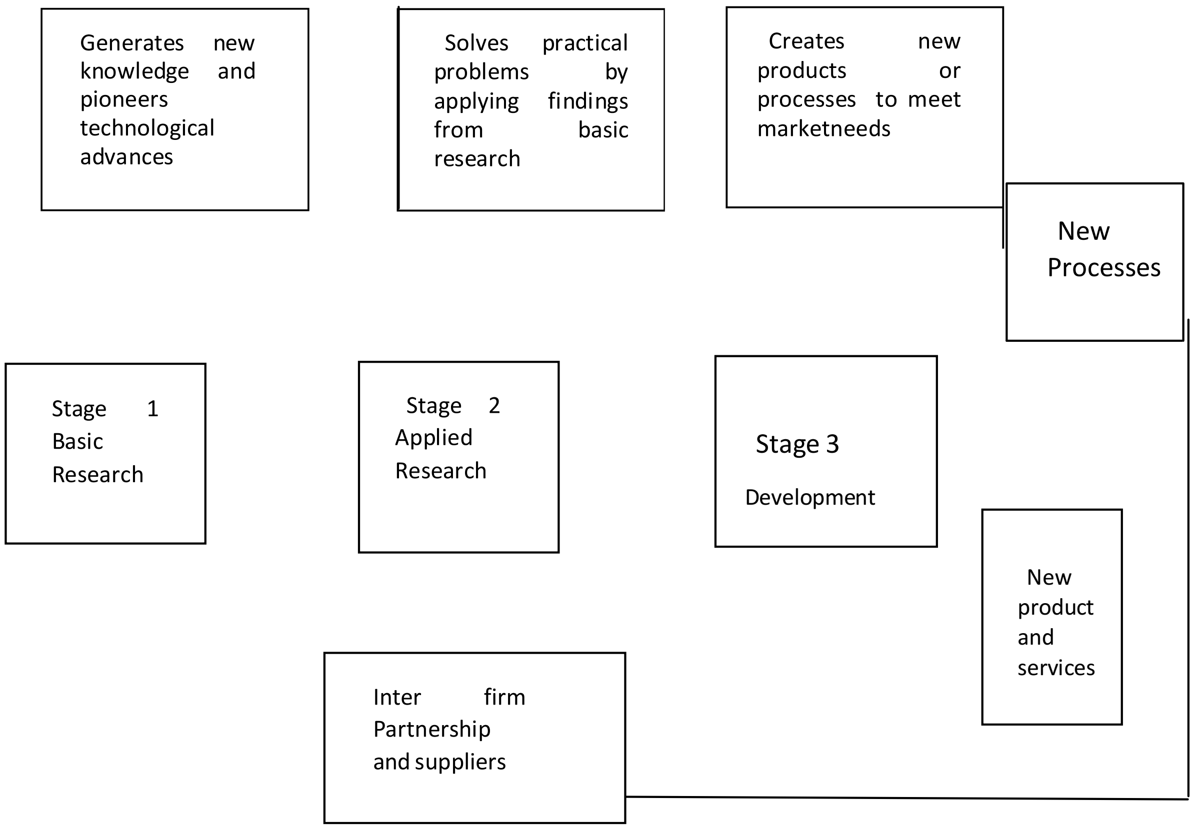
Many of the telecommunications systems in use today employ electrical orelectromagnetic media as carriers of signals. There are different types of networks, for example, data networks (as in when two or more computers are connected together to communicate data); television networks (e.g. CNN and NTA stations); and radio networks (FRCN, BBC, and VOA stations).

The ability of computers to communicate to one another in even very far away locations has given rise to the Internet (commonly referred to as the information superhighway).

1.5 Creating and Applying Technology

One of the major challenges facing most firms today is how to apply emerging product and process technologies to their businesses. For the purposes of understanding these technologies better, it is necessary for us to examine theconcept of innovation process. Figure 6.2 shows an overview of the innovation process, which is aimed at creating and applying technology to improve afirm's products, production processes, and services. The innovation process focuses technical and scientific efforts on better ways to meet market needs.

Figure 6.3: Research and Development Stages



1.5.1 Research and Development (R & D) Stages

Very often innovation and R & D projects go through the stages already shown in Figure 2. You can see from the figure that stages 1 and 2 are research stages, while stage 3 is the development stage.

1.5.1.1 Basic Research

A study that explores the potential of narrowly defined technological possibilities, and attempting to generate new knowledge and pioneer technological advances is called basic research. It seeks fundamental truths, such as the knowledge that ultimately made space ships possible. It is generally non-directive research that is not targeted for a particular product or process. Basic research is usually science based, as with computer and biotechnology.

This is however, not always the case. Successes may come from an inventive mind or aflash of genius. Since basic research is often capital-intensive, it is performed in laboratories owned by government agencies, or some large firms, and universities.

1.5.1.2Applied Research

Applied research attempts to solve the practical problems involved in turning an idea or invention into a commercially feasible product, process or service. It tends to the carried out mostly by large firms. Applied research is also more directed than basic research for example, a small group of engineers and scientists might be formed to build a small-scale pilot plant to test and refine ideas coming from basic research efforts.

1.5.1.3 Development

Development here refers to the activities that turn a specified set of technologies into detailed designs and processes. Product and process designs are developed with an eye to both marketability and ease of production. Both large and small firms are usually involved in development. Some studies have shown that many development ideas begin with the recognition of marketproduction needs, rather than from a new technological opportunity.

Generally, development of product technology moves through several phases:
(1) Concept development (2) technical feasibility (3) detailed product or service design and (4) process design. At the concept development phase, theproduct idea is just conceived. During the technical feasibility phase, tests are conducted to determine whether the concept will work or not.

During the detailed product design phase, prototypes of the product features may be built, tested and analysed. Normally, detailed design goes beyond engineering, with operations and marketing personnel getting involved in assessing the design for its manufacturability and marketability. Details of product characteristics are examined by utilizing lists of specifications, process formulas, and drawings.

Still, on the detailed product design phase, the marketing department uses trial tests in limited markets or with consumer panels to help measure market reactions to specific product features or packaging. At times, test results may lead to changes in the product or the way it is presented before it is actually produced and marketed. Tests such as these often provide reasonable assurance that the product is technically feasible, can be produced in quantity at the desired quality level, and has customer appeal.

At the final development phase, process design, final decisions are maderegarding the inputs, operations, work flows, and methods to be used to make the product.

The service providers too, can employ the R &D stages to their business operations. However, stages 1 and 2 are far less formal and extensive than they have for manufacturers. For instance, when developing new services, service providers still must define their customer benefit packages, which is an important part of the development stage. For example, at a restaurant, the core products are food and drink. The peripheral products are chairs, tables, and tableware. The services include courtesy, speed, quality and the less tangiblecharacteristics of taste, atmosphere, perceptions of status, comfort, and a general sense of well being.

You should realise that the development stage is very crucial to a firm's future profitability. A future-looking organization that is technology and resource –rich should always develop and compete with the new technologies that they helped create. That is, they shouldcontinue to develop innovations into products and services. This is the only way to prevent organisational complacency from depriving them of the initial leadership.

1.6 Choosing Technologies

Operations managers need to make intelligent, informed decisions about new product and process technologies now, more than ever before. This is because of the rapid rate at which technology is changing, coupled with the numerous technologies available all over the place, whether choices that are eventually made are bound to have effects on both human, as well as technical aspects of operations. Consequently, we shall attempt to examine how technologies should be chosen and how these choices link with strategy to create a competitive advantage. It is necessary to stress at this point that, an appropriate technology is one that fits corporate and operations strategies and gives the firm a sustainable advantage.
In addition, several tests of a potential technological change should be made. For instance, if the change being considered fails these tests, it should never be pursued even if it represents an impressive technological accomplishment.

1.6.1 Assessing the Technologies

Almost out of necessity, a new technology should create some kind of competitive advantage. This competitive advantage is created by either increasing the value of a product to a customer, or reducing the costs of bringing it to the market. Generally, there are great potentials for increasing value and reducing costs from a new technology.

The most common cost-reduction strategy is that of cutting the direct cost of labour and materials. Though labour savings have generally been used to justify most automation projects, it has been reported that labour is a shrinking component, being only between 10 to 15 percent of total costs. Hence, in order to understand a new technology's true value, an operations manager should assess factors other than cost savings.

For instance, the presence of the following factors may indicate the existenceof competitive advantage in a new technology:

(i) Increase in sales and/or customer satisfaction.
(ii) Improvement in quality.
(iii) Quicker delivery times through reductions in processing times.
(iv) Improvement in inventory control.
(v) Reduction in costs.
(vi) Improvement on the environment.
(vii) Improvement in product design.
(viii) Increase in production.
(ix) Increase in product variety.

As should be expected, new technologies are not without costs. For instance, investment in a new technology can be very intimidating and discouraging especially for complex and expensive projects requiring new facilities or extensive facility overhaul. In addition, the investment can be risky because of uncertainties in demand and in per-unit benefits. Furthermore, the technology may have hidden costs, such that could require employee knowledge and skills to maintain and operate the new equipment. Sometimes, such new requirementsmay lead to employee resistance, lower morale, and increased labour turnover. For these and other reasons, the operations manager must sort out the numerousbenefits and costs of different technological choices.

Another important test is how the technological change will help a firm achieve the competitive priorities of cost, quality, time, and flexibility. For a new technology to be certified for use, it should normally have a positive impact on one or more of these priority areas, especially those already emphasised for the product orservice in question. It is also essential to check whether this advantage can be protected from imitation.

You need to also note that achieving strategic fit (as discussed in the previous paragraph), whereby the technologies chosen help achieve current corporate and operations strategies, is necessary, but not sufficient.

Hence, the organization should look out for new technologies that can build new production capabilities. Thesecan then form the basis for new strategies, thereby leading down a long-term path to improvement. The point being made here is: instead of just preserving the past, management must create the firm's future with new operating capabilities. This is done by developing a set of core competencies and technologies that enable the firm to adapt quickly to changing opportunities.

In addition to core competencies, management must identify a firm's core technologies, which are crucial to the firm's success. For obvious reasons, these should be developed internally. The best thing is for a firm to possess a broader set of core technologies, in order to be less vulnerable to new entrantsin the industry.

Another strategic consideration deals with when to launch a new technology. Very often, being the first to market with a new technology offers a firm many advantages that may actually outweigh the financial investment needed. In the first place, technological leaders define the competitive rules that others will follow with regard to a new product or process. Secondly, a "first-mover" may be able to gain a large market share early, and this can create an entry barrier for other firms. Even if competitors are ableto match the new technology, the first mover's initial advantage in the market can endure. Thirdly, being the first can give a firm the reputation that emulators will find difficult to overcome.

Fourthly, a first-mover strategy may lead to a least temporary advantage with suppliers of outside materials and services over those of its late-comer competitors. Finally, technological leadership might also allow the firm to get patents that discourage imitation.

However, a number of risks are being faced by a company thatadopts a first-mover strategy. First, the pioneering costs are often high, with R& D costsexceeding the firm's financial capabilities. Second, market demand for a new technology is speculative, and estimates of future financial gains might be overstated. Third, a new product or process technology may soon become outdated because of new technological break-through. It is therefore imperative formanagers to carefully analyse these risks and benefits of which technologies to adopt.

Economic justification is another important strategic factor to be taken into account when examining our earlier considerations, with respect to:

(i) sources of competitive advantages;
(ii) fit with competitive priorities;
(iii) existence of core competencies; and
(iv) first-mover strategy.

It is therefore important to perform some financial analyses in order to determine whether investment in the new technology is economically justified.

Towards this end, operations managers should state in clear and unambiguous terms, what they expect from a new technology, and then quantify costs and performance goals. Next, they should determine whether the expected after-tax cash flows arising from the investment are likely to outweigh the costs, after taken the time value of money into consideration. The application of the traditional financial appraisal techniques such as the net present value, internal rate of return and the pay back methods can be employed to measure the financial impact of new technologies. Though uncertainties and intangibles are not easily measurable, they must necessarily be considered.

It has also been suggested that operations managers need to look beyond the direct costs of a new technology to its impact on customer service, delivery times, inventories, and resource flexibility. In many instances, these are the most important considerations. It is true that quantifying such intangible goals as the ability to move quickly into a new market prove difficult. At the same time, a firm that fails to make technological changes along with its competitors can quickly lose its competitive advantage and subsequently experience declining revenues and layoffs.

In the light of the above, economic justification should begin with financial analyses, through the recognition of all quantifiable factors that can be translated into financial values. Thereafter, the resulting financial measures should be merged with an evaluation of the qualitative factors and intangibles involved. The manager can then estimate the risks associated with uncertain cost and revenue estimates.

1.7 Implementation Guidelines for New Technologies

Apart from making the right choice, managing technology also means supporting the particular technology selected throughout its implementation. In actual fact, job satisfaction and positive employee attitudes can be sustainedonly if technological change is managed well.

To this end, some useful implementation guidelines have been developed, and these relate to technology acquisition, technology integration, the human side, and leadership. It is necessary to examine each of these areas in the guidelines.

1.7.1 Technology Acquisition

Technology acquisition deals with how far back in the R&D stream a firm gets involved (i.e. in basic research, applied research or development) for the purposes ofsecuring new technologies and which options it uses to do so. Generally, large firms are more likely to enter the early stages of the R& D stream, whereas small firms are more likely to enter later, usually at the development stage. There are three main options for acquiring a new technology. These are internal sources; inter firm relationships, and purchasing from suppliers.

With respect to internal sources, a firm may decide to do its own R & D or, more likely, some part of it. It might also look to its engineering department to refine product and process designs during the development stage, or ask other departments that have successfully applied new technologies to do the refinement. However, it is relatively unrealistic to rely exclusively on internal sources, most especially at the earliest research stages at R & D.

The second, major option for technology acquisition is inter-firm relationships. Here, firms turn to outside sources more than ever for new technologies. This source is particularly attractive to many firms (including most small firms), who do not have their own R&D and engineering departments. Their main pre-occupation therefore, is to choose and refine the best mix of available technologies created by others. Sometimes some of them simply wait until information about a new technology comes into public domain. The major limitation inherent in this passive option, is the long delay and possibly, incomplete information. There is a continuum of more aggressive options, with varying levels of commitment required of the firm. There are four of such approaches:

(i) **Outsourcing research:** A firm may outsource research to universities or laboratories by giving research grants. Very often, this approach requires the least commitment by the firm, but most probably minimises the transfer of knowledge to the firm.

(ii) **Obtaining a license: A firm may also decide to obtain a license for the** technology from another organisation, thereby gaining the legal right to use such in its processes or products. One limitation of this approach is that the agreement with the licensing company might contain clauses which may invariably limit the flexibility of the licensee.

(iii) **Entering a joint venture or alliance: In this approach two or more** firms may enter into a joint venture or alliance. In a joint venture, thefirms agree to jointly produce a product or service. In the case of an alliance, the firms share the costs and benefits of R & D. This approach requires a greater degree of commitment. However, it establishes moreof a market presence than the first two options.

(iv) **Buying out: A firm may buy out another firm which has the desired**technological know-how. It should be clear to you that this approach requires the greatest commitment to exploiting the new technology and can lead to market dominance.

The third main option for acquiring a new technology is from outside suppliers. For example, suppliers can be the source of parts for a firm's own technology products, or they can be the source of new innovative equipment or services that the firm uses in its processes. The operations managers of organisations interested in this option must always be on the lookout for new technologies available from suppliers that will increase productivity, improve product quality, shorten lead times, or increase product variety. Generally, outsourcing gives a firm access to the latest technology that has been developed throughoutthe world.

1.7.2 Technology Integration

For proper management of technology, there is the need to raise cross- functional teams to implement the new technology. It is the responsibility of these teams to bridge the gaps between research and development, and between development and manufacturing. The act of bringing design engineers, manufacturing engineers, buyers, quality specialists, information technology specialists, and others at this stage is called concurrent engineering. Thisexercise significantly shortens the time to market, and equally allow the firm to meet time-based and quality competition better. These teams are after charged to take a broad, systematic outlook in choosing technologies to pursue.

1.7.3 Technology and Human Resources

There is no doubt that new technology affects jobs at all levels, for instance, eliminating some, upgrading some, and downgrading others. In this regard therefore, operations managers must be able to anticipate such changes and prepare for them. Usually, education and employee involvement help a firm identify new technological possibilities and then prepare employees for the jobs modified or created when the new technologies are implemented.

1.7.4 Leadership

Managing technology in an appropriate way requires that managers play several, often conflicting roles. For instance, they must be good stewards and hold the right budgets and schedules. It also requires good project management skills for implementation speed to keep pace with technological changes. Therefore, operations managers must continually monitor programme targets and completion dates. It is necessary for them to be realists when accessing the risks, costs, and benefits of a new technology. As visionaries, managers should have a technical vision of the goal and vigorously pursue it.

Managers must also play the role of advocates, by making strong commitment to the project as well as stand behind it.
Finally, they must act asgatekeepers by keepingeveryone focused.
It must also be mentioned that when new technologies are being developed or implemented, the operations manager should raise a team, made up of representatives of all relevant departments. This team should then be made to lead and coordinate the work. The head of the team (a project champion) should be someone who promotes the project at every opportunity and who naturally has contagious enthusiasm.

SELF-ASSESMENT EXERCISES 3

Why should operations manager be interested in the three aspects of technology?

1.8 Summary

We have explored ho technology can create a competitive advantage. The Unit started with a general definition of technology, and then applied it specifically to products, processes and information. We also examined the various stages of technological development from its creation to its application to products and processes.

1.9 References/Further Readings/Web Resources

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1.10 Possible Answers to Self-Assessment Exercises

Why should operations manager be interested in the three aspects oftechnology?

The reason why operation manager are interested all aspects of technology first, product technology is important because the production system must be designed to produce products andservices generated by technological advances. Similarly, process technology is important because it can improve the methods currently used in the production system. Lastly, information technology is important because it can improve how information is used to operate the production system.

UNIT 2 SITE SELECTION

Unit Structure

2.1 Introduction

This unit emphasizes the importance of site selection in a firm's operation and looks into many factors that need to be taken into consideration before a site-selection decision is made. The unit looks into the importance of markets, labour costs and other human-resource - related issues. Emphasis is also placed on inherent local conditions, the infrastructures of a region, subsidies by government and accessibility to resources. Attention is also given to quantitative methods for site selection. The methods include weighting, break- even, probability and centre-of-gravity methods.

2.2 Learning Outcomes

By the end of this unit, you will be able to:

- Understand the meaning of site selection
- Understand the factors that need to be considered before site-selectiondecisions are made
- Know the interrelationships among relevant factors of site selection
- Use quantitative methods to decide on site-selection.

2.3 Definition of Site Selection

Site selection is deciding on a location for constructing, expanding or acquiring a physical entity of a firm in order to reach new markets, increase production capacity of serve customers better. It is otherwise called facility location and it could be for either a manufacturing or a service organisation.

Site selection decision may be for a small regional company of a large multinationals. Depending on the size of the location, the ease of the decision making process varies from small companies to a large - multinationals. Inother word, it could be domestic or international.

Domestic Example

1. Lever Brothers, based in Lagos, Nigeria selects to have another branch in Gbongan, a town in Ayedaade Local Government Area of Osun State,Nigeria.

2. Eleganza (Nig) Plc, based in Lagos selects to have a distribution centrein Osu, Atakumosa L.G.A., Osun State, Nigeria.

International Examples

Lever Brothers, based in Lagos Nigeria decides to have a distribution centre in Detroit, Michigan, USA Eleganza (Nig) Plc, based in Lagos, Nigeria selects to have a new plant in Watford, north of London, Great Britain.

However, site selection is always based on the cost of operating the newfacility, or on the returns expected to be realised.

2.4 Factors in Site Selection

2.4.1 Staffing

This includes the availability of all the types of personnel needed to run a facility, direct and indirect operating personnel and management. Labour cost is an essential criterion that should be considered under staffing. It helps to explain why many companies based elsewhere have built facilities away from their own countries. The reason might not be unconnected with the fact thatlabour costs enter directly into the cost of manufactured products or the cost of rendering a service. The cost includes basic salary, wages as well as all social and other charges paid to the employee or paid to government by employer inthe form of taxes Social laws with the accompanied social charges affect labour flexibility and cover areas such as basic work week, overtime permitted, weekend workingliving and termination laws. This is very important in deciding where a company should be located.

For example, a great impediment to sitting companies in France and Italy is the consideration of introducing a 35 hour working week, which is lower than what operates in many other countries

Availability of skilled labour is also important. There must be a good pool of labour which can be trained for the type work. Choosing a place where there is high unemployment level confirms labour availability e.g IBM of USA locating in Glasgow Scotland because of significant labour availability in the areas.

Productivity of labour should also accompany the availability of labour. Productivity (absolute) is measured as the outputdivided by the input of resources. For example, companies tend to locatein South Korea and HongKong because of their high labour productivity.

Strong Trade - Union power in a country can also contribute to unwillingness to locate a firm in the region: This manifests in the conditions attached to Union membership and the frequency of industrial actions in the region. This explains why many trade memberships are declining and companies avoid strikes celebrated regions.

Education level of the available work force is also important. This has a direct relationship with how much training would be required and the training facilities available. For example, North Caroline, USA, because of her high education level is attracting many companies.

Local labour should also be able to handle sophisticated plant technology. Sometimes sitting a company or a facility where the labour lacks the required sophistication may compel the reduction of the complexity of the plant to adapt to the level of the local labour.

Labour mix which affects reputations governing the percentage of local labour that must be used in either the construction of a new firm or the subsequent operation is also an important factor in staffing a company or a facility. The consideration of the specification of some countries stating the minimum levels of local labour that should be in a company is important.

2.4.2 Inherent Local Condition

Inherent local conditions include factors such as climate, culture and language.

Climate may present attractivelocations for facilities if associated with many days of sunshine and good weather. This is because people prefer to live in regions with good weathers and it is easier to recruit personnel in such a place.
This explains the rapid growth of Florida and Texas in USA to the detriment ofsome other areas in the country.

Culture of a region may present difficult situation for the expatriates. Expatriates are nationals of the country where the head office is located, whoare sent overseas on a time-limited contract. They receive a premium on their salary according to the “difficulty” of the location. Using expatriates is verycostly, not only because of the salary premium but because housing and transportation have to be provided for the. For example, South Arabia would be considered more difficult than England.

Ethics of certain regions may not match those of others and therefore acting as a deterrent to siting a facility or company in some regions. For example, in Europe, Italy puts itself at a disadvantage for possible invertors because of its Mafia dealings.

Language should also be a subject of consideration under inherent local conditions. Common language among regions is an asset for the establishment of firms or facility. One reason why UK is attractive to US companies is the common language. Japan and UK are also attracted because English is the common language of Japanese. The same is true of Nigeria and the USA

2.4.3 Infrastructure

This comprises the physical facilities put in place by the region, business environment, and laws enacted by the government. It also includes “family services” such as housing, schools, University, shops, medical services as well as telephone, fax lines, computer net work facilities and video conferencing. Other aspects of infrastructure include:

Environmental regulations cover local regional and national rules for air, water, land and noise pollution. For instance, locating a facility in an area where the environmental laws are strict can be costly. In California U.S.A., an environmental impact statement has to be prepared before, a company can construct. The document should address all the possible effects that construction and operation will have on the environment. This is lengthy andconstitutes a delay in constructing a plant in such a location.

Legal framework is another important factor. Litigationlaws are not the same amongcountries. Damage claims for infringement, such as faulty products, faulty operation, environmental spills can cost huge some of money. In some countries like USA, companies are expected to have programmes that stress the living and promotion of less privileged individuals.

Transportation is another consideration under infrastructure. It covers the transportation facilities and networks for raw materials, finished goods and personnel. A good road network and rail services are advantageous. Transportation costs can add in great measure to the cost of finished products.

Rental costs also play an important consideration in the location of site.
Because rental costs add to the price of customers, it may influence companies in sitting at adjacent towns where the costs are lower instead of capital where they ought to use. In Europe, for example, Paris and London are most expensive.

Living costs is also an aspect of infrastructure. It covers all the expenses foremployees to live in an area. High living costs are limiting factors in recruiting the appropriate personnel because intending employee may find relocation extremely difficult. For instance, personnel find it expensive to relocate to Tokyo because of high living costs in the place except if the recruiting company can shoulder the responsibility (financial).

Stability of a country may also affect site location by presenting a high risk to companies because of the fragility of the government, the threat of civil strife or local in tolerance to foreign companies. Iraq is one the riskiest countries inthe world asa result of great instability in the country. Other countries considered as being risk are Russia, Venezuela, Nigeria, Mexico etc.

2.4.4 Construction

Construction costs can reduce the profitability of the facility.
Land cost is often high where land is scarce and this could be of limiting factor in sitting a company Europe, for example is considered high relative to manyother regions.

Construction labour which refers to the pool of construction labour available. Getting this pool of labour is difficult, many a time, in developing regions necessitating the import of labour for the duration of the construction -local regulation may also stipulate the proportion of local labour in the construction crews.

Land preparation involves the work necessary to prepare land for constructing of the facility. Some regions require little land preparation while other regions require great land preparations. For example Industrial Parks, created by regional districts for the purpose of attracting companies require little land preparation and often all the utilities look ups are in place as well. This characterizes developing countries such as Brazil, Philippines and the Middle East.

Expansion possibilities are also relevant needs to be given to whether expansion possibilities exist. Non existence of such a factor may hindercompanies from being sited in a place.

Zoning regulations which involve laws regarding construction in particular areais an important consideration. In some regions, an area has to be designated as an industrial zone before plant can be constructed in such a place. The operation phase of the company should also be considered.

Availability of materials for construction must also be considered. Construction materials such as cement, fibre board, wood and construction steel may not be available locally and have to be imported. And this adds to costs.

2.4.5 Factors Affecting Cash Flows

Some factors directly affect a firm’s cash flow. The importance of such factorsis looked into under the factors that impact cash flows.

Fluctuating exchange rates impact cash flow. Stability of currency is important in site for an operating company. Currency of the country of the parent company can affect the revenue realized, the cost of raw materials, operating costs and investment amount needed. In developed countries the German Mark, the Swiss France and the Dutch Guilder have increased in strength over 20% relative to the US dollar during the period 1994 to March 1995. The revenues acrued to the US in US dollars have increased by some 20 per cent. The changes in operating cost and raw material cost depend on the currency onwhich the costs are dominated.

Repatriation of funds is the ability of the parent company to repatriate the funds to the country where the headquarters are located. Where strict exchange control exists transfer is not easy.

Taxes on operations levied by government on companies will diminish the net return to the corporation. For example in California, USA, there is a long- running unitary taxation situation concerning the ability of the state to tax not only the operation of a foreign company in the state, but also income generated by worldwide operations. This tells on the profits of the company establishing in that region.

2.4.6 Financial Aid

This includes direct cash grants or tax incentives on the land, operation or product produced. Example of a case where the financial aid influenced the citing of company occurred when in 1993 Mercedez-Benz of Germany planned to build US 300 million dollar plant somewhere in USA to produce a new four-wheel drive sports utility vehicle. A detailed analysis of the states in the country reduced the states to three: North Carolina, South Carolina and Alabama. These three all presented the attractions of a relatively low-cost but skilled and abundant work-force, anti-union sentiments, affordable housing, attractive life style and good transport links. In addition, the governments of the states were willing to throw money at companies ready to locate in their state

2.4.7 Proximity of Resources

Raw materials are very important and particularly their closeness to the process-flow plants is critical factors in site selection. This informs reason behind locating Oil refineries, which produce gasoline, kerosene and diesel close to oil field and the finished products are shopped to customers. Coal power stations, are often located close to coal mine.

Process and utility water should be close to some companies especiallycompanies like oil refineries and metal processing plants use a large quantity of utility water for cooling and / or in the process itself. The same is also true of food-processing plants particularly brewing and soft drinks industry; the water supply is integral part of the product and therefore should be located close to water supply. The quality of the water is also very important.

Reliable power supplies are also important. Countries in Africa have unreliable power supplies. In cases like this, back-up power facilities need to be constructed close to the facility. These add to the cost of operation.

Supplier or subcontractor of companies which depend heavily on their services should be located also close to one another. This is important becausereliability in delivery of goods is necessary if a just-in-time production criterion is used at the company.

2.5 Quantitative Approaches to Site Selection

Four quantitative methods might be used as a basis for site selection if parameters and variables related to site selection can be estimated with somecertainty. These includes: weighting the site criteria; breaking even analysis; probability analysis; centre - of - gravity method. These methods quantitatively determine the best location.

Weighting the Selection Criteria

This method applies weighting factors to the criteria for site selection. The site that has the highest overall value would be the preferred location. Theprocedure includes:

(a) Select the site criteria that are considered the most important for the site. These might be, for example, cost, labour availability, transport etc.

(b) Assign a weighting factor F to all the site criteria according totheirimportance in the selection. The total weighting will be equal to unity.

(c) Apply a numerical score S / Out of 100, for example, for all the site criteria for each possible location being considered

(d) Multiply the weighting factor by the numerical score, F x S for each siteand for each criterion.

(e) Sum the total F x S

(f) The value £ (F x S) that is the maximum indicates the preferred site.(g)

Example

Table 7.1 shows weighting factor (F) and numerical scores of five different locations in Nigeria: Oyo, Ogun, Ondo, Kwara and Lagos as analysed by a company desiring to have new production facilities.

Table 7.1: Weighting Factors and Scores for each Site

Site Criteria	Weighting factor F	Oyo State	Ogun State	Ondo State	Kwara State	Lagos State
Productivity	2.75	25	65	90	60	75
Construction cost	1.35	60	50	30	70	40
Labour cost	2.50	70	30	25	35	50
Proximity to clients	1.25	40	75	85	60	55
Suppliers Proximity to	1.15	30	65	55	35	45
Weather/quality of living	1.00	85	25	25	90	35
Total	10.00					

Production facility

1. Based on the data provided, determine the preferred location for theconstruction of this new production facility?
2. What can you say about the sensitivity of using this approach for siteselection?

Solution

(1) The weighting factor F is multiplied by the score S for each location and the total £(F x S) is determined. The values are given in the last line ofTable 7.2

Table 7.2

Site Criteria	Weighting factor F	Oyo State	Ogun State	Ondo State	Kwara State	Lagos State
Productivity	2.75	25	65	90	60	75
Construction cost	1.35	60	50	30	70	40
Labour cost	2.50	70	30	25	35	50
Proximity to clients	1.25	40	75	85	60	55
Suppliers Proximity to	1.15	30	65	55	35	45
Weather/quality of living	1.00	85	25	25	90	35
Total	**10.00**	**494.25**	**514.75**	**545.00**	**552.25**	**540.75**

From table 2, maximum score = 552.25 preferred location Kwara.

Break-even analysis

Break-even analysis is a common evaluating method when costs can bedetermined with some certainty. The procedures are itemised below:

(a) Determine the fixed and variable costs for each site

(b) If a site has a variable cost higher than another site but a lower fixed cost then there will be a break-even point. There will be no break-even point if both the fixed costs and variable costs are higher than the corresponding costs at another location.
(c) determine the production level expected from each site
(d) the preferred site will be that which has the lowest total cost.

Example
Table 7.3

Fixed costs/year	Akure	Ibadan	Osogbo
Salaries/management/staff	3,400,000	2,700,000	3,200,000
Depreciation	750,000	600,000	400,000
Insurance	250,000	225,000	210,000
Energy costs	310,000	275,000	290,000
Taxes	100,000	90,000	80,000
Total	**4,810,000**	**3,890,000**	**4,180,000**

Variable cost/unit			
Raw materials	21.50	25.96	24.75
Labour	12.50	11.30	11.10
Packing	1.30	2.05	1.50
Transportation	0.30	1.10	0.95
Total	**35.60**	**40.35**	**38.30**

Table7.3 shows the fixed costs and variable costs of Cadbury (Nig.) Plc in its attempt to site new branch at state capital. Three state capitals are beingconsidered. Akure, Ibadan and Osogbo.

Determine the break-even levels in terms of units produced in the three states.

Solution

Break-even point is
Total costs = fixed costs + variable cost x production level
The first step is to determine if therewill be break-even points comparing their fixed and variable costs with one another shows thatthere will be:

Total cost for Akure
TCA = FCA + QA x VCd
And for Ibadan
TCI = FCI + QI x VCI

The break-even point is when the total costs are equal for the two sites at some production level Q or FCA + QA x VCA = FCI + QI x VCI making Q, the subject of the formula.
Similar relationships hold between Akure and Osogbo and between Ibadan and Osogbo.

Table7.4 gives the values of the production units at the break-even point, and the total cost for each of the twin sites.

Table7.4

Units produced to break-even	Akure	Ibadan	Osogbo
141,463	9,846,098	9,598,049	9,598,049
193,684	11,705,158	11,705,158	11,598,105
233,333	13,116,667	13,305,000	13,116,667

The equal break-even units are in bold prints.

Uncertainty and risk
Uncertainty is when it is difficult to assign probabilities to a situation. In this case, the criteria of minimax, maximin, equally likely and Minimax regret may be used, depending on the approach of the decision maker.

Probabilities
If probabilities can be assigned, then the expected outcome of a particular site selection may be determined by weighing according to various probabilities.

Examples
Nestle Nig. (Plc), based in Nigeria, manufactures and distributes Nescafe. As a result of an expected increase in demand for its product, the company is considering four possibilities or capacity expansion.
Table7.5 gives estimates of the profits from each facility in the four possible locations: Kano, Kaduna, Sokoto, Lagos; for over five years estimation period

Table 7.5 Estimates of the profits from each facility in Naira

Market change	40%	25%	1%	-10%
Over five years	Increase	Increase	Increase	Increase
Kano	22,250,000	19,250,000	-625,000	-11,250,000
Kaduna	26,290,000	15,500,000	-1,479,000	-18,925,000
Sokoto	6,273,500	5,250,000	-1,790,000	12,920,000
Lagos	7,400,000	5,500,000	-50,000	-100,000

Based on the above information, what would be the preferred site:

(a) If management is pessimistic in its approach

(b) Using the concept of minimax regret

Solution

Table 7.6

Market change	40%	25%	1%	-10%	Minimum
Kano	22,250,000	19,250,000	-625,000	-11,250,000	-11,250,000
Kaduna	26,290,000	15,500,000	-1,479,000	-18,925,000	-18,925,000
Sokoto	6,273,500	5,250,000	-1,790,000	12,920,000	12,920,000
Lagos	7,400,000	5,500,000	-50,000	-100,000	-100,000

If the management is pessimistic in its approach, then maximim is the criterionto be used.

Based on Table 6, maximum of the minimum is -100,000 which imply that Lagos is the preferred site.

1. Using the concept of minimax regret.

Minimax regret matrix is shown in Table 7.7 which is determined for each column. Each cell value is obtained by finding the difference between the maximum outcome in that column and the possible outcome of the cell.

Table 7.7

Kano	4,040,000	0	575,000	11,150,000	11,150,000
Kaduna	0	3,750,000	1,429,000	18,825,000	18,825,000
Sokoto	20,016,500	14,000,000	1,740,000	12,820,000	20,016,500
Lagos	18,890	13,750,000	0	0	18,890,000

The minimum of the maximum regrets in the last column is the chosen, and it is 11,150,000. Hence, the preferred location using the concept of minimax regret is Kano.

Centre of Gravity

The fourth method to determine site/selection is centre-of-gravity. It may be used to establish the location of a primary central distribution centre that supplies secondary centres. It takes cognisance of the volume of goods transported from primary to secondary centres and also the distance between sites. The cogent procedures are itemised below:

(a) Position the network on a grid identified by X and Y co-ordinates. The units of the co-ordinates are not important.

(b) The co-ordinates of the centre of gravity are calculated using the following relationship.

$$Xc = \frac{SXQi}{SQi} \text{ and } Yc = \frac{SYiQi}{SQi}$$

Where,

Xc and Yc has the co-ordinates for the centre of gravity.

Xi and Yi are the co-ordinates for supply center, Qi is the quantity delivered from the central site to the secondary centre.

Self-Assessment Exercise

State factors which influence the choice of location

2.6 Summary

What you have learnt in this section concerns the meaning of site selection, the relevance of different relevant factors in selection decision and methods of determining the preferred location.

The factors considered include staffing with conditions which embraces the influence of labour costs, labour productivity, and availability of good training facilities as well as cultural implications on expatriates. The role of language differentials was also accentuated.

