NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF MANAGEMENT SCIENCES

COURSE CODE: MBA 801

OURSE CODE: PRODUCTION AND OPERATIONS MANAGEMENT

COURSE GUIDE

MBA 801
PRODUCTION AND OPERATIONS MANAGEMENT

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Introduction

MBA 801 Production and Operations Management (POM), is a one semester, two credit unit course. It is available to all MBA students in the School of Business and Human Resource Management.

The course consists of 20 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 with 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 MBA 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 that are 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 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 organization, foster teamwork, the degree of specialization, 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 there 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 organisation.
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 take to making 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 four modules as follows:

Module	Title	Unit	Topic
1	POM: Introduction and Overview	1	POM- An Introduction
		2	Operations Strategy
		3	Forecasting in POM
2	Design of Production Systems	4	Process Management
		5	Job Design
		6	Management of Technology
		7	Site Selection
3	Operating Decisions	8	Supply-Chain Management
		9	Inventory Management
		10	Aggregate Planning
		11	Linear Programming
		12	Materials Requirements Planning
		13	Just-In-Time Systems
		14	Project Management
4	Control Decisions	15	Productivity
		16	Work Methods
		17	Work Measurement
		18	Learning Curves
		19	Total Quality Management
		20	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)

With respect to TMAs, you are expected to apply the information, knowledge and techniques gathered during the course. The assignments must be submitted to your tutor for formal assessment in accordance with the laid down rules. The total secure obtained in the TMAs will account for 50% of your overall course mark.

There are many TMAs in the course. You should submit any eight to your tutor for assessment. The highest five of the eight assessments will be counted and this credited to your overall course mark.

Final Examination and Grading

At the end of the course, you will need to sit for a final written examination of three hours' duration. This examination will also count for 50% of your overall course mark. The examination will consist of questions, which reflect the types of self-testing, practice exercises and TMAs you have previously encountered. You are advised to prepare adequately for the examination. Since the general broad area of the course will be assessed.

Course Marking Scheme

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

Assessment	**Marks**
Eight assignment Submitted	Best five marks of the eight count @ 10% each = 50% of course marks
Final Examination	50% 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 in support 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 and phone 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 provide assistance 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 help necessary:

- 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 an assignment or with the grading of 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, and then 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 a competitive 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 systems and 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 the operations function focused on satisfying customers' needs.

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

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MODULE 1

UNIT 1 PRODUCTION AND OPERATIONS MANAGEMENT

CONTENTS

1.0 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 relates to the other parts of the organisation.

2.0 OBJECTIVES

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

(i) Define the term production/operations management (POM)
(ii) Identify the three major functional areas of organisations and describe how they interrelate
(iii) Compare and contrast service and manufacturing operations
(iv) Briefly describe the historical evolution of POM

3.0 MAIN CONTENT

3.1 Introduction to Production and Operations Management

Operations management deals with the production of goods and services that people buy and use everyday. 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 some people, the term production conjures up images of factories, machines and assembly hires. 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, however, the scope of production management has broadened considerably. Production concept and technologies are applied to a wide range of activities and situations; 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 its concepts and techniques are applied.

Formally stated, therefore, production and operations management (POM) is the 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.

3.1.1 Function within Business Organisations

A typical business organisations has three basic function: finance, marketing and production/operations. (see Figure 1.1)

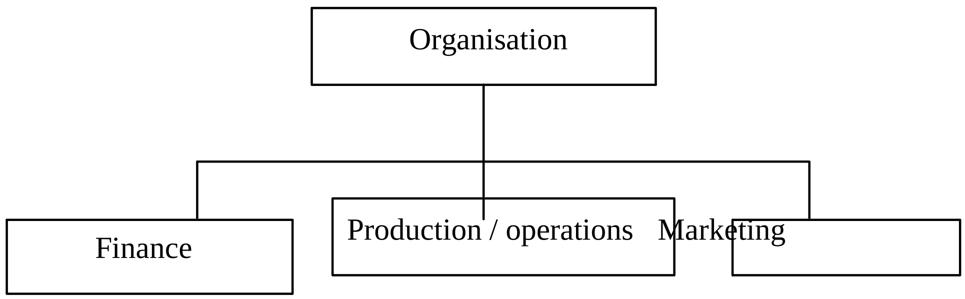


Figure 1.1: The three basic functions of business organizations

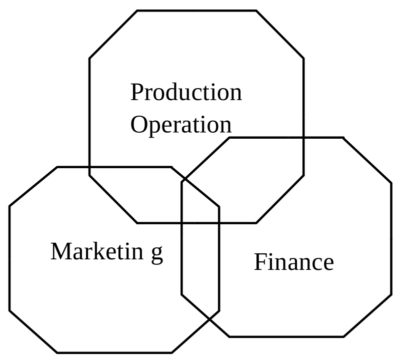


Figure 1.2: The 3 major functions of business organisation overlap

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 organisation 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 goods that 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 will take a closer look at these functions:

3.1.2 Operations

The operational function consists of all activities directly related to producing goods 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). Fig 1.3 shows the conversion process.

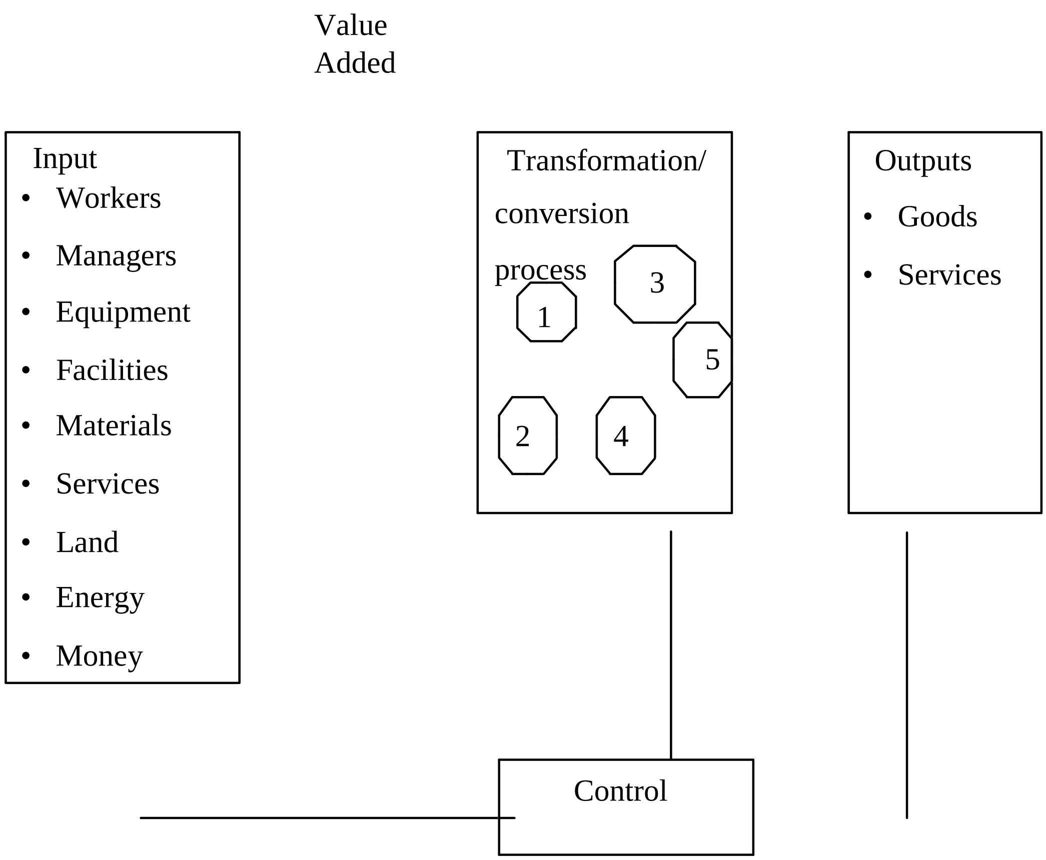


Figure 1.3: The conversion process of the operations function

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

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

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 the cost 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.

3.1.3 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.

3.1.4 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 and pricing decisions are made by the marketing people. 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 department also needs information that relates to improving current products and services and designing new ones.

In essence therefore, departments of marketing, design and production must work closely to successfully 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 operationality 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 to include the finance people in 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 3.1.1, 3.1.2 and 3.1.3, it is clear that department of marketing, operations and finance must interface on product and process design, forecasting, setting realistic schedules, quality and quantity decisions and keeping each other informed on the other's strengths and weaknesses.

3.1.1 Other Functions

Apart from the three core functions, there are a host of 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 as income 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 the purchased 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, retail outlets or to customers.