Climate and issues that directly relates to construction per se as well as the factors that impact cash-flow were also meticulously looked into. Labour costs, as they affect manufacturing firms, the proximity of raw materials, water availability etc. were not ignored.

Importance of exchange rate and the stability of the regions add to factors that were considered. Quantitative methods for evaluating the location of site were looked into at break-even analysis, weighting the evaluation criteria, probability analysis of various returns, and the centre of gravity method with regard to transportation.

2.7 References/Further Readings/Web Resources

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2.8 Possible Answers to Self-Assessment Exercises

The following are some of the factors which influences the choice of location:

Proximity to market, availability of labour and skills, Amenities, Transport, inputs, services, stability of land and climate, regional regulations, room for expansion, safety requirement, site cost etc.

UNIT 3 SUPPLY CHAIN MANAGEMENT

Unit Structure

3.1 Introduction

The purpose of supply–chain management is to synchronise a firm's function with those of its suppliers in order to match the flow of materials, services, and information with customer demand. Its strategic implications lie on the fact that the supply system can be used to achieve important competitive priorities. In addition, it involves the coordination of key functions in the firm such as marketing, finance, engineering, information systems, operations, and logistics.

3.2 Learning Outcomes

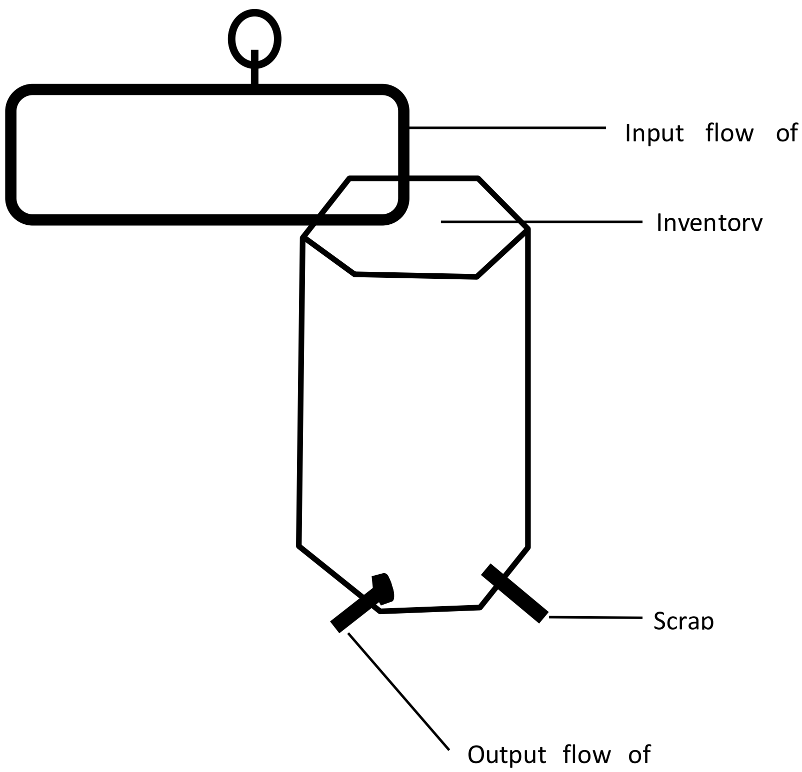
At the end of this unit, you should be able to:

- Define the nature of supply-chain management for both manufacturers and service providers.
- Describe the strategic importance of supply-chain management
- Explain the important roles of purchasing and distribution in the design and execution of effective supply chains.

3.3 An Overview of Supply – Chain Management

One major consequence of supply-chain management is to control inventory by managing the flow of materials. As discussed, an inventory is a stock of materials used to satisfy customer demand or support the production of goods or services. Figure 1 uses the analogy of a water tank to illustrate how inventories are created. The flow of water into the tank raises the water level. This inward flow of water represents input materials or a finished product.

Figure 8.1: Creation of Inventory



The water level represents the amount of inventory held at a plant, service facility, warehouse, or retail outlet. The flow of water from the tank lowers the water levels and this depicts the demand for materials inventory. Examples of such include customer orders for a finished product or requirements for component parts or supplies to support the production of a good or service. In addition to these, we also have scrap as another possible outward flow from materials inventory.

It should be clear to you, that both the input and output flows determine the level of inventory. For instance, inventories will normally rise when more materials flow into the tank that flows outside. Conversely, they fall when moreflows out than flows in.

There are three categories of inventory: raw materials (RM) work-in-process(WIP) and finished goods (FG). Raw materials are inventories needed for the production of goods or services; they are generally seen as inputs necessary in the transformation processes of the firm. Work-in-process consists of items such as components or assemblies needed for a final product in manufacturing as well as in some service operations (such as service shop, mass service providers, and service factories). Finished goods in manufacturing plants, warehouses, and retail outlets are the items that are sold tothe firm's customers. Please note that the finished goods of one firm may be the actual raw materials sought by another firm for its transformation processes.

Organisation (such as governments, churches, manufacturers, wholesalers, retails and universities) in almost all segments of an economy are becoming more conscious of the need to manage the flow of materials. Manufacturers make products from materials and services they purchased from outside suppliers.

Service provides too, use materials in the form of physically items purchased from suppliers. The values of these materials that are purchased from outside sources often represent substantial portions of the total income earned by business organisations. Hence, firms can reap large profits with asmall percentage reduction in the cost of materials. This is perhaps one of the reasons why supply-chain management is becoming a key competitive weapon.

3.3.1 Materials Management

Materials management is concerned with decisions about purchasing materials and services, inventories, production levels, staffing, patterns, schedules and distribution. Such decision often affects the entire organisation, either directly, or indirectly. Operations and logistics therefore play a major role in supply- chain management. The belief in some quarters is that ideally, one person within the firm should make all such decisions concerned with materialsmanagement, more so that they are so inter-related. However, the sheer magnitude of this task in most firms (for example; with thousand of employees, tens of thousands of inventory items, husbands of work centres, several plants and thousands of supplies) often makes the suggestion impossible.

The relevantquestion then is: what organisational structure is best suited to handle the materials management function? Traditionally, organisations have divided the responsibility for materials management among three departments: purchasing, production control and distribution. This form of organization is called a segmented structure. Here the manager of each of these departments reports to a different person. The approach obviously requires a great amount of coordination in order for its to achieve a competitive supply system.

Consequently, many firms have restructured to centralize most materials management task in one department, and the manager of that department elevated to a higher position inthe organisation. This form of organisation is called an integrated structure, while the unified department is referred to as materials management or logistics management.

The advantage in this integrated structure is that it elevates the materials management function. In addition, it also recognizes that the various materials management task are all part of the same supply chain management activity. In other words, it brings together all the tasks related to the flows of materials, from the purchase of raw materials to the distribution of the finished product or service. However, most firms have been found to adopt the hybrid structures, whereby two of the three departments (i.e. purchasing and production control) typically report to the same executive. The distribution department then continues to report to the marketing manager.

Granted thatthe organisational structure and management hierarchy can helpintegrate decisions and activities in materials management, a lot of cross –functional coordination is still required. Let us use an example to buttressthis important point: the marketing department typically makes forecasts and processes incoming customerorders. The production control department uses this information to organise work-force schedule and set work priorities.

Simultaneously the marketing department needs to know the current scheduleand production capability when processing incoming orders for the purposes of making realistic delivery promises. Immediately purchased materials have been received or furnished goods shipped, the accounting department must necessarily follow through with payments or billing. In order to achieve better cross functional coordination, organisations may have to push responsibilities lower in the organisation; group traditional functions around each major product or service; or create inter-functional coordination units. It has also been suggested that information systems and the reward system maybe used to facilitates coordination across the functional boundaries.

Figure 8.2 illustrates the scope of materials management and the typical domains of responsibility for purchasing, production control, and distribution for a baker. As can been seen from the figure, the flow of materials begins with the purchase of raw materials (e.g. flour, eggs, sugar baking powder) and services (e.g. maintenance – technicians to service equipment) from outside suppliers. The incoming raw materials are stored and then converted into bread by one or more processes, which involves some short-term storage of work-in-process inventory. The loaves of bread are stored for a brief period as finished goods and later shipped by means of transportation services suppliers to various outlets with their distribution centres. Cycle is repeated as necessary, as the firm responds to customer demand.

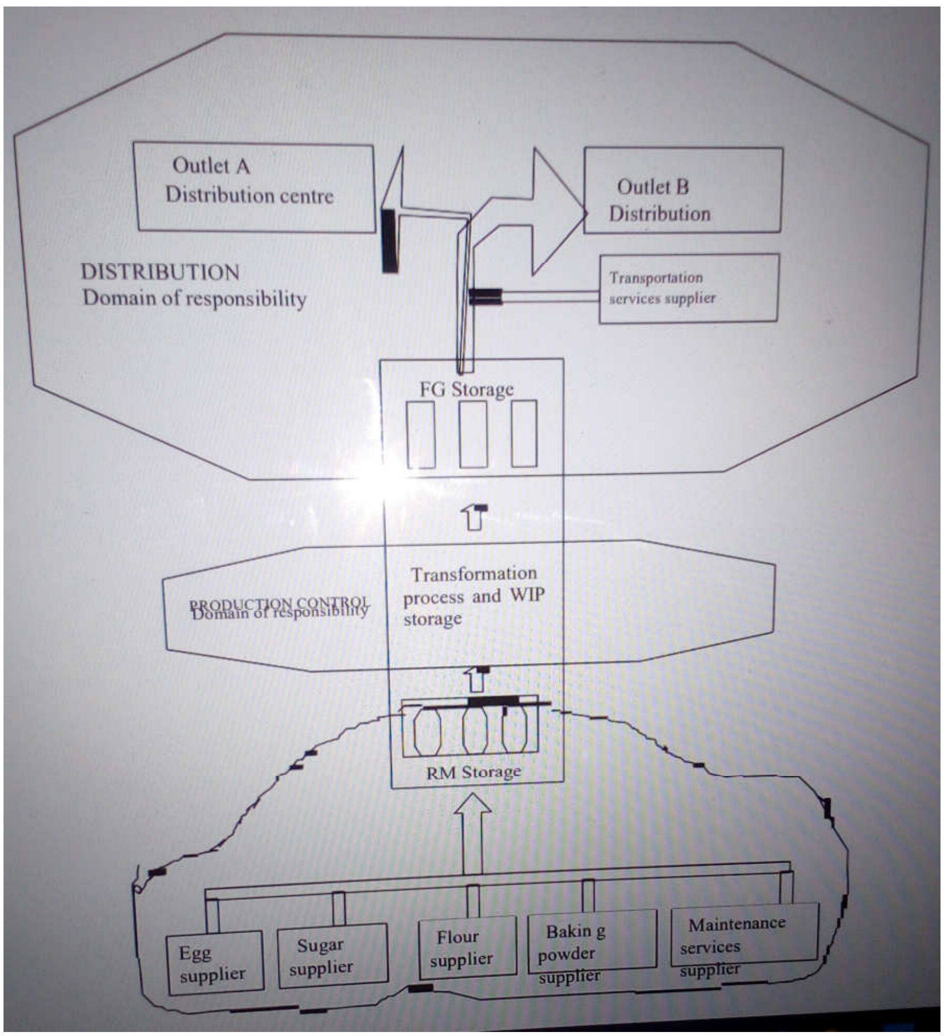


Figure 8.2: Materials management for a Bakery and the Domains of Responsibility for its Three Primary areas of operation

The purchasing department is often responsible for working with supplies to ensure the desired inward flow of materials and services. This department may also be responsible for inventories of raw materials. The determination of production qualities and scheduling of machines and employees directly responsible for the production of goods and services are all within the domain of the production central department. The department handling distribution is usually responsible for the outward flow of materials from the firm to its customers. It may also be responsible for finished goods inventories and selection of transportation suppliers. It can be clearly seen that materials management is responsible for coordinating the efforts of purchasing and distribution. Hence, as we have already mentioned, materials management decisions have a major cumulative effect on the profitability of a firm and thus attract considerable managerial attention.

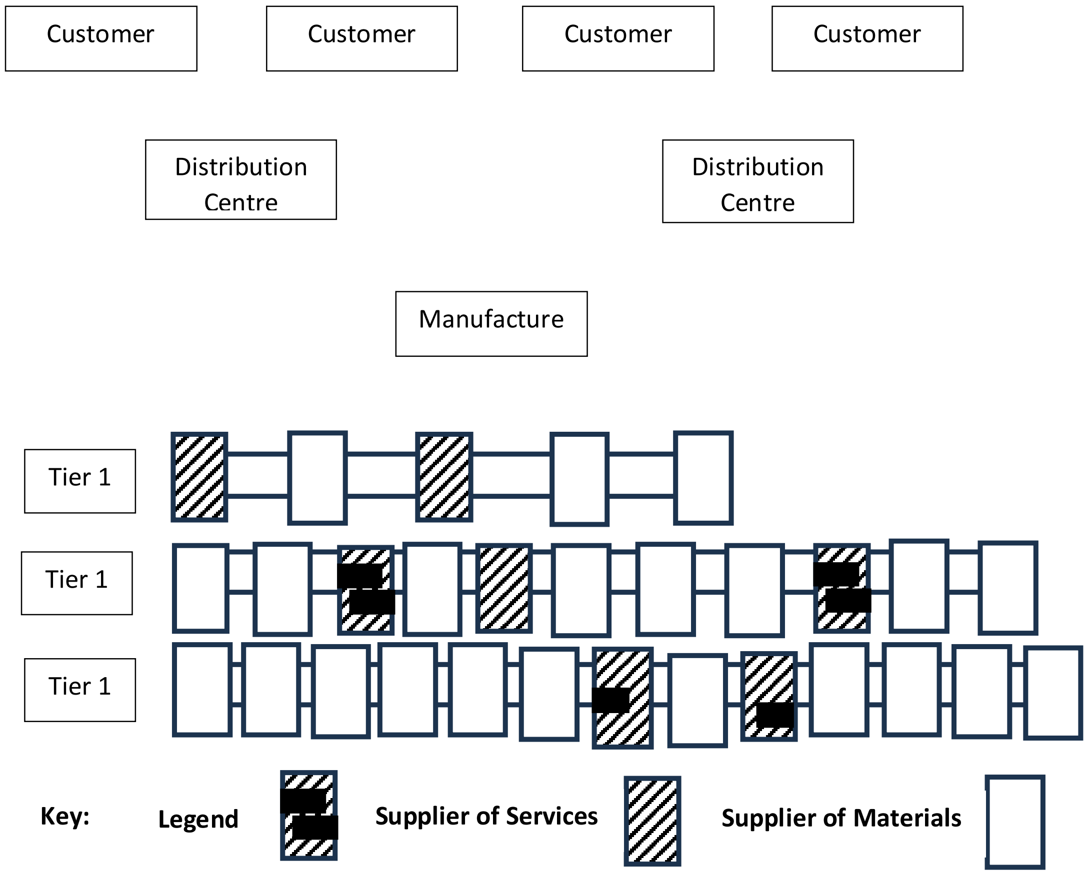
3.3.2 Supply Chains

A supply chain is the inter-connected set of linkages between suppliers of raw materials and services that spans the transformation of raw materials into products and services, and delivers them to a firm's customers. The provision of information needed for planning and managing the supply chain is an important part of the process just described.

The supply chain for a firm can be very complicated. Figure 8.3 is a simplified version. Here the firm owns its own distribution and transportation services. Note that firms that manufactured products to customer specifications don't usually have distribution centres of their own. They often ship the products directly to their customers. It is customary to identify suppliers by their position in the supply chain. For example, tier 1 suppliers provide materials or services that are used directly by the firm; tier 2 suppliers usually supply tier 1 suppliers etc.

Having observed that supply chains can often be complicated, what then, is the best way to control suppliers in a complex supply chain? One sure way to gain control is to buy a controlling interest in the firm's major suppliers. This is known as backward vertical integration. This way, the firm can ensure its priority with the supplier and even more forcefully lead efforts to improve efficiency and productivity. It should however be noted that buying into other companies involves a lot of capital, which may reduce a firm's flexibility.

Figure 8.3: Supply Chain for a manufacturing firm.



Legend Supplier of services Supplier of materials

Most importantly, if demand drops, the firm can't simply reduce the amount ofmaterials purchased from the supplier to reduce costs since the supplier's fixed costs remain unchanged. Another approach of controlling suppliers is to enterinto some agreements with the first-tier suppliers, such that these suppliers can be held accountable for the performance of their own suppliers.

3.3.3 Developing integrated Supply chain

From our discussion so far, it is clear that a successful supply chain management requires a high degree of functional and organizational integration. Such integration usually comes through some form of evolution. Usually, firms willing to undergo the rigours of developing integrated supply chains move through a series of phases as displayed by figure 4. The starting point for most firms is phase 1, where external suppliers and customers are considered to be independent of the firm. This situation makes relations with these entities to be formal, have there is little sharing of operating information and costs. Similarly, the firm's purchasing, production control and distribution departments act independently. Each of these internal departments attempts to optimize its own activities without considering other entities. Each external and internal entity in the supply chain will then try to control its own inventories, and also utilizes control systems and procedures that are incompatible withthose ofother entities. The existence of organizational and functional boundaries oftenleads to large amounts of inventories in the supply chain.Consequently, the overall flow of materials and services is ineffective.

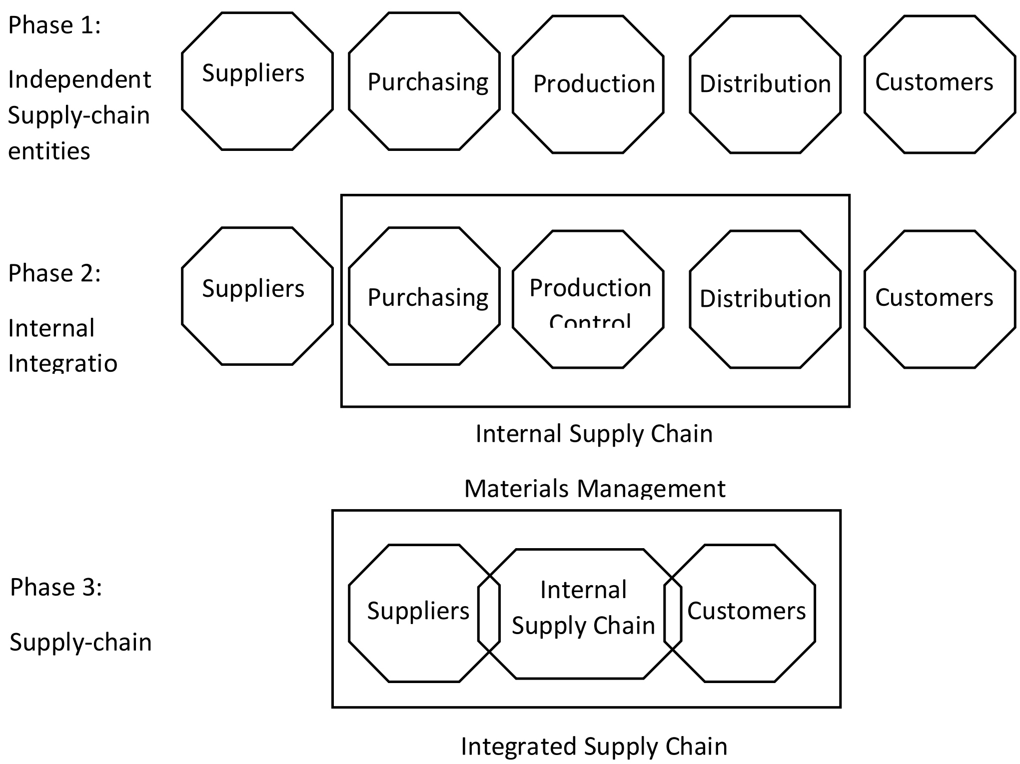


Figure 8.4: Phases in the Development of an Integrated Supply Chain Source: Adapted from: Krajweski, L.J. and L.P. Ritzman 1999.

In the second phase, the firm attempts to initiate internal integration by combining purchasing, production control and distribution into a materials management department. The major interest here is on the integration of such aspects of the supply chain directly under the firm's control in order to create an internal supply chain. It is usually for firms already in this phase to utilize a seamless information and materials control system right from distribution to purchasing, integrating marketing, finance, accounting and operations. While efficiency and close linkages to customers areemphasized, the firm still considers its suppliers and customers to be independent entities, thus focusingon tactical rather than strategic issues.

It is necessary for internal integration (Phase 2) to precede phase 3 (external integration). What happens in the third phase is that the internal supply chain is extended to embrace suppliers and customers. By so doing, the internal supply chain is linked to the external supply chain (which initially, is notunder thedirect control of the firm). At this phase, the firm needs to change its orientation from a product or service outlook to a customer orientation. This in essence means that the firm must identify the appropriate competitive priorities for each of its market segments. In order to serve its industrial customers better, the firm should develop a good understanding of their products, culture, markets and organisation. Furthermore, the first should not just react to customer demand; rather it should strive to work with its customers so that the two of them benefit from improved flows of materials and service. In the same vein, the firm needs to develop better understanding of its supplier's organisations, capacities, and strength and weakness. It is also necessary for the firm to include its suppliers earlier in the design process for new products or services. It is this phase 3 that embodies supply – chain management, which seeks to integrate the internal and external supply chains.

3.4 Purchasing

Purchasing is the management of the acquisition process, and it involves deciding, decoding which suppliers to use, negotiating contracts, as well as deciding whether to buy locally. It is basically the duty of purchasing to satisfy the firm's long-term supply needs.

Furthermore, it should support the firm's capabilities to produce goods and services. We need to understand that the performance of both the internal and external supply chains depends on how well this critical task is performed.

3.4.1 The Acquisition Process.

There are five basic steps in the acquisition process. These are:

(i) **Recognise a need: The first step starts with the receipt of a request to**buy outside materialsor services by the purchasing department. This request is generally known as a purchase requisition and it usually includes the item's description, quantity and quality desired as well as the delivery date. The purchasing department is well positioned toappraise supplier capabilities and performance. In a manufacturing firm, the purchasing department normally receives such authority to buy from the production control department. Production control department, in turn, is guided by the outsourcing and make or buy decision that havealready been made.

At a retailing firm the decision of what merchandise to buy is usually the same as that of what to sell, hence marketing and purchasing decisions are intermingled. In the case of service provides, purchase decisions are generally based on the need to replenish items and services consumed in the delivery of services by the firm.

(ii) Select Suppliers: in this second step, there is the identification of suppliers that are capable of providing the items, grouping items that can be provided by the same supplier, requesting bids on the needed items, evaluating the bids in terms of multiple criteria and finally selecting asupplier.

(iii) Place the Order: This step involves the actual placement of orders. The ordering procedure can be very complex, especially when it involves expensive one-time purchases. However, it is usually very simple in the case of standard items that are routinely ordered from the same supplier. It is usual for suppliers to make shipments daily or even shift by shift without being prompted by purchase orders. This is often the case in some high-usage situations.

(iv) Track the order: This includes routine follow-up of orders to avoid the late deliveries or deviations from requested order quantities. The usual practice is for the suppliers to be contacted by letter, fax, telephone or e- mail. This step is particularly important **for large purchases, especially** when a delay could disrupt production schedules or mean the loss ofcustomer goodwill as well as future sales.

(v) Receive the order: This is the last step. Here, the in-coming shipments are normally checked forquantity andquality, with notices going to purchasing department, the unit placing the purchase requisition, inventory control and accounting. In a situation where the shipment isnot satisfactory, the purchasing department should decide whether to return itto the supplier. It is also very important to keep a track ofpunctuality, quality and quantity deviations and price.

Furthermore, the purchasing department should coordinate closely with account department to ensure that suppliesare paid accurately and punctually too.

3.4.2 Criteria for the selection and certification of suppliers

From our discussion so far, it should be clear that the purchasing department is the eyes and eyes of the organisation in the suppliers' market place. It therefore continuously seeks better buys and new materials from suppliers For this reason, the purchasing department is in a good position to select suppliers for the supply chain and to conduct certification programmes. With respect to supplier selection decision and the review of the performance Of current suppliers, it is necessary for the organisation to review the marketsegments it wants to serve and relate their needs to the supply chain. Usually, the starting point in developing a list of performance criteria to be used is competitive priorities being adopted by the organisation. For example, food- service firms use on-time delivery and quality as the top two criteria for selecting suppliers.

The three most commonly considered by firms selecting new suppliers are price, quality and delivery. It has been shown earlier that firms spend a large proportion of their total income on purchase items. Hence, their key objective is finding suppliers that charge low prices. However, low prices should not be made to overshadow quality, since this should equally be given an importantconsideration. For instance, the hidden costs of poor quality can be very high, most especially if defects are not detected until after substantial value has been added by subsequent operations. In the case of a retailer, poor merchandize quality can lead to loss of customer goodwill and future sales. Finally, shorter lead times and on-time delivery can assist the buying firm maintainingacceptable customer service with fewer inventories.

Let us now consider issues involved in supplier certification: The essence of supplier certification programmes is to verify that potential suppliers have the capacity to provide the materials or services the buying firm requires. Usually, certificationinvolves actual site visits by a cross-functional team (made up of operations, purchasing, engineering, information systems and accounting) from the buying firm. This team performs an in-depth evaluation of the supplier's capability to meet cost, quality, delivery and flexibility targets from process and information system perspectives. All the aspects of producing the materials or sources are examined through real observation of the processes in action and review of documentation for completion and accuracy. If the team is satisfied, the supplier is certified, hence can be subsequently used by the purchasing department. Thereafter, the performance of the supplier is monitored and the records of such are appropriately kept. After a particular period of time, or if performance declines, the supplier may need to be re-certified.

3.4.2.1Types and Effects of Supplier Relations

The nature and type of relations maintained with suppliers can affect the quality, delivery andprice of a firm's products and services. There aretowmajor types of relationships a firm may develop with its suppliers: competitive and cooperative.

3.4.2.2Competitive Relationship

In this type of relationship, the negotiation between the buyer and supplier is viewed as a zero-sum game, that is, whatever one side loses, the other side gains. Consequently, short-term advantages are preferred to long-term commitments. On one hand the buyer may want to beat the supplier's price down to the lowest level. The buyer may also push demand to high levelsduring boom times, thereby ordering almost nothing during recessions. On the other hand, the supplier presses for higher prices for specific levels of quality,customer services, and volume flexibility.

Whichever party wins depends on who has the most clarify. Usually, purchasing power determines that that a firm has. A firm is said to havepurchasing power when its purchasing volume represents a significant share of the supplier's sales or the purchased item or service is standardized and manysubstitutes are available.

3.4.2.3 Cooperative Relationship

In this type of relationship, the buyer and supplier see themselves as partners. Thus, each tries to help the other as much as possible. This in essence means long-term commitment, joint work on quality and support by the buyer of the supplier's managerial, technological and capacity development. Generally, a cooperative relationship favours few suppliers of a particular item or service, the ideal number being just tone or two suppliers. With some increase in order volume, the supplier gains repeatedly, and this helps the line flow strategy of high volume at a low cost. In addition, when contract are large and a long-term relationship is assured, the supplier might even decide to build a new facility and, then hire a new work force. The supplier might even re-locate close to the buyer's plant.

Another interestingfeature of the cooperative relationship is that he buyershares more information with the supplier on its future buying intention. This then allows suppliers to make better, more reliable forecasts of future demand.

The buyer at times, visits supplier's plants for familiarization purposes, andmay actually suggest ways to improve the supplier's operations. This relationship may grow so well that the buyer wouldn't see the need to inspect incoming materials. Moreover, the supplier may be given more freedom in specifications involving the supplier more in designing parts, implementing cost-reduction ideas, and sharing in savings. One major advantage of the cooperative relationship is the potential to reduce the number of suppliers in the supply chain, thereby reducing the complexity of managing them.

3.5 Distribution

Distribution is the management of the flow of materials from manufacturers to customers and from warehouses to retailers, involving the storage and transportation of products. Generally, distribution broadens the marketplace for a firm, adding time and place value to its products. In the sections that follow, we will look at three types of decisions facing distribution managers. Theseare:

(i) Where to stock finished goods;
(ii) What transportation mode to use; and
(iii) How to schedule, route, and select carriers

3.5.1 Placement of Finished Goods inventory

This is often a fundamental decision in any business organisation. One solution is to consider forward placement, which means locating closer to customers at a warehouse or distribution centre (DC) or with a wholesaler orretailer. The advantages here are two-fold:, there is fast delivery times, accompanied by reduced transportation costs. Ordinarily, these opportunities usually stimulate sales. Firms using a make-to-stock strategy often use forward placement.

However, if competitive priorities call for customized products, storing an inventory of finished goods, risks creating unwanted products. The solution then lies on backward placement, which is the holding of inventory at themanufacturing plant or maintaining no inventory of finished goods. At times backward placement (also referred to as inventory pooling), is advantageous when the demand in various regions maybe unpredictably high inone month, and low in the next. What backward placement does in this instance is to pool demand so that the highs in some regions cancel the lows in others. This isbased on the fact that demand on a centralised inventory is less erratic and more predictable than demand on regional inventories. Inventories for the whole system can be lower, and costly re-shipments from one distributioncentre to another can be minimized.

3.5.2 Selection of Transportation Mode

There are basically five modes of transportation: high way, rail, water, pipeline and air. Providers of these transportation services normally become part of a firm's supply chain. Since each of these modes has its own advantages and disadvantages, the selection of a particular one to adopt should be made with the competitive providers for each of the firm's products or services in mind.

For instance, if flexibility is a key competitive priority, highway transportation canbe used to ship goods to almost any location within a geographical region. One of the advantages inherent in the highway mode is that, no re-handling is needed as so is often the case with other modes that rely on trucks for initial pick up and final delivery. In addition, transit times are good, and rates are usually less than rail rates for small quantities and short hauls. If cost is the competitive priority, rail or water transportation may be appropriate. Rail transportation, in particular can ship large quantities of goods very cheaply. However, its transit times are long and variable. This mode is usually recommended for shipping raw materials, rather than finished goods.
Rail shipments often require pickupand delivery rehandling. Water transportation provides high capacity at low unit cost, but its transit times arelow. It also has limited geographical flexibility.

In the case of certain products in high volumes at low cost, pipelines may be the choice. Pipeline transportation is highly specialised, but with limited geographical flexibility. It is naturally limited to liquids, gases, or solids inslurry form. No packaging is needed and costs per kilometer are low.

Finally, if fast delivery times are the competitive priority, air transportation is the fastest but most expensive mode. This mode is limited by the availability of airport facilities and also requires pickup and delivery re-handling.

Apart from these primary modes, special service modes and hybrids are available. These include parcel post, air express, bus service, and freight forwarder.

3.5.3 Scheduling, Routing and Carrier Selection

The decisions on how to schedule, route and select carriers are usually very complex. For instance, several activities essential to the performance of the supply chain are involved in the day-to-day control of freight movement. In addition, the shipping schedule must fit into purchasing and production control schedules. It also reflects the trade-off between transportation costs and customer response times. For instance, by delaying a shipment for another day or two so as to combine it with others will make it possible to have a full carload rate for a rail shipment or a full truckload for truck shipment. With respect to routing choices, a manufacturer can gain a lower freight rate by selecting a routing that combines shipments to multiple customers. In fact, the firm may even negotiate lower overall rates, if it develops routings by which large volumes can be shipped regularly.

3.6 Measures of Supply-Chain Performance

It is now clear to you, that supply chain management involves managing the flow of materials that create inventories in the supply chain. Hence, managers need to closely monitor inventories in order to keep them at acceptable levels.

For instance, the flow of materials affects various financial measures of concern to the firm. It is therefore necessary to examine the typical inventory measures that are usually used to monitor supply-chain performance.

3.6.1 Inventory Measures

Measures of inventories are usually reported in three basic ways: average aggregate inventory value, weeks of supply, and inventory turnover.

The average aggregate inventory value is the total value of all items held in inventory for a firm. All the monetary values in this inventory measure are expressed at cost since we can then sum the values of individual items in raw materials, work-in-process, and finished goods. Final sales monetary values have meaning only for final products or services, and cannot be used for all inventory items. It is an average because it usually represents the inventory investment over some period of time.

Let us illustrate with an example: suppose that item A is a raw material that is transformed into a finished product, item B. One unit of item A may be worth only a few

$$\text{Average aggregate inventory value} = \left(\begin{array}{c}\text{Number units of item A}\\ \text{typically on hand}\end{array}\right)\left(\begin{array}{c}\text{Value of each}\\ \text{unit of item A}\end{array}\right) + \left(\begin{array}{c}\text{Number of units of item B}\\ \text{typically on hand}\end{array}\right)\left(\begin{array}{c}\text{Value of each}\\ \text{unit of item B}\end{array}\right)$$

naira. On the other hand, one unit of item B maybe valued in the hundreds of naira because of the labour, technology, and other value-add operations performed in manufacturing the product. For an inventory consisting of only item A and B, this measure is given as:

By summing up over all items in an inventory, the total tells managers howmuch of a firm's assets are tied in inventory. Typically, manufacturing firms have about 25 percent of their total assets in inventory, whereas wholesalersand retailers average about 75 percent.

To some extent, it is possible for managers to decide whether the aggregate inventory value is too low or too high by a recourse to historical or industry comparison, or by managerial judgement. It is however very important to take
demand into consideration.

Another inventory measure is weeks of supply, and this is obtained as follows:

$$\text{Weeks of supply} = \frac{\text{Average aggregate inventory value}}{\text{Weekly sales (at cost)}}$$

You will observe that the numerator includes the values of all items (e.g. raw materials, work-in-process, and finished goods),while the denominator represents only the finished goods sold – at cost, rather than the sale price after mark ups or discounts. This cost is often referred to as the cost of goods sold.

The third measure of inventory is inventory turnover (or turns), which is obtained by dividing annual sales at cost by the average aggregate inventory value maintained during the year. The formular is:

$$\text{Inventory turnover} = \frac{\text{Annual sales (at cost)}}{\text{Average aggregate inventory value}}$$

Example

A company averaged N2million in inventory last year, and the cost of goods sold was N10million. If the company has 52 business weeks per year, howmany weeks of supply were heldin inventory? What was the inventory turnover?

Solution

(a) weeks of supply = $\frac{N2m}{(N10m)/(52\ weeks)}$

= 10.4 weeks

(b) Inventory turnover = $\frac{N10m}{N2m}$

= 5 turns per year

Self-Assessment Exercise

Explain Details integrated supply chains move through a series of phases as displayed by figure 4.

3.7 Summary

A basic purpose of supply-chain management is to control inventory by managing the flows of materials that create it. Three aggregate categories ofinventories are raw materials, work-in-process andfinished goods. An important aspect of supply-chain management is materials management, which coordinates the firm'spurchasing, production control, and distributionfunctions.

3.8 References/Further Readings/Web Resources

Fisher, M.L. (1997): "What is the Right Supply Chain for your Product?" Harvard Business Review (March – April) pp 105- 116.

Lee, H.L. and C. Billington (1992): "Managing Supply Chain Inventory: Pitfalls and Opportunities" Sloan Management Review (Spring) pp 65 - 73

3.9 Possible Answers to Self-Assessment Exercises

Explain in Details the integrated supply chains move through a series of phases as displayed by figure 4. The starting point for most firms is phase 1, where external suppliers and customers are considered to be independent of the firm. This situation makes relations with these entities to be formal, have there is little sharing of operating information and costs. Similarly, the firm's purchasing, production control and distribution departments act independently. Each of these internal departments attempts to optimize its own activities without considering other entities. Each external and internal entity in the supply chain will then try to control its own inventories, and also utilizes control systems and procedures that are incompatible withthose ofother entities. The existence of organizational and functional boundaries oftenleads to large amounts of inventories in the supply chain.Consequently, the overall flow of materials and services is ineffective.