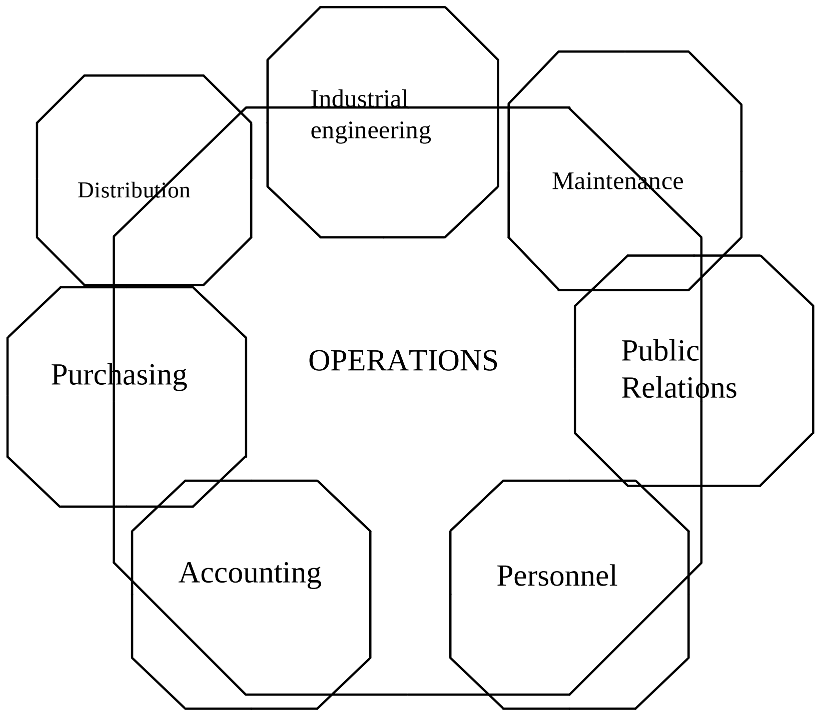


Figure 1.4: Interface of operations with supporting functions.

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.

3.2 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)

3.2.1 Differences between Manufacturing and Services

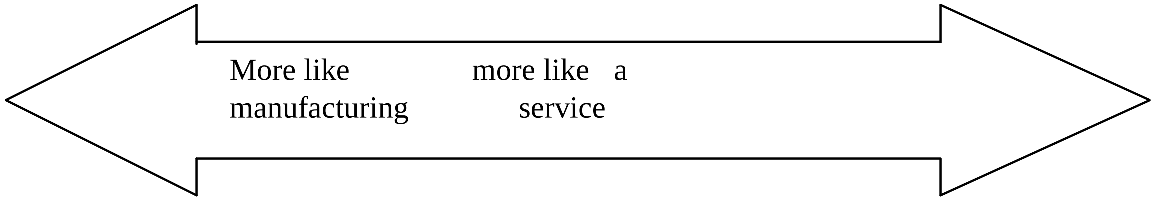
The differences between manufacturing and service operations fall into the eight categories show in figure 1.5. You should however note that these distinctions actually represent the ends of a continuum. The first distinction arises from the physical nature of the product: manufactured goods are physical, 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 inventories allows 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 not have the luxury of using finished goods inventories as a cushion against erratic customer demand.

Customer contract is the third distinction between manufacturing 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 five minutes 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 and size 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 can not be moved to distant locations. Hence, service organisation requiring direct customer contact must locate relatively near the customer



* Physical, durable product	* Intangible, perishable product
* Output can be inventoried	* Output cannot be inventoried
* Low customer contact	* High customer contact
* Long response time	* Short response time
* Large facilities	* Small facilities
* Capital intensive	* Labour intensive
* Quality easily measured	* Quality not easily measured
* Regional, national, or International markets.	* Local markets

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.

3.2.2 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 it manual 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 make choices about capacity, location, and layout of their facilities. Fifthly, both deal with suppliers of outside services and materials, as well as scheduling problems. Sixthly, matching staffing levels and capacities with forecasted demand is a universal problem.

3.3 The Historical Evolution of Production and Operations Management

Systems for production have existed since ancient times. The Egyptian pyramids, the Greek Parthenon, the Great Wall of China, and the aqua ducts and 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, at least in the modern sense, and the factory system had their roots in the industrial revolution.

3.3.1 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 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 organising them in logical ways to produce products.

It was around this 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 practice had not progressed much from early days.

3.3.2 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 economics incentives.

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 relieve foremen of their traditional responsibility or driving workers.

   Each of the scientific management pioneers listed in Table 1.3 took active 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 has dramatically 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.

Table 1.3: Scientific Management: The Players and Their Parts

Contributor	Life span	Contributions
Fredrick Winslow Taylor	1856 -1915	Scientific management principles, exception principle, time study, method analysis, standards, planning, control
Frank B. Gilbreth	1868-1934	Motion study, methods, therbligs, construction contracting, consulting
Lillian M. Gilbreth	1878- 1973	Fatigue studies, human factor in work, employee selection and training
Henry L. Gantt	1961 -1919	Gantt charts, incentive pay system, humanistic approach to labor, training
Carl G. Barth	1860-1939	Mathematical analysis, slide rule, feeds and speeds studies, consulting to automobile industry
Harrington Emerson	1885-1931	Principles of efficiency, million –dollars –day savings in railroads, methods of control
Morris L. Cooke	1872-1960	Scientific management application to education and government

3.3.3 Human Relations and Behaviouralism

During the 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 and efficiently.

However, between World War 1 and World War II, there began to emerge in the United States a philosophy among managers that workers were human beings 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.

SELF ASSESSMENT EXERCISE (SAE)

1. Define POM
2. What was the industrial Revolution? When did it happen?
3. List five important differences between manufacturing and service operations.

4.0 CONCLUSION

Unit one has thrown light on an understanding of the term 'Production and Operations Management. You have been able to identify the three major functional areas of an organization, as well as how these functions interrelate. The unit has also enabled you to compare and contrast services and manufacturing operations. A special emphasis was placed on the historical evolution of Production and Operations Management.

5.0 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.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly discuss each of these terms related to the historical evolution of POM:

   (a) Industrial Revolution
   (b) Scientific management
   (c) Interchangeable parts

(d) Division of labour

2. Describe Frederick W. Taylor shop management Approach.

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UNIT 2 OPERATIONS STRATEGY

CONTENTS

1.0 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's products and services, operations should also lead to some competitive 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.

2.0 OBJECTIVES

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

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

3.0 MAIN CONTENT

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 the literature, 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, operations decisions 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 also developed 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.

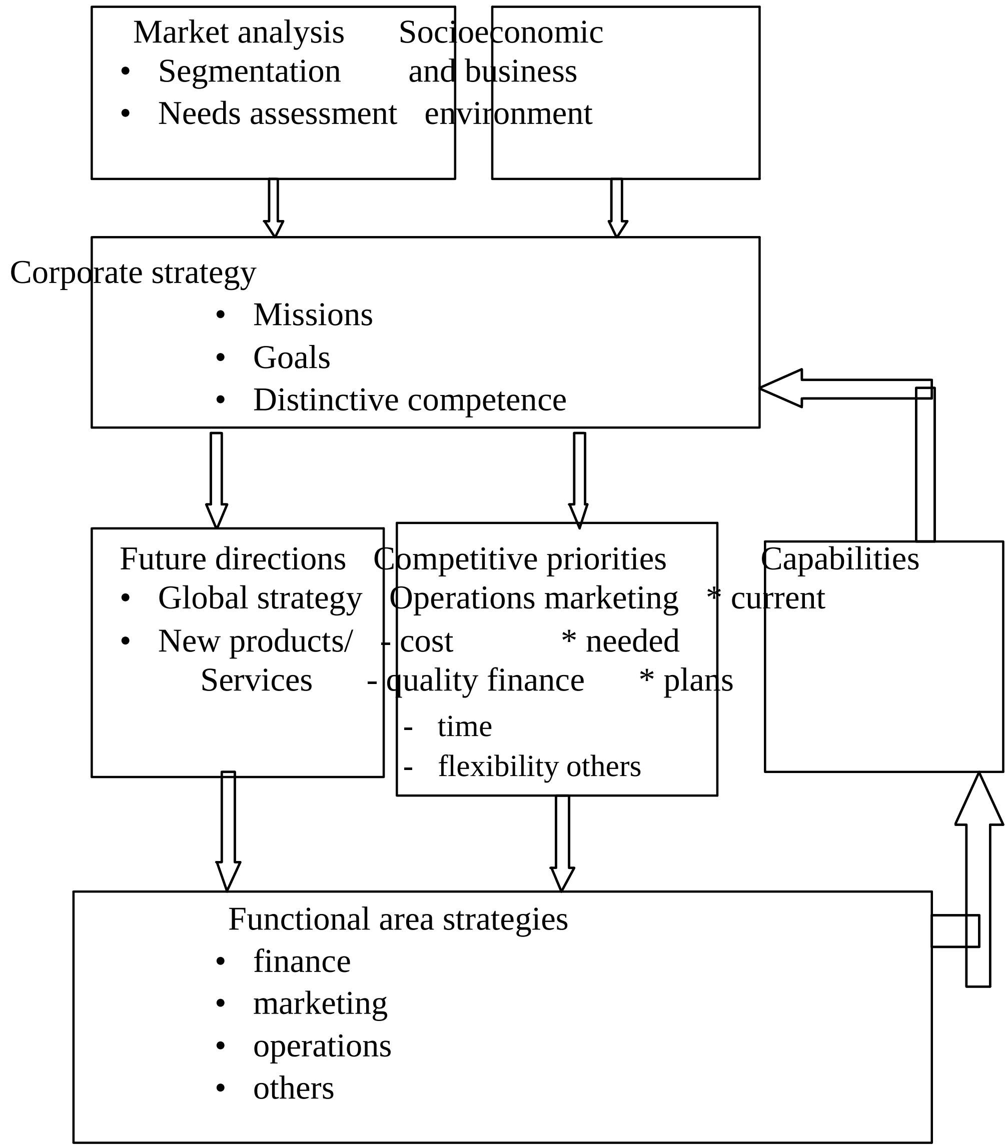
These various approaches we just examined should give us some insight into what operations strategy is, and how the strategy can be developed or improved.

3.2 Relationship Between Operations Strategy and Corporate Strategy

Developing a customer driven operations strategy begins with market analysis, which categorizes the firm's customers, identifies their needs and assesses competitors' strength. You should note that this 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 must possess to meet customer demand.