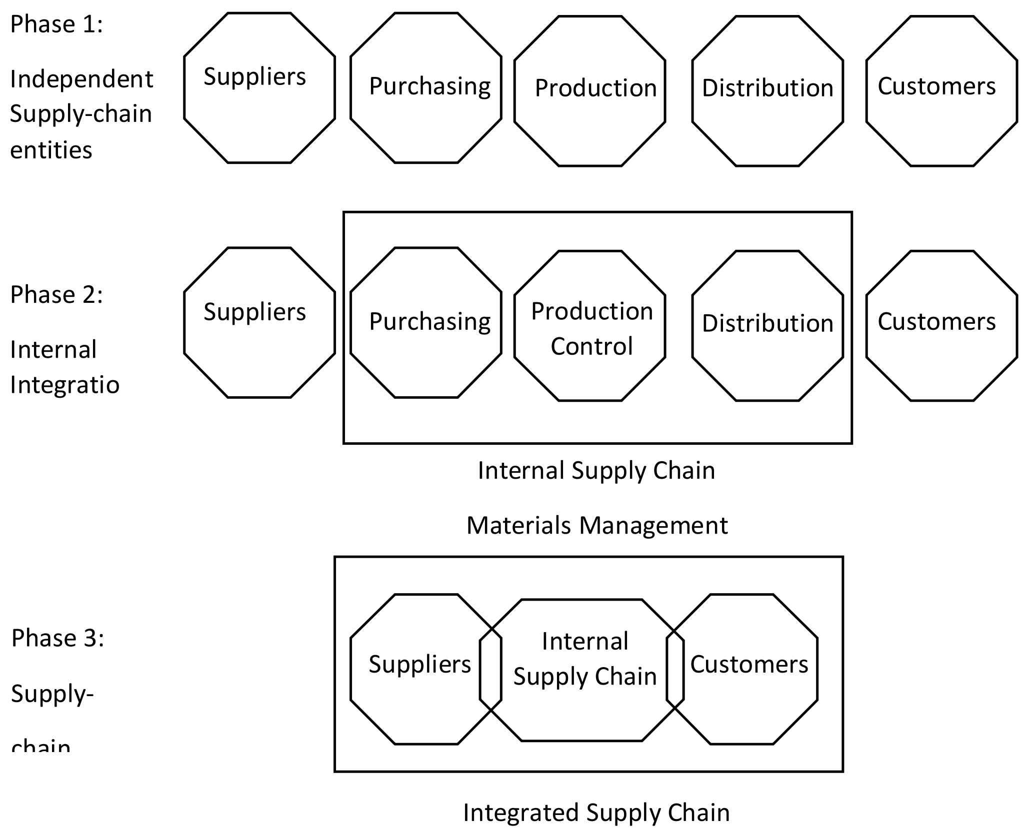


Figure 8.4: Phases in the Development of an Integrated Supply Chain Source: Adapted from: Krajweski, L.J. and L.P. Ritzman 1999.

In the second phase, the firm attempts to initiate internal integration by combining purchasing, production control and distribution into a materials management department. The major interest here is on the integration of such aspects of the supply chain directly under the firm's control in order to create an internal supply chain. It is usually for firms already in this phase to utilize a seamless information and materials control system right from distribution topurchasing, integrating marketing, finance, accounting and operations. While efficiency and close linkages to customers areemphasized, the firm still considers its suppliers and customers to be independent entities, thus focusingon tactical rather than strategic issues.

It is necessary for internal integration (Phase 2) to precede phase 3 (external integration). What happens in the third phase is that the internal supply chain is extended to embrace suppliers and customers. By so doing, the internal supply chain is linked to the external supply chain (which initially, is notunder thedirect control of the firm). At this phase, the firm needs to change its orientation from a product or service outlook to a customer orientation. This in essence means that the firm must identify the appropriate competitive priorities for each of its market segments. In order to serve its industrial customers better, the firm should develop a good understanding of their products, culture, markets and organisation. Furthermore, the first should not just react to customer demand; rather it should strive to work with its customers so that the two of them benefit from improved flows of materials and service. In the same vein, the firm needs to develop better understanding of its supplier's organisations, capacities, and strength and weakness. It is also necessary for the firm to include its suppliers earlier in the design process for new products or services. It is this phase 3 that embodies supply – chain management, which seeks to integrate the internal and external supply chains.

UNIT 4 INVENTORY MANAGEMENT

Unit Structure

4.1 Introduction

A convenience point to start our discussion in this unit is to provide an answer to the question: what is an inventory? An inventory is a stock or store of goods. Firms typically stock hundreds or even thousands of items in inventory, ranging from small things such as pencils, paper chips to large items such as machines and trucks. Naturally, many of the items a firm carries in inventory relate to the kind of business it engages in. Thus, manufacturing firms carry supplies of raw materials, purchased parts, partially completed items, and finished goods, as well as spare parts for machines, tools and other supplies. Hospitals stock drugs, surgical supplies, life monitoring equipment etc; supermarket stock fresh and canned foods, frozen foodsetc. To test your understanding of inventory, try to identify the different types of inventoriescarriedin the following organizations: Banks, Laboratory, clothing store and petrol station.

4.2 Learning Outcomes

After completing this unit you should be able to:

1) Definethe term inventory and list the major reasons for holdinginventories.
2) Contrast independent and dependent demand
3) List the main requirement for effective inventory management
4) Discuss period and perpetual review system.
5) Describe the A. B. C approach and explain how it is useful
6) Discuss the objectives of inventory management
7) Describe the basic EOQ model and its assumptions and solve typicalproblems.
8) Describe the economic run size model and solve typical problems.
9) Describe the quantity discount model and solve typical problems.
10) Describe reorder point models and solve typical problems.
11) Describe situation in which the single period model would beappropriate.
12) Solve typical problems that involve shortage costs and excess costs.

4.3 Purpose of Inventories

To understand why firms have inventories at all, you need to know something about the various functions of inventory. Inventories serve a number of functions. Among the most important are the following:

1. To meet anticipated demand or planned demand.
2. To smooth production requirements – This is true for firms that experience seasonal patterns in demand often build up inventories during off-season periods to meet overly high requirements during certain seasonal periods. For example, poultry farmers keepinventory of birds until festival periods when they will be sold. Can you think of examples of firms that keep seasonal inventories?.

To decouple components of the production distribution system –manufacturing firms have used inventories as buffers between successive operations to maintain continuity of production that would otherwise be disrupted by events such as breakdown of equipment and accidents that cause a portion of the operation to shut down temporarily.

The buffers will permit other operations to continue temporarily whilethe problem is resolved. Similarly, firms can use buffers of raw materials to insulate production from disruptions in deliveries from suppliers, and finished goods inventory to buffer sales operations from manufacturing disruptions.

To protect against stock-outs, that is, one can reduce the risk of shortages – resulting, for example, from delays due to weather condition– by holding safety stocks, which are stocks in excess of anticipated demand. Can you identify possible causes of shortages in raw materials; work in process and finished goods?

To allow economic production and purchase or to takeadvantage of order cycles. To minimize purchasing and inventory costs, a firm can buy in quantities that exceed immediate requirements.

This necessitates storing some or all of the purchased amount for later use. Similarly, it is usually economical to produce in large rather than small quantities.

Again, the excess output must be stored for later use. Thus inventorystorage enables a firm to buy and produce in economic lot sizes without having to try to match purchases or production with demand requirements in the short run. This results in periodic orders, or ordercycles. The resulting stock is known as cycle stock. You have to know that economic lot sizes are not the only cause of order cycles.In some instances, it is practical or economical to group orders and/or to order at fixed intervals.

To hedge against price increases or to take advantage of quantity discounts. Occasionally, a firm can suspect that a substantial price increase is about to be made and therefore purchase larger-than normal amounts to avoid the increase. The ability to store extra goods also allows a firm to take advantage of price discounts for large orders.

To permit operations. The fact that production operations take a certain amount of time (i.e. they are not instantaneous) means that there willgenerally be some work-in-progress inventory. In addition, intermediate stocking of goods – including raw materials, semi-finished items and finished goods at production sites, as well as goods stored in warehouses, - leads to pipeline inventories throughout a production – distribution system. As a follow up to question asked in section 1: What functions do those inventories identified perform?

4.3.1 Inventory Cost Structures

One of the most important prerequisites for effective inventory management is an understanding of the cost structure. Inventory cost structures incorporate thefollowing four types of costs:

4.3.2 Item cost

This is the cost of buying or producing the individual inventory items. The item cost is usually expressed as a cost per unit multiplied by the quantity procured or produced. Sometimes item cost is discounted if enough units are purchased at one time.

4.3.3 Ordering (or set up) costs

These are costs of ordering and receiving inventory. They include typingpurchase order, expediting the order, transportation costs, receiving costs, and so on. Ordering costs are generally expressed in fixed Naira per ordering regardless of order size. When a firm produces its own inventory instead of ordering it from a supplier, the costs of machine setup (e.g., preparing equipment for the job by adjusting the machine, changing cutting tools) are analogous to ordering costs; they are expressed as a fixed charge per run regardless of the size of the run.

4.3.4 Carrying (or holding) cost

This is associated with physically having items in storage for a period of time. Holding costs are stated in either of two ways: as a percentage of unit price, for example, a 15 percent annual holding cost means that it will cost 15kobo tohold N1 of inventory for a year or in Naira per unit. The carrying cost usually consists of three components:

4.3.4.1Cost of capital

When items are carried in inventory, the capital invested is not available forother purposes. This represents a cost of foregone opportunities for other investments, which is assigned to inventory as an opportunity cost.

4.3.4.2 Cost of storage

This includes variable space cost, insurance, and taxes. In some cases, a part of the storage cost is fixed, for example, when a ware house is owned and cannot be used for other purpose. Such fixed costs should not be included in the cost of inventory storage. Similarly, taxes and insurance should be included only if they vary with inventory levels.

4.3.4.3 Costs of obsolescence, deterioration, and loss

Obsolescence costs should be assigned to items which have a high risk ofbecoming obsolete; the higher the risk, the higher the costs. Perishable products such as fresh seafood, meat and poultry and blood should be charged with deterioration costs when the item deteriorates over time. The costs of loss include pilferage and breakage costs associated with holding items in inventory. For example, items that are easily concealed (e.g. pocket cameras, transistor radios, calculators) or fairly expensive (e.g. cars TVs) are prone to theft.

Stock out or shortage costs result when demand exceeds the supply of inventory on hand. These costs can include the sale lost because material is not on hand, loss of customer goodwill due to delay in delivery of order, late charges and similar costs. Also, if the shortage occurs in an item carried for internal use (e.g. to supply and assembly line), the cost of lost production or downtime is considered a shortage cost. Shortage costs are usually difficult to measure, and they are often subjectively estimated. Estimates can be based onthe concept of foregone profits.

4.4 Independent versus Dependent Demand

A crucial distinction in inventory management is whether demand is independent or dependent. Dependent demand items are typically subassemblies or component parts that will be used in the production of a final or finished product. Demand (i.e.usage) of subassemblies and component parts is derived from the number of finished units that will be produced. Aclassic example of this is demand for wheels for new cars. If each car is to have five wheels, then the total number of wheels required for a production run is simply a function of the number of cars that are to be produced in that run. For example, 200 cars would require 200 x 5 = 1,000 wheels.

Independent demand items are the finished goods or end items. Generally these items are sold or at least shipped out rather than being used in making another product. This demand includes an element of randomness.

The nature of demand leads to two different philosophies of inventory management. A replenishment philosophy, that is, as the stock is used, an order is triggered for more material and inventory is replenished.

A requirements philosophy, that is, as one stock begins to run out. Morematerials or ordered only as required by the need for other higher-level or end items.
The sections that follow focus on independent demand items.

4.5 Requirements for Effective Inventory Management

Management has two basic functions concerning inventory. One is to establish a system of keeping track of items in inventory and other is to make decision about how much and when to order. To be effective management must have the following:

1. A system to keep track of the inventory on hand and on order.
2. A reliable forecast of demand that includes an indication of possibleforecast error.
3. Knowledge of lead times and head time and lead time variability.
4. Reasonable estimates of inventory holding costs, ordering costs and shortage costs.
5. A classification system for inventory items.

Let's take a close look at each of these requirements.

4.5.1 Inventory Counting Systems

Inventory counting system can be periodic or perpetual. Under a periodic system, a physical count of items in inventory is made at periodic intervals(e.g., weekly, monthly) in order to know how much to order of each item. An advantage of this type of system is that orders for many items occur at the same time, which can result in economies in processing and shipping orders. There are also several disadvantages of periodic reviews. One is a lack of control between reviews. Another is the need to protect against shortages between review periods by carrying extra stock. A third disadvantages is the need tomake a decision on order quantities at each review.

A perpetual inventory system (also known as a continual system) keeps tracks of removal from inventory ona continuous basis, so when the system canprovide information on the current level of inventory for each item, when the amount on hand reaches a pre determined minimum a fixed quantity, Q, is ordered. The advantages of this system include;

(i) Continuous monitoring of inventory withdrawals.
(ii) Fixed order quantity that makes it possible for management to identify an economic order size (discuss in detail later in the unit). Thedisadvantages include added cost of record keeping and also a physical count shall be performed.

Bank transactions such as customer deposit and withdrawals are examples ofcontinuous recording of inventory changes. An example of perpetual system is in two- bin system that uses two containers of inventory; reorder is done when the first is empty. It does not demand record of withdrawal.

Perpetual system can be batch or on line. In batch system inventory records are collected periodicallyand entered into the system. In on-line system the transactions are recorded instantaneously. The advantage of latter over theformer is that they are always up to date.

4.5.2 Demand Forecasts and Lead Time Information

Since inventories are used to satisfy demand requirement it is essential to;

(i) have reliable estimates of the amount and timing of demand
(ii) know how to long it will take for orders to be delivered
(iii) know the extent to which demand and lead time (the time betweensubmitting an order and receiving it) might vary.

4.5.3 Classification System

Since items held in inventory are not of equal importance in terms of nairainvested, profit potential, sales, or usage volume or stock out penalties. They must be classified in order of their importance to the business. One way you can do this is to employ A-B- Capproach which classifies inventory items according tosome measures of importance, usually annual naira usage (i.e. naira value per unit multiplied by annual usage rate) and then allocates control efforts accordingly. Here, A is used for very important items, B for moderately important and C for least important.

A items generally account for about 15 percent to 20 percent of the items in inventory but 60 percent to 70 percent of the naira usage. While C items might account for about 60 percent of the number of items only abort 10 percent of the items of the naira usage of aninventory. In mostinstances A items account for large share of the value or costassociated with an inventory; and they should receive a relatively greater share of control efforts. The C items should receive only loose control and Bitems should have controls that lie between the two extremes.

The A. B. Concept is used by managers in many different settings toimprove operations. For example in customer service, a manager can focus attention on the most important aspects of customer service as very important, or of only minor importance. This is to ensure that he does not overemphasize minor aspect of customer service at the expense of major aspects.

A-B- C. concept can also be used as a guide to cycle counting, which is a physical count of items in inventory. The purpose of cycle counting is to reduce discrepancies between the amounts indicated by inventory records and the actual quantities of inventory on hand. Using A- B- C. concept let us attempt to classify the inventory items contained in the following table as A, B, or Cbased on annual naira value.

Item	**Annual Demand X Unit Cost**	**N**	**Annual Naira Value N**
1	1,000	4,300	4,300,000
2	5,000	720	3,600,000
3	1,900	500	950,000
4	1,000	710	710,000
5	2,500	250	625,000
6	2,500	192	480,000
7	400	200	80,000
8	500	100	50,000
9	200	210	42,000
10	1,000	35	35,000
11	3,000	10	30,000
12	900	3	27,000

When you look at the information contained in the table carefully, we can say that the first two items have a relatively high annual naira value so it seemsreasonable to classify them as A items. The next four items appear to have moderate annual naira values and should be classified as B items. The remainders are C items, based on their low naira value. The key questions concerning cycle counting for management are:

1. How much accuracy is needed
2. When should cycle counting be performed
3. Who should do it?

The American Production and Inventory Control Society (APICS) recommends the following guideline for inventory record accuracy ± 0.2 percent for A items, 1 percent for B items and± 5 percent for C items.

On when cycle counted be performed, you can decide to do it on periodic(scheduled) basis or certain events may trigger you do it on a periodic (scheduled) basis. An-out-of-stock report written on an item indicated by inventory records to be in stock, an inventory report that indicate a low or zero balance of an item and a specified level of activity (e.g. every 2000 units sold.)
On who should do it, you may use regular stock room personnel especiallyduring period of slow activity or give the contract to outside firms to do it on a periodic basis. The latter provides an independent check on inventory and may reduce the risk of problem created by dishonest employees.

4.6 Economic Order Quantity Model

The question of how much to order is frequently determined by using economic order quantity (EOQ) models. EOQ models identify the optimal order quantity in terms of minimising order costs. These models can take the following forms:

1. The economic order quantity model
2. The quantity discount model
3. The economic order quantity model with no instantaneous delivery.

4.6.1 Basic Economic Order Quantity Model

This basic model assumes the followings:
1. Only one product is involved.
2. Annual demand requirements are known

3. Lead time do not vary
4. Each order is received in a single delivery
5. There are no quantity discount
6. Demand is spread evenly throughout the year so that the demand rate isreasonably constant.

The exact amount to order will depend on the relative magnitudes of carrying and ordering cost. Annual carrying cost is computed by multiplying the average amount of inventory on hand by the cost to carry one unit for one year, eventhough any given unit would not be held for a year. The average inventory is simply half of the order quantity. Using the symbol H to represent the average annual carrying cost per unit, the total annual carrying cost is Annual carrying cost

$= \frac{QH}{2}$ ……………………. (1)

Annual ordering cost is a function of the number of orders per year and theordering cost per order

Annual ordering Cost $= \frac{DS}{Q}$

Where
S = ordering cost
D = annual demand
Q = order size

The equation shows that annual ordering cost varies inversely with respect toorder sizes.

The total cost associated with carrying and ordering inventory when Q units areordered each time is therefore:

TC = Annual carrying cost + Annual ordering cost = $\frac{QH}{2} + \frac{DS}{Q}$

Where
D = Demand, usually in units per year
Q = Order quantity, in units
S = Ordering cost in Naira
H = Carrying cost, usually in Naira per unit per year.

If TC is differentiated with respect to Q and equated to zero, and solving for Q, we will obtain the expression which we use to determine optimum order quantity,

$Q0 = \sqrt{\frac{2DS}{H}}$ …………………. (3)

The minimum total cost is then found by substituting Q0 in total cost formula. The length of an order cycle is obtained by dividing optimum quantity (Q0) by annual demand (D).

To illustrate the use of expression (3), suppose a local distributor for Michelin tyre expect to sell approximately 9,600 steel-belted radial tires of a certain size
and tread designs nextyear. Annual carrying costs are N16 per time, and ordering cost are N75. The distributor operates 288 days a year

(a) What is the EOQ?
(b) How many times per year does the store reorder?
(c) What is the length of an order cycle?

To answer these question demands that you know the value of D, H and S.These are as follows D= 9,600 tyres per year
H = N 16 per unit per year
S = N 75
Having determined these values, answers to those questions are thus:

(a) $Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(9{,}600)75}{16}} = 300$

(b) Number of order per year: $\frac{D}{Q} = \frac{9{,}600\ tyres/yr}{300\ tyres/order} = 32$ orders

(c) Length of order cycle: $\frac{D}{Q}\ \frac{300\ tyres}{9{,}600\ tyres/year} = \frac{1}{32}$ of a year, which is $\frac{1}{32}$ x 288 or nine workdays.

Now, if your carrying costs are stated as a percentage of the purchase price of an item rather then as a naira amount per unit, is (3) still appropriate to determine Q0, optimum order size? The answer is yes as long as you can convert the percentage in naira equivalent.

Let us illustrate this with an example: suppose Tijani and Osot. Ltd assembled television sets. It purchases 3,600 black and white picture tubes a year at N65 each. Ordering costs are N31, and annual carrying costs are 20 percentage of the purchase price. Compute the optimal quantity andthe total annual cost ofordering and carrying the inventory

Solution

D= 3,600 picture tubes per year
S = N 31
H= 20% of (N65) = N13 (since this can be done, Q0 expression is therefore appropriate)

(a) $Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(3{,}600)31}{13}} = \sqrt{17{,}169}$ = 131 picture tubes

TC = carrying costs + ordering costs

$= \left(\frac{Q_0}{2}\right)H + \left(\frac{D}{Q_0}\right)S$

$= \frac{131}{2}(13) + \left(\frac{3{,}600}{131}\right)31$ = 852 + 852 = N1,704

4.6.2 EOQ with Non instantaneous Replenishment

Recall the assumptions of the basic EOQ model discussed in the last section, it as assumed that each order is delivered at a single point in time. In some intime instances, however, such as when a firm is both a producer and user or when deliveries are spread over time, inventories tend to build up gradually instead of instantaneously.

When a company makes the product itself there are no ordering costs as such.
Nonetheless, with every run there are setup costs. Setup costs are similar to ordering cost hence they are treated in (3) in exactly the same way. In this case, the number of runs is D/Qo and the annual setup cost is equal to thenumber of runs per year times the setup cost per run: (D/Qo)S
Total cost is

TC_{mh} = carrying cost + setup cost

$= \left(\frac{1_{max}}{2}\right)H + \left(\frac{D}{Q_0}\right)S$

Where

1_{max} = Maximum Inventory

The economic run quantity is

$Q_0 \quad = \quad \sqrt{\frac{2DS}{H}} = \sqrt{\frac{P}{P-u}}$

Where

P = production or delivery rate
U = usage rate

The cycle time (the time between orders or between the beginning of runs) for the economic run size is dependent on the run size and use (demand) rate:

Cycle time $= \frac{Q_0}{U}$

Similarly, the run time (the production phase of the cycle) is dependent on therun size and the production rate:

Run time $= \frac{Q_0}{P}$

The maximum and average inventories are

$1_{max} = \frac{Q_0}{P}$ (p – u) and $1_{average} = \frac{1_{max}}{2}$

Now let us illustrate our discussion in this section with an example:

A toy manufacturer uses 48,000 rubber wheels per year for its popular dump truck series. The firm makes its own wheels which it can produce at a rate of 800 per day. The toy trucks are assembled uniformly over the entire year.

Carrying cost for a production run of wheel is 45. The firm operates 240 dayspper year. Determine each of the following:

(a) optimal run size
(b) minimum total annual cost for carrying and setup
(c) cycle time for the optimal run size
(d) run time

Solution

D = 48,000 wheels per year
S = N45
H = N1 per wheel per year
P = 800 wheels per day
U = 48,00 wheels per 240 days or 200 wheels per day

(a) $\sqrt{\frac{2DS}{H}} \sqrt{\frac{P}{P-u}} = \sqrt{\frac{2(48,000)45}{1}} \sqrt{\frac{800}{800-200}}$ = 2,400 wheels

(b) TC_{min} = carrying cost + setup cost = $\left(\frac{1_{max}}{2}\right)H + \left(\frac{D}{Q_0}\right)S$

2

Thus, you must first compute 1_{max}

$1_{max} = \frac{Q_0}{P}$ (p – u) = $\frac{2{,}400}{800}$ (800 – 200) = 1,800 wheels

TC = $\frac{1{,}800}{2}$ x N1 + $\frac{48{,}000}{2{,}400}$ x N45 = N900 + N900 = N1,800

Note again the quantity of cost (in this example, setup and carrying costs) at the EOQ.

(c) Cycle time = $\frac{Q_0}{U} = \frac{2{,}400\ wheels}{200\ wheels\ per\ day}$ = 12 days

Thus, a run of wheel will be made every 12 days

(d) Run time = $\frac{Q_0}{P} = \frac{2{,}400\ wheels}{800\ wheels\ per\ day}$ = 3 days

Thus, each run will require 3 days to complete.

4.6.3 Quantity Discounts

This section discusses the third variant of EOQ model. This requires that the assumption of no quantity discounts is relaxed. A convenient point to start our discussion in this section is to understand what quantity discounts mean. We would define quantity discounts as a price reduction for large orders offered to customers to induce them to buy in large quantities.

The buyer's goal with discount is to select the order quantity that will minimize total cost, which is the sum of carrying cost, ordering cost, + purchasing cost:

TC = Carrying cost + Ordering cost + Purchasing cost

$$= \frac{QH}{2} + \frac{DS}{Q} + PD$$

Where

P = unit price

Recall that in thebasic EOQ model,determination of order size does not involve the purchasing cost. The rationale for not including unit price is that under the assumption of no quantity discounts, price per unit is the same for all order sizes.

There are two general cases of the model. In one, carrying costs are constant (e.g. N per unit) in the other, carrying costs are stated as a percentage of purchase price (e.g. 20 percent of unit price).

The procedure for determining the overall EOQ differs slightly, depending on which of these two cases is relevant. For carrying cost that is constant, theprocedure is as follows:

(1) Compute the common EOQ
(2) Only one of the unit price will have the EOQ in its feasible range sincethe ranges do not overlap. Identify that range

(a) if the feasible EOQ is on the lowest price range, that is the optimumorder quantity.
(b) If the feasible EOQ is in any other range, compute the total cost for the EOQ and for the price break of all lower unit cost. Compare the total costs: the quantity (EOQ or the price break) that yield the lowest total is the optimum order quantity.

This is illustrated with the following example:
The maintenance departments of a large hospital used about 816 cases of liquidcleaner annually. Ordering costs are N12, carrying costs are N4 per case a year and the new price schedule indicate that orders of less that 50 cases will cost N20 percase, 50 to 79 cases will cost N18 per case 80, to N99 will cost N17 per case, and the large order will cost N16 per case. Determine the optimal order quantity and the total cost.

Solution

D= 816 cases per year S= N 120 H = N40 per case per year.

Range	Price
1 to 49 …………..	N20
50 to 79 ………...	18
80 to 99 …………	17
100 or more …….	16

1. Compute the common EOQ = $\sqrt{\frac{2DS}{H}}$ = $\sqrt{\frac{2(816)12}{4}}$ = 70 cases
2. The 70 cases can be bought at 18 per case since 70 falls in the range of 50 to 79 cases. The total cost to purchase 816 cases a year, 70 cases a year, at the rate of 70 cases per order will be

TC_{70} = Carrying cost + Order cost + Purchase cost

$$= \frac{QH}{2} + \frac{DS}{Q} + PD$$

$$\left(\frac{70}{2}\right) 4 = \left(\frac{816}{70}\right) 12 + 18(816) = N14{,}968$$

Since lower cost ranges exist, each must be checked against the minimum cost generated by 70 cases at 18 each. In order to buy at 17 per case, at least 80 cases must be purchased. The total cost at 80 cases will be:

TC80 = (80/2) 4 + (816/100) 12 + 17 (816) = N14,~~1~~.
To obtain a cost of 16 per case, at least 100 cases per order are required andthe total cost will be

TC100 = (100/2)4 + (816/100) 12+16 (816 = 13,354.
Therefore, since 100 cases per order yields the lowest total cost, 100 cases is the overall optimal order quantity. Next let us consider a situation, when carrying costs are expressed as a percentage of price; in this case you can determine the best purchase quantity with the following procedure

(1) Beginning with the lowest price compute the EOQs for each price range until an EOQ is found (i.e., until an EOQ is found that falls in the quantity range for its price).
(2) If the EOQ for the lowest price is feasible, it is the optimal order quantity. If the EOQ is not the lowest price range, compare the total cost at the price break for all lower prices with the total cost of the highest feasible EOQ. The quantity that yields the lowest total cost is the optimum.

To illustrate this, suppose Tijani electric uses 4,000 toggleswitches a year priced as follows: 1 to 499, 90 kobo each; 500 to 999, 85 kobo each: and 1,000 or more, 82 kobo each. It costs a approximately N18 to prepare an order and receive it and carrying costs are 18 percent of purchase price per unit on an annual basis. Determine the optimal order quantity and the total annual cost.

Solution

D = 4, 000 switches per year S = N18 H = 0.18P

Range	Unit Price	H
1 to 499	0.90	0.18 (0.90) = 0.1620
500 to 999	0.85	0.18 (0.85) = 0.1530
1000 0r	0.82	0.18 (0.82) = 0.1476

(a) Find the EOQ for each price, starting with the lowest price until afeasible EOQ is located.

EOQ0.82 = H

$$= \sqrt{\frac{2(4,00)\,18}{0.1476}} = 988 \text{ switches}$$

Since 988 stitches will cost N0.85 each, 988 is not a feasible EOQ. Next try 0.85 per unit

$$EOQ\ 0.85 = \sqrt{\frac{2\,(4000)18}{0.153}} = 970 \text{ switches}$$

This is feasible; 970 switches falls in the N0.85 range of 500 to 999.

(b) Compute TC for 970, and compare it to the total cost at the minimumquantity necessary to obtain a price of N0.82 per switch.

TC = carrying cost + ordering cost + purchase cost

$$= \left(\frac{Q}{2}\right) H + \left(\frac{D}{Q}\right) S + PD$$

TC 970= (970/2) (0.153) + (4,000/970) 18 + 0.85 (4,000) = N3, 548

Tc100= (1000/2 (0.1476) + (4,000/1,000) 18 + 0.82 (4,000) = N3, 426

Thus, the minimum cost order size is 1,000 switches.

4.6.4 When to Reorder with EOQ Ordering

EOQ models answer the question of how much to order but not the question of when to order. The latteris the function of models that identity the reorderpoint (ROP) in terms of a quantity: thereorder point occur when the quantity on hand drop to a Predetermine amount. The amount generally includes expected demand during lead time and perhaps an extra cushion of stock, which serves to reduce the probability of experiencing a stock out during lead time. There are four determinants of the reorder point quantity.

(1) The rate of demand (usually based on a forecast).
(2) The length of lead time.
(3) The extent of demand and/or lead time variability.
(4) The degree of stock-out risk acceptable to management.

If demand and lead time are both constant, the reorder point is simply: ROP =D x LT

Where

D = demand per day or week LT = lead time in days or weeks
Note: Demand and lead time must be in the same units.

The following example illustrates this concept: Osot takes Two – a Day vitamins, which are delivered to his home by salesman seven days after an order is called in. At what point should Osot telephone his order in?
Usage = 2 vitamins per dayLead time = 2 days
ROP = Usage x lead time
= 2 vitamins per day x 7 days
= 14 vitamins

Thus, Osot should reorder when 14 vitamin tablets are left. Now let us look at a scenario where demand or lead time is not constant as earlier assumed. If this is the case, there is the possibility that actual demand will exceed expected demand. It therefore becomes necessary to carry additional inventory called safety stock, to reduce the risk of running out of inventory (a stock-out) during lead time. The reorder point then increased by the amount of the safety stock.

ROP = Expected demand + safety stock during lead time.
For example, if expected demand during lead time is 100 units and the desireamount of safety stock is 10 units the ROP would be 110 units.

Service Level: Because it cost money to hold safety stock, a manager must
carefully weigh the cost of carrying safety stock against the reduction in stock– out risk it provides, since the service level increases as the risk of stock-out decreases. Order cycle service level can be defined as the probability thatdemand will not exceed supply during lead time

(i.e., that amount of stock on hand will be sufficient to meet demand) Hence a service level of 95 percentimplies a probability of 95 percent that demand willnot exceed supply during lead time.
An equivalent statement that demand will be satisfied in 95 percent of suchinstance does not mean that as percent of demand will be satisfied. The risk of a stock out is the compliment of service level; a customer service level of 95 percent implies a stock-out risk of 5 percent. That is service level = 100 percent – stock-out risk. Later you will see how the order cycle service level relates to annual service level.

The amount of safety stock that is appropriate for a given situation depends onthe following factors:

(1) The average demand rate & average lead time.
(2) Demand and lead time variability.
(3) The desire service level.

For a given order cycle, service level the greater the variability in either demand rate or lead time, the greater the amount of safety stock that will beneeded to achieve that service level. Similarly, for a given amount of variation in demand rate or head time, achieving an increase in the service level will require increasing the amount of safety stock. Selection of a service level may reflect stock out costs (e.g. lost sales, customer dissatisfaction) or it mightsimply be a policy variable (e.g. manager wanting to achieve a specified service level for a certain item). Several models will be described that can be used in cases when variability is present. Thefirst model can be used if an estimate of expected demand during lead time and its standard deviation are available. The formula:

ROP = expected demand + Z dLT during lead time.

Where

Z = Number of standard deviations
dLT = The standard deviation of lead time demand.
The models generally assume that any variability in demand rate or lead time can be adequately described by a normal distribution.

However, this is not astrict requirement; the models provide approximately reorder points even where actual distribution departs from normal.

The value of Z, used in a particular instance depends on the stock-out risk that the manager is willing to accept. Generally, the smaller the risk the manager is willing to accept, the greater the value of Z.

Let us illustrate this withanexample:

Suppose that the manager of a construction supply house determined from historical records that the lead time demand for sand averaged 50 tons. Inaddition, suppose the manager determined the demand during lead time could be described by a normal distribution that has a mean of 50 tons and a standard deviation of 5 tons. Answer the following questions assuming that the manager is willing to accept a stock out risk of no more than 3 percent.

(a) What value of Z is appropriate?
(b) How much safety stock should be held?
(c) What reorder point should be used?

Expected lead time demand = 50 tonsdLT = 5 tons
Risk = 3 percent

(a) From normal deviate table, using a service level of 1 – 0.3 =.9700 youobtain a value of Z = +1.82.
(b) Safety stock = Z dLT
= 1.88 (5)
= 9.40 tons
(c) ROP = expected lead time demand + safety stock
= 50 + 9.40
= 59.40 tons

If data are available, a manager can determine whether demand and/or lead time is variable, and if variability exist in one or both, the related standarddeviation. For those situations, one of the following formulae can be used.

If only demand is variable, then d LT =

1LT d and the reorder point is

ROP = *- d X LT + Z LT d (1)*

Where

$\bar{d}$ = *Average daily or weekly demand*
d = standard deviation of demand per day or week
LT = lead time in days or weeks if only lead time is variable, than dLT =d dLT

and the reorder point is ROP = d x LT + Z dLT

Where

d = Daily or weekly demand
LT = Average lead time in days or week
dLT = Standard deviation of lead-time in days or weeks. If both demand and lead-time are variables, then.
.... 2)

LT =
LT 22
d + d 2 LT

and the reorder point is

ROP = d1 x L1T1 + Z LT d 2 + d2 LT2 (3)

Note: each of these models assumes that demand and time are independent. Let us illustrate the use of these formulas with the following.

Example

Suppose a restaurant uses an average of 50 jars of a special sauce each week.
Weekly usage of sauce has a standard deviation of 3 jars. The manager iswilling to accept no more than a 10 percent risk of a stock-out during lead time, which is two weeks. Assume the distribution of usage is normal.

(a) Which of the above formulas is appropriate for this situation? Why?
(b) Determine the value of Z
(c) Determine the ROP

Solution

d = 50 jars per weekLT = 2 weeks
d = 3 jars per week
Acceptable risk = 10 percent, so service level is .90

(a) Because only demand is variable (i.e., has a standard deviation) formula (l) is appropriate
(b) From the normal distribution table, using a service level of. 9000, youobtain Z = + 1.28.
(c) ROP = d X LT + Z LT d

$= 50 \text{ X } 2 + 1.28\sqrt{2}\,(3)$
$= 100 + 5.43$
$= 105.43.$

4.7 How Much to Order: Fixed –Order-Interval Model.

When inventory replenishment is based on EOQ /ROP model, fixed quantities of items are ordered at varying time interval. Just the opposite occurs under the fixed-order-interval (FOI) model orders for varying quantities are placed at fixed time intervals (e.g. weeks, every 20 days).

4.7.1 Reasons for Using the Fixed-Order-Interval Model

In some cases, a supplier policy might encourage orders at fixed interval.Grouping orders for items from the same supplier can produce saving in shipping costs. Furthermore some situations to not readily lend themselves to continuous monitoring of inventory levels. Many retail operator (e.g. drug stores) falls into this category. The alternative for them is to use fixed-interval-ordering, which requires only periodic checks on inventory levels.

4.7.2 Determining the Amount to Order

If both the demand rate and lead time are constant, the fixed interval model and the fixed quantity model function identically. The difference in the two models becomes apparent only when examined under condition of variability. Like the ROP model, the two models can have variation in demand only, in lead timeonly, or in both demand and lead time. However, for the sake of simplicity ad because it is perhaps the most frequently encountered situation, the discussionhere will focus on variable demand and constant lead time.

Order size in the fixed-interval model is determined by the followingcomputation:
Amount = Expected demand during protection interval + safe stock –Amount on hand <u>at</u> reorder time
$= d\,(OI + LT) + Z\,d\,\sqrt{O1 + LT} - A$

Where

01 = order interval (length of time between order)
A = Amount on hand at reorder time

As in previous models, it is assumed that demand during the protection intervalis normally distributed.

Given the following information determine the amount to order d = 30 unit per day Desired service = 99 percent
d = 3 units per day
LT = 2 days Amount on hand at reorder time = 71 units
01 = 7 days

Solution

Z = 2.33 for 99 percent service level

Amount =$\bar{d}$ (01 + LT) + Z d $\sqrt{01 + LT}$ - A
= 30 (7+2) + 2.33 (3) $\sqrt{7+2}$ – 71 = 220 units

4.7.3 Benefits and Disadvantages

The fixed-interval system result in the tight control need for A items in an A-B-C classification due to the periodic review it requires. In addition, when two or more items come from the same supplier, grouping orders can yield saving in ordering, packing and shipping costs. Moreover, it may be the only practical approach if inventory withdrawal cannot be closely monitored.

On the negative side, the fixed system necessitate a large amount of safelystock fora given risk of stock-out because of the need to protect against shortage during an entire order interval pluslead time (instead of lead time only) and this increases the carrying cost. Also, there are the costs of the periodic reviews.

4.8 The Single-Period Model.

The single-period is used to handle ordering of perishable (e.g. fresh fruits, vegetables, seafood, cut flowers) and items that have a limited useful life (e.g. newspaper's magazines, spare parts for specialized employment.) The period for parts is the life of the equipment (assuming that the part cannot be used for other equipment) what sets unsold or unused goods apart is that they are nottypically carried over from one period to the next, at least not without penalty.

Day-old baked goods, for instance, are often sold at reduced prices, left overseafood may be discarded, and out of-date magazines may be offered to used book stores at bargain rates. At times, there may even be some cost associated with disposing of left over goods.

Analysis of single – period situation generally focuses on two costs: Shortages and excess shortage cost may include a charge for loss of customer goodwill as well as the opportunity cost of lost sales. Generally shortage cost is unrealised profit per unit. That is,

C shortage = C = Revenue per unit-cost.

If a shortage or stock – out relates to an items used in production or to a spare parts for a machine, thenshortage cost refer to the actual cost of production. Excess costpertains to items left over at the endof the period. In effects, excess cost is the difference between purchase cost and salvage value. That is C excess = C2 = Original cost per unit – salvage value per unit.

If there is cost associated with disposing of excess items, the salvage will be negative and will therefore increase the excess cost per unit. The goal of the single-period model is to identify the order quantity or stocking level that will minimize the long-run excess and shortages costs.

There are two general categories of problem that we will consider; those for which demand can be approximated using a continuous distribution (perhaps a theoretical one such as a uniform or normal distribution) and those for which demand canbe approximatedusing a discrete distribution (say historical frequencies or a theoretical distribution such as the Poisson). The kind of inventory can indicate which types of model might be appropriate. For example demand for petroleum, liquid and gases tend to vary over some continuousscale, thus lending itself to description by a continuous distribution. Demand for tractors cars and computer is expressed interms of the number of unitsdemanded and lends itself to description by a discrete distribution.

4.8.1 Continuous Stocking Levels

The concept of identifying an optimal stocking level is perhaps easiestto visualize when demand is uniform. Choosing the stocking level is similar tobalancing a seesaw, but instead of a person on each end of the see saw, we have excess cost per unit (Ce) on one and of the distribution and shortage cost perunit (Cs) on the other. The optioned stocking level is analogous to the fulcrum of the seesaw; the stocking level equalizes the cost weights, as illustrated in the figure below.

The service level is the probability that demand will not exceed the stocking level, and computation of the service level is the key to determining the optimal stocking level, so

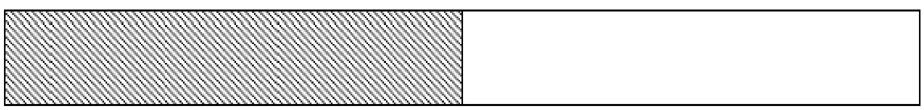
$$\text{Service level} = \frac{C_s}{C_s + C_e}$$

Where

C_s = shortage cost per unit
C_e = Excess cost per unit

$\uparrow C_e$ $\downarrow C_s$

Service level



S_0 quantity
Balance point
S_o = optimum stocking quantity

If actual demand exceeds S0 there is a shortage: hence Cs is on the right end of the distribution. When Ce = Cs the optimal stocking level is half way between the end points of the distribution. If one cost is greeter than the other, S0 will be
closer to the larger cost.

A similar approach applies if demand is normally distributed.

Example

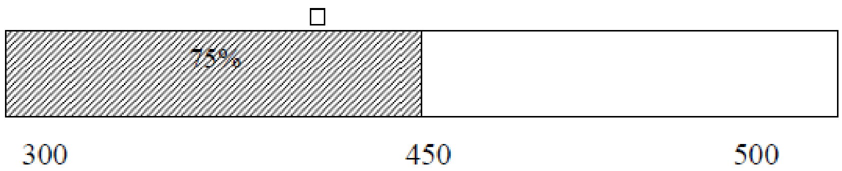
Sweet order is delivered whereby to Osot's produce stand. Demand varies uniformly between 300 litres and 500 litres per week. Osot pays 20 kobo per litres for the cider and charges 80 kobo per litre for it. Unsold cider has no salvage value and cannot be carried over into the next week due to spoilage. Find the optimal stocking level and its stock-out risk for that quantity.

C_e = cost per unit – Salvage Value per Unit
= ₦ 0.20 - ₦ 0
= ₦ 0.20 per unit

$$SL = \frac{C_s}{C_s + C_e} \quad \frac{₦\,0.06}{₦\,0.06 + ₦\,0.20} = .75$$

Thus, the optimal stocking level must satisfy demand 75 percent of the time. For the uniform distribution this will at a point equal to the minimum demand plus 75 percent of the difference between maximum and minimum demands

$S_0 = 300+0.75\ (500 - 300) = 450$ litres



The stock out risk is $1.00 - 0.75 = 0.25$

Suppose Osot's stand also sells blend of cherry juice and apple cider. Demand for the blend is approximately normal with a mean of 200 litres per week and a standard deviation of 10 litres per week. C_s = 60 kobo per litre, and C_e = 20 kobo per litre find the optimal stocking level for the apple cherry blend.

$$S_L = \frac{C_s}{C_s + C_e} = \frac{₦\,0.60}{₦\,0.60 + ₦\,0.20} = .75$$

This indicates that 75 percent of the normal curve must be to the left of the stocking level. Normal Table shows that a value of Z between + 0.67 and 0.68 say, + 0.675, will satisfy this.

$$\text{Thus, } S_0 = 200 \text{ litres} + 0.675\ (10 \text{ litres})$$
$$= 206.75 \text{ litres}$$

4.8.2 Discrete Stocking Level

When stocking level are indiscrete rather than continuous, the service level computed using the ratio C_s / (Cs + Ce) usually does not coincide with a feasible stocking level (e.g. the optimal amount may be between a five and six units). The solution is to stock at the next higher level (e.g. six units).

In other words, choose the stocking level so that the desire service level is equalled or exceeded.

Example

Historical records on the use of spare pats for several large hydraulic presses are to serve as an estimate of usage for spares of a newly installed press. Stock-out costs involve downtime expenses and special ordering cost. There average ₦4, 200 per unit short. Spares cost ₦ 800 each, and unused parts have zero salvage. Determine the optimal stocking level.

Nos of spare used	Relative frequency	Cumulative frequency
0	.20	. 20
1	.40	. 60
2	.30	.90
3	.10	1.00
4 or more	.00	1.00
	1.00	

C_s = ₦ 4,200 C_e = ₦ 800

$$S_L = \frac{Cs}{C_e + C_s} = \frac{₦\ 4{,}200}{₦\ 800 + ₦\ 4{,}200} = 0.90$$

The cumulative frequency column indicates the percentage of time that demand did not exceed (has equal to or less than) some amount. For example, demand does not exceed one spare 60 percent of the time or two spares 90 percent of the time. Thus, in order to achieve a service level of at least 90 percent, it will be necessary to stock two spare (i.e. to go to the next highest stocking level). Let's consider another example:

Suppose the demand for long steamed red roses at a small flower shop can be approximated using a Poisson distribution that has a mean of four dozens per day. Profit on the roses is N 3 per dozen. Left over flowers are marked down and sold the next day at a loss of N 2 per dozen. Assume that all marked down flowers are sold. What is the optimal level?

C_s = ₦ 3 C_e = ₦ 2

$$SL = \frac{Cs}{C_s + C_e} = \frac{₦\ 3}{₦\ 3 + ₦\ 2} = .60$$

Obtain the cumulative frequency from the Poisson table for a mean of 4.0

Demand (dozen per day)	Cumulative frequency
0	018
1	092
2	238

3	434
4	629
5	785
-	-
-	-

Compare the service level to the cumulative frequency. In order to attain aservice level of at least .60 it is necessary to stock four dozens.

4.8.3 Operation Strategy

Inventories are necessary parts of doing business, but having too much inventory is not good. One reason is that inventories tend to hide problems: they make it easier to "live with" problems rather than eliminate them. Another reason is that inventories are costly to maintain. Consequently, a wise operation strategy is to work toward cutting back inventories by (1) reducing lot size (2) reducing safety stocks.

Japanese manufactures use smaller lots sizes than their western counterparts because they have a different perspective on inventory carrying costs. Recall that carrying costs and ordering costs are equal at the EOQ. A higher carrying cost, results in a steeper carrying-cost line, and the resulting intersection with the ordering-cost line at a smaller quantity; hence, a smaller EOQ.

The second factor in the EOQ mode that can contribute to smaller lot seizes is the set up or ordering processing cost. Numerous cases can be cited where these costs have been reduced through research efforts.

However while reduction due to carrying costs stems from a reassessment of those costs, a reduction due to ordering or set up cost must come from actually pursuing improvement. Together, these cost reduction can lead to even smaller lot seizes.

Additional reductions in inventory can be achieved by reducing the amount of safety stock carried. Important factor in safety stock are lead time variability, reductions of which will result in lower safety stocks. These reductions can often be realized by working with supplier, choosing suppliers located close to the buyer, and shifting to smaller lot sizes.

To achieve these reductions, an A-B-C approach is very beneficial. This means that all phases of operation should be examined, and those showing the greatest potential for improvement (A items) should be attacked first.

Last, it is important to make sure that inventory records be kept accurate and up to date. Estimated of holding costs, setup costs, and lead time should be reviewed periodically and updated as necessary.

SELF-ASSESSMENT EXERCISES

What are the effective requirement for inventory management

4.9 Summary

Good inventory management is often the mark of a well-run organization. Inventory levels must be planned carefully in order to balance the cost ofholding inventory and the cost of providing reasonable levels ofcustomer service. Successful inventory transactions, accurate information about demand and lead times, realistic estimates for certain inventory-related costs, and a priority system for classifying the items in inventory and allocating control efforts.

The models described in this unit are relevant for instances where demand for inventory items is independent. Four classes of models are described; EOQ, ROP, fixed-interval and the single-period models. The first three are appropriate if unused items can be carried over into subsequent periods. The single-period model is appropriate when items cannot be carried over. EOQ models address the question of how much to order. The ROP models address the question of when to order and are particularly helpful in dealing with situations that include variations in either demand rate or leadtime. ROP models involve service level and safety stock considerations. When the time between orders is fixed, the F0I model is useful. The single-period model isused for items that have a "shelf life" of one period.

4.10 References/Further Readings/Web Resources

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Bonini, C.P, W.H. Hansman and H. Bierman, Jr (1997): Quantitative Analysis for Management Chicago: Irwin.

4.11 Possible Answers to Self-Assessment Exercises

What are the effective requirement for inventory management
To be effective management must have the following:

1. A system to keep track of the inventory on hand and on order.
2. A reliable forecast of demand that includes an indication of possible forecast error.
3. Knowledge of lead times and head time and lead time variability.
4. Reasonable estimates of inventory holding costs, ordering costs and shortage costs.
5. A classification system for inventory items.

MODULE 3 CONTROL DECISIONS

UNIT 1 AGGREGATE PLANNING

Unit Structure

1.1 Introduction

This unit introduces the concept of aggregate planning, which is the intermediate range of capacity planning that typically covers a time horizon of 2 to 12 month. In some organisations, this time horizon might be extended to as much as 18 months. It is particularly useful for organisations that experienceseasonal orother fluctuations in demand or capacity. The goal of aggregate planning is to achieve a production plan that will effectively utilizethe organisations resources to satisfy expected demand.

1.2 Learning Outcomes

By the end of this unit, you will be able to:

- Explain what aggregate planning is and how it is useful
- Identify the variables decision makers have to work with in aggregate planning
- Identify some of the possible strategies decision makers use
- Describe some of the techniques planners use.

1.3 Production – Planning Hierarchy

Generally, organisations become involved with capacity decisions on three levels: Long-term, intermediate term, and short-term. Long term decisions usually relate to:

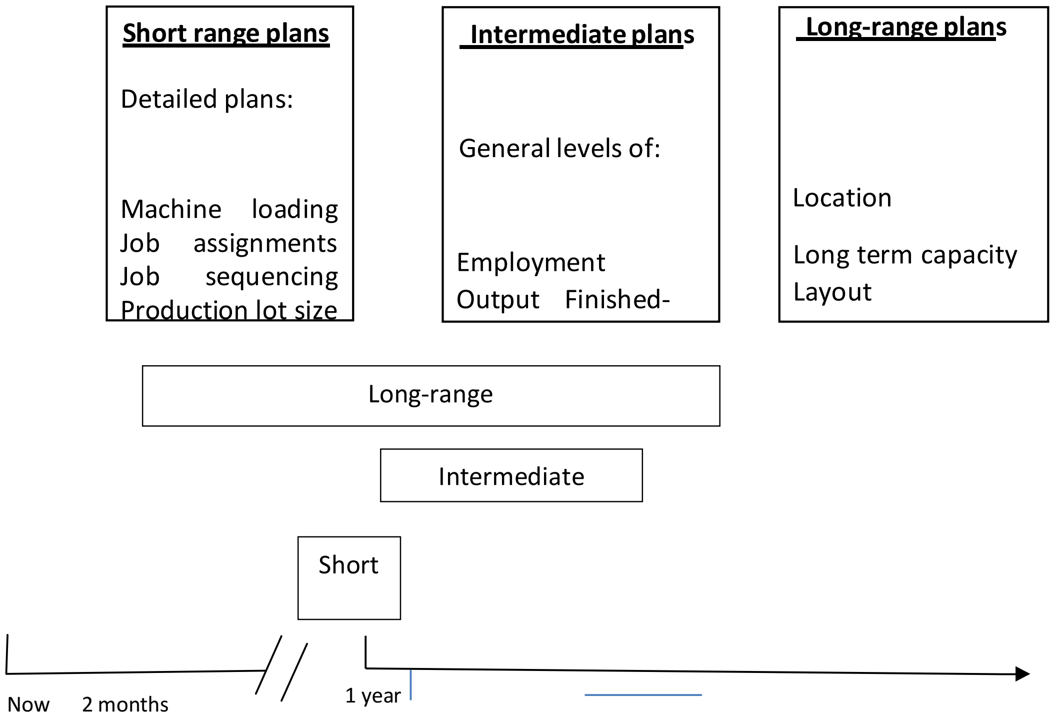
(i) Product and service selection i.e. determining which predicts or servicesto offer;
(ii) Facilities i.e. plan locations, layout, size send capacities
(iii) Processing plans i.e., new production technology, new productionprocesses, new systems of automation etc; and
(iv) Major supplier plans and amount of vertical integration.

These long-term decisions essentially define the capacity decisions naturally set the capacity constraints within which intermediate planning must function.

Aggregate planning develops medium-range production plans concerning employment level and changes, inventory levels and changes, utilities, facility modifications, back orders, and subcontracting.

These aggregate plans in turn impose constraints on the short range production plans that follow. Short term decisions, therefore, essentially relate to taking decisions onthe best way to achieve desired results within the constraints resulting from long-term and intermediate decisions. These involve scheduling jobs, machine loading, job sequencing etc. the three levels of capacity decisions are illustrated in Table10.1

Table 10.1: Overview of planning levels



It is usual to find many business organisations developing a business plan that comprises both long-term and intermediate-term planning. This business plan sets guidelines for the organisations, taking into account the organisationsstrategies and policies; forecasts of demand for the organisation's products or services; and economic, competitive,and political conditions. A major objective in business planning is to coordinate the intermediate plans of various organisations functions, such as marketing, operations, and finance. In the case of manufacturing firms elements of engineering and materials management also form part of the coordination.

The business plan guidesthe planningprocesses of each functional area. Forexample, in operations functions, a production plan (or operations plan in the services organisation) is usually developed to guide the more detailed planning that eventually leads to a master schedule. The illustration of the planningsequence is given in Figure 10.2.

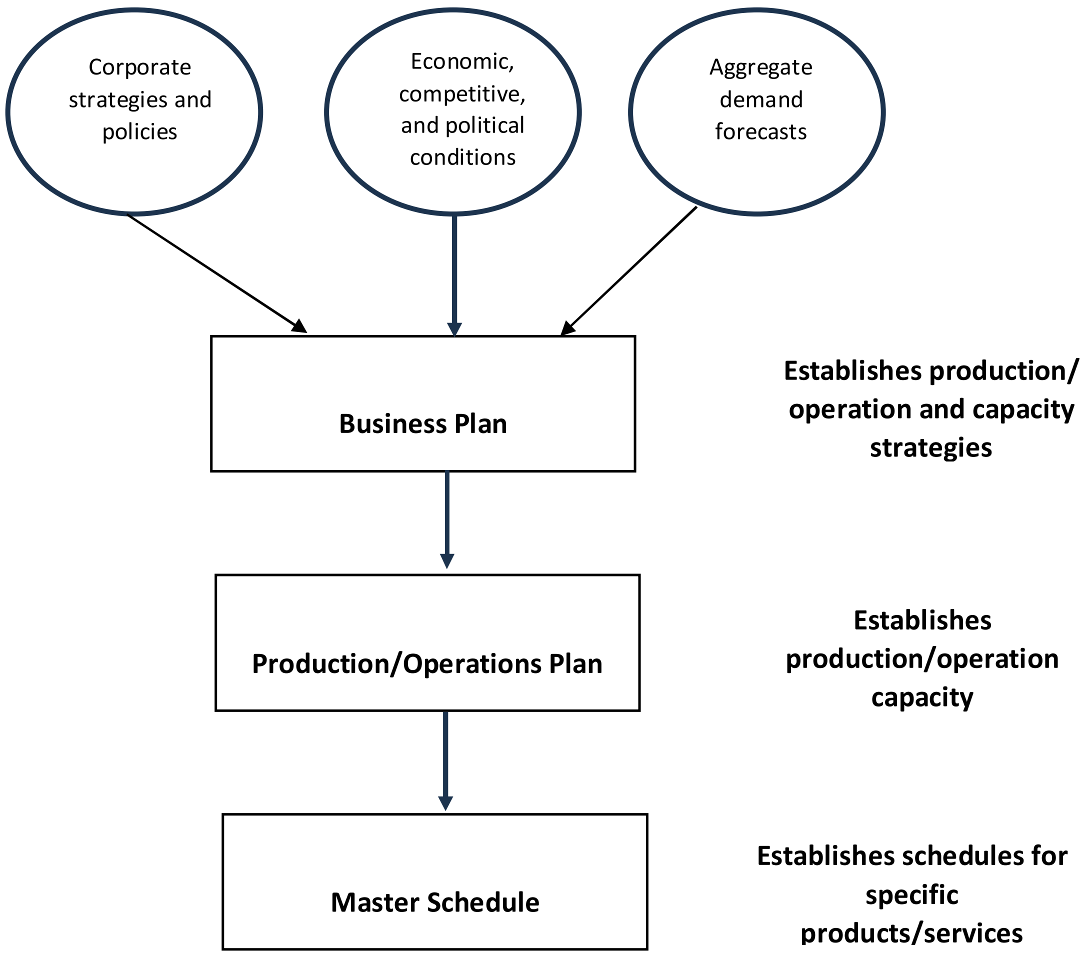
SELF-ASSESSMENT EXERCISE (SAE) 1

What three levels of planning involve operations managers? What kinds of decisions are made at the various levels?

1.4 The Concept of Aggregation

Aggregate planning can be looked at as a "big picture" approach to planning. It is the usual practice for planners to try to avoid focusing on individual products or services, unless the organisation deals in only product or service. Rather, they focus on a group of similar products or sometimes an entire product line.

Figure 10.2: Planning Sequence



Let's look at some examples:

(a) For purposes of aggregate planning, planners in a television manufacturing firm would not concern themselves with 21 –inch setsversus 18-inch or 14-inch. Instead, they would lump all models together and deal with them as a simple product. Hence, the term aggregateplanning.

(b) Again, for the purposes of aggregate planning, a refrigerator manufacturing firm might lump all different sizes and styles of refrigerators it produces into a single category of "frigdes".

(c) In the same vein, when fast-food outfit such as Mr. Biggs, sweet sensation, and Tasty Fried Chicken plan employment and output levels, they would not try to determine how demand will be broken down into the various options they offer. Instead, they focus generally on overall demands and the overall capacity they want to provide.

In each of the examples cited above, it can be seen that an aggregate approach permits planners to make general decisions about intermediate – range capacity without having to deal with highly specific details. Instead, they often concern themselves with overall decision on levels of output, employment and inventories. This is done by lumping demand for all products into one or a few categories, and then planning on that basis.

For purposes of aggregate, it is better to think of capacity in terms of labour hours or machine hours per period, or output rates (e.g. barrels per period, units per period), without necessarily worrying about how much of a particular itemwill actually be involved .

The advantage in this approach is that it frees planners to make generaldecision about the use of resources without having to get into the complexities of individual product or service requirements.

1.4.1 The Purpose and Scope of aggregate Planning

We shall briefly examine the basic problem addressed by aggregate planning(i.e the balancing of supply and demand) along with the purpose of aggregate planning, the primary decision variable available to planners and associated costs.

1.4.2 Demand and Capacity

Aggregate planners are usually pre-occupied with the quantity and timing ofexpected demand. For instance, it total expected demand for the planning period is much differentfrom available capacity over the particular planning period, the major approach of planners is either to try to increase demand (incase demand is less than capacity) or increase capacity (demand exceeds capacity). It could happen that capacity and demand are approximately equal for the planning horizon as a whole. Even here, planners may still be faced with the problem of dealing with uneven demand within the planning interval. For example, in some periods, expect demand may exceed projected capacity; in others, expected demand may be less than projected capacity, and in some periods, the two may be equal, thus, the task of aggregate demand is to achieve rough equality of demand and capacity over the entire planning horizon.

1.4.3 The Purpose of Aggregate Planning.

The major purpose of aggregate planning is to develop a feasible production plan on an aggregate level that achieves a balance of expected demand and supply. Furthermore, planners are usually concerned with minimising the cost of the production plan. However, cost is not the only consideration.

Generally, aggregate planning is necessary in Production and OperationsManagement because it provides for:

- (i) Fully loaded facilities and minimisies over-loading and under-loading,thereby reducing production costs.
- (ii) Adequate production capacity to meet expected aggregate demand
- (iii) A plan for the orderly and systematic change of production capacity to meet the peaks and valleys of expected customer demand.
- (iv) Getting the most output for the amount of resources available, which isimportant in time of scarce production resources.

1.4.4 Inputs to Aggregate Planning

For an effective aggregate planning to take place, at least three important informational needs must be met. First, the available resources over the planning period must be known. Second, a forecast of expected demand must also be available. Thirdly, planners much take into account any policies regarding changes in employment levels. For example, some organizations view layoffs as extremely undesirable, so they would exclude that option from consideration, or use it only as a last resort). Added to these inputs are the costs of activities, such as inventory carrying costs, general costs of backorders, hiring/firing, overtime, inventory changes and subcontracting.

1.4.5 Demand and Capacity Options

For the purposes of aggregate planning, management has a wide range of decision options at its disposal. Among these are changing prices, promotion, backlogging orders, using overtime, using part-time workers, subcontracting, adding or deleting extra shifts, and stockpiling inventories. Some of these options are for the purposes of altering the pattern of demand. Examples here include pricing and promotion. Others, suchas using part-timeworkers, overtime, and subcontracting represent options that are being used to alter capacity or supply we shall examine these options in the section that follow:

1.4.5.1Demand Options

There are four basic demand options: pricing, promotion, back-orders and newdemand.

1. **Pricing: Differential pricing is often used to shift demand from peak** periods to off-peak periods. For example, some air-lines offer lower fares for mid-week travel and change higher fares other times. Similarly, some restaurants offer "early bird specials" in an attempt to shift someof the heavier dinner demand to an earlier time that traditionally has less traffic. Another example is to be found in the telephone service sector, where there are different rates for peak and off-peak periods. If the pricing is effective, demand will be shifted so that it corresponds closely to capacity, except for an opportunity cost that represents the lost profit stemming from capacity insufficient to meet demand during certain period. The major analytical factors to consider is the degree of priceelasticity for the product or service: the more the elasticity, the more effective pricing will be in influencing demand patterns.

2. **Promotion: Promotional tools such as advertising, displays, direct** marketing etc., can sometimes be effective in shifting demand so that it conforms more closely to capacity. The timing of these efforts and knowledge of response rates and response patterns will needed to achieve the desired results. However, unlike pricing policy, there ismuch less control over the timing of demand.

3. **Back orders:** Back orders involves taking orders in one period, and promising deliveries for a later period. This approach can be used by an organisation to shift demand to other periods. The success of back orders however depends on the willingness of customers to want for later delivery. In addition, the hidden costs associated with back orders can be difficult to pin down, since it would include lost sales, annoyed or disappointed customers, and additional paperwork.

4. **New Demand: In situations where demand is very uneven,** organizations often face the problem of having to provide productsor services for peak demand, for instance, demand for public transportation tends to be more intense during the moving and late afternoonrush hours; ironically, the demand is much lighter at other times. By creating new demand for buses at these other times, (e.g. excursions by school, clubs etc) there would be an opportunity to make use of the excesscapacity during such slack periods. This way, organisations can achieve a more consistent use of labour, equipment and facilities.

1.4.5.2 Capacity Options

There are five basic options available for altering the capacity (or supply) orproduction. These are discussed below:

1. **Hire and Fire Workers:** The main determinant of the impact changes in the workforce level will have on capacity is the labour – intensiveness of operations. Another factor is the resource requirements of each worker. For instance, if a transport service firm has 15 drivers for its fleet of 22 buses, an additional seven drivers could be hired.

   Thus, the ability to add workers is constrained at some point by other resources needed to support the workers. On the other hand, there may be a lower limit on the number of workers needed to maintain a viable operation (e..g a skeleton crew).

   At times, union contracts may restrict the amount of hiring and firing anorganisation can do. Furthermore, since the issue of firing and laying-off can give workersserious problems, some or ganisations have policiesthat either disallowed or limit downward adjustments to a workforce. On the other hand, hiring presumes an available supply of workers. There are times when labour may be in short supply, and hence have an impact on the ability of an organisation to pursue this approach.

It is necessary to know that hiring and firing entails certain costs. Forinstance, hiring costs include recruitment, screening, and training to bring newworkers "up to speed". Andquality may suffer.

However,some savings may occur if previously laid off workers are re-hired.

Firing costs include payment of terminal benefits, the cost of realigning the remaining workforce, potential bad feelings toward the firm on the part of fired workers, and some lossof morale for workers who areretained.

2. **Overtime/Slack time:** The use of overtime or slack time is a less severe method for changing capacity than hiring and firing workers. It cangenerally be used across the board or selectively as needed. In addition, it can also be implemented more quickly than hiring and firing, and allows the firm to maintain a steady base of employers. In particular, overtime can be very attractive in dealing with seasonal demand peaks by reducing the need to hire and train people who will eventually be laid off during the off-season. Overtime also allows the firm to maintain a skilled workforce and employees to increase earnings. However, overtime often results in lower productivity, poorer quality, more accidents, and increased payroll costs, whereas idle time results in less efficient use of machines, and other fixed assets.

3. **Part-time workers:** The use of part-time workers has been found to be a viable option in particular situations. It usually depends on the nature of the work, training and skills needed, and union agreements. Seasonal work that require low-to-moderate job skills lends itself to part-time workers, who generally cost less than regular workers in hourly wages and fringe benefits.

4. **Inventories: The use of finished goods inventoriesallows forms to**produce goods in one period and sell them in another period. This normally involves holding or carrying such goods as inventory until they are needed. In essence, inventories can be built up during periods when production capacity exceeds demand and drawn down in periods when demand exceeds production capacity.

   The use of inventories is not without its costs, such as storage costs, cost of money tied up, costs of insurance, obsolescence, deterioration, spoilage, breakage etc.

5. **Subcontracting:** Subcontracting allows organizations to acquire temporary capacity. However, organisations often have less control over the output; hence this approach may lead to higher costs and qualityproblems. The decision of whether to make or buy (i.e., in manufacturing) or to perform a service or hire someone else to do the work generally depends on such factors as available capacity, relative expertise, quality considerations, costs and the amount and stability of demand.

It is possible for a firm to choose to perform part of the work itself, and let others handle the remaining so as to maintain flexibility and as a hedge against loss of a subcontractor. In addition, this approach gives the firm a bargaining power in negotiations with contractor and a head start, if it decides at a later date to take over the production entirely.

SELF-ASSESSMENT EXERCISES 2

i. Why is there a need for aggregate planning?
ii. What are the three phases of aggregate planning?

1.5 Basic strategies for Meeting Uneven Demand

From our discussions in section 3.3.34 and its subsections, it should be clear to you that manages have a wide range of decision options they can consider for achieving a balance of demand and capacity in aggregate planning. The options that are most suited to influencing demand fall more in the area of marketing than in Operations (with the exception ofbacklogging). Hence we will be concentrating on the capacity options here, within the ambit of operations (With the inclusion of back orders).

There are anumber of strategies open to aggregate planners. Some of thenotable ones include:

1. Maintaining a level workforce
2. Maintaining a steady output rate
3. Matching demand period by period
4. Using a combination of decision variables.

The first three strategies can be regarded as “pure” strategies since each of them has a single focal point. The fourth strategy is however “mixed” because it lacks the single focus. With respect to the level capacity strategy, variations in demand are met by using some combination of inventories, overtime, part- time workers, subcontracting and back orders. The purpose here is to maintain a steady rate of regular-time output, although total output could vary. Maintaining a steady rate of output means absorbing demand variations with inventories, subcontracting, or backlogging. In the case of Chain demand strategy, capacity is match to demand, whereby the planned output for a period is set at the expected demand for that period.

Maintaining a level workforce has been found to have strong appeals in some organisations. And as earlier mentioned, workforce changes through hiring and firing often have a major impact on the lives and morale of employees hence can be disruptive for managers. Consequently, organisations usually prefer to handle uneven demand in other ways. Again, as already mentioned, changes in workforce size can be very costly and there is always the risk that a sufficient pool of workers with the appropriate skills may not be forthcoming when needed. Furthermore, such changes can involve a significant amount of administrative work.

In order to maintain a constant level of output and still meet demand requirements, an organisation necessarily needs to resort to some combination of subcontracting, backlogging, and use of inventories to absorb fluctuations: subcontracting requires an investment in evaluating sources of supply as well as possible increased costs, less control over output, and quality considerations.
Backlogs may lead to lost dales, increased record keeping and lower levels of customer services. With regard to the issue of allowing inventories to absorb fluctuations, it has been realized that such an alternative also has substantial costs. These including having money tied up in inventories, having to maintain relatively large storage facilities, and incurring other costs related to inventories.

Actually, inventories are not usually an alternative for service – oriented organisations, however, there are certain advantages inherent in the strategy: minimum costs of recruitment and training, minimum overtime and idle-time costs, fewer morale problems and stable use of equipment and facilities.

It is assumed in the chase demand strategy, that there is a great deal of ability and willingness on the part of managers to be flexible in adjusting to demand.

One important advantage of this approach is that inventories can be kept relatively low, and this can yield substantial savings for an organisation. A major limitation is the lack of stability in operations i.e the organisation has to dance to demand's tune.

In addition, where there are gaps between forecasts and reality, morale maysuffer since it quickly dawns on workers and managers that lot of efforts have been wasted.

Another alternative approach for organisations is to opt for a strategy that involves some combination of the pure strategy. This often permits managers greater flexibility in dealing with uneven demand, as well as in experimenting with a wide choice of alternatives. The major problem inherent in this mixed strategy is the absence of a clear focus, which may lead to an erratic approach and confusion on the part of employees.

3.5.1 How to choose a strategy

All the four strategies discussed above have their merits as well as limitations. Organisations are free to choose anyone. Whatever strategy an organization is considering however depends on two important factors: company policy andcosts. Company policy may set constraints on the available options or the extent to which they can be used. For instance, company policy may discourage firing and layoffs, except under unavoidable conditions. Similarly, sub-contracting may not be a viable option due to the desire to maintain secrecyabout some aspects of the manufacturing of the product.

1.6 Analytical Techniques For aggregate Planning

There are many techniques which can assist planners with the task of aggregate planning. These are broadly placed into one of two categories; informal trial- an-error techniques and mathematical techniques. The informal techniques are re widely used.

1. Determine demand for each product
2. Determine capacities (regular time, overtime, subcontracting) for eachperiod
3. Identify company or departmental policies that are pertinent.(e.g. maintaina safety stock of 5 percent of demand, maintain a reasonably stable workforce).
4. Determine unit costs for regular time, overtime, subcontracting, holdinginventories, back orders, and other relevant costs.
5. Develop alternative plans and compute the costs for each
6. If satisfactory plans emerge, select the one that best satisfies objectives.Otherwise, return to step 5.

It may be helpful to use a worksheet that summarises demand, capacity, and cost for each plan. This is shown in Figure – 3. Graphs can also be used to guide the development of alternatives.

Figure 3: Example of a Worksheet

Period	**1**	**2**	**3**	**4**	**5**		**Total**
Forecast							
Output Regular time Overtime Subcontract Output- Forecast Inventory Beginning Ending Average Backlog							
Costs Output Regular Overtime Subcontract Hire/Lay off Inventory Back orders							
Total							

1.6.1 Informal Techniques

These usually consist of developing simple tables or graphs that allow planners to virtually compare projected demand requirements with existing capacity.The various alternativesare then evaluated on the basis of their overall costs.

The major limitation of these techniques is that they do not necessarily result inthe optional aggregate plan.

Let us make use of an examples provided by Stevenson (1996). It is based onthe following assumptions:

1. The regular output capacity is the same in all periods. No allowance is made for holidays, different numbers of workdays

in different months. Etc. this has been done for simplicity and ease of computation.

2. Cost (back order, inventory, subcontracting etc) is a linear functioncomposed of unit cost and number of units, this often has a reasonable approximation to reality, although there maybe only narrow ranges over which this is true. Cost is sometimes more of a step function.
3. Plans are feasible: i.e. sufficient inventory capacity exists to accommodate a plan, sub-contractors with appropriate quality andcapacity are standing by and changes in output can be made as needed.
4. All costs associated with a decision option can be represented by a lump sum or by unit costs that are independent of the quantity involved.Again, a step function may be more realistic; but for purposes of illustration and simplicity, this assumption is appropriate.
5. Cost of figures can be reasonably estimated and are constant for theplanning horizon.
6. Inventories are built up and drawn down at a uniform rate and output occurs at a uniform rate throughout each period. However, backlogs are treated as if they exist for an entire period, even though in periods where they initially appear, they would tend to build up toward the end of the period. Hence, this assumption is a bit unrealistic for some periods, but it simplifies computations.

   In addition to the assumptions above, the following relationships are used in the determination of the number of workers, the amount of inventory, and the cost of a particular plan.

(a) the number of workers available in any period is:

Number of *Numbers* of Number of new Number of laid ɵf Workers in a = workers at end of + -workers at start workers at start of Period the previous period of the period the period

(b) The amount of inventory at the end of a given period is:Inventory at the end of a period Inventory at end Production in Amount used to satisfy =o+f -the previous the current demand in the currentperiod period period

(c) The average inventory for a period is equal to:

Beginning Inventory + Ending Inventory

(d) The cost of a particular plan for a given period can be determined bysumming the appropriate costs:

Cost for a period
Output cost Hire / Fire Inventory Back - order
= + + +
(Regular + Overtime + SubcontraCtos cost Cost
The appropriate costs are calculated as follows:

Type of Cost	How to Calculate
Output	
Regular	Regular cost/unit x quantity of regular output
Overtime	Overtime cost/unit x overtime quantity
Subcontract	Subcontract cost/unit x subcontract quantity
Hire/Fire	Cost/hire x Number hired
Hire Fire	Cost/Fire x Number fired

Let us make use of an example to illustrate the process of developing and evaluating an aggregate plan; with the trial and error techniques. Note that the intention here is not to find the lowest cost plan. With trial and error, one can never be completely sure that the lowest cost alliterative has been found, unless all possible alternatives are evaluated.