The competitive priorities and the future directions the form will take, such as 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 fed back 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 Functional Area 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 that 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.

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 competencies

Let 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 organisation to organisation, depending on the nature of their business. It is important that an organisation have a clear and simple mission statement, one which answers several fundamental 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 the organisation, 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 organisation needs 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 an organisation that gives it 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 the ways that organisations compete.

Competitiveness is an important factor in determining whether a company prospers, 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 product or 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 product or 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 a company 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.

3.3 Strategies and Tactics

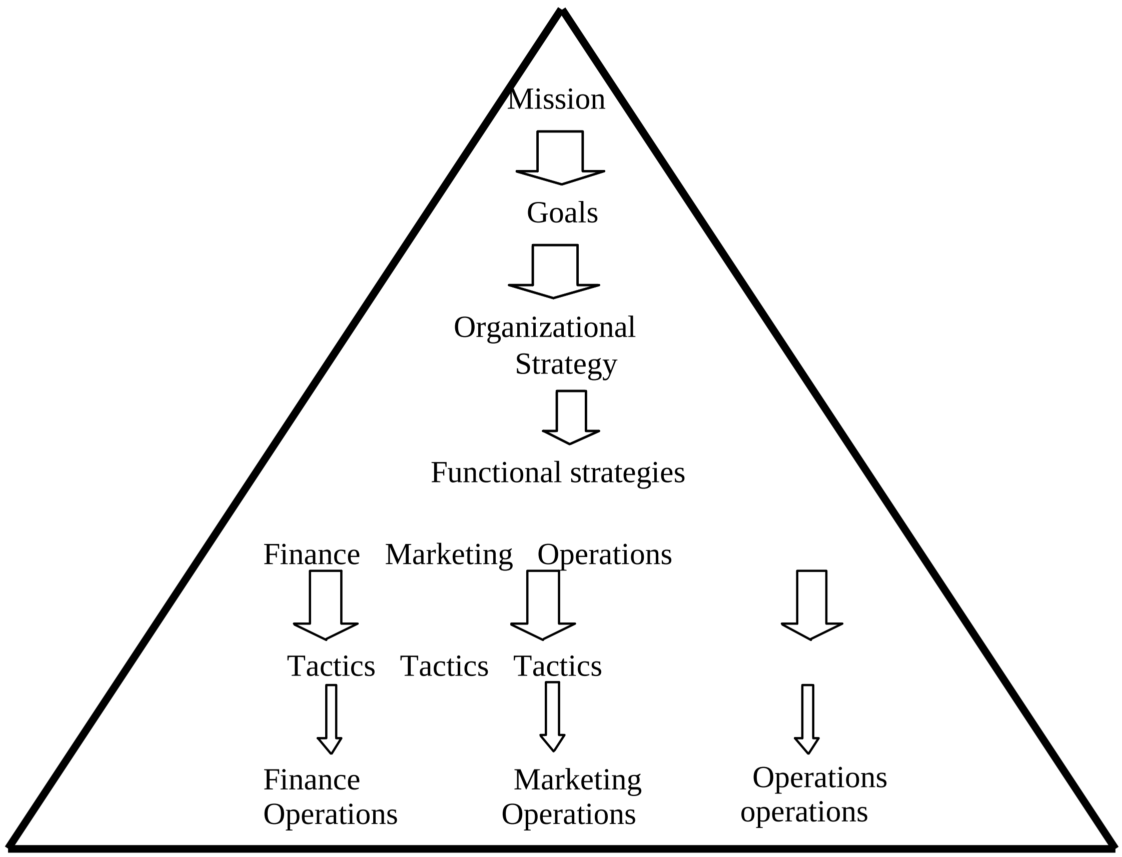
As you are already aware, a mission statement provides a general direction for an organisation and gives rise to organizational goals, which provide substance to the overall mission. For example, one goal of an organisation may be to capture a certain percentage of market share for a product; another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

Strategies are plans for achieving goals. If we have already likened goals to destinations, then, strategies may be seen as road maps for reaching the destination. Strategies provide focus for decision making. organisations usually have overall strategies refereed to as organisation strategies (i.e.Corporate

Strategies), which relate to the entire organisation. They also have functional strategies, which relate to each of the functional areas of the organisation.

Tactics are the methods and actions used to accomplish strategies. They are more specific in nature than strategies, and they provide guidance and direction for carrying out actual 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



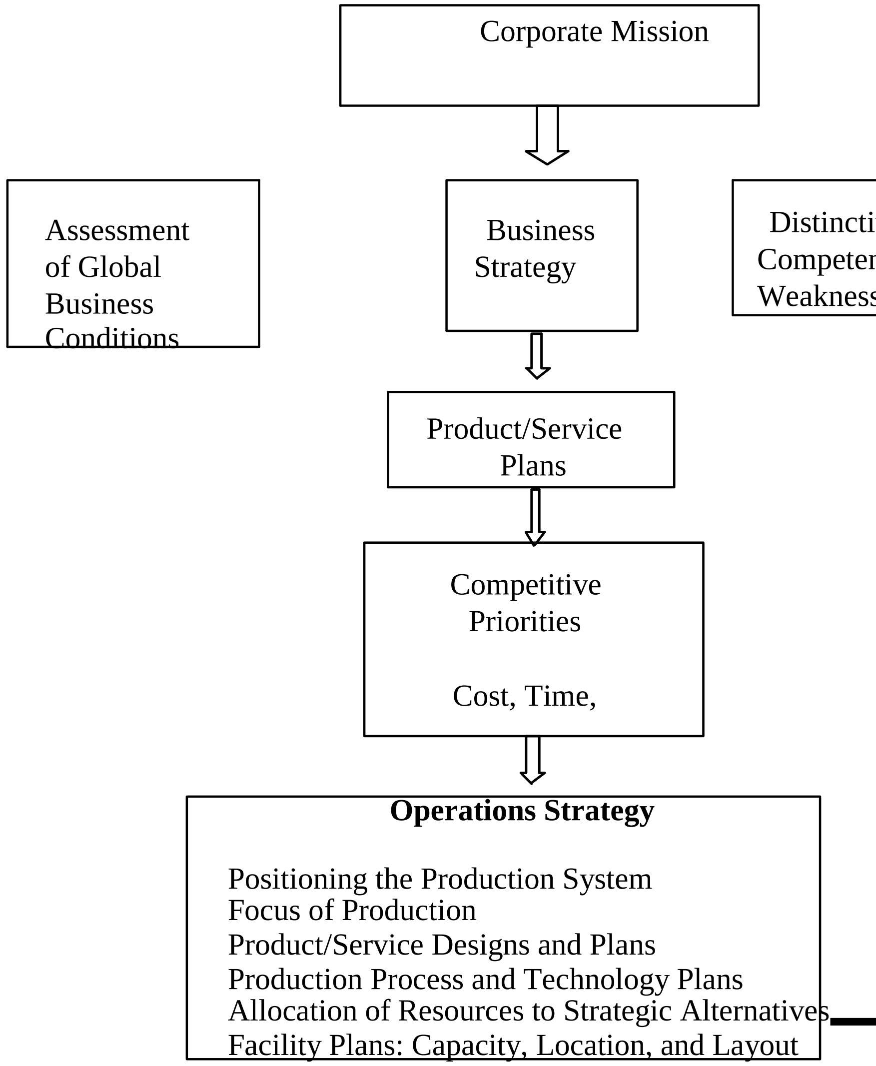
3.4 Operations Strategy

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 capitalise on strengths and deal squarely 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 an organisation. 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 will be successful.

Figure 2.3: Developing Operations Strategy



3.4.1 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 tow 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 priorities needed 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, each with 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.

3.4.1.2 Focus of Production

Another important element of operations strategy is the plan for each production facility to be specialized in some way. This idea of the specialized factory has been labeled "focused factory" by Skinner (1974). According to him "a factory 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: specializing in 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 will not 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 while choosing the size of production facilities.

3.4.1.3 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 product are established;
(ii) Each product characteristics directly affects how the product can be made or produced; and
(iii) How the product is made determines the design of the production system, which is the heart of operations strategy.

3.4.1.4 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.

3.4.1.5 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.

3.4.1.6 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.

Market Analysis

One important key to success in formulating a customer-driven operations strategy 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.

3.4.1.1 Market 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 marketing plan.

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 differentiate markets.
(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.

3.4.3 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 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.

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 a market segment? How would you make a need assessment?

4.0 CONCLUSION

This unit has taken you through operations strategy, which is embodied in the long-range production plan. This plan specifies positioning strategies, focus of production, product and production process and technology plans, allocation of resources to strategic alternatives, and facility planning. Once these issues have been decided and set in place, the fundamental structure of the operations function is established.

5.0 SUMMARY

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. Functional strategies are narrower in scope and should be linked to overall strategy.

6.0 TUTOR-MARKED ASSIGNMENT (TMA)

1. Why should a firm not attempt to excel in al the areas of competitive priorities?

2. What determines the choice of the competitive priorities that a company should emphasize?

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UNIT 3 FORECASTING IN POM

CONTENTS

1.0 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.

2.0 OBJECTIVES

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

(i) Describe at least four qualitative forecasting techniques and the advantages and limitations of each.

(ii) Compare and contrast qualitative and quantitative approaches to forecasting.
(iii) Identify the five basic demand patterns that combine to produce some series.
(iv) Choose an appropriate forecasting technique for a given decision problem.

3.0 MAIN CONTENT

3.1 Introduction to Forecasting in POM.

Customer demand is the backbone 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 to forecast 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 an integral 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 that span only the next few weeks.