Example

Planners for a company are about to prepare the aggregate plan that will coversix periods. They have assembled the following information:

Period	1	2	3	4	5	6	Total
Forecast	200	200	300	400	500	200	1,800

Costs
Output
Regular time = N2/unit
Overtime = N3/unit
Subcontract = N6/unit
Inventory = N1/unit/period on average inventory
Back orders = N1/unit/period

They now want to evaluate a plan that calls for a steady rate of regular time output, mainly using inventory to absorb the uneven demand, but allowing some backlog. They intend to start with zero inventories on hand in the first period. Prepare an aggregate plan and determine its cost using the preceding information. Assume a level output rate of 300 units per period with regular time (i.e. 1,800/6 = 300). Note that the planned ending inventory is zero. There are 15 workers.

Solution

Period	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Output							
Regular	300	300	300	300	300	300	1,800
Overtime	-	-	-	-	-	-	
Subcontract	-	-	-	-	-	-	
Output – Forecast	100	100	0	(100)	(200)	100	0
Inventory							
Beginning	0	100	200	200	100	0	
Ending	100	200	200	100	0	0	
Average	50	150	200	150	50	0	600
Backlog	0	0	0	0	100	0	100
Costs							
Output							
Regular	N600	600	600	600	600	600	3,600
Overtime	-	-	-	-	-	-	
Subcontract	-	-	-	-	-	-	
Hire/Fire	50	150	200	150	50	0	600
Inventory	0	0	0	0	500	0	500
Back orders							
Total	**650**	**750**	**800**	**750**	**1,150**	**600**	**4,700**

Note that the total regular-time output of 1,800 units equals the total expected demand. Ending inventory equals beginning inventory plus or minus thequantity output-forecast.

1.6.2 Mathematical Techniques

Some mathematical techniques are available to handle aggregate planning. The notable one include linear programming techniques, linear decision rule and simulation models. We shall briefly describe these techniques.

1.6.2.1Linear Programming

These are methods for obtaining optimal solutions involving the allocation of scarce resources in terms of cost minimization or profit maximisation. With aggregate planning, the goal is usually to minimise the sum of costs related to regular labour time, overtime, subcontracting, inventory,holding costs, and costs associated with changing the size of the workforce. The capacities of the workforce, inventories, and subcontracting constitute the constraints.

1.6.2.2Linear Decision Rule

The Linear decision rule is another optimising technique. It was developed in the1950s, by CharlesHolt, Franco Modigliand, John Mush, and Herbert Simon. Its objectives are to minimize the combined costs of regular payroll, hiring and layoffs, overtime, and inventory by using a set of cost- approximation function.

Three at these functions are quadratic in order to obtain a single quadratic equation. With the use of calculus, two linear equations can be derived from the quadratic equation. One of the equations can be used to plan the output for each period in the planning horizon, and the other can be used to plan the workforce for each period. The model has been found to suffer from three limitations. In the first place, a specific type of cost function is assumed. Secondly, considerable efforts must usually be expended in obtaining relevant cost data and developing cost functions for each organisation. Finally, the method can produce solutions that are unfeasible orimpractical.

1.6.2.3Simulation Models

In addition to the first two techniques, some simulation models have beendeveloped for aggregate planning. The essence of simulation is the development of computerized models that can be tested under a variety ofconditions in an attempt to identify reasonably acceptable solutions to problems.

1.7 Disaggregating the Aggregate Plan

There is the need to disaggregate the aggregate plan so that the production plan might be translated into meaning terms for production. This generally involves breaking down the aggregate plan into specific product requirements in order to determine labour requirements (skill, size of work force), materials and inventory requirements.

It is a fact that working with aggregate units often facilitates intermediate planning. However, for the production plan to be put into operation, those aggregate units must be decomposed into units of actual products or services that are to be produced or offered.

The result of disaggregate the aggregate plan is a master schedule, showing the quantity and timing of specific and items for a schedule horizon (Which often covers about six to eight weeks ahead).

The master schedule shows demand for individual products rather than an entire product group, along with the timing of production. The master schedule usually contains important information for marketing as well as for production. It reveals when orders are scheduled for production and when completed orders are to be shipped.

Self-Assessment Exercise (SAE)

1. In aggregate planning, outline and discuss the four basic demand options
2. There are five basic options available for altering the capacity, elucidate?

1.8 Summary

Aggregate planning establishes general levels of employment, output, and inventories for periods of two to twelve months. In the spectrum of planning, it falls between the broad design decisions of long-range planning and the veryspecific and detailed short-range planning decisions. It begins with overallforecasts for the planning horizon and ends with preparations for applying the plans to specific products and services.

1.9 References/Further Readings/Web Resources

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Vollmann, T.E., Berry W.L. and D.C. Whyback (1992): Manufacturing Planning and Control System. 3rd ed. Burr Ridge. Ill: Richard O. Irwin.

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1.10 Possible Answers to Self Assessment Exercises

1. There are four basic demand options: pricing, promotion, back-orders and newdemand
2. The five basic options available for altering the capacity are 1) Hire and fire; 2) Overtime/slack time; 3) Part-time workers; 4) Inventories and 5) subcontracting

UNIT 2 LINEAR PROGRAMMING (LP)

Unit Structure

2.1 Introduction

In many business situations, resources are limited while demand for them is unlimited. For example, a limited number of vehicles may have to be scheduled to make multiple trips to customers or a staffing plan may have to be developed to cover expected variable demand with the fewest employees. In this unit we describe a method called Linear programming (LP), which is useful for allocating scarce resources among competing demands. The resources may be time, money, or materials, and the limitation are known as constraints. Linear programming can help managers find the best allocation solution and provide information about the value of additional resources.

2.2 Learning Outcomes

By the end this unit you will be able to:

- Explain the characteristics and assumption of linear programming model.
- Formulate models for various problems
- Perform graphic analysis for two-variable problems and find the algebraic solution for the corner point found to be optimal.
- Describe the meaning of slack and surplus variables

- Discuss the meaning of sensitivity analysis on the objective function co-efficient and right hand side parameters.
- Interpret the computer output of a linear programming solution.

2.3 Linear Programming

Linear programming deals with how to meet a desired objective subject to certain constraints which have linear variability. For example, the desired objective might be to minimize costs of production where the constraints are limited time, for machine operation or limited non-hour input. The linear variability comes in as you use two minutes to produce one item, four minutes to product two items variably.

Linear describes a relationship between two or mere variables which is directly or approximately proportional. Linear Programming is invariably a mathematical programming technique. Note that mathematical programming refers to use of certain mathematical techniques to get the best possible solution to a problem involving limited resources.

Linear programming in its attempt to get the best possible solution is an optimization techniques which considers number of possible decisions or feasible solutions which could be put into practice, e.g. ($d_{1,}$ $d_{2,}$ $d_{3,}$ . . . d_n) and selects the best possible of these sets of solution which seems to promise the highest degree of economic efficiency either by highest minimizing costs or by maximizing profit /production volume. It assumes the range of feasible solutions under certain conditions called constraints.

Linear programming technique is the simplest among all the mathematical programming methods, and as such has a very wide application because linearity or approximate linearity frequently occurs in all human endeavours. There is a linear or direct relationship between cost of travel and distance traveled, cost and volume/tones of goods carried, cost and volume of good produced. Therefore, linear programming is very useful in transport planning where the cost of transporting good from several sources to several destinations may be analyzed. How do we minimize cost or how do we maximize profit are the questions whose solution could be obtained by the use of linear programming.

If we are unlucky to have over hundred sources of goods supplied and hundreds distribution/destination points, this might be problematic. Here the use of computer comes in. But assuming we have three (3) villages supplying garri to four towns, we need only to know the cost of transporting a bag of garri from one village to the town; (2) the quantity of garri required at each town; (3) the quantity of garri available at each village. Under this exercise, we arrange our data in a matrix form and apply the linear programming method. Like all other optimizing model, linear programming seek to produce a plan in such a way that final solution will be minimum in terms of time or maximized in terms of money (revenue or profit) made subject to the constraint.

2.3.1 Definition of Linear Programming

1. Linear programming could be defined as a mathematical technique for determining the best allocation of firms' limited resources.

2. It is a method of solving problems in which an objective function must be maximum or minimized when considering certain constraints.
3. An economist can define it as a method for allocating limited resources in a manner that satisfies the laws of supply and demand for the firm's products.

A business man will look at a linear programming as one of the management's tool for solving problems that are in conformity with the firm's clearly defined objectives.

2.3.2 The Five Requirements Necessary Before This Technique Can Be Employed In Business Problem

1. ***Well defined objective functions:*** A well defined objective must be stated; this objective may serve to maximize contribution by utilizing the available resources, or it may produce the lowest possible cost by using a limited amount of productive factors, or it may determine the best distribution of the productive factors within a certain time period. It should be remembered that sales volume is linearly related not to profits but to total contribution.

2. ***Alternative courses of action:*** secondly, there must be alternative course of action. For example it may be possible to make selection between various combinations of manpower and automatic machinery; or it may be possible to locate manufacturing capacity in a certain ratio for the manufacture of a firm's products.

3. ***Objective function and constraints must be expressed mathematically:*** Another, requirement is that equations and inequalities must describe the problem in linear form. Linearity in linear programming is a mathematical term used to describe systems of simultaneous equations of the first degree, which satisfy the objective functions and the constraints (restrains). The requirements dictate that the firm's objective and its constraint are expressed mathematically as linear equations or inequalities.

4. ***Variables must be inter-related****:* Another necessary condition is that it must be possible to formulate mathematical relationships among the variable describing the problem.

5. ***Resources must be in limited supply:*** The resources must be finite and economically quantifiable. For example, each plant has a limited number of hours available-labour hours are finite. Since the cost of direct labour has an impact on profit, it is also economic.

2.3.3 Applications of Linear Programming Method

Though, in the world we live, most of the events are non-linear, yet there are many instances of linear events that occur in day-to-day life. Therefore, an understanding of linear programming and its application in solving problems is utmost essential for today's managers.

Linear programming techniques are widely used to solve a number of business, industrial, military, economic, marketing, distribution and advertising problems. Three primary reasons for its wide use are:

i. A large number of problems from different fields can be represented or at least approximated to linear programming problems.
ii. Powerful and efficient techniques for solving linear programming problems are available.
iii. Linear programming models can handle data variation (sensitively analysis) easily.

However, solution procedures are generally iterative and even medium size problems require manipulation of large amount of data. But with the development of digital computers, this disadvantage has been completely overcome as these computers can handle even large linear programming problems in comparatively very little time at a low cost.

2.3.3.1 Areas of Application of Linear Programming

Linear programming is one of the most widely techniques of operations research in business, industry and numerous other fields. A few areas of its application are given below.

1. Industrial Applications

(a) ***Product mix problems:*** An industrial concern has available a certain production capacity (men, machines, money, materials, market etc) on various manufacturing processes to manufacture various products. Typically, different products will have different selling prices, will require different amounts of production capacity at the several processes and will therefore have different unit profits; there may also be stipulations (conditions) on maximum and / or minimum product levels. The problem is to determine the product mix that will maximize the total profit.

(b) ***Blending problems:*** These problems are likely to arise when a product can be made from a variety of available raw materials of various compositions and prices. The manufacturing process involves blending (mixing) some of these materials in varying quantities to make a product of the desired specifications, for instance, different grades of gasoline are required for aviation purposes. Prices and specifications such as octane ratings, tetra ethyl lead concentrations, maximum vapour pressure etc of input ingredients are given and the problem is to decide the proportion of these ingredients to make the desired grades of gasoline so that (i) maximum output is obtained and (ii) storage capacity restrictions are satisfied. Many similar situations such as preparation of different kinds of whisky, chemicals, fertilizers and alloys etc have been handled by this technique of linear programming.

(c) ***Production scheduling problems****:* They involve the determination of optimum production schedule to meet fluctuating demand. The objective is to meet demand, keeping inventory and employment at reasonable minimum levels, whole minimizing the total cost of production and inventory.

(d) ***Trim loss problems:*** They are applicable to paper, sheet metal and glass manufacturing industries where items of standard sizes have to be cut to smaller sizes as per customer requirements with the objectives of minimizing the waste produced.

(e) ***Assembly-line balancing****:* It relates to a category of problems wherein the final product has a number of different components assembled together. These components are to be assembled in a specific sequences or set of sequences. Each assembly operation is to be assigned the task/combination of tasks so that his task time is less than or equal to the cycle time.

(f) ***Make-or-buy (sub-contracting) problems:*** They arise in an organization in the face of production capacity limitations and sudden spurt in demand of its products. The manufacturer, not being sure of the demand pattern, is usually reluctant to add additional capacity and has to make a decision regarding the products to be manufacture with his own resources and the products to be sub-contracted so that the total cost is minimized.

2. Management Applications

(a) ***Media selection problems****:* They involve the selection of advertising mix among different advertising media such as TV; radio, magazines and newspapers that will maximize public exposure to company's product. The constraints may be on the total advertising budget, maximum expenditure in each media, maximum number of insertions in each media and the like.

(b) ***Portfolio section problems****:* They are frequently encountered by banks, financial companies, insurance companies, investment services, etc. A given amount is to be allocated among several investment alternative such as bonds, saving certificates, common stock, mutual fund, real estate, etc. to maximize the expected return or minimize the expected risk.

(c) ***Profit planning problems****:* They involve planning profits on fiscal year basis to maximum profit margin from investment in plant facilities, machinery, inventory and cash on hand.

(d) ***Transportation problems****:* They involve transportation of products from, say X sources situated at different locations to, say, Y different destinations. Supply position at the sources, demand at destination freight charges and storage costs etc. are known and the problem is to design the optimum transportation plan that minimizes the total transportation cost (distance or time).

(e) ***Assignment problems****:* They are concerned with allocation of facilities (men or machines) to jobs. Time requires by each facility to perform each job is given and the problem is to find the optimum allocation (one job to one facility) so that the total time to perform the jobs is minimized.

(f) ***Man-power scheduling problems****:* They are faced by big hospitals, restaurants and companies operating in a number of shifts. The problem is to allocate optimum manpower in each shift so that the overtime cost is minimized.

3. **Miscellaneous Applications**

(a) ***Diet problems****:* They form another important category to which linear programming has been applied. Nutrient contents such as vitamins, proteins, fats, carbohydrates, starch, etc. in each of a number of food stuffs is known. Also the minimum daily requirement of each nutrient in the diet as well as the cost of each type of food stuff is given and the problem is to determine the minimum cost diet that satisfies the minimum daily requirement of nutrients.

(b) ***Agriculture Problems****:* These problems are concerned with the allocation of input resources such as acreage of land, water, labour, fertilizers and capital to various crops so as to maximize net revenue.

(c) ***Flight scheduling problems****:* They are devoted to the determination of the most economical patterns and timings of flights that result in the most efficient use of aircrafts and crew.

(c) ***Environment protection****:* They involve analysis of different alternatives for efficient waste disposal, paper recycling and energy polices.

(e) ***Facilities location:*** These problems are concerned with the determination of best location of public parks, libraries, recreation areas, hospital ambulance depots, telephone exchanges, nuclear power plants, etc.

LINEAR EQUATION:

A linear equation is an equation of the form

$A_1 x_1 + a_2 x_2 + a_3 x_3 + \ldots + a_n x_n = b$

Where not all $a_i = 0$ and X_i is unknown or variables. The products of the variables, e.g. XY is not a linear equation. The word linear refers to the fact that the graph of a linear equation in two unknowns is a straight line. Examples of linear equations are $3x - 2y = 7$ and $5x + 4y - z = 17$. Examples of non-linear equations are $xy = 4$; $x^2 + x = 4$.

Example 2.1

Suppose a store sales nut in three types of containers A, B and C. container A contains 1 ton of cashews, and 1 ton of peanut, container B contains 6 tons of cashews and peanuts and 3 tons of walnuts while container C contains 1 ton of cashew and 2 tons of walnuts. If an order is received for 31 tons of cashew nuts, 36 tons of peanuts and 12 tons of walnuts, how can it be filled?

Solution

Let x = number of A containers
y = number of B containers
z = number of C containers

Cashew **Peanut** **Walnut**

Container	A	1	**Hence**	1	X	+	6y + Z	= 31……..(1)
Container	B	2		6	X	+3	6y + 2Z	= 36……..(2)
Container	C	3		2			3y	= 12……..(3)

Capacity/total order	31	36	12

From equation (3) we have

$3y = 12$

$y = 4$

Put i**n y = 4 in equations 1 & 2**

$X + 24 + Z = 31 \ldots\ldots (1)$

$X + 24 + 2Z = 36 \ldots\ldots (2)$

$X + Z = 7$

$X + 2Z = 12$

$Z = 5$

Substituting z = 5, y = 4 in equation (1)

$X + 24 + 5 = 31$

$X + 29 = 31$

$X = 31 – 29$

$X = 2$.

The answer to the problem is that we have 2 containers of A, 4 containers of B and 5 containers of C.

2.3.3.2 Formulating a Linear Programming Problem

Example 2.2

A company is experiencing a slowdown of normal activities. During the next month, the planning, milling and assembly departments are expected to have idle capacities of 60, 100 and 80 hours respectively. Three specialty items can be produced with these facilities: - product 1, product 2, and product 3, product 1 require 2 hours of planning; 3 hours of milling and 6 hours of assembly. Product 2 requires 2 hours of planning, 4 hours of milling and 5 hours of assembly. Product 3 requires 4 hours of planning and 2 hours each of milling and assembly. The company has already accepted orders for two units of product 1 and four units of product 3. Product 1 provides a per unit profit contribution of N150, products 2 and 3 are worth N160 and N200 respectively. The objective is to allocate the available resources so as to maximize profits. A properly formulated linear programming problem will contain and objective function, structural constrains and non-negativity constraint.

A) The objective function is the maximum of profits (Remember, it can either be maximize or minimize).

B) The decision variables are the product outputs producing profits:-

X_1 = the No of Units of product 1

X_2 = the No of Units of product 2

X_3 = the No of Units of product 3

C) The per unit profit contributions are provided:-
C_1 = N150; C_2 = N160; and C_3 = N200.
The objective function is
Max Z = $150X_1 + 160X_2 + 200X_3$

D) The values of the decision variables are restricted by the availability of the resources required to produce the products. There are three resources with specified levels of availability- the planning, milling and assembly departments with 60, 100 and 80 hours respectively. Since the availability of the resources cannot be exceeded, we have:

For planning constrains we have
$2x_1 + 2x_2 + 4x_3 \leq 60$
(i)
For milling constraints we have
$3x_1 + 4x_2 + 2x_3 \leq 100$
(ii)
For assembly, we have
$6x_1 + 5x_2 + 2x_3 \leq 80$

Again, the problem contains two other specified restrictions on the values of the decision variables. Orders have been already taken for two units of product 1 and four units of products 3. To maintain these orders the resulting constraints are:
$1x_1 \geq 2$, $1x_3 \geq 4$

The formulation problem becomes:
Find (x_1, x_2, x_3): MaxZ = $150x_1 + 160x_2 + 200x_3$
Subject to $2x_1 + 2x_2 + 4x_3 \leq 60$
$3x_1 + 4x_2 + 2x_3 \leq 100$
$6x_1 + 5x_2 + 2x_3 \leq 80$
$1x_1 \geq 2$
$1x_3 \geq 4$
Where $x_1, x_2, x_3 \geq 0$;

This problem is now ready for a linear programming solution.

Problem 2.3

A feed company must blend 600kg of grain to satisfy a customer weekly demand. The final product contains 3 ingredients: I_1, I_2, I_3. Not more than 200kg of I_1, or less than 100Kg of I_3 many be used. The ingredients cost respectively are N10, N20 and N40 per Kg. Find the blend of the ingredients satisfying the requirement at the lowest cost.

Formulation

The decision variables are I_1, I_2, I_3 which be denoted by denoted by x_1, x_2, and x_3 respectively. The cost of ingredients per kg becomes the coefficient of the decision variables, hence the objective function.

$$\text{Min. } Z = 10x_1 + 20x_2 + 40x_3$$

Subject to

$$x_1 + x_2 + x_3 = 600\text{kg}$$
$$x_1 \le 200\text{kg}$$
$$x_3 \ge 100\text{kg.}$$

Linear Programming Can Be Solved By

i. graphic method
ii. Simplex method
iii. Algebraic method

We shall use simplex method in solving the problems but refresh our mind we few example with graphic method.

2.4.1 Graphic Method

Suppose a manufacturer produces plastic toys and ball. To produce one toy requires 1 minute work on machine A, 5 minutes work on Machine B and 1 minute work on machine C. to produce one ball requires 1, 2 and 2 minutes work on machine A, B and C respectively. In a given period, machine A, B and C are available for 25, 100 and 40 minutes respectively. If the profit on toys and ball in N1 and N1.20 respectively how many of each should be made in order to maximize profit.

Solution

Let optimum no of toys = t
,, ,, ,, ,, balls = b

Amount of work in machine A requires (t + b) minutes which must be less than 25 minutes. Amount of work in machine B requires (5t + 2b) and must be less than 100 minutes. And for machine C, amount of work is (t + 2b) and must be less than 40 minutes.

Mathematically:

$$\text{FMAX} = t + 1.2b$$

Subject to

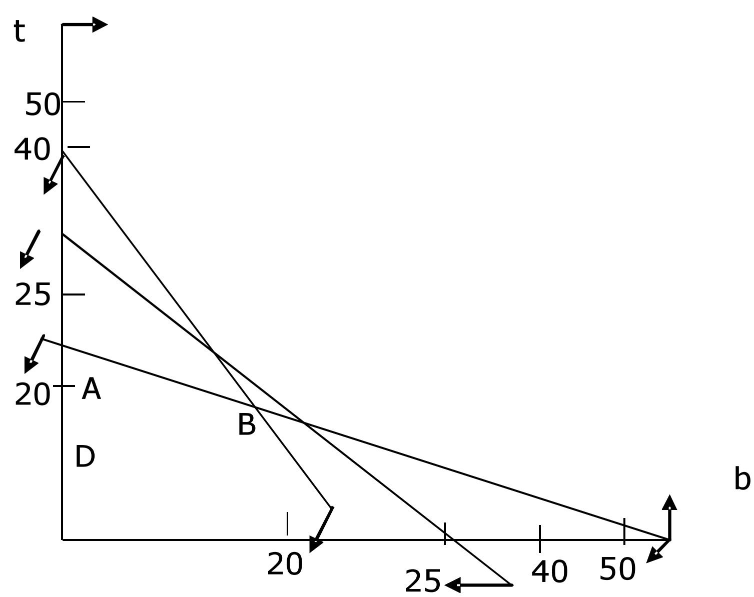
$$t + b \le 25 \quad \ldots (1)$$
$$5t + 2b \le 100 \quad \ldots (2)$$
$$t + 2b \le 40 \quad \ldots (3)$$

non-negativity $t, b \ge 0$

Solve:

In Equation (1) Put t = 0 ; b = 25
Then b = 0 ; t = 25
,, ,, (2) Put t = 0 ; b = 50
Hence b = 0 ; t = 20
,, ,, (3) Put t = 0 ; b = 20
Then b = 0 ; t = 40

Plotting the graph we have



The feasible regions are A, B, C and D where their points are A (0, 20), B (10, 16), C (20, 0) and D (0, 0).

Substituting the points for optimality we have

F max	=	+ 1.2 b		
At	A	we have 20 + 1.2 (20)	=	N21.20
At	B	16 + 1.2 (10)	=	N28.00
At	C	0 + 1.2 (20)	=	N24.00
At	D	0 + 1.2 (0)	=	N0.00

Hence the optimal solution is at B where the value of F max is at the highest.

Problem II

Given a maximum problem which is mathematically stated as this:

$$\begin{aligned} \text{Max } Z &= X_1 + 2x_2 \\ \text{S.t} \quad X_1 + x_2 &\leq 4 \\ -X_1 &\leq -1 \\ X_1 - x_2 &\leq 2 \\ X_1, x_2 &\geq 0 \end{aligned}$$

Solve Graphically

Solution

In the constraint equation (1)

Put $X_1 = 0$; $X_2 = 4$

Then $X_2 = 0$; $X_1 = 4$

In equation (2) $-X_1 \leq -1$

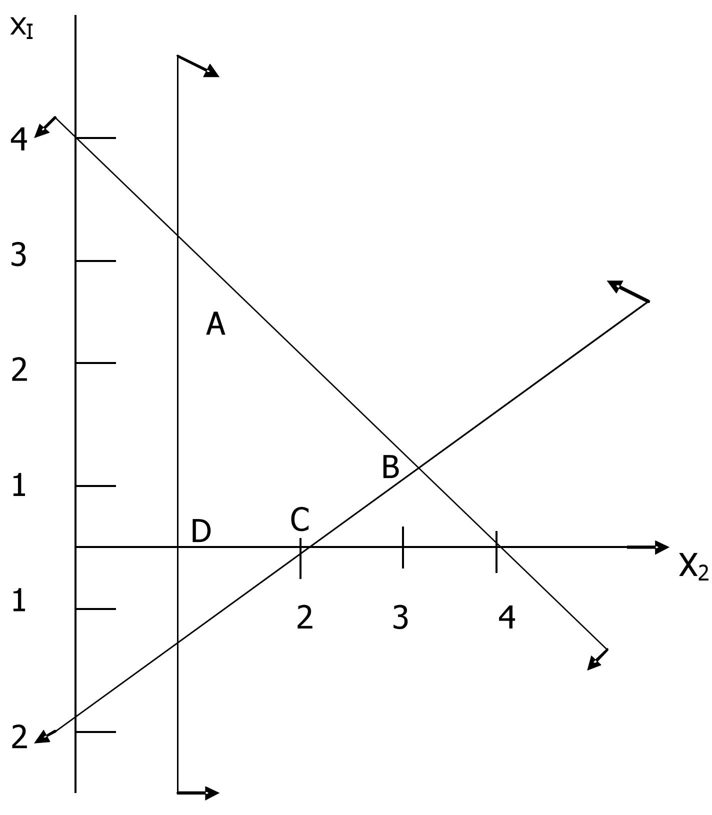
Divide through by – 1

$X_1 \geq 1$

In equation (3) put $X_1 = 0$, $X_2 \geq 2$

$X_2 = 0$; $X_1 \leq 2$

Plotting the graph we have:



The co-ordinate within the feasible regions are A, B, C & D and they are A(1,3), B(3,1.2), C(2,0) and D(1,0).

Substituting for the optimality in the objective function we have;
At A (1, 3) are have 3 + 2 (1) = 5

B (3, 1.2) 1.2 + 2 (3) = 7.2
C (2, 0) 0 + 2
(2) = 4
D (1,0) 0 + 1
(2) = 2

Therefore the greatest value is chosen value which is 7.2 at the co-ordinate (3, 1.2) as the optimal solution.

2.4.2 Simplex Method

Simplex method is a mathematical techniques used in solving linear programming problems. The computational procedure uses iterative process, sometimes it is referred to as algorithm technique. This means that technique uses step-by-step type of solution where the previous solution is improved until the optimal solution is reached.

Properties of Simplex Method

1.
or maximization problem, the optimal solution is reached when the net contribution of the variables in less than or equal to zero .i.e. $Cj- Zj \leq 0$ and vice versa for minimization.

2.
If an article variable is in the optimum solution of the model at a non-zero level, then no feasible solution for the original model exists. On the contrary if the optimum solution of the equivalent model does not contain an artificial variable at a non-zero level, the solution is also optimal for the original model.

3.
If all of the slack variables, surplus and artificial variable are zero ($S_{I,}$ S_2 and A). When an optimal solution of the model are strictly equalities for the value of the variables that optimize the objective function.

4.
f a non-basic variable has a zero coefficient in the objective function equation when an optimum is reached there are multiple optimum solutions. Infact there is infinity of optimum solutions. The simplex method only finds one optimal solution and stops.

5.
nce an article variable leaves a state of basic variable (the basis). It will never enter the basis again, so all calculations for the variable can be ignored in future steps.

6.
hen selecting the variable to leave the current basis, as if two or more ratios are smallest (equal), choose one arbitrarily. If a non negative ratio does not exist the objective function in the original model is not bounded by the constraints. Thus a finite optimal solution for the original model does not exist.
7.
f a basis has a variable at zero level, it is called a degenerate basis.

Among the various methods of solving LP problems, the simplex method is one of the most general and powerful techniques. The graphical method was presented earlier to give you a feel of LP problems and to acquaint you with some of the technical terminology so essential in understanding the rationale and mechanics of simplex method.

In practice, LP problems of any significance are usually solved by the application of the simplex method (revised simplex and dual simplex are two such variants).

2.4.2.1 The Rational For Simplex Method

The simplex method rests on the concepts, feasibility, and optimality. The search for the optimal solution starts from a basis feasible on two concepts, feasibility and optimality. The search for the optimal solution starts from a basic feasibility solution (as in graphical method, we search only the extreme point solution). The solution is tested for optimality and if it is optimal, the search is stopped. If the test of optimality shows that the current solution is not optimal, a new and better basic feasible solution is designed. The feasibility of the new solution is guaranteed by the mechanics of the simplex methods as is the fact that each successive solution is designed only if it is better than each of the previous solution. These iterative processes are continued until an optimal solution has been obtained. The simplex method is based on the property of the optimum solution to a linear programming problem. If it exists, can always be found in one of the basic feasible solutions. Thus in the simplex method, the first thing is always to obtain a basic solution. This solution is then tested for optimality by examining the net effect on the linear objective function of introducing one of the current basic variables. If any improvement potential is noted, the replacement is made always by introducing only one non-basic variable at a time. The replacement proceeds is such that the new solution is always feasible.

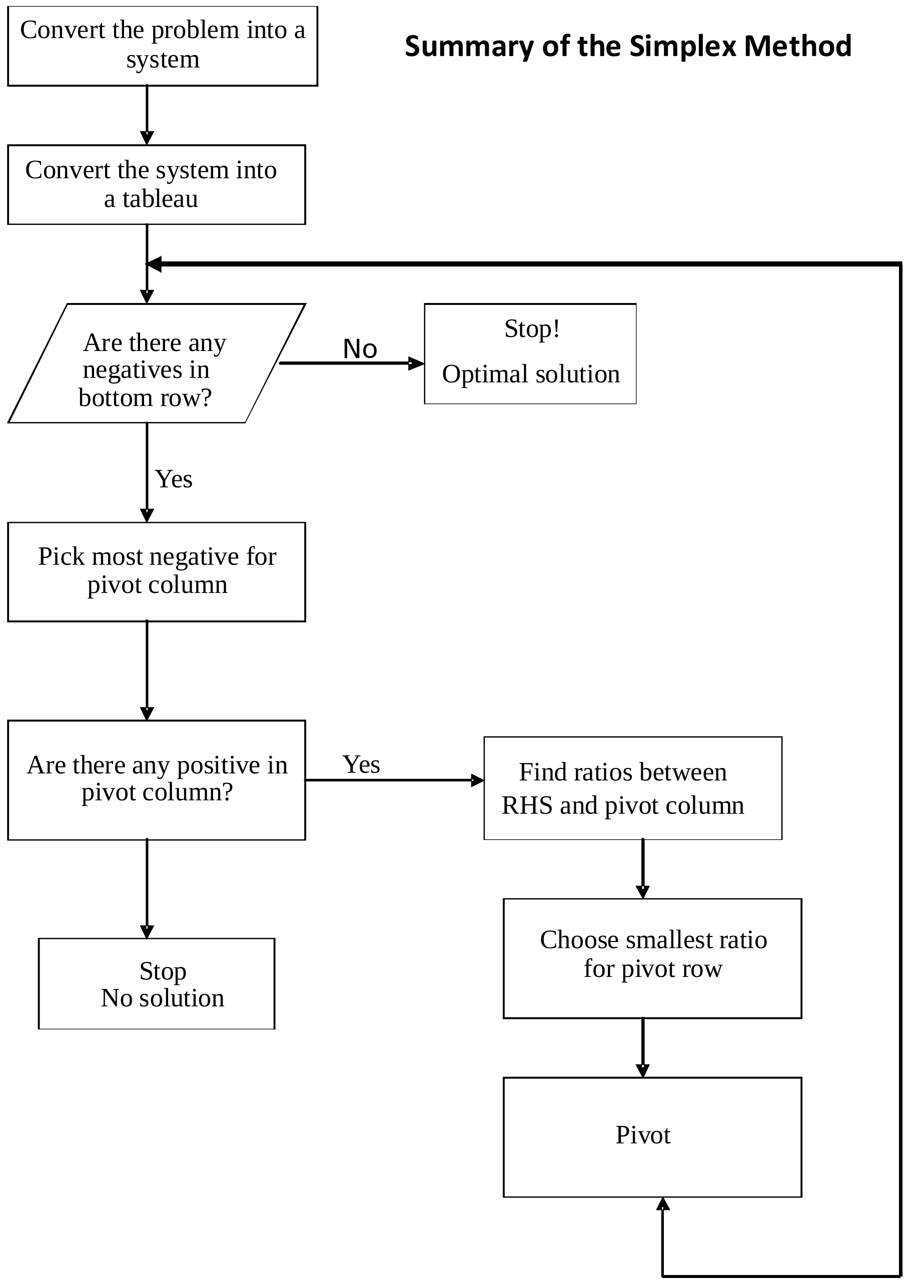


Fig16. 1 Flow chart for simplex method

4.3 Problem

A Delta corporation has one small plant located on the outskirts of a large city called Aba, its production is limited to two industrial products A and B. The unit contributions for each product have been computed as N10 per product A and N12 per product B. Each passes through three departments of the plant. The time requirements for each product and total time available in each department are as follows;

HOURS REQUIRED

epartment	oduct A	Product B	vailable Hours for a Month
1	2	3	1,500
2	3	2	1,500
3	1	1	600

The delta corporation wishes to maximize her net profit

Question 1. Formulate the above linear programming problem

2. Using simplex methods, what is maximum profit that this corporation can achieve?

Solution

Let product A represent X

And product B represents Y

Hence formulating the linear programming problem we have

$$\text{Max } Z = 10x + 12y$$

Subject to $2x + 3y \leq 1500$

$3x + 2y \leq 1500$

$x + y \leq 600$

non-negativity constraint $X, y \geq 0$.

Standardization of the equations

Max $Z = 10x + 12y + 0S_1 + 0S_2 + 0S_3$

Subject to $2x + 3y + S_1 + 0S_2 + 0S_3 = 1,500$

$3x + 2y + 0S_1 + S_2 + 0S_3 = 1500$

$x + y + 0S_1 + 0S_2 + S_3 = 600$

Where S_1, S_1 and S_3 are slack variables.

Forming Initial Feasible Solution

Cj			**10**	**12**	**0**	**0**	**0**
	Max. Prof	Q	X	Y	s_1	S_2	S_3
0	S_1	1,500	2	(3)	1	0	0
0	S_2	1,500	3	2	0	1	0
0	S_3	600	1	1	0	0	1
	Zj	0	0	0	0	0	0
	Cj - Zj		10	12	0	0	0

Pivot element

Is $Cj - Zj \leq 0$?, No continue. Y then in circled as the variable that will enter the basis because it has the highest value 12.

To determine the variable to leave the basis along the column of Y.

$$\frac{Q}{Y} = \frac{1500}{3} = 500; \quad \frac{1500}{2} = 750; \quad \frac{600}{1} = 600$$

Computing for the new value or element to enter the cell we use.

$$\text{New cell} = \text{Old cell} - \frac{\text{(Corresponding number) In pivot row}}{\text{Number}} \times \frac{\text{(Corresponding number) In pivot row}}{\text{Number}}$$

The PivotElement

However, in the row where we have pivot element, we divide through by the pivot element.

FIRST TABLEAU

Cj			10	12	0	0	0
	Max.Prof	Q	X	Y	S_1	S_2	S_3
12	Y	500	2/3	1	1/3	0	0
0	S_2	500	5/3	0	-2/3	1	0
0	S_3	100	(1/3)	0	-1/3	0	1
	Zj	6000	8	12	4	0	0
	Cj - Zj		2	0	-4	0	0

Pivot element

Qty/X =
500/2/3 =750
500/5/3 = 300
100/1/3 = 300

Is Cj – Zj $\leq$ 0? No continue. The optimality is not yet reached. The highest value enters the basis.

Second Iteration

Cj			10	12	0	0	0
	Max.Prof	Q	X	Y	S_1	S_2	S_3
12	Y	300	0	1	1	0	-2
0	S_2	0	0	0	1	1	-5
10	X	300	1	0	-1	0	3
	Zj	6600	10	12	2	0	6
	Cj - Zj		0	0	-2	0	-6

Is Cj – Zj $\leq$ 0? Yes, stop. The optimality is reached.

However, before the final tableau, it is seen that we have equal ratio, hence in this problem; the simplex method will give the correct answer if we choose either of the two rows. Therefore the S_3 row will be arbitrarily designated as the replaced row. The optimal value is N6,600 and the quantities for x = 300; Y = 300 and S_2 = 0.

Minimization Problem: Drawing from the from the problem early given in the beginning of the topic we have

Min Z = $10x_1 + 20x_2 + 40x_3$

Subject to $x_1 + x_2 + x_3 = 600kg$

$x_1 \leq 200kg$

$x_3 \geq 100kg$

Standardizing The Equation

Min Z $= 10x_1 + 20x_2 + 40x_3 + MA_1 + 0S_1 + 0S_2 + MA_2$

Subject to $x_1 + x_2 + X_3 + A_1 = 600kg$

$x_1 \quad S_1 = 200kg$

$X_3 - S_2 + A_2 = 100kg$

Where S_1, S_2, A_1 and A_2 are slack, surplus and artificial variables respectively.

INITIAL TABLEAU

Cj			10	20	40	M	0	0	M	Ratio
	Sol. Vari.	Q	X_1	X_2	X_3	A_1	S_1	S_2	A_1	
M	A_1	600	1	1	1	1	0	0	0	$\frac{600}{1}=600$
0	S_1	200	1	0	0	0	1	0	0	$\frac{200}{0}= 0$
M	A_2	100	0	0	(1)	0	0	-1	1	$\frac{100}{1}=100$
	Zj	700m	M	m	2m	m	0	-m	M	
	Cj Zj		-M+10	-M+20	-2m+40	0	0	m	0	

Pivot element

Is Cj – Zj $\geq$ 0? No. continue

Note:

The value of "M" which is artificial variable is so large that it is larger than any real number. Also in the minimization problem the variables to enter the basis is the non-basic variable with less values.

FIRST TABLEAU

Cj			10	20	40	M	0	0	M	Ratio
	Sol. Var.	Q	X_1	X_2	X_3	A_1	S_1	S_2	A_2	
M	A_1	500	1	1	0	1	0	1	-1	$\frac{500}{1}$ = 500
0	S_1	200	(1)	0	0	0	1	0	0	$\frac{200}{1}$ = 200
40	X_2	100	0	0	1	0	0	-1	1	$\frac{100}{0}$ = 0
	Zj	400 + 500m	M	m	40	m	0	-40+m	40 - m	
	Cj Zj		-m+10	-m+20	0	0	0	-M+ 40	-40+m	Pivot element

Is Cj – Zj ≥ 0? No. continue searching for optimality

SECOND TABLEAU

Cj			10	20	40	M	0	0	M	Ratio
	Sol. Variable	Q	X_1	X_2	X_3	A_1	S_1	S_2	A_2	
M	A_1	300	0	(1)	0	1	-1	1	-1	$\frac{300}{1}$ = 300
10	X_1	200	1	0	0	0	1	0	0	$\frac{200}{0}$ = 0
40	X_3	100	0	0	1	0	0	-1	1	$\frac{100}{0}$ = 100
	Zj	600 + 300m	10	m	40	m	m-10	m-40	m+40	Pivot element
	Cj - Zj		0	-m+20	0	0	+m-10	-m+40	- 40	

Is Cj – Zj ≤ ? No. continues searching for optimality.

THIRD TABLEAU

Cj			10	20	40	M	0	0	M
	Sol. Var.	Q	X_1	X_2	X_3	A_1	S_1	S_2	A_2
20	X_2	300	0	1	0	1	-1	1	-1
10	X_1	200	1	0	0	0	1	0	0
40	X_3	100	0	0	1	0	0	-1	1
	Zj	12,000	10	20	40	20	-10	-20	20

Is Cj – Zj ≥ 0 ? Yes. Stop. Optimality is reached. Which is 12,000; with

X_1 = 200
X_2 = 300
X_3 = 100

2.6 Conclusion

We have been able to see how the knowledge of LP can be of help in management decisions to boost the performance of a business unit or production organisation.

Self-Assessment Exercise

Identify and discuss the requirements necessary before LP can be employed in business problem.

2.7 Summary

We are now able to take some economic and managerial decision on the use of resources, what resource would contribute better to our objective has been pointed out from slack activities column and the Z-C row of the optimal strategy. The limitations of graphical method compared to the simplex method was seen in that graphical solution cannot handle clearly more than two objective function case, whereas the simplex approach would do us better. The surplus resource(s) or the shadow prices was equality highlighted in the simplex method but cannot be depicted on the graphical solution.

2.7 References/Further Readings/Web Resources

Chase R B and Aquilano N J (1985), Production and operations Management, Irwin, Homewood, IL, USA

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2.9 Possible Answers Self-Assessment Exercises

The Five Requirements Necessary Before This Technique Can Be Employed In Business Problem

1. Well defined objective functions: A well defined objective must be stated; this objective may serve to maximize contribution by utilizing the available resources, or it may produce the lowest possible cost by using a limited amount of productive factors, or it may determine the best distribution of the productive factors within a certain time period. It should be remembered that sales volume is linearly related not to profits but to total contribution.

2. Alternative courses of action: secondly, there must be alternative course of action. For example it may be possible to make selection between various combinations of manpower and automatic machinery; or it may be possible to locate manufacturing capacity in a certain ratio for the manufacture of a firm's products.

3. Objective function and constraints must be expressed mathematically: Another, requirement is that equations and inequalities must describe the problem in linear form. Linearity in linear programming is a mathematical term used to describe systems of simultaneous equations of the first degree, which satisfy the objective functions and the constraints (restrains). The requirements dictate that the firm's objective and its constraint are expressed mathematically as linear equations or inequalities.

4. Variables must be inter-related*:* Another necessary condition is that it must be possible to formulate mathematical relationships among the variable describing the problem.

5. Resources must be in limited supply: The resources must be finite and economically quantifiable. For example, each plant has a limited number of hours available-labour hours are finite. Since the cost of direct labour has an impact on profit, it is also economic.

UNIT 3 MATERIAL REQUIREMENTS PLANNING

Unit Structure

3.1 Introduction

Material requirements planning (MRP) is a computer-based information system for ordering and scheduling of dependent-demand inventories (e.g. rawmaterials, component parts, and subassemblies).(Recall that dependent-demand is the demand foritems that are subassemblies or component parts tobe used in the production of finished goods).

What is involved in MRP is the translation of a production plan for a specified number of finished products into requirements for component parts and raw materials working backward, using lead time information to determine when and how much to order.

MRP is as much a philosophy as it is a technique, and as much an approach to scheduling as it is to inventory control. MRP begins with a schedule of finished goods that is converted into a schedule of requirements for subassemblies, components parts, and raw materials needed toproduce the finished items in the specified time frame. What this amounts to, is that MRP is designed to answer three questions: What is needed? How much is needed? And when it is needed? The primary inputs of MRP necessary to answer these questions are (i) a bill of material, which tells the composition of a finished product; (ii) amaster schedule which tells how much finished product is desired and when; and (iii) an inventory records file, which tells how much inventory is on hand or on order. This information is then processed to determinethe planninghorizon.

Outputs from the process include planned-order schedule, order releases, changes performance-control reports, planning repots and exception reports. These inputs and output are discussed in more detail in subsequent sections.

3.2 Objectives

By the end of this unit, you should be able to:

- Describe the conditions under which MRP is most appropriate.
- Describe the input, outputs and nature of MRP processing.
- Explain how requirements in a master production schedule are translatedinto material requirements for lower-level items.
- Discuss the benefits and requirements of MRP.
- Explain how an MRP system is useful in capacity requirementsplanning.
- Outline the potential benefits and some of the difficulties users haveencountered with MRP.
- Describe MRP II and how it relates to MRP.

3.2 Material Requirements Planning

3.2.1 MRP Inputs

As already mentioned in proceeding section, an MR system has three major sources of information: a master schedule, a bill- of-material file, and an inventory records file. Let's consider each of these inputs.

3.2.2 The Master Schedule

The master schedule states which end items are to be produced, when they are needed, and in what quantities. Figure 12.1 illustrates a portion of a master schedule that shows planned output for end items X for the planninghorizon.

The schedule indicates that 100 units of X will be needed (e.g., for shipments to customers) at the start of week 4 and that another 150 units will be needed at the start of week 8.

Figure 12.1. A portion of master schedule.

Week Number								
Item X	1	2	3	4	5	6	7	8
Quantity				100				150

The quantities in a master schedule come from a number of different sources, including customer orders, forecasts, orders from warehouses to build upseasonal inventories, and external demand.

The master schedule separates the planning horizon into a series of time periods or time buckets, which are often expressed in weeks. However, the time bucket need not be of equal length.

It is important that the master schedule cover the stacked or cumulative leadtime necessary to produce the end items. This cumulative lead time is the sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of final assembly.

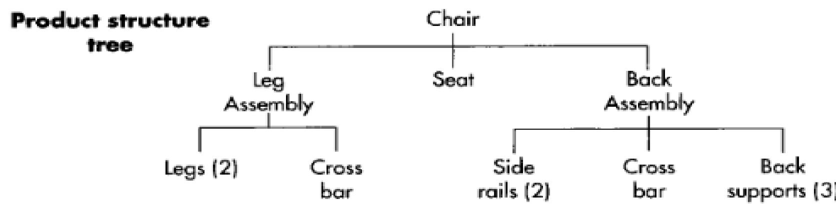
Stability in short-term production plans is very important; without it, changes in order quantity and/or timing can render material requirements plans almost useless. To minimize such problems, many firms establish a series of time intervals, called time fences, during which changes can be made to orders. For example, a firm might specify time fences of 4,8, and 12 weeks, with the nearest fence being the most restrictive and farthest fence being less restrictive.
Beyond 12 weeks changes are expected; from 8 to 12 weeks, substitutions of one end item for another may be permitted as long as the components are available and the production plan is not compromised; from 4 to 8weeks, the plan is fixed, but small charges may be allowed; and the plan is frozen out tothe four-week fence.

3.2.3 The Bill-of-Material File.

A bill of materials(BOM) containing a listing of all the assemblies, sub- assemblies, parts, and raw materials that are needed to produce one unit of afinished product. This means that each finished product has its own bill of materials.

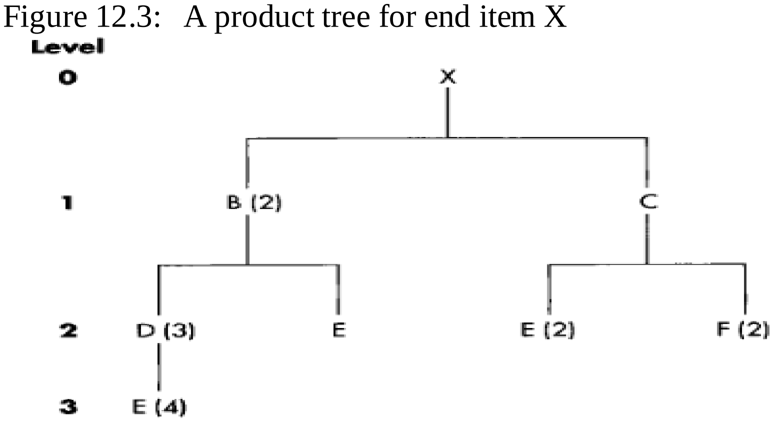
The listing in BOM is hierarchical; it shows the quantity of each item needed to complete one unit of the following level of assembly. The nature of this aspect of a BOM is perhaps grasped most readily by considering a product structure tree, which provides a visual depiction of the subassemblies and components that are needed to assemble a product. Figure 12.2 shows a product tree for a chair.

Figure 12.2: Product Structure



A product structure tree is useful in illustrating how the bill of materials is used to determine the quantities of each of the ingredients (requirements) needed to obtain a desired number of end items. Let's consider the product tree shown in figure 12.3.

Figure 12.3: A product tree for end item X

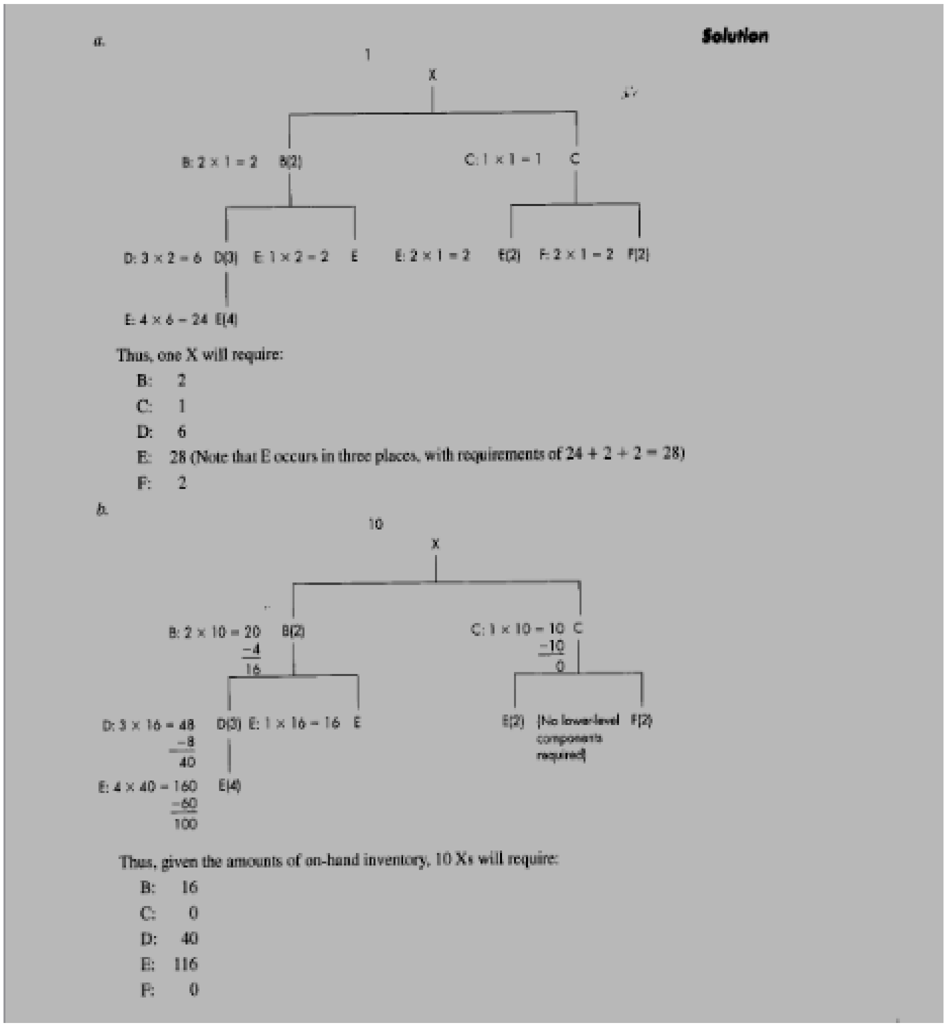


Note that the quantities of each item in the product structure tree refer only to the amounts needed to complete the assembly in the next higher level. We can use the information presented in figure12.3 to do the following:

(a) Determine the quantities of B, C, D, E, and F needed to assemble one X.

(b) Determine the quantities of these components that will be required to assemble 200Xs

(c) Component Quantity



B ----------------- 213s = 2
D----------------30s per B X 213s per X = 6
E ----------------- 4 Es per D X 3Ds per B X 2Bs per X = 24
E -----------------lE per B X 213s per X = 2
C --------------- 1 C per X = 1
E ------------------ 2 Es per C X 1 C per X = 2
F --------------- 2 Fs per C X 1 C per X =2

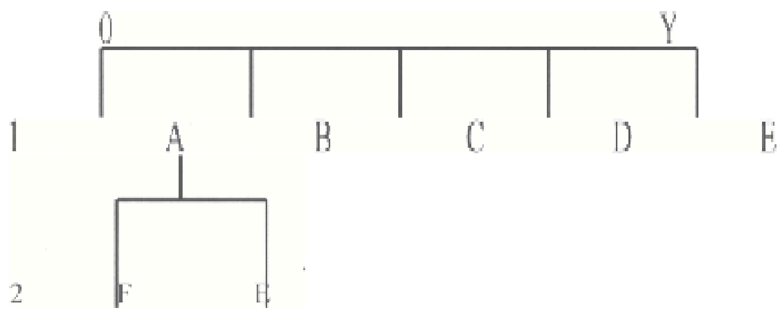
Note that E appears in three separate places. Its total requirements can be determined by summing the separate amounts, which yields 28.

(b) In order to assemble 200 units of X, the quantities of each component must be multiplied by 200. Hence, there must be 200 (2) = 400Xs, 200 (6) = 1,200Ds, 200 (28) = 5,600Es, and so on.

When requirements are calculated in an MRP system, the computer scans the product structure level by level, starting at the top. When a component (such as E in figure 12.3 appears on more than one level, its total requirements cannot be determined until all levels have been scanned. From a computational standpoint, this is somewhat inefficient. A simplification sometime used to increase efficiency is low-level coding, which involves restructuring the BOM so that all occurrences of an item are made to coincide with the lowest level in which the item appears. Figure 12.4 illustrates how component E, which appear in three different levels of product Y, can be rearranged so that it appears atonly one level.

Figure 12.4: Low-level coding for component E.

Level



3 E E E

3.2.4 The Inventory Records File

The inventory records file is used to store information on the status of each item by time period. This includes gross amount on hand. It also includes other details for each item, such as supplier, lead time, and lot size - changes due to stock receipts and withdrawal, canceled orders, and similar events also arerecorded in this file.

3.3 MRP Processing

MRP processing takes the end-item requirements specified by the master schedule and "explodes" them into time-phased requirements for assemblies, parts, and raw materials using the bull of materials offset by lead times.

The quantities that are generated by exploding the bill of materials are gross requirements. It is the total expected demand for an item or raw material during each time period without regard to the amount on hand. For end items, these quantities are shown in the master schedule; for components, these quantities equal the planned-order releases of their immediate "parents"

Scheduled Receipt: Open orders scheduled to arrive from vendors or elsewhere in the pipeline by the beginning of a period.

Projected on hand: - The expected amount of inventory that will be on hand at the beginning of each time period; schedule receipts plus available inventoryfrom last period. Net-requirements: - The actual amount needed in each time period.

Planned-order receipts: - The quantity expected to be received by the beginning of the period in which it is shown. Under lot-for-lot ordering, this quantity will equal net requirements. Under lot-size ordering this quantity may exceed net requirements. Any excess is added to available inventory in the nexttime period.

Planned-order releases: - Indicates a planned amountto order in each time period; equal planned-order receipts offset by lead time. This amount generates gross requirements at the next level in the assembly or production chain. When an order is executed, it is removed from "planned-order releases" and entered under "Scheduled receipts"

Let us illustrate MRP processing with the following example.

Suppose firm that produces wood shutters and bookcases has received twoorders for shutters: one for 100 shutters and one for 150 shutters. The 100-unit order is due for delivery at the start of week 4 of the current schedule, and the 150-unit order is due for delivery at the start of week 8. Each shutter consists of four slatted wood sections and two frames. The wood sections are made by the firm, and fabrication takes one week. The frames are ordered and lead time is two weeks. Assembly of the shutters requires one week. There is a scheduledreceipt of 70 wood sections in (i .e. at the beginning of) week 1. Determine the size and timing of planned-order releases necessary to meet deliveryrequirements under each of these conditions:
Lot-for-lot ordering (i e order size equal to net requirements)

Lot-size ordering with a lot size of 20 units for frames and 70 units for wood sections to answer tree question, you first develop a master schedule asfollows:

Week number	1	2	3	4	5	6	7	8
Quantity	100	150						

Secondly, develop a product structure tree: Shutter

Shutter

Frame (2) wood sections

Next, using the master schedule, determine gross requirements for shutters. Then, compute net requirements. Assuming lot-for-lot ordering, determine planned-order receipt quantities and the planned - order release timing to satisfy the master schedule Since the master schedule calls for 100 shutters to be ready for delivery, and no shutters are projected to be on hand at the start of week 4, the next requirements are also 100shutters. Therefore planned receipts for week 4 equals 100 shutters. Some shutters are assembled during week 7 in order to beavailable for delivery at the start of week 8.

The planned-order release of 100 shutters at the start of week 3 means that 200 frames (gross requirements) must be available at that time. Since more are expected to be on hand, this generates net requirements of 200 frames and necessitates planned receipts of 200 frames by the start of week 3. With a two- week lead time, this means that 200 frames must be ordered at the start of week Similarly, the planned-order release of 150 shutters at week 7 generates gross net requirement 300 frames for week 7as well as planned receipts for that time. The two-week lead time means frames must be ordered atthe start of week 5.

The planned-order release of 100 shutters at the start of week 3 also generates gross requirements of 400 wood sections at that time. However, because 70wood sections are expected to be on hand, net requirements are 400-70 =330.

This means a planned receipt of 330 by the start of week 3. Since fabrication time is one week, the fabrication must start (planned order release) at the beginning of week 2.

Similarly, the planned-order release of 150 shutters in week 7 generates grossrequirements of 600 wood sections at that point. Since no on-hand inventory of wood sections is projected, net requirements are also 600, and planned-order receipt is 600 units. Again, the one week lead time means 600 sections are scheduled for fabrication at the start of week 6.

Finally under lot-size ordering, the only difference is the possibility that planned receipts will exceed net requirements. The excess is recorded as projected inventory in the following period. For example, the order size for frames is 320 units. Net requirements for week 3 are 200; thus, there is an excess of 320-200 = 120 units, which become projected inventory in the next week. Similarly, net frame requirements of 180 units are 140 less than the 320 order size; again, the excess become projected inventory in week 9. The same thing happens with wood sections; an excess of planned receipt in weeks 3 and 7 is added to projected inventory in weeks 4 and 8. Note that the order size must be in multiples of the lot size; for week 3 it is 5 times 70 and for week 7 it is 9 times 70.

The importance of computer becomes evident when you consider that a typical firm would have not one but many end items for which it needs to develop material requirements plans, each with its own set of components.

Inventories on hand and on order, schedules, order releases, and so on must all be up dated as changes and rescheduling occurs. Without the aid of a computer, the task would be almost hopeless; with the computer, all of these things can be accomplished with much less difficulty.

Updating the System. The two basic systems to update MRP records are regenerative and net change. A regenerative system is updated periodically; a net-change system is continuously updated.

A regenerative system is essentially a batch-type system, which compiles all changes (e.g. new orders, receipts) that occur within the time interval (e.g. week) and periodically updates the system. Using that information, a revised production plan is developed (if needed) in the same way that the original plan was developed (e.g. exploding the bill of materials level by level).

In a net-change system, the basic production plan is modified to reflect changes as they occur. If some defective purchased parts had to be returned to a vendor, this information is entered into the system as soon as it becomes known. Only the changes are exposed through the system, level by level; the basic plan would not be regenerated.

The regenerative system is best suited to fairly stable systems, whereas the net-change system is best suited to systems that have frequent changes. The obvious disadvantage of a regenerative system is the potential amount of lag between the time information becomes available and the time it can be incorporated into the material requirements plan. On the other hand, processing costs are typically less using regenerative systems; changes that occur in a given time period could ultimately cancel each other, thereby avoiding the need to modify and then remodify the plan. The disadvantages of the net-change system relate to the computer processing costs involved in continuously updating the system and the constant state of flux in a system caused by many small changes. On way around this is to enter minor changes periodically and major changes immediately. The primary dvantage of the net-change system is that management can have up-to-date information for planning and controlpurposes.

3.4 MRP Outputs

MRP systems have the ability to provide management with a fairly broad range of outputs. These are often classified as primary reports, which are the main reports, and secondary reports, which are optional outputs.

3.4.1 Primary Reports

Production and inventory planning and control are part of primary reports.These reports normally include the following:

(1) Planned orders, a schedule indicating the amount and timing of futureorders.
(2) Order releases, authorizing the execution of planned orders.
(3) Changes to planned orders, including revisions of due dates or orderquantities and cancellations of orders.

3.4.2 Secondary Reports

Performance control, planning, and exceptions belong to secondary reports.

(1) Performance-control repots are used to evaluate system operation. They aid managers by measuring deviations from plans, including missed deliveries and stock-outs, and by providing information that can be usedto assess cost performance.
(2) Planning reports are useful in forecasting future inventory requirements. They include purchase commitments and other data that can be used toassess future material requirements.
(3) Exception reports call attention to major discrepancies such as late and overdue orders, excessive scrap rates, reporting errors and requirements for none existent parts. The wide range of output generally permits users to adapt MRP to their particular needs.

3.4.3 Safety Stock

Theoretically, inventory systems with dependent demand should not requiresafety stock below the end-item level. This is one of the main advantages of an MRP approach. Supposedly, safety stock is not needed because usage quantities can be projected once the master schedule has been established. Practically, however, there may be exceptions. For example, a bottleneck process or one with varying scrap rates can cause shortage in downstreamoperations. However, a major advantage of MRP is lost by holding safety stock for all lower-level items. When lead times are variable, the concept of safetytime instead of safety stock is often used. This results in scheduling orders for arrival or completion sufficiently ahead of the time they are needed in order to eliminate or substantially reduce the element of chance in waiting for thoseitems. Frequently, managers elect to carry safety stock for end items, which are subject to random demand and for selected lower-level operations when safetytime is not feasible.

3.4.4 Lot Sizing

Choosing a lot size to order or for production is an important issue in inventory management for both independent- and dependent-demand items. This is calledlot sizing. For independent-demand items, economic order sizes and economic run sizes are often used.

Mangers can realize economies of scale by grouping order or run sizes. Thiswould be the case if the additional cost in covered by holding extra units until they were used led to a saving in set up or ordering cost. This determination can bevery complex at times. Let's consider some of the methods used to handle lot sizing.

3.4.4.1Lot-for-lot ordering

The order or run size for each period is set equal to demand for that period.This method wasdemonstrated in the example insection 3.3. Not only is the order size obvious, but it also virtually eliminates holding casts for parts carried over to other periods. Hence, lot-for-lot ordering minimizes investment in inventory. Its two chief draw backs are that it usually involves many different order sizes and thus cannot take advantage of the economies of fixed order size and it involves a new setup for each run.

3.4.4.2 Economic Order Quantity Model

Sometimes economic order quantity models (EOQ) are used. They can lead to minimum costs if usage is fairly uniform. This is sometimes the case for lower- level items that are common to different parents and for raw materials. However, the more lumpy demand is, the less appropriate such an approach is.

3.4.4.3Fixed - Period Ordering

This type of ordering provided coverage for some predetermined number of periods (e.g., two or three). A simple rule is; order to cover a two period interval. The rule can be modified when common sense suggests a better way.
For example, take a look at the demand shown in Figure 12.5. Using a two-period rule, an order size of 120 units would cover the first two period. The next two periods would be covered by an order size of 81 units.However, the demand, in period 3 & 5 are so small, it would make sense to combine themboth with the 80 units and order 85 units.

Figure 12.5: Demand of partPeriod

	Period 1	2	3	4	5
Demand	70	50	1	80	4
Cumulative demand	70	120	121	201	205

3.4.4.4Part-Period Model

The term part-period refers to holding a part or parts over a number of periods.
For example, if 10 parts were held for two periods, this would be 10x2 = 20 part periods. The economic part period (EPP) can be computed as:

EPP = Setup Cost
Unit holding cost per period.

In order to determine an order size that is consistent with EPP, various order sizes are examined for a planning horizon, and each one's number of part periods is determined. The one that comes closest to the EPP is selected as the best lot size. The ordersizes that are examined are based on cumulative demand. The following example illustrates this approach.

Now use the part-period method to determine order sizes for this demandschedule: set cost is N80 per run for this item, and unit-holding cost is N95 per period.

Solution

	Period							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Demand	60	40	20	2	30	–	70	50
Cumulative demand	60	100	120	122	152	152	222	272

First compute the EPP: EPP = N80/=N95 = 84.21 which rounds to 84 part period.

Next, try the cumulative lot sizes beginning with 60, until the port periods approximate the EPP. Continue this process for the planninghorizon. This leads to the following:

Period When Order Is Placed	Lot Size	Extra Inventory Carried	x	Periods Carried	=	Part Periods	Cumulative Part Periods
1	60	0		0		0	0
	100	40		1		40	40
	120	20		2		40	80
	122	2		3		6	86*
5	30	0		0		0	0
	100	70		2		140	140*
8	50	0		0		0	0

*Closes1184

The computations of part periods indicate that 122 units should be ordered to be available at period 1, and 100 units should be ordered to be available at period 5. The next lot will be ordered for period 8, but there is insufficient information now to determine its size.

The lot sizes considered for 1 correspond to cumulative demand. Once the best lot size has been identified, the cumulative demand is set equal to zero and then summed beginning with the next period. In this case, the lot size of 122 covers the first four periods, so cumulative demand is started next for period 5. The next lot size covers through period 7, and the count begins again at period 8.

The process works well for the first lot size because then cumulative number of part periods is close to the EPP, but the effect of Lumpy demand is apparent for the second lot size of 100 (140 part periods is not very close to 84 part periods).

3.5 Capacity Requirements Planning

One of the most important features of MRP is its ability to aid manager in capacity planning. As noted, a master production schedule that appears feasible on the surface may turn out to be far less feasible in terms of the resourcesrequirements needed for fabrication and /or subassembly operations of lower-level items.

Capacity requirement planning is the process of determining shortage capacity requirements. The necessary inputs include planned-order releases for MRP, the current shop load, routing information and job times. Outputs include load report for each work center. When variances (under loads or over loads) are projected, managers might consider remedies such as alternative routing, changing or eliminating lot splitting. Moving production forward or back ward can be extremely challenging because of precedence requirements andavailability of components.

The capacity planning begins with a proposed or tentative masterproductionschedule that must be tested for feasibility and possibly, adjusted before it becomes permanent. The proposed schedule is processed using MRP to ascertain the material requirements the schedule would generate. These are then translated into resource (i e capacity) requirements often in the form of a series of load reports for each department or work p center, which compares known and expected future capacity requirement with projected capacity availability.

An important aspect of capacity requirements planning is the conversion of quantity requirements into labour and machine requirements. This is accomplished by multiplying each period's quantity requirements by standard labor and/or machine equirements per unit. For instance, if 100 units of product A are scheduled in the fabrication department, and eachunit has a labor standard time of 2 hours and a machine standard time of 1.5 hours, then 100 units of A convert into these capacity requirements.

Labor:- 100 units x 2 hours/unit = 200 labor hours Machine: 100 units x 1.5 hours/unit = 150 machine hours

These capacity requirements can then be compared with available department capacity to determine the extent to which this product utilizes capacity. Forexample, if the department has 200 labour hour, and 200 machine hours available, labor utilization will be 100 percent because of all of the labor capacity will be required by this product. However machine capacity will be underutilized.

$$\frac{\text{Required}}{\text{Available}} \times 100 = \frac{150\text{hours}}{200\text{ hours}} \times 100 = 75 \text{ percent.}$$

Underutilization may mean that unused capacity can be used for other jobs; over utilization indicates that available capacity is insufficient to handle requirements. To compensate, production may have to be rescheduled or overtime may be needed.

3.6 Benefits and Requirements of MRP

3.6.1 Benefits

MRP offers a number of benefits forthe typical manufacturing or assemblytype of operation, including:

(1) Low levels of in-process inventories
(2) The ability to keep track of material requirements.
(3) The ability to evaluate capacity requirements generated by a givenmaster schedule.
(4) A means of allocating production time.

A range of people in a typical manufacturing company are important users of information provided by an MRP system. Production mangers who must balance work loads across departments and make decisions about scheduling work, and plant foremen, who are responsible for issuing work orders and maintaining production schedules, also rely heavily onMRP output. Other users include customer service representatives, who must be able to supply customers with projected delivery dates, purchasing managers, and inventory managers. The benefits of MRP depend on large measure on the use of a computer to maintain up-to-date information on material requirements.

3.6.2 Requirements

In order to implement and operate an effective MRP system, it is necessary tohave:

(1) A computer and the necessary software programs to handlecomputations and maintain records.

(2) Accurate and up-to-date
(a) Master schedule
(b) Bills of materials
(c) Inventory records

(3) Integrity of file data

On the whole, the introduction of MRP has led to a major improvement inscheduling and inventory management but it has not proved to be the cure-all that many hoped it would be. Consequently, manufacturers are beginning totake a much broader approach to resource planning one such approach is referred to as MRP 11.

3.7 MRP II

MRP II refers to manufacturing resources planning. It represents an effort toexpand the scope of production resource planning and to involve other functional areas of the firm in the planning process. A major purpose of MRP His to integrate primary functions and other functions such as personnel, engineering and purchasing in the planning process.

Material requirement planning is at the heart of the process. Process beginswith an aggregation of demand from all sources (e.g. firm orders, forecasts, safety stock requirement).Production, marketing and finance personnel work toward developing a master production schedule. Although manufacturing people will have a major input in determining the schedule and a major responsibility for making it work, marketing and finance will also have important inputs and responsibilities. The rationale for having these functional areas work together is the increase likelihood of developing a plan that worksand with which everyone can live. Moreover, because each of these functional areas has beeninvolved in formulating the plan, they will have reasonably good knowledge of the plan and more reason to work toward achieving it. In addition to the obvious manufacturing resources needed to support the plan, financing resources will be needed and must be planned for, both in amountand timing. Similarly, marketing resources will also be needed in varying degree throughout the process. In order for the plan to work, all of the necessary resources must be available as needed. Often, an initial plan must be revised based on an assessment of the availability of various resources. Oncethese have been decided, the master production schedule can be firmed up.

At this point, material requirement planning comes into play generating material and schedule requirements. More detailed capacity requirement planning must be made next to determine whether thesemore specific requirements can be met. Again some adjustment in the master productionschedule may be required.

As the schedule unfold, and actual work begins, a variety of reports help managers to monitor the process and to make any necessary adjustments tokeep operations on track.

In effect, this is a continuing process where the master production schedule is updated and revised as necessary to achieve corporate goals. The business plan that governs the entire process usually undergo changes too although this tend to be less frequent than the changes made at lower levels (i. e. themaster production schedule).

Finally, it shouldbe noted that most MRP 11 systems have the capability ofperforming simulation, enabling managers to answer a variety of "what if" questions so they can gain a better appreciation of available options and their consequences.

3.8 Summary

Material requirements planning (MRP) is an information system used to handle ordering of dependent-demand items (i e, components of assembled products).

The planning process begins with customer orders, which are used along with any back order to develop a master schedule that indicates the timing andquantity of finished items. The end items are exploded using the bill of materials, and material requirements plans are developed that show quantity and timing for materials, and timing for ordering or producing components.

The main features of MRP are the time-phasing of requirements, calculating component requirements, and planned-order releases. To be successful, MRP requires a computer program and accurate master production schedules, bills of materials, and inventory data. Firms that have not had reasonably accurate records or schedules have experienced major difficulties in trying to implement MRP.

MRP 11 is a second-generation approach to planning which incorporates MRP but adds a broader scope to manufacturing resource planning because it linksbusiness planning, production planning, and the master production schedule.

SELF ASSIGNMENT EXERCISES

Compare and contrast MRP with MRP II and state the advantage MRP offersas also compared to "Order Point" control.

3.9 References/Further Readings/Web Resources

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UNIT 4 JUST-IN-TIME SYSTEM

Unit Structure

4.1 Introduction

The term just-in-time (JIT) is used to refer to a production system in which both the movement ofgoods during production and deliveries from suppliers are carefully timed so that at each step of the process the next (usually small) batch arrives for processing just as the preceding batch is complete-thus, the name just-in-time. The result is a system with no idle items waiting to be processed and no idle workers or equipment waiting for items to process.

The just-in-time phenomenon is characteristic of lean production system, which operates with very little "fat" (e.g. excess inventory, extra workers, and wasted space). JIT pertains to the timing of the flow of parts and material through the systems, and the timing of services. Companies that employ the JIT/lean production approach have lower processing costs, fewer defectives, and greater flexibility; and are able to bring new or improved products to the market more quickly.