Figure 3.1 Forecasting as an Integral Part of Business Planning

INPUTS

Market Conditions
Competitor Actions
Consumer Tastes
Products' Life C ycles
Season
Customers' Plans

Economy Outlook
Business Cycle Status
Leading Indicators-Stock
Prices, Bond Yields, Material
Prices, Business Failures, Money
Supply, Unemployment

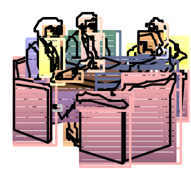
Other Factors
Legal
Political
Sociological
Cultural

Forecasting
Method(s)
Or Model(s)

OUTPUTS
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
And Motives
Social and
Cultural Values
Other factors

Forecast Errors/

Feedback

Procedure for Translating Sales Forecast into Production Resource Forecasts

Business Strat egy

Marketin g Plan – Advertising,
Sales Efforts, Price, Past Sales
Production Plan – Quality
Levels, C ustomer Service,
Capacity,
Costs
Finance Plan –
Credit Policies, Billing Policies

PRODUCTION RESOURCE FORECAST S

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

Source: Adapted From Gaither, N. (1996), Belmont, Duxury Press, p.64.

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 be scaled 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 of weekly demands.

3.3 An Overview of Demand Measurement:

We need to realize right from here, that demand management is a shared responsibility. 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 and cash flow.

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:

3.4.1 Short Range

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

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

3.4.2 Medium Range

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

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

3.4.3 Long Range

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

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

3.5 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 marketing activities * Planning and evaluating the personal selling efforts * Setting sales quota * As an input into compensation plan * Evaluating the field sales force.

3.6 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

Sales Forecasting Methods

Subj ective / Qualitative Methods

Users' expectations
Sales force Composite
Jury of Ex ecutive Opinion
Delphi technique.

Objective / Quantitativ e Methods

Market test
Time Series analysis
Moving averages
Exponential smoothing
Decomposition
Statistical demand analysis.

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 sales personnel, 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 been scientifically 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.

3.6.1.2 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 to the sales people have the best knowledge of the market.

Advantages

(i) A primary advantage of the sales force composite method is that it uses the 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 the factors influencing sale.
(iii) The approach makes no provision for bringing the systematic consideration of uncontrollables into the analysis.
(iv) The approach does not provide for discovery of important facts through statistical analysis of historical data.

3.6.1.3 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 specialised 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.

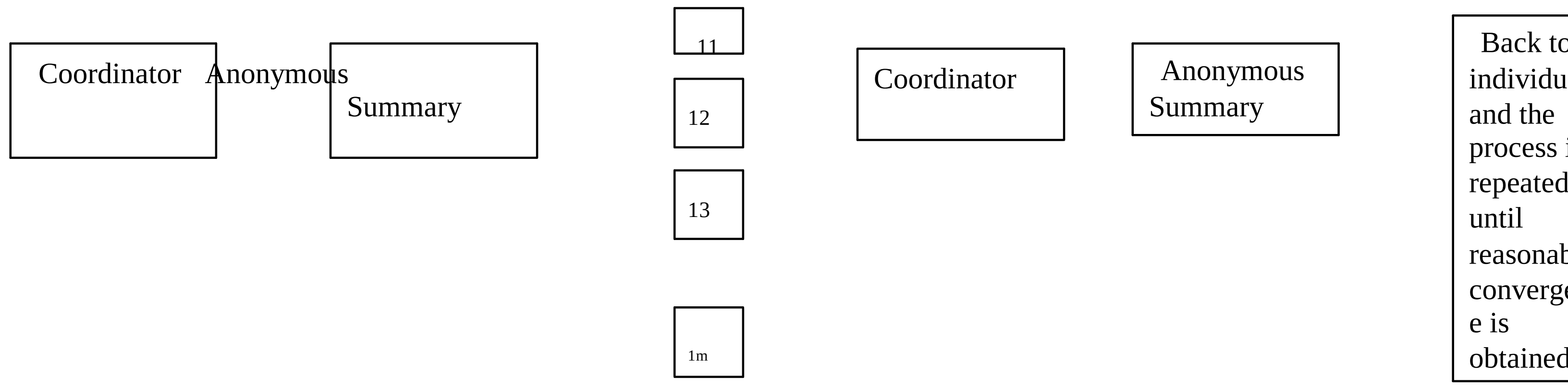
Disadvantages

(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.

3.6.1.4 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



hod is based on the following two premises:

(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 the distribution 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 ultimately agreed 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.

3.6.2 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.

3.6.2.1 Market Test

Market testing is a relatively recent phenomenon in demand estimation and is mostly 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 of the marketplace, whose aim is to predict the sales or profit consequences, 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 testing consumer 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 not going 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 display rooms. The details of these methods are under Marketing Research.

Advantages

(i) Market testing can indicate the product's performance under actual operating 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 marketing programme
(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.

3.6.2.2 Time 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 a mature 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. Still further along the continuum, the forecaster might attempts 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 to predict 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 with hundreds 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, $\bar{Q}$t; and a smoothing parameter, a . The sales forecast for next period's sales is then given by:

$$\bar{Q}_{t+1} = a Q_t + (1 - a)\bar{Q}_t$$

Where:

$\bar{Q}_{t+1}$ = sales forecast for next period

a = the smoothing constant, where 0 = a = 1

Qt = current sales in period t

$\bar{Q}_t$ = smoothed sales in period t.

Example:

Suppose the smoothing constant is 0.3, current sales are N600, 000, and smoothed 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 forecast that 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 years sales, the last three years' sales, etc. The forecast would simply be the average that resulted. The term moving average is used because a new average can be computed 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.

Year	Actual Sales	Forecasted Two-Year Moving Average	Sales 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 averages 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 4,200 units in 1974 and 4,410 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 the same 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 be accurately assessed and included
(iii) Technical skill and good judgement required.
(iv) Final forecast may be difficult to break down into individual territory estimates.

3.6.2.3 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:

$$Q = f\,(X1, X2, \ldots, Xn)$$

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 and equation.

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 equation for 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; and
- Estimated 1961 disposable personnel income should be put in X5.

The result of multiplying these numbers by the respective coefficients and summing 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 intuitive reasoning may not uncover.
(iv) The method is objective in the results can be reproduced by different analysts 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.

4.0 CONCLUSION

In this unit, you have learned that planning is an integral part of a manager's job. If uncertainties cloud 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.

5.0 SUMMARY

Forecasts are vital inputs for the design and the operation of the productive systems 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.

6.0 TUTOR-MARKED ASSIGNMENT

1. given the following data:

Period	Number of complaints
1	60
2	65
3	55
4	58
5	64

Prepare a forecast using each of these approaches:

(a) The naïve approach
(b) A 3 – period moving average
(c) Exponential smoothing with a smoothly constant of 0.40.

7.0 REFERENCES/FURTHER READINGS

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UNIT 4 PROCESS MANAGEMENT

CONTENTS

1.0 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 in how 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

2.0 OBJECTIVES

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 five choices differ.
(ii) Explain when less vertical integration and more outsourcing are appropriate and how resource flexibility supports competitive priorities.
(iii) Describe the different ways that customer contact can affect a process.

3.0 MAIN CONTENT

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 an interconnected set of linkages among suppliers of materials and services that spans the transformation process that convert ideas and raw materials 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 purchased materials 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.

3.2 Major Types of Process Decisions

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

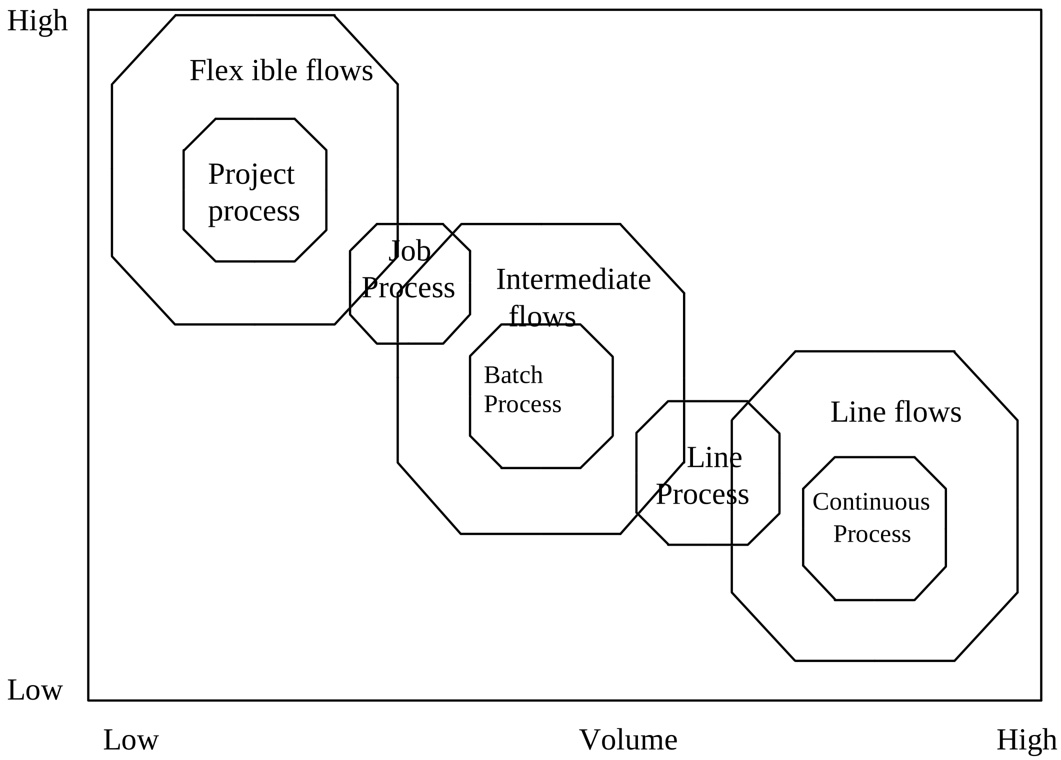
3.2.1 Process Choice

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 characterised 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.