The JIT approach was developed at the Toyota Motor Company ofJapan byTaiichi Ohno (who eventually became vice president of manufacturing)and several of his colleagues. JIT regards scrap and rework as waste, and inventory as an evil because it takes up space and ties up resources. JIT represents aphilosophy that encompasses every aspect of the process, from design to after the sale of a product. The philosophy is to pursue a system that functions well with minimal levels of inventories, minimal space, and minimal transactions. Itmust be a system that is not prone to disruptions and is

flexible in terms of the product variety and range of volume that it can handle. The ultimate goal is to achieve a balanced system that permits a smooth, rapid flow of materials through the systems.
Companies that use JIT have achieved a level of quality that enables them to function with small batch sizes and tight schedules. JIT systems have high reliability: major sources of inefficiency and disruption have been eliminated, and workers have been trained not only to function in the system but also to consciously improve it.

4.2 Learning outcomes

By the end of this unit, you should be able to:

- Explain what is meant by the term just-in time (JIT) production system.
- List each of the goals of JIT and explain its importance.
- List and briefly describe the building blocks of JIT.
- List the benefits of the JIT systems.

4.3 Just-In-Time System

4.3.1 JIT Goals

The ultimate goal of JIT is a balanced system; that is, one that achieves a smooth, rapid flow of materials through the system. The idea is to make the process time as short as possible by using resources in the best possible way.
The degree to which the overall goal is achieved depends on how well certain supporting goals are achieved. These goals are:

1. Eliminate disruptions.
2. Make the system flexible.
3. Reduce setup times and lead times
4. Minimise inventory.
5. Eliminate waste.

Disruptions are caused by a variety of factors, such as poor quality, equipment breakdowns, changes to the schedule and late deliveries. These should be eliminated as much as possible. Inefficiency and disruption have been eliminated, and workers have been trained not only to function in the system but also to consciously improve it.

A flexible system is one that is robust enough to handle a mix of products, often on a daily basis, and to handle changes in the level of output while still maintaining balance and throughput speed.

Setup times and delivery lead times prolong a process without adding any value to the product. Moreover, long setup times and long lead times negatively impact the flexibility of the system. Hence, reduction of setup and lead times is important, and is one objective of continuous improvement.

Inventory is an idle resource, taking up space and adding cost to the system. Itshould be minimized or even eliminated wherever possible.

Waste represents unproductive resources: eliminating waste can free up resources and enhance production. In the JIT philosophy, waste includes.

- Overproduction
- Waiting time
- Unnecessary transporting
- Inventory storage
- Scrap
- Inefficient work methods
- Product defects

The existence of these wastes is an indication that improvement is possible.Alternatively, the list of wastes identifies potential targets for continuous improvement efforts.

4.3.2 Building Blocks

The design and operation of a JIT system provide the foundation for accomplishing the aforementioned goals. The foundation is made up of fourbuilding blocks:

1. Product design
2. Process design
3. Personnel/organizational elements
4. Manufacturing planning and control.

Let us discuss these blocks in turn.

4.3.3 Product Design

Three elements of product design are key to JIT systems:

1. Standard parts
2. Modular design
3. Quality

The first two elements relate to speed and simplicity.

The use of standard parts means that workers have fewer parts to deal with, and training times and costs are reduced. Purchasing, handling, and checking quality are more routine and lend themselves to continual improvement. Another importance benefit is the ability to use standard processing.

Modular design is an extension of standard parts. Modules are clusters of parts treated as a single unit. This greatly reduces the number of parts to deal with, simplifying assemble, purchasing, handling, training, and so on.

Standardization has the added benefit of reducing the number of different parts contained in the bill of materials for various products, thereby simplifying thebill of materials.

Disadvantage of standardization are less product variety and resistance to change in a standard design. These disadvantages are partly offset where different products have some common parts or modules. Using a tactic that is sometimes referred to as delayed differentiation; a decision concerning which products will be produced can be delayed while the standard portions are produced. When it becomes apparent which products are needed, the systemcan quickly respond by producing the remaining unique portions of those products.

Quality is the sine qua non ("without which not") of JIT. It is crucial to JIT systems because poor quality can create major disruptions.

JIT system uses a three-part approach to quality: One part is to design quality into the product and the production process. High quality levels can occur because JIT systems produce standardized products that lead to standardized job methods, workers who are very familiar with their jobs, and the use of standardized equipment. Moreover, the cost of product design quality (i.e., building quality in at the design stage) can be spread over many units, yielding a low cost per unit. It is also important to choose appropriate quality levels in terms of the final customer and of manufacturing capability: Thus, product design and process design must go hand in hand.

4.3.4 Process Design

Seven aspects of product are particularly important for JIT systems:
(1) Small lot sizes
(2) Setup time reduction
(3) Manufacturing cells
(4) Limited work in process
(5) Quality improvement
(6) Production flexibility
(7) Little inventory storage.

Small lot sizes in both the production process and deliveries from suppliers yield a number of benefits that enable JIT systems to operate effectively: First, with small lots moving through the systems, in-process inventory is considerably less that it is with large lots. This reduces carrying costs, space requirements, and clutter in the workplace. Second, inspection and rework costs are less when problems with quality occur, because there are fewer items in a lot to inspect and rework.

Small lots also permit greater flexibility in scheduling. This flexibility enables JIT systems to respond more quickly to changing customer demands for output: JIT systems can produce just what is needed, when it is needed.

Small lots and changing product mixes require frequent setups. Unless theseare quick and relatively inexpensive, the time and cost to accomplish them is prohibitive. Often, workers are trained to do their own setups. Moreover, programs to reduce setup time and cost are used to achieve the desired results; a deliberate effort is required, and workers are usually a valuablepart of theprocess.

One characteristic of many JIT systems is multiple manufacturing cells. Thecells contain the machine and tools needed to process families of parts having similar processing requirements. In essence the cells are highly specialized and efficient production centres. Among the important benefits of manufacturingcells are reduced changeover times, high utilization of equipment, and ease of cross-training operators. The combination of high cell efficiency and small lotsizes results in very little work-in-process inventory.

JIT systems sometimes minimize defects through the use of autonomation (notethe extra syllable 'no' in the middle of the word). This refers to the automatic detection of defects during production. It can be used with machines or manual operations. It consists of two mechanisms: one for detecting defects when they occur and another for stopping production to correct the cause of the defects.

Thus, the halting of production force immediate attention to the problem, after which an investigation of the problem is conducted, and corrective action istaken to resolve the problem.

Because JIT systems have very little in-process inventory, equipment breakdowns can be extremely disruptive. To minimize breakdowns, companies use preventive maintenance programs, which emphasize maintaining equipment in good operating condition and replacing parts that have a tendency to fail before they fail. Workers are often responsible for maintaining their own equipment.
Guidelines for increasing production flexibility are as follows:

1. Reduce downtime due to changeovers by redoing changeovers time
2. Use preventive maintenance on key equipment to reduce breakdownsand downtime.
3. Cross-train workers so they can help when bottlenecks occur or other workers are absent. Train workers to handle equipment adjustments and minor repairs.
4. Use many small units of capacity: many small cells make it easier than a few units of large capacity to shift capacity temporally and to add orsubtract capacity.
5. Use off-line buffers. Store infrequently used safety stock away from the production area to decrease congestion and to avoid continually turningit over.
6. Reserve capacity for important customers.

One way to minimize inventory storage in a JIT system is to have deliveries from suppliers go directly to the production floor, which completely eliminates the need to store incoming parts and materials. At the other end of the process, completed units are shipped out as soon as they are ready, which minimize storage of finished goods. Coupled with low work-in-process inventory; these features result in systems that operate with very little inventory.

Among the advantages of lower inventory are less carrying cost, less spaceneeded, less tendency to rely on buffers, less rework if defects occur, and less need to "work off' current inventory before implementing design improvements. But carrying fewer inventories also has some risks. The primary one is that if problems arise, there is no safety net. Another is that opportunitiesmay be lost if the system is unable to respond quickly enough.

4.3.5 Personnel Organizational Elements

There are five elements of personnel and organizational that are particularlyimportant for JIT systems:

1. Workers as assets.
2. Cross-trained workers
3. Continuous improvement
4. Cost accounting
5. Leadership project management.

Worker as Assets:- A fundamental tenet of the JIT philosophy is that workers
are assets. Well-trained and motivated workers are the heart of a JIT system. They are given more authority to make decisions than their counterparts in more tradition systems, but they are also expected to do more.

Cross-Trained Worker:- Worker are cross-trained to perform several parts of a process and operate a variety of machines. This adds to system flexibility because workers are able to help one another when bottlenecks occur or when a co-worker is absent.

Continuous Improvement:- Workers in a JIT system have greater responsibly forquality than worker in traditional systems, and expected to be involved in problem solving and continuous improvement. JIT workers typically receive extensive training in statistical process control, quality improvement, and problem solving.

Problem solving is a cornerstone of any JIT interest are problems that interrupt, or have the potential to interrupt, the smooth flow of work through the system.

A central theme of a true just-in-time approach is to work toward continual improvement of the system-reducing inventories, reducing setup cost and time, improving quality; increasing the output rate, and generally cutting waste and inefficiency. Toward that end, problem solving becomes a way of life a "culture" that must be assimilated into the thinking of management and workers alike. It becomes a never ending quest for improving operations as all membersof the organization strive to improve the system.

Cost Accounting:- Another feature of some JIT systems is the method of allocating overhead. Traditional accounting methods sometimes distort overhead allocation because they allocate it on the basis of direct labour hours. However, that approach does not always accurately reflect the consumption ofoverhead by different jobs.

One alternative method of allocating overhead is activity-based costing. Thismethod is designed to more closely reflect the actual amount of overhead consumed by particular job or activity. Activity-based costing first identifiestraceable costs and then assigns those costs to various types of activities such as machine setups, inspection, machine hours, direct labour hours, and movement of material. Specific jobs are then assigned overhead based on the percentage of activities they consume.

Leadership/Project Management:- Another feature of JITsystems relates to leadership. Managers are expected to be leaders and facilitators, not ordergivers. Two-way communication between workers and managers is encouraged.

Project managers are often given full authority over all phasesof a project. They remain with the project from beginning to end; in the more traditionalforms of project management, the project manger often has to rely on the cooperation of other managers to accomplish project goals.

4.3.6 Manufacturing Planning and Control

Five elements of manufacturing planning and control are particularly importantfor JIT systems:

1. Level loading
2. Pull system
3. Visual system
4. Close vendor relationships
5. Reduced transaction processing.

Level Loading:- JIT systems place a strong emphasis on achieving stable level daily mix schedules. Toward that end, the master production schedule is developed with level capacity loading. That may entail a rate-based production schedule instead of the more familiar quality -based schedule. Moreover, once they are established, production schedules are of short time horizon, which provide certainty to the system. This is needed in day-to-day schedules to achieve level capacity requirements.

Pull Systems:- The terms push and pull are used to describe two different systems for moving work through a production process. In push systems, when work is finished at a workstation, the output is pushed to the next station: or, in the case of the final operation, it is pushed on to final inventory Conversely, in a pull system, control of moving the work rests with the following operation: each workstation pull the output from the preceding station as it is needed; output of the final operation is pulled by customer demand or the master schedule. Thus, in a pull system, work is moved response to demand from the stage in the process, whereas in push system, work is pushed in as it is completed, without regard to the next station's readiness for the work.

Consequently, work may pile up at workstations that fall behind schedule because of equipment failure or the detection of a problem with quality.

JIT systems use the pull approach to control the flow of work, with each workstation gearing its output to the demand presented by the next workstations. Traditional production systems use the push approach for moving work through the system. JIT system communication moves backward through the system from station to station. Work moves "just in time" for the next operation; the flow of work is thereby coordinated, and the accumulation of excessive inventories between operations is avoided. Of course, some inventory is usually present because operations are not instantaneous.

Visual Systems:- Another way to describe the pull system is that work flow is dictated by "next-step demand". Such demand can be communicated in a variety of ways, including a shout or a ware, but by far the most commonly used device is the kanban card. Kanban is a Japanese word meaning "signal" or "visible record". When a worker needs materials or work from the preceding station, he or she used a kanban card. In effect, the kanban card is the authorization to move or work on parts. In Kanban system, no part or lot can be moved or worked on without one of these cards. The ideal number of Kanban cards can be computed using this formula:

N= DT(l+X) C

Where

N = Total number of containers
D = Planned usage rate of using work centre
T = Average waiting time for replenishment of parts plus average productiontime for a container of parts
X = Policy variable set by management that reflects possible inefficiency inthe system (the closer to 0. the more efficient the system
C = Capacity of a standard container (should be no more than 10 percent ofdaily usage of the part).

Note that D and T must use the same time units (e.g., minutes, days). Let's illustrates the use of the formula with the following example:
Suppose the usage at a work centre is 300 parts per day, and a standard container holds 25 parts. It takes an average of 12 day for a container to complete a circuit from the time a kanban card is received until the container is returned empty. Compute the number of kanban cards need if X = 20.

N = ?
D = 300 parts per dayT = 12day
C = 25 parts per containerX = 20
N = 300(12)(1 +20)(25) = 1,890,000 containers

Close Vendor Relationships: JIT systems typically have close relationshipwith vendors, who are expected to provide frequent small delivers of high- quality goods. Traditionally, buyers have assumed the role of monitoring the quality of purchased goods, inspecting shipments for quality and quantity, and returning poor-quality goods to the vendor for rework. JIT systems have little slack, so poor-quality goods cause a disruption in the smooth flow of work.

Moreover, the inspection of incoming goods is viewed as inefficient because it does not add value to the product. For these reasons, the burden of ensuring quality shifts to the vendor. Buyers work with vendors to help them achieve the desired quality levels and to impress upon them the importance of consistent, high-quality goods. The ultimate goal of the buyers is to beable to certify avendor as product A producer of high-quality goods. The implication of certification is that a vendor can be relied on to deliver high quality goods without the need for buyer inspection.

Suppliers must also be willing and able to ship in small lots on regular basis.

Under JIT purchasing, good vendor relationships are very important. Buyerstake measures to reduce their list to suppliers, concentrating on maintaining close working relationships with a few good ones. Because of the need for frequent, small delivers many buyers attempt to find local vendors to shorten the lead time for deliveries and to reduce lead time variability. An added advantage of having vendors nearby is quick response when problems arise.

Suppliers: A key feature of many lean production systems is the relatively small number of suppliers used. Lean production companies may employ atiered approach for suppliers. They use relatively fewfirst-tier suppliers who work directly with the company or who supply major subassemblies. The first- tier suppliers are responsible for dealing with second-tier suppliers who provide components for the subassemblies, thereby relieving the final buyer fromdealing with large numbers of suppliers.

A good example of this situation is found in the automotive industry. Suppose acertain model has an electric seat. The seat and motor together might entail 250 separate parts. A traditional producer might use more than 50 suppliers for the electric seat, but a lean producer might use a single (first-tier) supplier who has the responsibility for the entire seat unit. The company would provide specifications for the overall unit, but leave to the supplier the details of the motor, springs and so on. The first-tier supplier, in turn, might subcontract the motor to a second-tier supplier, the track to another second-tier supplier, and cushions and fabric to still another. The second-tier suppliers might subcontract some of their work to third-tier suppliers, and so on. In this "team of suppliers" approach, all suppliers benefits from a successful product, and each supplier bears full responsibility for the quality of its portion of the product.

Reduced Transaction Processing:- The transactions can be classified as logical, balancing, quality, or change transactions.

Logical Transactions:- Include ordering, execution,and confirmation **of**materials transported from one location to another. Related costs cover shipping and receiving personnel, expediting orders, data entry, and data processing.

Balancing transactions:- Include forecasting, production control, procurement, scheduling, and order processing. Associated costs relate to thepersonnel involve in these and supporting activities.

Quality transactions:- Include determining and communicating specifications, monitoring, recording, and follow-up activities. Costsrelates to appraisal, prevention, internal failures (e.g., scrap, rework, retesting, delay, administration activities) and external failure (e.g., warranty cost, product liability, returns, potential loss of future business).

Change transactions:- Primarily involve engineering changes and the ensuing changes generated in specifications, bills of material, scheduling, processing instructions and so on. Engineering changes are among the most costly of alltransactions.

JIT systems cut transaction costs by reducing the number and frequency oftransactions. For example, supplier deliver goods directly to the production floor, by passing the store-room entirely, thereby avoiding the transactions related to receiving the shipment into inventory storage and later moving the materials to the production floor. In addition, vendors are certified for quality, eliminating the need to inspect incoming shipment for quality. The unending quest for quality improvement that pervades JIT systems eliminates many of the above mentioned quality transactions and their related costs. The use of bar coding (not exclusive to JIT systems) can reduce data entry transactions and increase data accuracy.

4.4 Benefits of JIT Systems

JIT systems have a number of important benefits that are attracting theattention of traditional companies. The main benefits are:

1. Reduced level of in-process inventories, purchased goods, and finishedgoods.
2. Reduced space requirements.
3. Increased product quality and reduced scrap and rework.
4. Reduced manufacturing lead times.
5. Greater flexibility I changing the production mix.
6. Smoother production flow with fewer disruptions caused by problems due to quality, shorter setup times, and multi-skilled workers who can help each other and substitute for other
7. Increased productivity levels and utilization of equipment
8. Worker participation in problem solving.
9. Pressure to build good relationships with vendors

10. Reduction in the need for certain indirect labour, such as materialhandlers.

4.5 Summary

Just-in-time (JIT) is a system of lean production used mainly in repetitivemanufacturing, in which goods move through the system and tasks are completed just in time to maintain the schedule. JIT systems require very little inventory because successive operations are closely coordinated.

The ultimategoal of a JIT system is to achieve a balanced, smooth flow ofproduction. Supporting goals include eliminating disruptions to the system, making the system flexible, reducing setup and lead times, eliminating waste, and minimizing inventories. The building blocks of a JIT system are product design, process design, personnel and organization, and manufacturing planning and control.

Lean systems require the elimination of sources of potential disruption to the even flow of work. High quality is stressed because problems with quality can disrupt the process. Quick, low-cost setups, special layouts, allowing work to be pulled through the system rather that pushed through, and a spirit of cooperation are important features of lean systems. So too, are problem solving aimed at reducing disruptions and making the system more efficient, and an attitude of working toward continual improvement.

Key benefits of JIT/lean systems are reduced inventory levels, high quality,flexibility, reduced lead times, increased productivity and equipment utilization, reduced space requirements.

SELF-ASSIGNMENT EXERCISES

“One reason for Japan’s high manufacturing productivity is the cost reductionsit achieved through its Just-in-Time”.

1. Define the conceptual framework of JIT as a philosophy to bring out itsfundamental characteristics.
2. Discuss fully the foundations building block of Just-In-Time.

4.6 References/Further Readings/Web Resources

Krajewski, L. J. and L.P Ritzman (1999): Operations Management: Strategyand Analysis, Reading, Massachutes. Addison Wesley

Bonini, C.P,W.H. Hansman and H. Bierman, Jr (1997): QuantitativeAnalysis for Management Chicago: Irwin.

MODULE 4 PROJECT MANAGEMENT AND PRODUCTIVITY

UNIT 1 PROJECT MANAGEMENT

Unit Structure

1.1 Introduction

Managers typically oversee a variety of operations. Some of these involve routine, repetitive activities, but other involves non routine activities. Under the non-routine are projects: unique, one-time operations designed to accomplish a set of objectives in a limited time frame. Examples of projects include constructing a shopping complex, drainage system, installing a new computer system, introducing a new product or service to the market place.

Projects may involve considerable cost. Some have a long time horizon, and some involve a large number of activities that must be carefully planned and coordinated. Most are expected to be completed within time, cost, and performance guidelines. To accomplish these, goals must be established and priorities set. Tasks must be identified and time estimates made. Resource requirements must also be projected and budget prepared. Once commenced, progress must be monitored to ensure that project goals and objectives are achieved.

1.2 Learning Outcomes

By the end of this unit, you should be able to:

- Discuss the behavioral aspects of projects in terms of project personneland the project manager.
- Discuss the importance of a work breakdown structure in projectmanagement
- Give a general description of PERT / CPM techniques
- Construct simple network diagrams.
- List the kinds of information that a PERT or CPM analysis can provide.
- Analyse networks with deterministic times.
- Analyze networks with probabilistic times
- Describe activity "crashing" and solve typical problems.

1.3 Main Content

1.3.1 Behavioural aspect of Project Management

Project management differs from management of more traditional activities which gives rise to a host of rather unique problems. This section will emphasize the nature of projects and their behavioural implications. Emphasis will be laid on the role of the project manager.

1.3.2 The Nature of Projects

Projects go through a series of stages, a life cycle, which include planning, execution, and project phase out. During this life cycle, a variety of skillful requirements are involved.

In effect, projects unit personnel are with diverse knowledge and skills, most of whom remain together for less than the full life of the project. Some personnel go from project to project as their contributions become needed, some on a full-time or part-time basis, from their regular jobs. Certain kinds of organisationtend to be involved with project on a regular basis; examples include consulting firms, architects, writers and publishers.

1.3.3 The Project Manager

The central figure in a project is the project manager. He or she bears the ultimate responsibility for the success or failure of the project manager. The role of the project is one of an organizer - a person who is capable of working through others to accomplish the objectives of the project.

Once the project is underway, the project manager is responsible for effectivelymanaging each of the following:

(i) The work, so that all of the necessary activities are accomplished in thedesired sequence.
(ii) The human resource, so that those working on the project have directionand motivation.
(iii) Communications, so that everybody has the information they need to dotheir work.
(iv) Quality, so that performance objectives are realized
(v) Time, so that the project can be completed on a time.
(vi) Costs, so that the project is completed within budget.

The job of project manager can be both difficult and rewarding. The manager must coordinate and motivate people who sometimes owe their loyal support to other managers in their functional areas. In addition, the people who work on a project frequently possess distinct knowledge and skill that the project manager lacks. Nevertheless, the manager is expected to evaluate and guide their efforts.

The rewards of the job of project manager come from the challenges of the job, the benefits of being associated with a successfulproject, and the personalsatisfaction of seeing it through to its conclusion.

1.3.4 The Merits and De-merits of Working on Projects

People are chosen to work on special projects because the knowledge or abilities they possess are needed. In some instances, however, their supervisor may be unwilling to allow them to interrupts their regular jobs, even on a part time basis, because it may require training a new person to do a job that will be temporary. Moreover, managers don't want to lose the output of good workers.
The workers themselves are not always eager to participate in projects because it may mean working for two bosses who impose differing demands and may cause disruption of friendships and daily routines, and the risk of beingreplaced on the current job.

In spite of the potential risks of being involved in a project, people are attracted by the potential rewards. One is the dynamic environment that surrounds a project, often a marked contrast to the more staid environment in which some may feel trapped. Then, too, projects may present opportunities to meet newpeople and to increase future job opportunities, especially if the project is successful. In addition, association with a project can be a source of status among fellow workers.

1.4 Project Life Cycle

The length, size and scope of projects vary widely according to the nature and purpose of the project. Nevertheless all projects have something in common. They go through a life cycle, which typically consists of five phases.

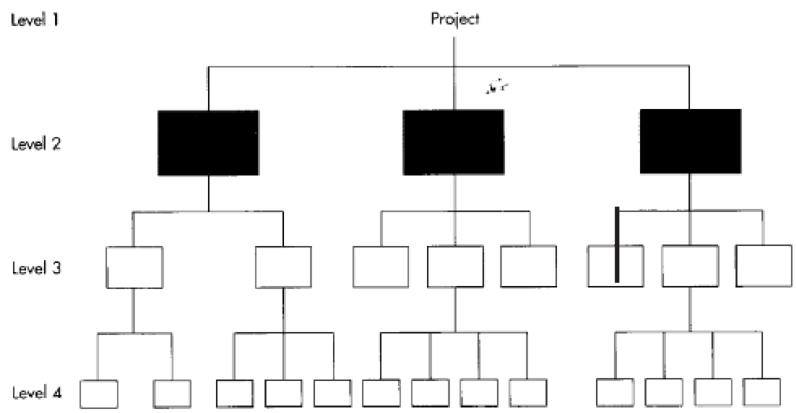
(i) Concept at which point the organisation recognizes the need for aproject or responds to a request for a proposal from a potential client.
(ii) Feasibility analysis, which examines the expected costs, benefits andrisk of undertaking the project.
(iii) Planning, this spells out the details of the work and provides estimatesof the necessary human resources, time and cost.
(iv) Execution, during which the project itself is done. This phase often accounts for the majority of time and resources consumed by a project.
(v) Termination, during which closure is achieved.

It should be noted that the phases can overlap, so that one phase may not befully completed before thenext phase begins. This can reduce the time necessary to move through the life cycle, perhaps generating some competitive advantage and cost saving.

1.5 Work Breakdown Schedule

Because large projects usually involve a very large number of activities,planners need some way to determine exactly what will need to be done so that they can realistically estimate how long it will take to complete the various elements of the project and how much it will cost. This is often accomplished by developing a work breakdown structure (WBS), which is a hierarchical listing of what must be done during the project. This methodology establishes a logical framework for identifying the required activities for the project. Theframework is illustrated below. The first step in developing the work breakdown structure is to identify the major elements of the project. These are the level 2 boxes in the structure below. The next step is to identify the major supporting activities for each of the major elements the level 3 boxes. Then,each major supporting activity is broken down into a list of the activities that will be needed to accomplish it, the level 4 boxes. Figure 14.1 below.

Figure 14.1 Schematic of a work breakdown structure

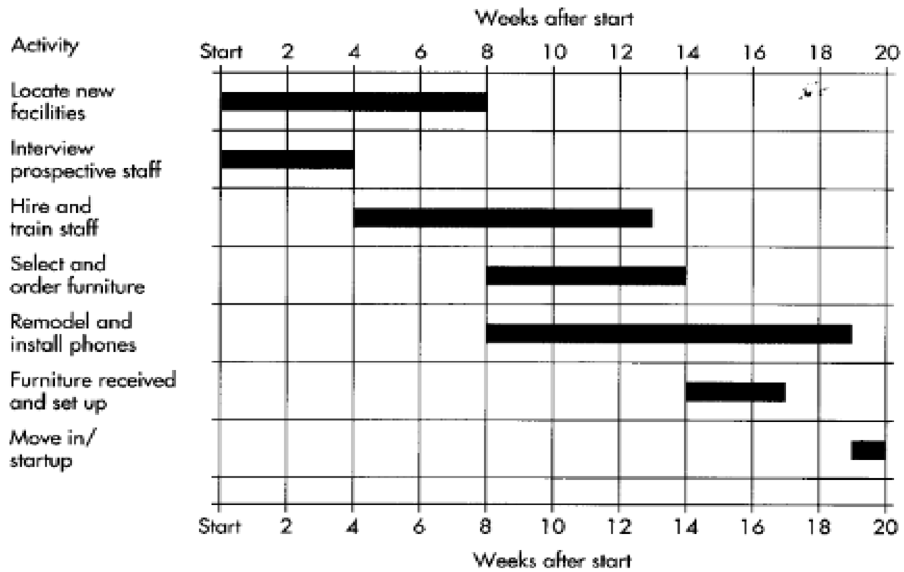


1.6 Planning and Scheduling with Gantt Charts

The Gantt chart is a popular tool for planning and scheduling simple projects. It enables a manager to initially schedule project activities and then to monitorprogress over time by comparing planned progress to actual progress. AGantt chart for a bank's plan to establish a new direct marketing department is givenin the figure below. To prepare the chart, the personnel in charge of the project first identify the major activities that would be required. Next, time estimates for each activity is made, and the sequence of activities is determined.

Once completed, the chart would indicate which activities will occur, their planned duration, and when they will to occur. Then, as the project progresses, the manager would be able to see which activities were ahead of schedule and which were delaying project. This enables the manager to direct attention where it was needed most to hasten the project in order to finish on schedule.

Figure 14.2



The obvious advantage of a Gantt chart is its simplicity, and this accounts for its popularity. However, Gantt Charts fails to reveal certain relationships among activities that can be crucial to effective project management. For instance, if one of the early activities in a project suffers a delay, it would be important for the manager to be able to easily determine which later activities would result in a delay.

1.7 PERT and CPM

PERM (Program Evaluation and Review Technique) and CPM (Critical PathMethod) are two of the most widely used techniques for planning and coordinating large -scale projects. By using PERT and CPM, managers are to obtain:

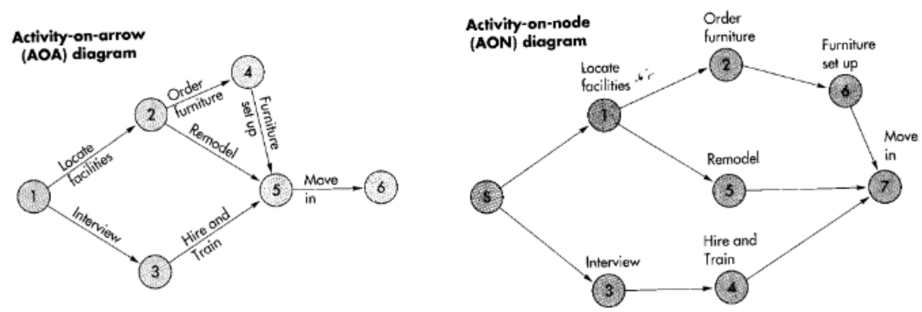
(i) A graphical display of project activities
(ii) An estimate of how long the project will take
(iii) An indication of which activities are the most critical to timely projectcompletion.
(iv) An indication of how long any activities can be delayed withoutlengthening the project.

1.8 The Network Diagram

One of the main features of PERT and related techniques is their use of anetwork or precedence diagram to depict major project activities and their sequential relationships. Recall the bank example that used a Gantt chart (Figure14.2).

A network diagram for the same problem is shown in Figure14.3 below. Thediagram is composed of a number of arrows and nodes. The arrows represent the project activities. Note how much clearer the sequential relationship of activities is with a network chart than with a Gantt chart. For instance it is apparent that ordering the furniture and remodeling both require that a location for the office has been identified. Likewise, interviewing must precede training. However, interviewing and training can take place independently of activities associated with locating a facility, remodeling, and so on. Hence, a networkdiagram is generally the preferred approach for visualportrayal of project activities.

Figure 14.3



There are two slightly different conventions for constructing these network diagrams. Under one convention, the arrows designate activities: under the other convention, the nodes designate activities. These conventions are referred to as activity - on- arrow (A-O-A) and activity –on-node (A-O-N), we will concentrate on the activity -on-arrow convention. For now, we shall use the arrows for activities. Activities consume resources and/or time. The nodes in the A-O-A approach represent the starting and finishing of activities, which are called events. Events are points in time. Unlike activities, they consume neitherresources nor time.

Activities can be referred to in either of two ways. One is by endpoints and the other is by a letter assigned to an arrow. Both methods are illustrated in this unit.

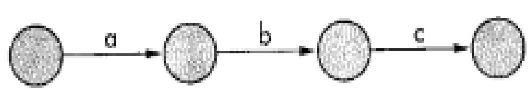
The network diagram describes sequential relationship among major activities on a project. For exampleactivity 2-4 cannot be started, according to the network until activity 1-2 has been completed (Figure 14.3 behind). A path is a sequence of activities that leads from the starting node to the finishing node.Thus, the sequence 1-2-4-5-6 is a path. There are two other paths in this network: 1-2-5-6 and 1-3-5-6. The path with the longest time is of particular interest because it governs project completion time. Project life cycle equals the expected time of the longest path; the longest path is referred to as the critical path, and its activities are referred to as critical activities. The allowable slippage for any path is called slack, and it reflects the difference between the length of a given path and the length of the critical path.

1.8.1 Network Conventions

Developing and interpreting network diagrams requiressome familiarity with networkingconventions. Although many could be mentioned, the discussionwill only itemize some of the most basic and most common features of network diagrams. This will provide us sufficient background for understanding thebasic concepts associated with precedence diagrams and allow us to solve typical problems.

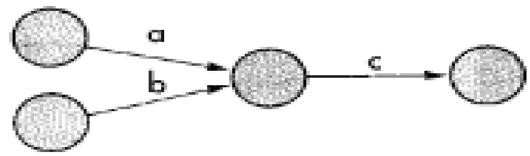
One of the main features of a precedence diagram is that it reveals which activities must be performed in sequence and which can be performed independently of each other. For example, in the following diagram, activity "a" must be completed before activity "b" can begin and activity "b" must be completed before activity "c" can begin (Figure 14.4 below).

Figure 14.4



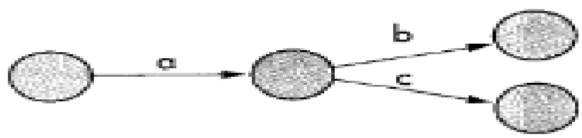
If the diagram had looked like the one below (Figure 14.5), both activities "a" and "b" would have to be completed before activity "c" could begin, but "a" and "b" could be performed simultaneously, performance of "a" is independent of performance of "b".

Figure 14.5



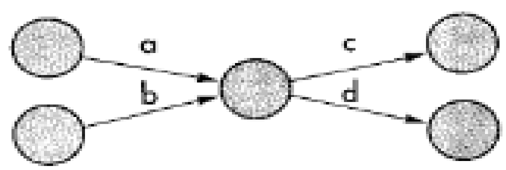
If activity a must precede "b" and "c", the appropriate network would look likethis:

Figure 14.6



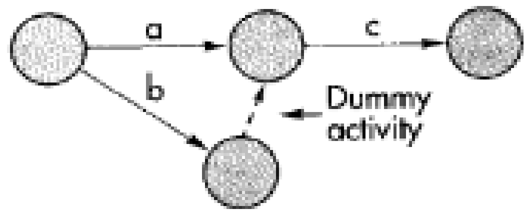
When multiple activities enter a node, this implies that all those activities must be completed before any activity that is to begin at that node can start. Hence, in this next diagram, activities "a" and "b" must both be finished before eitheractivity "c" or activity "d" can start.

Figure 14.7



When two activities both have the same beginning and ending nodes, a dummy note and activity is used to preserve the separate identity of each activity. In the diagram below, activities "a" and "b" must be completed before activity "c" can be started.

Figure 14.8



1.9 Deterministic Time Estimates

The main determinant of the way PERT and CPM networks are analyzed and interpreted is whether activity time estimates are probabilistic or deterministic.

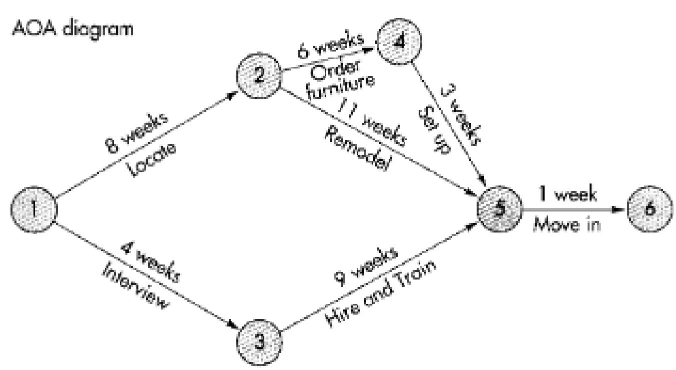
If time estimates can be made with a high degree of confidence the actual times will not differ significantly, we say the estimates are deterministic. If estimated times are subject to variation, we say the estimates are probabilistic. Probabilistic time estimates must include an indication of the extent of probable variation.

This section describes analysis of networks with deterministic time estimates. A later section deals with probabilistic times.

We would most understand the nature of network analysis with the following simple example.

Example 1

Given the following information



Determine

(a) The length of each path
(b) The critical path
(c) The expected length of the project
(d) Amount of slack time for each path.

Solution

(a) As shown in the following table, the path lengths are 18 weeks, 20 weeks and 14 weeks
(b) The longest path (20 weeks) is 1-2-5-6, so it is the critical path.
(c) The expected length of the project is equal to the length of the criticalpath (i.e. 20 weeks)
(d) We find the slack for each path by subtracting its length from the length of the critical path, as is shown in the last column of the table.

Path	Length (weeks)	Slack
1-2-4-5-6	8 + 6 + 3 + 1 = 18	20 − 18 =2
1-2-5-6	8 + 11 + 1 = 20*	20 − 20 = 0
1-3-5-6	4 + 9 + 1 = 14	20 − 14 = 6

*Critical path length.

1.9.1 A computing algorithm

Many real-life project networks are much larger than the simple network illustrated in the preceding example; they often contain hundreds or thousands of activities. Because the necessary computations can become exceedingly complex and time -consuming, large networks are generally analyzed by computer programmes instead of being done manually. The intuitive approach just demonstrated does not lend itself to computerization because, in many instances, path sequences are not readily apparent. Instead, an algorithm is used to develop four pieces of information about the network activities:

ES, the earliest time activity can start, assuming all preceding activities start asearly as possible. EF, the earliest time the activity can finish.

LS, the latest time the activity can start and not delay the project LF, the latest time the activity can finish and not delay the project Once these values have been determined they can be used to find:

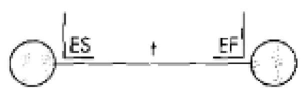
(i) Expected project duration
(ii) Slack time
(iii) Those activities on the path.

With reference to example 1, compute the earliest starting time and earliestfinishing time for each activity in the diagram.

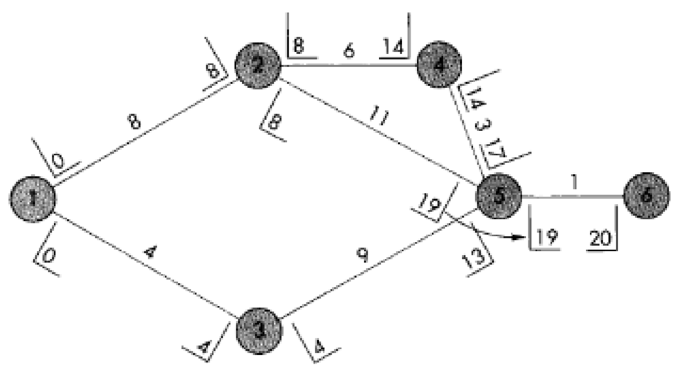
The earliest starting time, ES is the time at the start off of an activity. Thus,activities 12 and 1-3 are assigned ES values of 0.

The earliest finishing time is the time taken for an activity added to ES and so,
EF1-2 = 0+8 = 8
EF1-3 = 0+4 = 4
EF3-5 = 4+9 = 13

By placing brackets at the two ends of each starting activity, wet get:



If we reference our example 1 as shown below



We observe that ES of the starting point is 0 and EF is the time from the originof the project, but note that ES for activity 2-4 would be the EF of activity 1-2 (8weeks would have been exhausted in the history of the project before we want to commence activity 2- 4) and EF of activity 2-4 would be 8+4 to give 12 weeks. This 12 weeks is equivalent to time taken from path 1- 2-4.

1.9.1.1Computing ES and EF times

Computation of earliest starting and finishing times is aided by two simple rules:

(i) The earliest finishtime for any activity is equal to its earliest starttime plus it expected duration t. EF = ES + t.

(ii) ES for activities at nodes with one entering arrow is equal to EF of the entering arrow. ES for activities leaving nodes with multiple entering arrows is equal to the largest EF of the entering arrow.

1.9.1.2Computing LS and LF Times

Computation of the latest starting and finishing times is aided by the use of tworules:

(i) The latest starting time for each activity is equal to the latest finishingtime minus its expected duration LS = LF- t

(ii) For nodes with one leaving arrow, LF for arrows entering that node equals the LS of the leaving arrow. For nodes with multiple leaving arrows, LF for arrows entering that node equals the smallest LS of leaving arrows.

Finding ES and EF times involve a "forward pass" through the network: finding LS and LF times involves a "backward pass" through the network. Hence, we must begin with the EF of the last activity and use that time as the LF for the last activity and use that time as the LF for the last activity. Then we obtain the LS for the last activity by subtracting its expected duration from its LF.

1.9.1.3 Computing Slack Times

The slack time can be computed in either of two ways:

Slack = LS - ESor LF-EF

The critical path using this computing algorithm is denoted by activities with zero slack time.

Probabilistic time estimates

The preceding discussion assumed that activity times were known and not subject to variation. While the assumption is appropriate in some situations there are many others where it is not. Consequently, thosesituations require a probabilistic approach.

The probabilistic approach involves three time estimates for each activityinstead of one:

1. Optimistic time: - The length of time required under optimum conditions; represented by the letter o.
2. Pessimistic time: The length of time required under the worstconditions: represented by the letter p.
3. Most likely time: The most probable amount of time required:represented by the letter m.
4. These time estimates can be made by managers or others with knowledge about the project.

The beta distribution is generally used to describe the inherent variability in time estimates. Although there is no real theoretical justification for using the beta distribution, it has certain features that make it attractive in practice: the distribution can be symmetrical or skewed to either the right or the left according to the nature of a particular activity: the mean and the variance of the distribution can be readily obtained from the three times estimates listed above: and the distribution is unimodal with a high concentration of probabilitysurrounding the most likely time estimate.

Of special interest in network analysis are the average or expected time for each activity te and the variance of each activity time d2 The expected time is computed as a weighted average of the three time estimates.

$$te = \frac{0+4M+P}{6}$$

The standard deviation of each activity time is estimated as one-sixth of the difference between the pessimistic and optimistic time estimates. The variance is found by squaring the standard deviation.

$$\sigma^2 = \left[\frac{(t_p - t_o)}{6}\right]^2$$

The size of the variancereflects the level of uncertainty associated with anactivity time: the larger the variance, the greater the uncertainty.

It is al so desirable to compute the standard deviation of the expected time for each path. This can be accomplished by summing the variances of theactivities on a pathand then taking the square root of that number: that is,

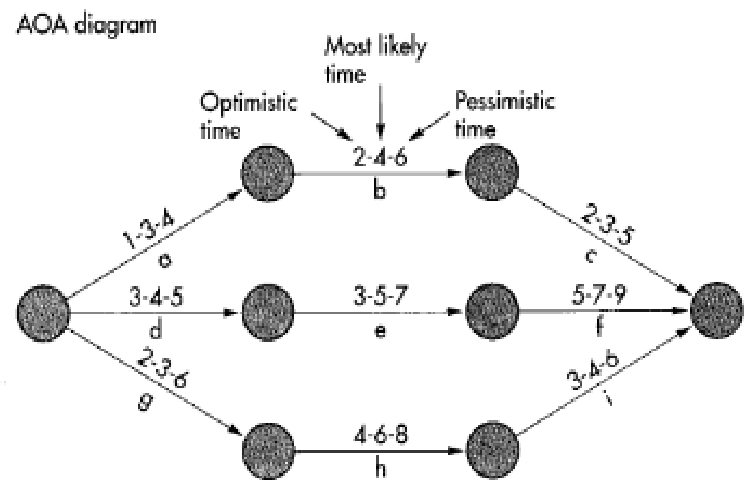
$$\sigma_{path} = \sqrt{\Sigma(\text{variances of activities on path})}$$

For simplicity the following example illustrates clearer.

The network diagram for a project is shown in the accompanying figure. Withthree time estimates for each activity. Activity times are in months.

Do the following:

(a) Compute the expected time for each activity and the expectedduration for each path.
(b) Identify the critical path.
(c) Compute the variance of each activity and the variance of each path.



Key: The left hand figure of each three digit is the optimistic time.
The middle figure, most likely time The right hand figure, pessimistic time

Solution

a.

Path	Activity	TIMES t_o	t_m	t_p	$t_e = \frac{t_o + 4t_m + t_p}{6}$	Path Total
	a	1	3	4	2.83	
a-b-c	b	2	4	6	4.00	10.00
	c	2	3	5	3.17	
	d	3	4	5	4.00	
d-e-f	e	3	5	7	5.00	16.00
	f	5	7	9	7.00	
	g	2	3	6	3.33	
g-h-i	h	4	6	8	6.00	13.50
	i	3	4	6	4.17	

(a) The path that has the longest expected duration is the critical path.

Sincepath d-e-f has the largest path, it is the critical path.

Path	Activity	TIMES t_o	t_m	t_p	$\sigma^2_{act} = \frac{(t_p - t_o)^2}{36}$	σ^2_{path}	σ_{path}
a-b-c	a	1	3	4	$(4-1)^2/36 = 9/36$		
	b	2	4	6	$(6-2)^2/36 = 16/36$	34/36 = 0.944	0.97
	c	2	3	5	$(5-2)^2/36 = 9/36$		
d-e-f	d	3	4	5	$(5-3)^2/36 = 4/36$		
	e	3	5	7	$(7-3)^2/36 = 16/36$	36/36 = 1.00	1.00
	f	5	7	9	$(9-5)^2/36 = 16/36$		
g-h-i	g	2	3	6	$(6-2)^2/36 = 16/36$		
	h	4	6	8	$(8-4)^2/36 = 16/36$	41/36 = 1.139	1.07
	i	3	4	6	$(6-3)^2/36 = 9/36$		

If we use the information from this preceding example, we may consider thefollowing question.

(a) What is the probability that the project can be completed within 17month of its start?

(b) What is the probability that the projectwill be completed within 15months of its start?

(c) What is the probability that the project will not be completed within 15months of its start?

Solution

(a) To answer this question, you must first compute the value of Z usingthe relationship

$$z = \frac{\text{Specified time} - \text{Path mean}}{\text{Path standard deviation}}$$

In this instance, we have for project d-e-f

$$z = \frac{17 - 16}{1.00} = +1.00$$

From the normal distribution table, the area under the curve to the left of Z is 0.8413. Hence, the probability of the project finishing within 17 months of its start is 0.8413.

Projects a-b-c and g-h-I are both sure to be completed within 17 months of its start.

Hence, their probabilities would be 1 each.

(b) If on the other hand we consider the probability of the project being completed within 15 months, we then have to compute Z values for each project.

Path	$z = \frac{15 - \text{Expected path duration}}{\text{Path standard deviation}}$	Probability of Completion in 15 Weeks
a-b-c	$\frac{15 - 10.00}{0.97} = +5.15$	1.0000
d-e-f	$\frac{15 - 16.00}{1.00} = +1.00$	.1587
g-h-i	$\frac{15 - 13.50}{1.07} = +1.40$	.9192

Although the figure is useful in expressing the concept of overlapping paths, you need a more rigorous approach to determine which paths to consider and what the probability of completion isfor each path. This requires computing Z values; any Z value that is greater than + 2.50 is treated ashaving a completion probability of 100 percent.

Time -cost trade -offs: Crashing

Estimates of activity times for projects usually are made for some given level of resources. In many situations, it is possible to reduce the length of a project by injecting additional resources. The necessity to shorten projects may reflect efforts to avoid late penalties, to take advantage of monetary incentives for timely or early completion of a project. In new product development, shortening may lead to a strategic benefit: beating the competition to the market. Managers often have certain options at their disposal that will allow them to shorten, or crash, certain activities. Among the most obvious options are the use of additional funds to support additional personnel or more efficient equipment and the relaxing of some work specifications.

In order to make a rational decision on which activities, if any to crash and on the extent of crashing desirable, a manager needs certain information.

1. Regular and time crash estimates for each activity.
2. A list of activities that are on the critical path
3. Regular cost and crash cost estimates for each activity.

Activities on the critical path are highly subjected to crashing, since shortening non critical activities would not have an impact on total project duration. From
an economic standpoint, activities should be crashed according tocrashingcosts: crash those with lowest cost first.

Moreover, crashing should continue as long as the cost to crash is less than thebenefits received from crashing.

1.10 Summary

Projects are made up of special activities established to realize a given set ofobjectives in a short while. The non-routine nature of project activities places a set of demands on the project manager that are different in manyrespects from those the manager of more routine operations activities require.

PERT and CPM are two commonly used techniques for developing and monitoring projects. Although each technique was developed independently and for expressly different purposes, time and practice have erased most of the original differences, so thatnow there is little distinction between the two.

Either provides the manager with a rational approach to project planning and a graphical display of project activities. Both show the manager the sequence of events which must be completed on time to achieve timely project completion.

Two slightly different conventions can be used for constructing network diagram. One designates the arrows as activities: the other designates the nodes as activities. This unit has emphasized only the activity-on-arrowmodel.

In some situations, it may be possible to shorten, or crash, the length of aproject by shortening one or more of the project activities. Typically, gains are achieved by the use of resources, although in some cases, it may be possible to transfer resources among project activities. Generally, projects are shortened to the point where the cost of additional reduction would exceed the benefit ofadditional reduction, or to a specified time.

1.11 References/Further Readings/Web Resources

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UNIT 2 TOTAL QUALITY MANAGEMENT

Unit Structure

2.1 Introduction

The challenge for business today is to produce quality products or servicesefficiently. A company that meets this challenge can use quality as a competitive weapon. This unit explores the competitive implications of quality, focusing on the philosophy of total quality management which is an aspect ofthe topic of quality.

Total quality management (TQM) stresses three principles: customer satisfaction, employee involvement, and continuous improvements in quality. TQM also involves benchmarking, product and services design, process design, purchasing, and problem-solving.

For most companies, superior product quality is at the core of their business strategy. For these companies, attaining near-perfect product quality is seen as the principal means of capturing market share in global competition. The prominence of product quality in business strategy for many firms has come from the painful knowledge that one may lose business to lower-priced products, but one wins it back with superior product quality. Achieving superior product quality within a business requires a long-term process of changing the fundamental culture of the organization.

2.2 Learning Outcomes

By the end of this unit, you should be able to:

- Define quality from the customer's perspective.
- Describe the principles of a TQM program and how the elements fit together to make improvements in quality and productivity
- Identify
- Discuss how TQM programs improve quality through benchmarking, product and service design, quality function deployment, and qualityconscious purchasing
- Distinguish among the various tools for improving quality and explainhow each should be used.
- Discuss the nature and benefits of NAFDAC and international standards for quality programs and environmental management programs.

2.1 Total Quality Management

2.1.2 Quality: A Management Philosophy

Starting in the 1970s, Japanese manufacturers, with the help of American consultants such as W. Edwards Deming and Joseph M. Juran, began making quality a competitive priority. Deming's philosophy was that quality is the responsibility of management, not the workers, and the management must foster an environment for detecting and solving quality problems. Juran believed that continuous improvement, hands-on management, and training are fundamental to achieving excellence in quality. Foreign competitors with superior goods may dominate the local market with inferior alternatives. A good example is the imported and local rice in Nigeria. Manufacturers need to listen to the customers or lose market share. This realization has helped the Japanese manufacturers over the years. The global economy of the 1990s and beyond dictates that companies provide the customer with an ever widening array of products and services having high level of quality.

2.1.1 Customer-Driven Definition of Quality

Customers define quality in various ways. Generally, quality may be defined as meeting or exceeding the expectations of the customer. However, quality has multiple dimensions in the mind of the consumer, and one or more of the following definitions may apply at any one time.

(a) Conformance to specifications

Customers expect the products or services they buy to meet or exceed certain advertised levels of performance. When Nestle advertises milo as "the drink of future champions, the expectation of the customers is high as to the pleasure they will derive from taking milo. They will be expecting to gain energy, strength or vitality. If they derive all these or even more, then milo conforms to specification.

(b) Value

Another way customers define quality is through value, or how well the product or service, serves its intended purpose at a price customers are willing to pay. How much value a product or service has in the mind of the customers depends on the customer's expectations before purchasing it. For example if you spent N 10 to buy an Eleganza ball point pen and it served you well for 3 weeks, you might feel that the purchase was worth the price. Your expectations for the product were met or exceeded. However, if the pen lasted only 3 days, you might be disappointed and feel that the value wasn't there.

(c) Fitness for use

In assessing fitness for use, or how well the product or service perform its intended purpose, the customer may consider the mechanical features of a product or the convenience of a service. Other aspects of fitness for use include appearance, style, durability, reliability, craftsmanship and serviceability. For example, a retailer of frozen fish may find a deep freezer fit for product storage while a wholesaler will need a cold room.

(d) Support

Often the product or service support provided by the company is as important to customers as the quality of the product or service itself. Customers get upset with a company if financial statements are incorrect, responses to warranty claims are delayed, or advertising is misleading. Good product support can reduce the consequences of quality failures in other areas. You may decide to buy your upholstery from a furniture worker who agrees to transport it to yourapartment.

(e) Psychological Impression

People oftenevaluate the quality of a product or service on the basis ofpsychological impressions: atmosphere, image, or aesthetics. The appearance and actions of the service provider are very important. Nicely dressed, courteous, friendly, and sympathetic employees can affect the customer's perception of service quality. For example, rumpled, discourteous, or grumpy waiters can undermine a restaurant's best efforts to provide high-quality service.

2.1.2 Quality as a Competitive Weapon

Attaining quality in all areas of a business is a difficult task because perceptions of quality by customers change over time. For instance, changes in life-styles and economic conditions have drastically altered customer perceptions of automobile quality. During austerity, most Nigerians go forsecond-hand (Tokunbo) cars especially models with economic fuel consumption. But as the economy improves, more people buy better cars.

A business's success depends on the accuracy of its prediction of consumer’s expectation and the ability to bridge the gap between those expectations and operating capabilities. Consumers are now quality-minded than in the past. Research findings indicate that a high quality product has a better chance of gaining market share than does a low-quality product. Most modern firms believe that their total quality management (TQM) programmes are highly successful in retaining customers and building satisfaction. More over, perception of a product as being of high quality by customers gives it better chance over those considered to be of low-quality even if the level of their quality is the same.

Good quality can pay off in higher profit. High-quality products and services can be priced higher than comparable lower quality ones and yield a greater return for the same sales naira. Poor quality erodes the firm's ability to compete in the market place and increase the costs of producing its products or service.

2.2 Employee involvement

One important component of TQM is employee involvement. A complete programme in employee involvement includes changing organizational culture, fostering individual development through training, establishing awards and incentives, and encouraging team work.

2.2.1 Cultural Change

The challenge of quality management is to instill an awareness of the importance of quality in all employees and to motivate them to improve product quality. With TQM, everyone is expected to contribute to the overall improvement of quality - from the administrator who finds cost- saving measures to the salesperson that learns of a new customer need, to the engineer who designs a product.

Customers can either be internal or external. External customers are the peopleor firms who buy the product or service. Thus the entire firm must do its best to satisfy them. It is often difficult for employees who are not dealing directlywith customers to see their contribution to TQM, but this is not to say that they are less important. Each employee has one or more internal customers - employees in the firm who rely on the output of other employees. For example, a printer who prints a book and passes it on to a binder has the binder as hiscustomer.

The binder will have similar perception of quality asfinal consumer. All employees have to do a good job of serving their internal customers forultimate satisfaction of the external customers. The concept of internal customers works, if each internal customer demands only value-added activities of their internal suppliers: that is, activities that the external customer will recognize and pay for. The concept of internal customers applies to allparts of a firm and enhances cross functional coordination.

TQM makes quality control everyone's business where errors are promptly detected and corrected internally before they get to the final consumers. Thisphilosophy is called quality at the source. Firms should try to avoid "inspecting quality into the product" by using inspectors to detect defective product after all operations have been performed. Some firms authorize workers to stop a production line if they spot quality problem.

2.2.2 Individual Development

On the job training can help improve quality. Teaching new work methods to experienced workers or training new employees in current practices can increase productivity and reduce the number of product defects. Some companies train workers to perform related jobs to help them understand how quality problems in their own work can cause problems for other workers. Managers too need to develop new skills in order to teach their subordinates.

They may have to embark on "train - the - trainer" programme to acquire skillsto train others in quality improvement practices.

2.2.3 Awards and Incentives

The prospect of merit pay and bonuses can give employees some incentive for improving quality. Companies may tie monetary incentives directly to qualityimprovements.

Non-monetary awards, such as recognition in front of co-workers, also can motivate quality improvements. Some companies periodically select an employee who has demonstrated quality workmanship and give them special recognition e.g. a special dinner, such performance may even be reported in the company newsletter.

2.3 Continuous Improvement

Continuous improvement, based on a Japanese concept called "Kaizen", is the philosophy of continually seeking way to improve operations. It is alsoapplicable to process improvement. Continuous improvement involves identifying benchmarks of excellent practice and instilling a sense of employee ownership in the process. The focus can be on reducing the length of time required to process request for loans at a bank. Continuous improvement can also focus on problems with customers or suppliers. The bases of continuous improvement is that if people involved in a process can identify the needed changes to be made, the process can be improved upon. An organization should not wait until massive problem occurs before acting.

2.3.1 Getting Started with Continuous Improvement.

Instilling the philosophy of continuous improvement involves the followingprocesses:

(a) Train employees in the methods of statistical process control (SPC) andother tools for improving quality and performance.
(b) Make SPC methods a normal aspect of daily operations.
(c) Build work teams and employee involvement
(d) Utilize problem-solving tools within the work teams.
(e) Develop a sense of operator ownership in the process.

Note that employee involvement is central to the philosophy of continuousimprovement. The last two steps are crucial if the philosophy is to become part of everyday operations. Problem solving addresses the aspects of operations thatneed improvement. A sense of operator ownership emerges when employees feel as though they own the processes and methods they use and take pride in the quality of the product or service they produce.

2.3.2 Problem-solving process

Firms that are actively involved incontinuous improvement train their workteams to use the plan-do-check-act cycle of problem solving. The approach is called Deming wheel and it lies in the heart of the continuous improvement philosophy. The steps involved are.

(i) Plan. The team selects a process (activity, method, machine, policy e.t.c.) that needs improvement. The team then documents the selected process, by analyzing data; sets qualitative goals for improvement; and discusses various ways to achieve the goal. After assessing the benefits and costs of the alternatives, the team develops a plan with quantifiablemeasures for improvement.

(ii) Do. The team implements the plan and monitors progress. Data are collected continuously to measure the improvements in the process. Any further revisions are made as needed.

(iii) Check. The team analyzes the data collected during the do step to findout how closely the results correspond to the goals set in the plan step. If major short comings exist, the team may have to reevaluate the plan or stop the plan or stop the project.

(iv) Act. If the results are successful, the team documents the revised process so that it becomes the standard procedure for all who may use it. The team may then instruct other employees in the use of the revised process.

2.4 The Cost of Poor Quality

Defective and unsatisfactory product may cost a company up to 20 to 30percent of its gross sales. For instance, a high electric power surge may damage all electrical appliances of a company as low current supply may delayoperations. Four major categories of cost are associated with quality management: prevention, appraisal, internal failure, and external failure.

2.4.1 Prevention Costs

These are incurred when preventing defects from happening. These include the cost of redesigning the process and product, training of employees and working with suppliers to increase the quality of purchased items. In order to improve quality, firms invest in additional time, efforts, and money.

2.4.2 Appraisal costs - are incurred in assessing the level of quality \ attained by the operating system

This helps to identify quality problems and proffer measures to improvequality, appraisal costs decrease due to quality inspections.

2.4.3 Internal failure costs

These result from defects that are discovered during the production of product or service. They fall into two categories: yield losses and rework costs. Yield losses are incurred if a defective item must be scrapped. Rework Costs are incurred if item is rerouted to some previous operation (s) to correct the defect or if the service must be performed again. Additional time spent to correct mistakes lowers productivity of a unit.

2.4.4 External failure costs:

Arise when a defect is discovered after the customer has received the product or service. For instance, suppose you discover that your dry cleaner has burntone of your clothes given to him, you may demand that he amends it for you.
External failure cost erodes market share of profits. The costs include warranty service and litigation costs. A warranty is a written guarantee

that the product will be replaced or repair the defective parts or perform the service to thecustomer's satisfaction.

Defective products can injure and even kill consumer who purchase them. Thus it is important to prevent them from getting to the final consumer. External failure costs also include litigation cost. These include legal fees, time and effort of employees who appear for the company in court. The cost of litigation is enormous and the negative publicity can be devastating.

2.5 Improving Quality through TQM

Employee involvement and continuous improvement generally improvequality. But, TQM often focuses on benchmarking, product and service design, process design and purchasing.

2.5.1 Benchmarking

Benchmarking is a continuous systematic procedure that measures a firm'sproducts, services and processes against those of industry leaders. Companies use the outstanding company in the industry as standard they would like to attain to. Typical measures used in, benchmarking include cost per unit, service per customer, processing time per unit, customer retention rates, revenue perunit, return on investment, and customer satisfaction levels. Benchmarking consists of four basic steps"

2.5.1.1**Planning -Identifying the product, service or process to be**benchmarked and the firms (s) to be used for comparison, determine the measures of performance for analysis, and collect data

2.5.1.2**Analysis - Determine the difference between the firm's current** performance and that of the benchmark firm (s) and identify the causes of significant gaps.

2.5.1.3**Integration** - Establishing goals and obtaining the support of managers who must provide the resources for achieving the goals.

Action - This involves determining the team affected by the changes,developing action plans and assignments, implementing the plan, monitoring progress and watching the level attained on the benchmark.

Benchmarking focuses on setting of quantitative goals for continuous improvement. Comparative benchmarking is based on comparisons with a direct industry competitor. Functional benchmarking compares areas such as administration, customer service and sales operations with those of outstanding firms in an industry. Internal benchmarking involves using an organisationalunit with superior performance as the benchmark for other units. All forms of benchmarking are applied when there is a need for continuous improvement.

2.5.2 Product and Service Design

Because design changes often require changes in methods, materials, or specifications, they can increase defect rates. Change increases the risk of making mistakes, so stable product and service designs can help reduce internal quality problems. Stable designs may not be possible when a product or service is sold in markets globally. Although changed designs have the potentialto increase market share, management must be aware of possible quality problems Resulting from changes. A firm may need to change design to remain competitive; it should carefully test new designs and redesign the product with a focus on the market. Higher quality and increased competitiveness areexchanged for added time and cost.

Another dimension of quality related to product design is reliability. Reliability is the probability that the product will be functional when used. Products often consist of a number of components that must be operative for them to perform as expected. Some products can be designed with extra components/subsystems so that if one system component fails another can be activated.

Suppose that a product has subsystems, each with its own reliability measure. The reliability of the product is equal to the product of the reliabilities of all the subsystems, i.e.

rs = (rl) (r2) ... (rn) (i)

Where

rs = reliability of the complete product.
n = number of subsystems
rn = reliability of the subsystem n

This measure is based on the assumption that the reliability of each componentdepends on those of others.

Suppose you have a table fan, and you discover that the reliability of its plug is
0.95, that of the cord 0.90 that of the switch is
0.88 and the coil has 0.70

reliability. The reliabilities are the probabilities that each subsystem will still beoperating three years from now. The reliability of the table fan is

Rs=(0.95) (0.90) (0.88) (0.70) = 0.53
The table fan thus has a reliability of 0.53. This is the probability that it will notfail to work when you put it on.

2.5.3 Process Design

Process designs greatly affect product quality. Wema Bank PLC may observethat the average waiting time to pay NEPA bill in all its branches is one hour. It may want to reduce the waiting time to 30 minutes by assigning only onecashier to customer waiting to pay such bills.

The purchase of new and efficient machinery can help to prevent or overcome quality problem. The cost of the machinery is the trade-off for reducing the percentage of defects and their cost.

One of the keys to obtaining high quality is concurrent engineering in whichoperation's manager work hand in hand with designers in the initial phases of product or service design to ensure that production requirements and process capabilities are synchronized. This results in better quality and shorter development time.

2.5.4 Quality Function Deployment

A key to improving quality is to link the design of products or services to the processes that produce them. Quality Function Deployment (QFD) is a means of translating customer requirements into the appropriate technical requirements for each stage of product or service development and production. This approach seeks answers to the following questions.

(a) Voice of the customer - what do our customers need and want?
(b) Competitive analysis - How well are we doing relative to our competitors, in terms of our customers?
(c) Voice of the engineer - what technical measures relate to our customers' needs?
(d) Correlation - what is the relationship between the Voice of customer and the voice of the engineer?
(e) Technical comparison - How does our product/service perform compared to that of our competitors?

(f) Trade-offs - what are the potential technical trade - offs?

The QFD approach provides a way to set targets and debate their effects onproduct quality. QFD encourages inter functional communication for the purpose of improving product quality.

2.5.5 Purchasing Considerations

Most firms depend on outside suppliers for some of the materials, services, or equipment used in producing their products and services. Large companies have many of such suppliers, some of which supply them the same material. The quality of these inputs can affect the quality of the firm's work

Both the buyer's approach and specification management are keys to controlling supplier quality. The firm's buyer must emphasize the cost, and speed of delivery of the supplier as well as the quality of the product. The buyer identifies suppliers with high - quality products and arranges to buy from them.

The specifications for the purchased items must be clear and realistic. The buyers initiate process capability studies for important products. This involves trial runs of small product samples to ensure that the quality is as specified and will perform as desired at the given cost. Management needs to allow sufficient time for the purchasing unit and may work closely with other units e.g. engineering to ensure quality control.

2.5.6 Tools for Improving Quality and Performance

The first step in improving quality of an operation is data collection. There are seven tools for organizing and presenting data to identify areas for quality and performance improvement. These are:
Checklists, histograms and bar charts, Pareto charts, scatter diagrams, cause-and-effect diagrams, graphs, and control charts. We discuss six of them here.

(a) Checklists

A checklist is a form used to record the frequency of occurrence ofcertain product or service characteristics related to quality. The characteristics may be measurable on continuous scale (e.g. weightor time) or on yes-or-no basis

(b) Histograms and Bar chats

A histogram summarizes data measured on a continuous scale, showing the frequency distribution of some quality characteristic. A bar chart is a series of bars representing the frequency of occurrence of datacharacteristics measured on a yes-or-no basis.

(c) Pareto Charts

When managers discover several quality problems that need to be addressed, they have to decide on which to tackle first. Vilfredo Pareto proposed that most of an "activity" is caused by relatively fewof its factors. In a restaurant quality problem, the activity couldbe customer complaints and the factor could be "discourteous waiter".

Pareto's concept, called the 80-20 rule, is that 80 per cent of the activityis caused by 20 percent of the factors. Thus, by concentrating on the 20 per cent of the factors, managers can attack 80 percent of the qualityproblem.

A Pareto chart is a bar chart on which the factors are plotted indecreasing order of frequency along the horizontal axis. The chart has two vertical axis, the one on the left showing frequency and the one on the right showing the cumulative percentage of frequency curve, identifies the few vital factors that warrants immediate managerialattention.

(d) Scatter diagram

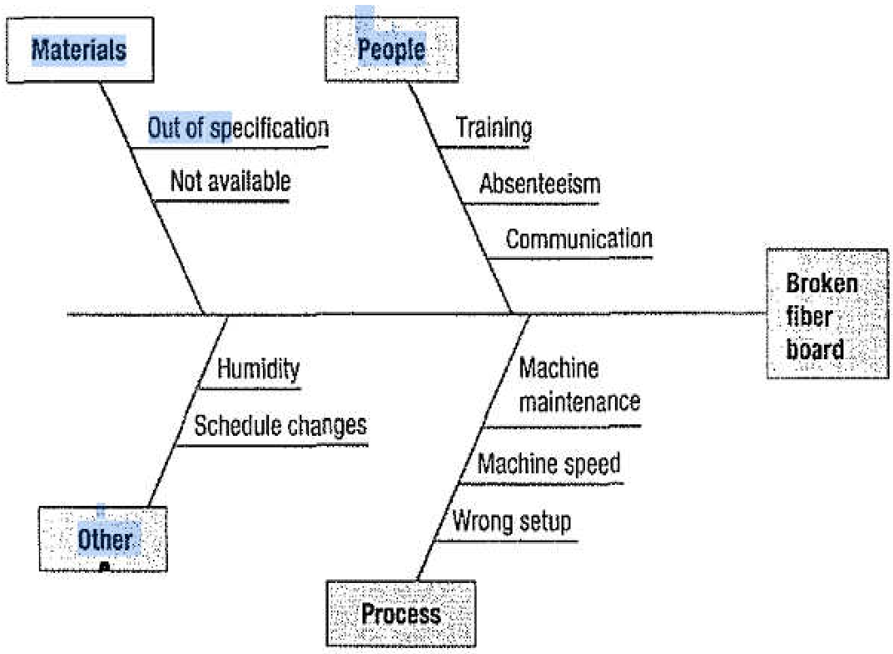
A scatter diagram is a plot of two variables showing whether they are related or not and can be used to clear doubt about a factor causing one quality problem. Each point on the scatter diagram represents a dataobservation.

(e) Cause-and-Effect Diagrams

One way to identify a design problem that needs to be corrected is to develop a cause-and -effect diagram that relates a key quality problem to its potential causes. The diagram helps management to trace customer complaints directly to the operations involved.

The cause-and-effect diagram is also known as a fishbone diagram. The main quality problem is labeled as the fish's "head", the major categories of potential causes as structural "bones" and the likely specific causes as "ribs". The diagram below is used to illustrate this.

Figure 19.1



From Figure 19.1, the head or problem is bad printing job. The main causes forming the structural bones are people, material, process and other causes. These all have specific causes.

(f) Graphs

Graphs represent data in a variety of pictorial formats, such as line graphs and pie charts. Line graphs represent data sequentially with data points corrected by line segments to highlight trends in the data. Piecharts represent quality factors as slices of a pie, the size of each slice is in proportion to the number of occurrence of the factor.

2.5.7 Data Snooping

Each of the tools for improving quality may be used independently, but their power is greatest when they are used together. Managers may need to shift data to clarify the issues involved in deducing the causes. This process is called data snooping.

2.6 National and International Quality Standards

2.6.1 National Quality Standards

Products and services quality are standardized by various public and private agents in Nigeria. These could be trade unions, professional bodies or government agencies e.g. licencing office. Accountants, Engineers e.t.c. have their professional bodies that maintain standard in their profession. The Nigerian University Commission for instance, maintains standard and quality of university education in Nigeria. The National Agency for Food and Drug Administration and Control(NAFDAC) is saddled with responsibility of maintaining standard in food and pharmaceutical industry.

2.6.2 International Quality Standard

Companies selling in international markets may have difficulty complying with varying quality documentation standards in countries where they do business.

To cope with this problem, the international organization for standardizationdevised a set of standards called ISO 9000 for companies doing business in the European Union. Also, a new set of standards, ISO14000, were devised forenvironmental management systems.

(a) The ISO 9000 standards is a set of standards governing documentation of a quality programme. Companies become certified buy proving to aqualified external examiner that they have complied with allthe requirements. Companies thus certified are listed in the directory for potential customer to know that such companies can own-up their claims on their products. This tells nothing on the actual quality of the product. The ISO 9000 consists of 5 documents: ISO 9000 - 9004

(b) ISO 14000 - An Environmental management system.
The ISO 14000 standards require participating companies to keep track of their raw materials use and their generation, treatment, and disposal of hazardous wastes. The standard is to ensure improvement in environmental performance. ISO 14000 is a series of 5 standards covering the following areas.

- Environmental management system
- Environmental performance evaluation
- Environmental labeling
- Life-cycle assessments

2.7 Summary

Total quality management is built on three principles: customer-driven focus, employee involvement, and continuous quality improvement. Quality means a variety of things to customers. A customer may make a qualitative judgment about whether a product or service meets specified design characteristic.

Another may make qualitative judgment about value, fitness for the customer's intended use, product or servicesupport, andaesthetic reasons. OneTQMresponsibility of marketing is to listen to customers and report their changing perceptions of quality.

Quality can be used as a competitive weapon. World-class competition requires businesses to produce quality products or services efficiently Responsibility for quality is shared by all employees in the organizations. Managers too need to develop skills for teaching their subordinates.

Continuous improvement involves identifying benchmarks of excellent practices and instilling a sense of ownership in employees so that they will continually identify product, services or process that need improvement.

Quality management is important because of its impact on market share, price, and profits and because of the costs of poor quality. The four categories of costs associated with quality management are prevention, appraisal, internal failure, and external failure. Benchmarking is a comparative measure used to establish goals for continuous improvement. Forms of benchmarking are competitive, functional and internal concurrent engineering improves the match between product design and production process capabilities. Quality improvement requires close cooperation among functions (design, operations,marketing, purchasing etc.)

Keys to controlling supplier quality are buyer's approach and specification management. The buyer must consider quality, delivery, and cost.

Approaches to organizing and presenting quality improvement data include check lists, scatter diagrams, cause-and-effect diagrams, Pareto charts, bar charts, graph and control charts.

Quality management in Nigeria is done by various public and private agencies.NAFDAC monitors quality in the food and drugs industry.

Two sets of standard, governing thedocumentation of quality programmes atthe global level are ISO 9000 and ISO 14000.

SELF-ASSESSMENT EXERCISES

A semiconductor has 3 components in series. Component I has a reliability of 0.96, Component 2, 0.98 and component 3, 0.97 what is the reliability of the semiconductor

2.8 References/Further Readings/Web Resources

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