3.2.1.2 Job Process

A job process creates the flexibility needed to produce a variety of products or services in significant quantities. Very often, customisation 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 and equipment 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 never ahead 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 organised around the process.

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

3.2.1.3 Batch Process

A batch process differs from the job process with respect to volume, variety and 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, and manufacturing capital equipment.

3.2.1.4 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 allowing resources 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 to customer 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 also referred 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.

3.2.1.5 Continuous Process

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

3.2.2 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 or services 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 products or services. The more processes in the supply chain that the organisation performs itself, the more vertically integrated 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.

3.2.3 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.

3.2.4 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 the service is to be provided.

3.2.5 Degree of Automation

A key issue in designing production processes is determining how much automation 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 of operations strategy.

3.3 Designing Processes

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

3.3.1 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 reinvention, rather than an incremental improvement. Though reengineering 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:

3.3.1.1 Critical 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, reengineering should be reserved for essential processes, such as new-product development or customer services, because of the time and energy involved.

3.3.1.2 Strong 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 radical change. Resistance can be over-come by providing the clout necessary to ensure that the project proceeds within a strategic choice.

3.3.1.3 Cross-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.

3.3.1.4 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.

3.3.1.5 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, subtract the desired profit, and then find an appropriate process 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.

3.3.1.6 Process Analysis

In spite of the clean slate philosophy discussed above, a reengineering 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 to examine 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.

3.3.2 Process Improvement

This is the systematic study of the activities and flows of each process to improve 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 price means 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.

4.0 CONCLUSION

You have learned in this unit that process decisions affect what the firm achieves with the competitive priorities of quality, flexibility, time, and cost. For example, firms can improve their ability to compete on the basis of time by examining each step of their processes and then finding ways to respond more quickly to their customers.

5.0 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.

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.

Figure 4.2

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

SUMMARY

Activity		Number of steps	Time (Min)	Distance (ft)
Operation	⬡	7	16.5	-
Transport	⇨	8	5.5	420
Inspect	□	4	5.0	-
Delay	▽	1	0.7	-

Step No.	Time (min)	Distance (ft)	⬡	⇨	□	D	▽	Step description
1	0.8	50		X				*Direct customer in to service bay*
2	1.8		X					*Record name and desired service*
3	2.3			X	X			*Open hood, verify engine type, inspect hoses, check fluid levels*
4	0.8	30						*Walk to customer in waiting area*
5	0.6		X					
6	0.7					X		*Wait fo r customer decision*
7	0.9	70		X				*Walt to storeroom*
8	1.9		X					*Look up filter number(s), find filter(s)*
9	0.4							*C heck filter number(s)*
10	0.6	50		X	X			*Carry filter(s) to service pit*
11	4.2		X					*Perform und er-car services*
12	0.7	40		X				*Climb from pit, walk to automobile*
13	2.7		X					*Fill engine with oil, start engine*
14	1.3							*Inspect for leaks*
15	0.5	40		X	X			*Walk to pit*
16	1.0							*Inspect for leaks*
17	3.0		X		X			*Clean and organize work area*
18	0.7	80		X				*Return to auto, drive from bay*
19	0.3							*Park the car*
20	0.5	60						*Walk to customer waiting area*
21	2.3		X					*Total charges, receive*

You are to analyse the process of changing automobile engine oil and also provide the summary. The subject of the study is the service mechanic. The process begins when the mechanic directs the customer's arrival, and ends when the customer pays for the services.

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 420 feet.

6.0 TUTOR MARKED ASSIGNMENT

Refer to the self-Assessed Question. What improvements can you make in the process shown in Figure 4.2?

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UNIT 5 JOB DESIGN

CONTENTS

1.0 INTRODUCTION

The importance of work system is underscored by the organisation's dependence on human efforts. (i.e work) to accomplish its goals. Work design is one of the oldest fields of operations management. In the past, it has often been de-emphasised in operations management courses in favour of other topics. In recent years, however, renewed interest has taken place, and it has come from an entirely different direction: some of the interest has resulted from studies that reveal a general dissatisfaction felt by workers with their jobs. It is therefore important for management to make design of work systems a key element of its operations strategy. This unit examines the important areas of job design as specified in the objectives below.

2.0 OBJECTIVES

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

i) explain the importance of job design
ii) describe the two basic approaches to job design
iii) rationalise the advantages of job specialisation, or its alternatives, for a particular situation.

3.0 MAIN CONTENT

3.1 Introduction to Job Design

Job design entails matching tasks or work activities to individuals or task groups. This is usually done by specifying a job's content, the employee skills and training needed to perform that job, and the degree of specialisation appropriate for the job. The ultimate intention here, is to increase efficiency of an organisation, with the parallel goal of making working conditions more agreeable. In addition, job design improves productivity through consideration of technical and human factors. It also increases the quality of the final product or service.

Let us pause for a moment to answer this question: Who are job designers? Job designers are concerned with who will do a job, how the job will be done, and where the job will be done. Stevenson (1969) has suggested four parameters for a successful job design. To him, the job design must be:

i. Carried out by experienced personnel who have the necessary training and background;
ii. Consistent with the goals of the organisation;
iii. In written form; and
iv. Understood and agreed to by both management and employees.

You need to realise that the factors that affect job design and the implications of various alternatives are often so complex, that a person without a good background in job design is likely to overlook important aspects of it. It is also necessary to consult workers and managers alike in order to take advantage of their knowledge, as well as keep them informed.

Since employees are particularly intimately involved with the work, they are veritable sources of ideas for job improvement. Management support for job design equally depends on the commitment and involvement of managers. Once these two important groups have been included in the process, it is often relatively easier for them to embrace the design.

The establishment of a written record of the job design can serve as a basis for referral, whenever there are clarifications to be made about it.

3.2 Approaches to the Study of Job Design

There are two basic schools of thought with respect to current practice in job design. One might be called the efficiency school, because it emphasises a systematic, logical approach to job design. The second one is called the behavioural school because it emphasises satisfaction of wants and needs.

We shall now examine each of these schools:

3.2.1 The Efficiency Approach

The efficiency approach, a refinement of Frederick Taylor's scientific management concepts, received considerable emphasis in the past. Taylor's approach is based on the philosophy that any operation can be improved by breaking it into components and studying the work content of each component in order to improve work methods. Taylor believed that managers should study jobs scientifically, using careful analysis, experimentation, and tools such as flow diagrams and process charts to find the most economic way to perform a task. Details of this will be covered under job specialisation in section 3.3.

3.2.2 The Behavioural Approach

The behavioural approach to job design emerged during the 1950s, and has continued to make impact on many aspects of job design. One of the major contributions of the behavioural approach is that it has reminded managers of the complexity of human beings, and that the efficiency approach may not be appropriate in ever instance. More of the behavioural approach will be treated under section 3.4.

3.3 Job Specialisation

A job with a high degree of specialisation involves a narrow range of tasks, a high degree of repetition, and presumably, great efficiency and high quality. Examples range from assembly lines to medical specialties. Some bakers specialise in wedding cakes; a heart specialist can diagnose and treat heart problems better than a general practitioner.

Generally, specialisation results in benefits such as:

- less training time needed per employee because the methods and procedures are limited,
- faster work pace, leading to more output in less time, and
- lower wages paid because education and skill requirements are lower.

However, the agreements against job specialisation suggest that narrowly defined jobs lead to:

- poor employee morale, high turnover, and lower quality because of the monotony and boredom of repetitive work;
- the need for more management attention because the total activity is broken into a larger number of jobs for a large number of employees, all

of whom have to be coordinated to produce the entire produce or service; and

- less flexibility to handle changes or employee absences.

3.4 Alternatives to Job Specialisation

From our previous discussions in unit 1, it should be clear to you now, that people work for a variety of reasons: economic needs (i.e. to earn a living), social needs (to be recognised and to belong to a group), and individual needs (to feel important and to feel in control). These factors influence how people perform their jobs.

In narrowly designed jobs (as in job specialisation), workers have few opportunities to control the pace of work, receive gratification for the work itself, advance to a better position, show initiative, and communicate with fellow workers. Suggestions have therefore been made on how to modify specialised jobs to provide for a broader range of needs satisfaction. These include job rotation, job enlargement, job enrichment, team production and empowerment. We will look at each of these in the sections that follow.

3.4.1 Job Rotation

Job rotation moves beyond specialisation, so that people who have the required skills can rotate from one job to another in order to get away from the job specialisation rut. For example, assembly line workers may work one week on engine mountings and then work on assembling dashboard components or tyre fixing, the following week. This process can help to reduce the monotonous aspects of the job.

Job rotation implies multi skills in personnel. It is not only advantageous and motivating for the employees, but it also gives the employer the flexibility to adjust to client needs. For instance, because workers learn many aspects of the job, job rotation increases the skills of the work force, thereby giving management to flexibility to replace absent workers, or to move more workers to different workstations as necessary. In addition, rotation of jobs can give a better appreciation for the production problems of others, and the value of passing only good quality to the next person.

3.4.2 Job Enlargement

Job enlargement is intended to avoid an employee being trapped in job specialisation by trying to improve the variety within a certain sphere of a person's ability and interest. It is done by adding additional similar tasks to workers' job. This is referred to as horizontal job enlargement. Apart form reducing boredom, job enlargement has the potential to increase employee satisfaction because the worker feels a greater sense of responsibility, pride, and accomplishment.

3.4.3 Job enrichment

This is the most comprehensive approach to job design. It involves a vertical expansion of job duties. This means that workers have greater control and responsibility for an entire process, not just a specific skill or operation. For example, a purchasing secretary whose basic job is the correspondence for a group of purchasing people could have the job enriched by planning the work assignments of the group, being an intermediate in customer contact and maybe helping in the evaluation of some proposals. That is, the secretary's job is enriched from being a secretary to becoming an assistant. This is what obtains today, when many of the classic secretarial duties are less required as more and more people have their own personnel computers.

3.4.4 Team Production

This entails organising workers into work teams; selecting workers and training them to work as a team; assigning some responsibility for management of production to teams. However, building effective work teams means more than just grouping workers into work groups. More still needs to be done. For instance, team building requires training in team effectiveness, conflict resolution, team measurement, and motivation systems.

One strong feature of effective work teams is that they can focus on processes, instead of departments. For example, if a team is to design and develop a new product, the team can focus on the process of designing and developing the new product and not be constrained by departmental boundaries and responsibilities.

3.4.5 Empowerment

This is an extension of job enrichment by adding to it, complete employee trust and responsibilities not initially associated with the job. It is basically a process of conveying authority from management to workers.

Let us see how it works: imagine a manager tells his workers that they have authority to stop production lines whenever the notice that product quality is beginning to deteriorate. In this situation, workers tend to accept responsibility for product quality and shut down product whenever the need arises. They then come together in order to correct the cause of low product quality. Worker safety, maintenance problems, materials' shortages, and other occurrences are other factors that can cause the need for production to be stopped.

Giving workers the authority to stop production for these and other causes is perhaps the most visible conveyance of authority to workers. This process leads to what is now termed "internal ownership", where workers feel that the production line belongs to them and that they are responsible for everything that occurs in production.

4.0 CONCLUSION

In this unit, you have learned about the importance of job designs and how you can apply this to increase the efficiency as well as the productivity of your organisation. You should also be able to recommend between job specialisation and its alternatives in particular situations.

5.0 SUMMARY

This unit has shown you that the importance of work system is underscored by the organisation's dependence on human efforts. It is therefore important for management to make design of work systems a key element of its operations strategy.

6.0 TUTOR-MARKED ASSIGNMENT

What are the major advantages and disadvantages of specialisation in business? Address these issues both from management and labour sides.

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MODULE 2

Unit 1 Management of Technology
Unit 2 Site Selection
Unit 3 Supply Chain Management
Unit 4 Inventory Management
Unit 5 Aggregate Planning

UNIT 1 MANAGEMENT OF TECHNOLOGY

CONTENTS

1.0 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:

2.0 OBJECTIVES

By the end of this unit, you should 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.

3.0 MAIN CONTENT

3.1 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 organisational 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.

3.1.1 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.

3.1.1.1 Product 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.

3.1.1.2 Process Technology

The methods by which an organisation does things usually rely on the application of technology. At times, some of the large number of process technologies used by an organisation 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

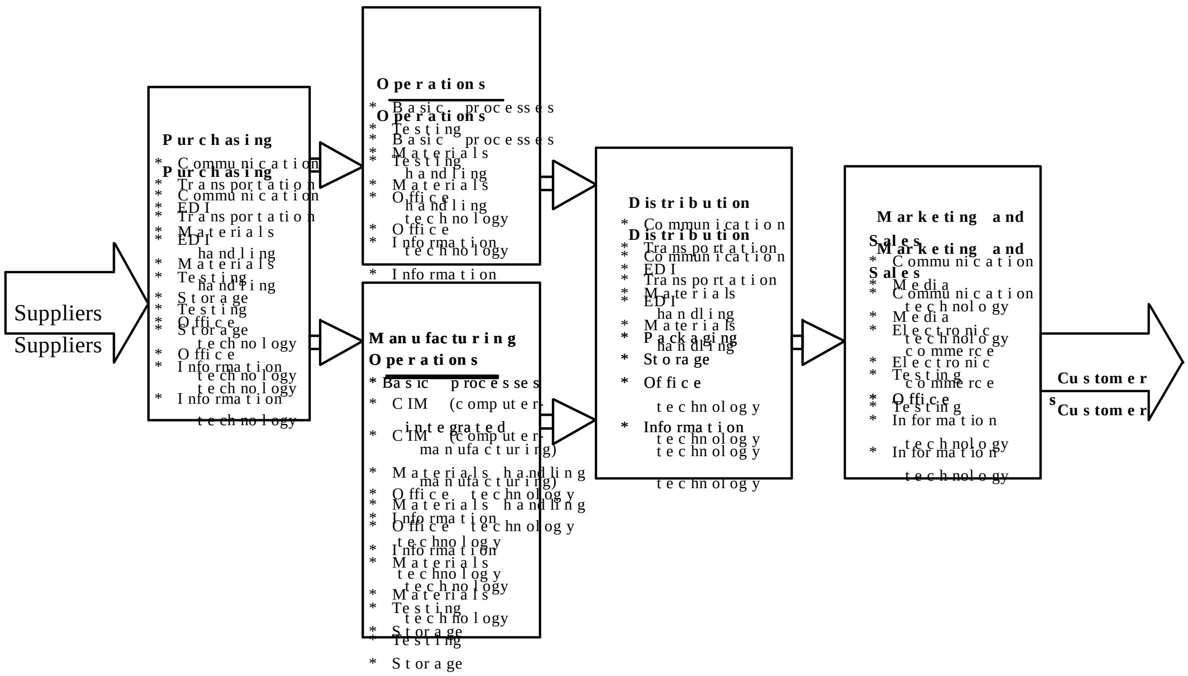
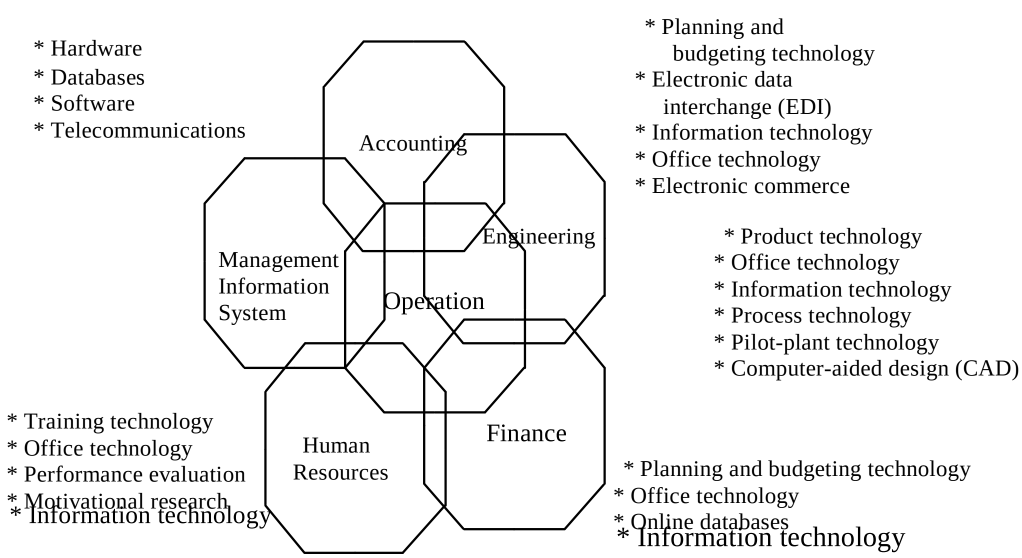


Figure 6.2: Process Technologies - Technologies for other functional areas



There continue to be great developments in process technology of almost all functional 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.

3.1.1.3 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.

3.1.2 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.

3.1.3 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.

3.2 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 changes and 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 cro 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 in the success of an organisation.

3.2.1 Components of Information Technology

IT comprises computing and telecommunications technologies. It is the merging of the above two technologies, and the organisational and management technologies that help in fashioning it for organisational use. On the whole, IT can be partitioned into four sub technologies:

(1) Hardware (2) Software (3) databases, and (4) telecommunications

3.2.1.1 Hardware

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.

3.2.1.2 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.

3.2.1.3 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 proprietary software 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 marketing process 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.

3.2.1.4 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 the transmission of signals representing voice data, physical data, and images between remote locations.

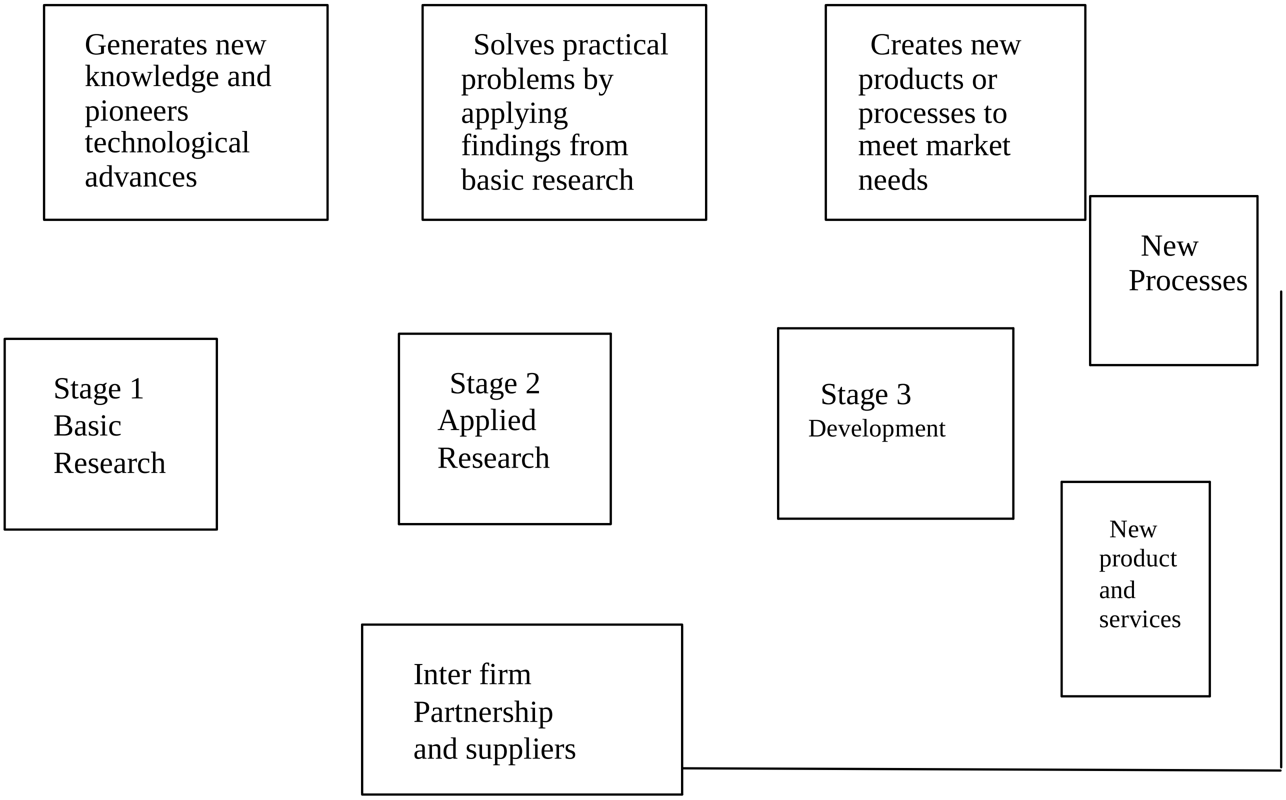
Many of the telecommunications systems in use today employ electrical or electromagnetic media as carriers of signals. There are different types of networks, for example, data networks (as in when two or more computers are connected together to communicate data); television networks (e.g. CNN and NTA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

3.3 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 the concept of innovation process. Figure 6.2 shows an overview of the innovation process, which is aimed at creating and applying technology to improve a firm's products, production processes, and services. The innovation process focuses technical and scientific efforts on better ways to meet market needs.

Figure 6.2: Research and Development Stages



3.3.1 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.

3.3.1.1 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 a flash of genius. Since basic research is often capital-intensive, it is performed in laboratories owned by government agencies, or some large firms, and universities.

3.3.1.2 Applied 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.

3.3.1.3 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 market production 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, the product 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 made regarding 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 tangible characteristics 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 organisation that is technology and resource - rich should always develop and compete with the new technologies that they helped create. That is, they should continue to develop innovations into products and services. This is the only way to prevent organisational complacency from depriving them of the initial leadership.

3.4 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.

3.4.1 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 existence of 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 requirements may lead to employee resistance, lower morale, and increased labour turnover. For these and other reasons, the operations manager must sort out the numerous benefits 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 or service 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 organisation should look out for new technologies that can build new production capabilities. These can 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 entrants in 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 able to 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 that adopts a first-mover strategy. First, the pioneering costs are often high, with R & D costs exceeding 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 for managers 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.

3.5 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 sustained only 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.

3.5.1 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 of securing 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, the firms 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 more of 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 look out 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 throughout the world.

3.5.2 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. This exercise 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.

3.5.3 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.

3.5.4 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 as gatekeepers by keeping everyone 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.

4.0 CONCLUSION

In this unit, you have learnt that technology plays a pivotal role in creating new products and improving processes. It can create whole new industries and dramatically alter the landscape in existing industries. You also learnt that the development and innovative use of technology can give a firm a distinctive competence that is difficult to match.

5.0 SUMMARY

We have explored how 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.

SELF-ASSESSMENT EXERCISE (SAE)

i. How do you understand the term technology?
ii. Why should operations manager be interested in the three aspects of technology?
iii. IT comprises computing and telecommunications technologies. Explain its basic partitions.

6.0 TUTOR-MARKED ASSIGNMENT

Describe the concept of technology strategy as discussed in this unit.

7.0 REFERENCES/FURTHER READINGS

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UNIT 2 SITE SELECTION

CONTENTS

1.0 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.

2.0 OBJECTIVES

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

(i) Understand the meaning of site selection
(ii) Understand the factors that need to be considered before site-selection decisions are made
(iii) Know the interrelationships among relevant factors of site selection
(iv) Use quantitative methods to decide on site-selection.

3.0 MAIN CONTENT

3.1 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. In other 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 centre in 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 new facility, or on the returns expected to be realised.

3.2 Factors in Site Selection

3.2.1 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 that labour 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 in the form of taxes
Social laws with the accompanied social charges affect labour flexibility and cover areas such as basic work week, overtime permitted, weekend working living 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 output divided by the input of resources. For example, companies tend to locate in South Korea and Hong Kong 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.

3.2.2 Inherent Local Condition

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

Climate may present attractive locations 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 of some 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, who are sent overseas on a time-limited contract. They receive a premium on their salary according to the "difficulty" of the location. Using expatriates is very costly, 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

3.2.3 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 and constitutes a delay in constructing a plant in such a location.

Legal framework is another important factor. Litigation laws are not the same among countries. 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 for employees 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 intolerance to foreign companies. Iraq is one the riskiest countries in the world as a result of great instability in the country. Other countries considered as being risk are Russia, Venezuela, Nigeria, Mexico etc.

3.2.4 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 many other 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 characterises 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 hinder companies from being sited in a place.

Zoning regulations which involve laws regarding construction in particular area is 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.

3.2.5 Factors Affecting Cash Flows

Some factors directly affect a firm's cash flow. The importance of such factors is 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 on which 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.

3.2.6 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

3.2.7 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 especially companies 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 because reliability in delivery of goods is necessary if a just-in-time production criterion is used at the company.

3.2.8 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 some certainty. 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. The procedure 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 to their importance 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 site and 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 S	Ogun S	Ondo S	Kwara S	Lagos S
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 the construction of this new production facility?
2. What can you say about the sensitivity of using this approach for site selection?

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 of Table 7.2

Table 7.2

Site criteria	Weighting factor (F)	Oyo S	Ogun S	Ondo S	Kwara S	Lagos S
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
Proximity to suppliers	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 be determined 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 being considered. Akure, Ibadan and Osogbo.

1. 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 there will be break-even points comparing their fixed and variable costs with one another shows that there 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

Table7.6

Market change	40% increase	25% increase	1%	-10%	Minimum
Kano	22,250,000	19,250,000	-625,000	-1,250,000	-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 criterion to 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 Table7.7 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	4,040,00	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.

4.0 CONCLUSION

In this unit, you have learnt a number of important issues that relates to site selection. The importance of site selection factors and the methods (quantitative) to determining preferred locations were brought into limelight. Apart from knowing the relevant factors that should be considered in site selection and the implications on the company in question, you should have used the basic quantitative techniques to establish the preferred locations for some indigenous companies such as Cadbury (Nig) Plc, Liver Brothers (Plc) etc. you should have known how the same technique especially under uncertainty and risk could give different preferred locations for site selection depending on the criterion used by the management. You need also, to know that there are some levels of interrelationships among the factors that need to be put into consideration before site selection decisions are made.

5.0 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 perse 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

6.0 TUTOR MARKED ASSIGNMENT

In Table 7.5 Assume the probability of the marked changes were estimated as follows

Market change	40% increase	25% increase	1% increase	-10% incline
Probability of occurrence	30% 45%	20% 5%		

Using expected values, what decision would be made for site selection?

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 SUPPLY CHAIN MANAGEMENT

CONTENTS

1.0 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.

2.0 OBJECTIVES

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

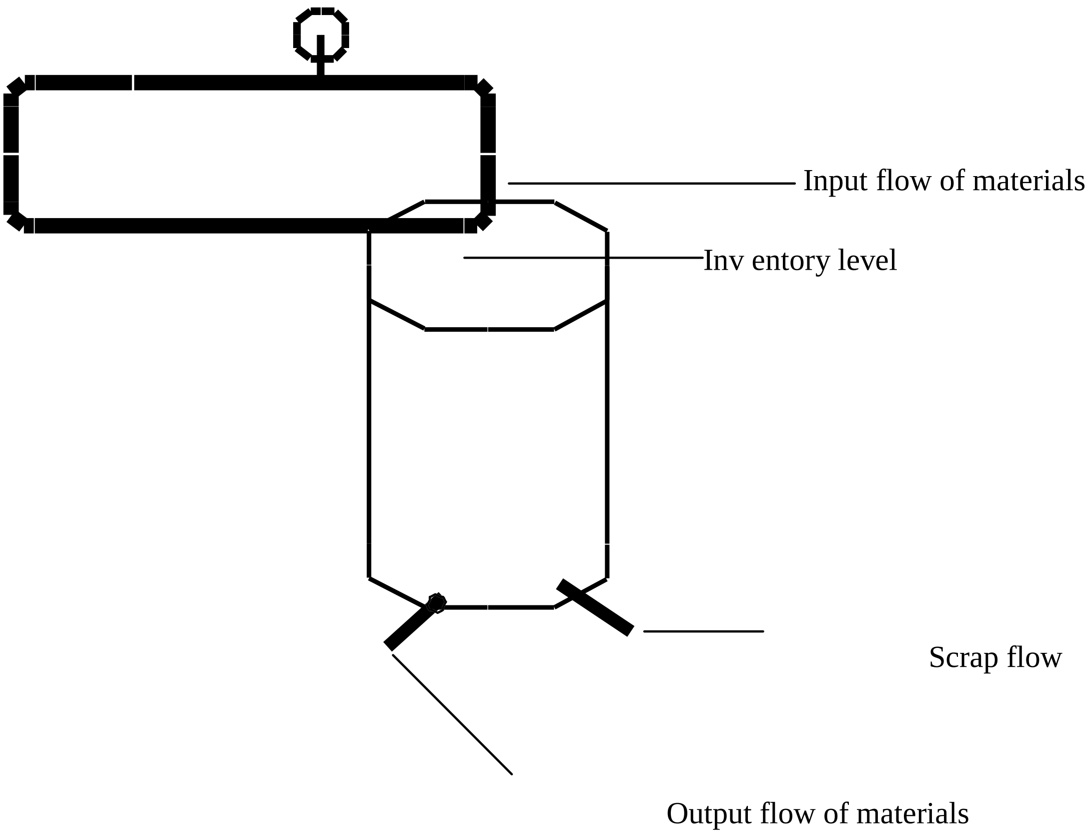
(i) Define the nature of supply-chain management for both manufacturers and service providers.
(ii) Describe the strategic importance of supply-chain management
(iii) Explain the important roles of purchasing and distribution in the design and execution of effective supply chains.

3.0 MAIN CONTENT

3.1 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 more flows 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 to the 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 eared by business organisations. Hence, firms can reap large profits with a small percentage reduction in the cost of materials. This is perhaps one of the reasons why supply-chain management is becoming a key competitive weapon.

3.1.1 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 materials management, 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 relevant question 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 organisation 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.

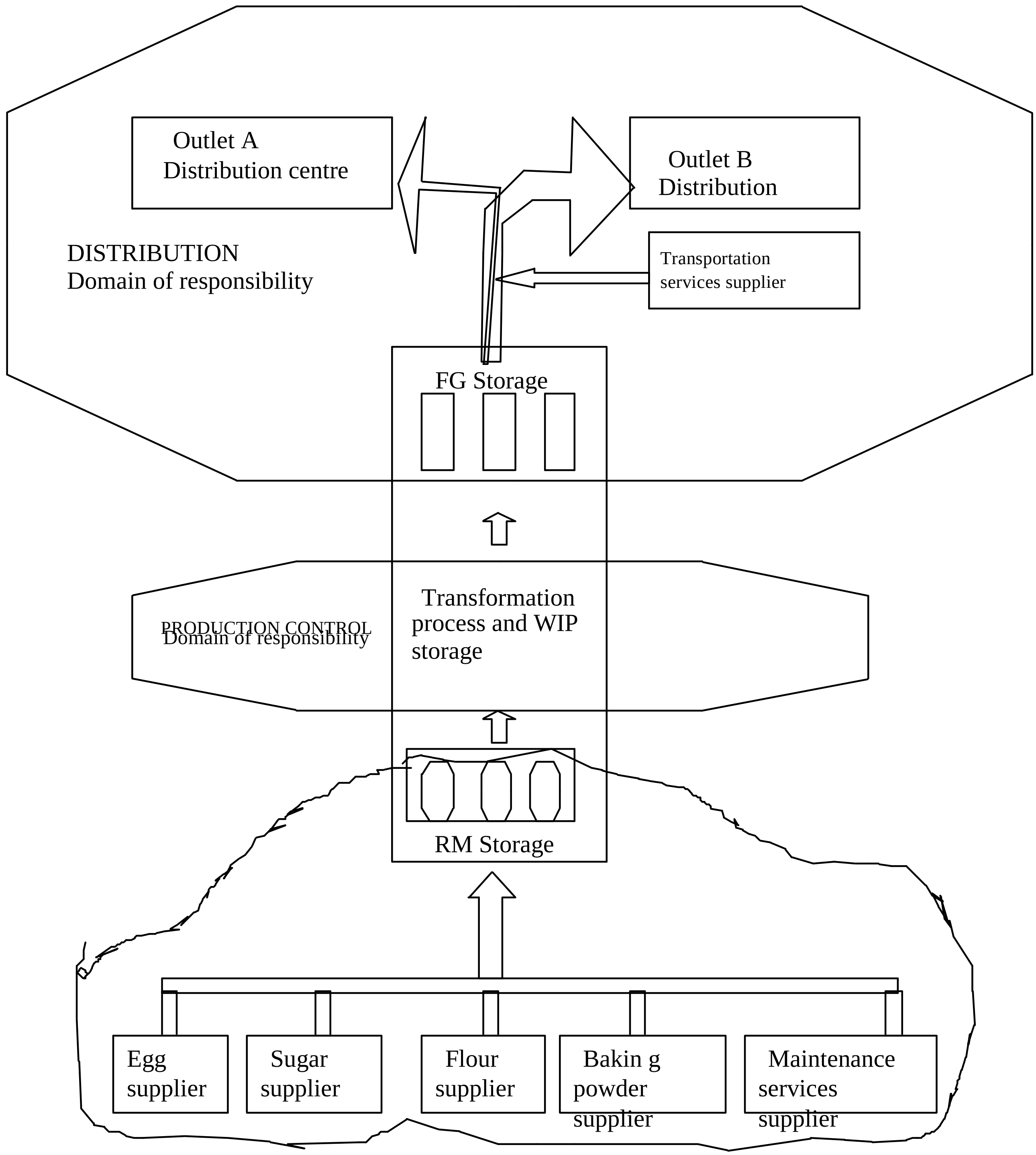
Consequently, many firms have restructured to centralize most materials management task in one department, and the manager of that department elevated to a higher position in the organisation. This form of organisation is called an integrated structure, while the unified department is referred to as 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 that the organisational structure and management hierarchy can help integrate decisions and activities in materials management, a lot of cross – functional coordination is still required. Let us use an example to buttress this important point: the marketing department typically makes forecasts and processes incoming customer orders. 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 schedule and 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.

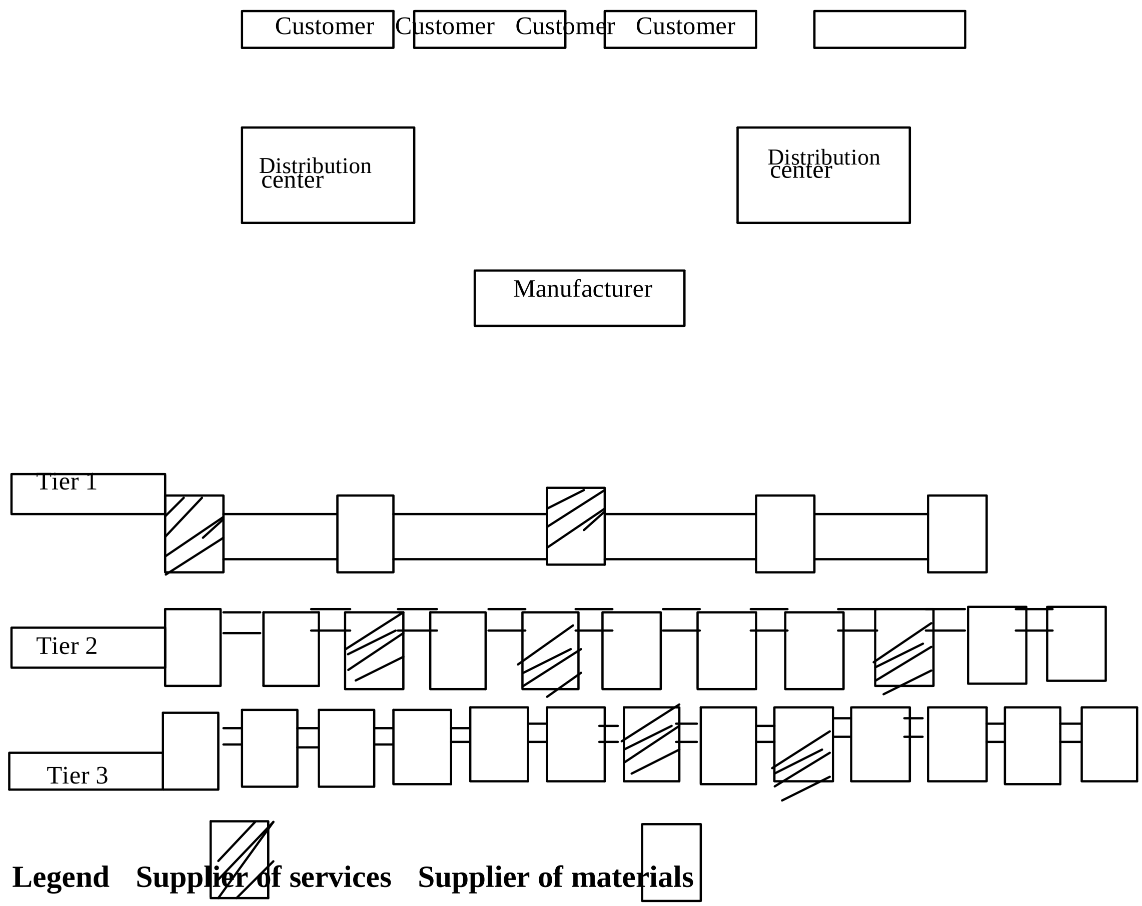
3.1.2 Supply Chains

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.

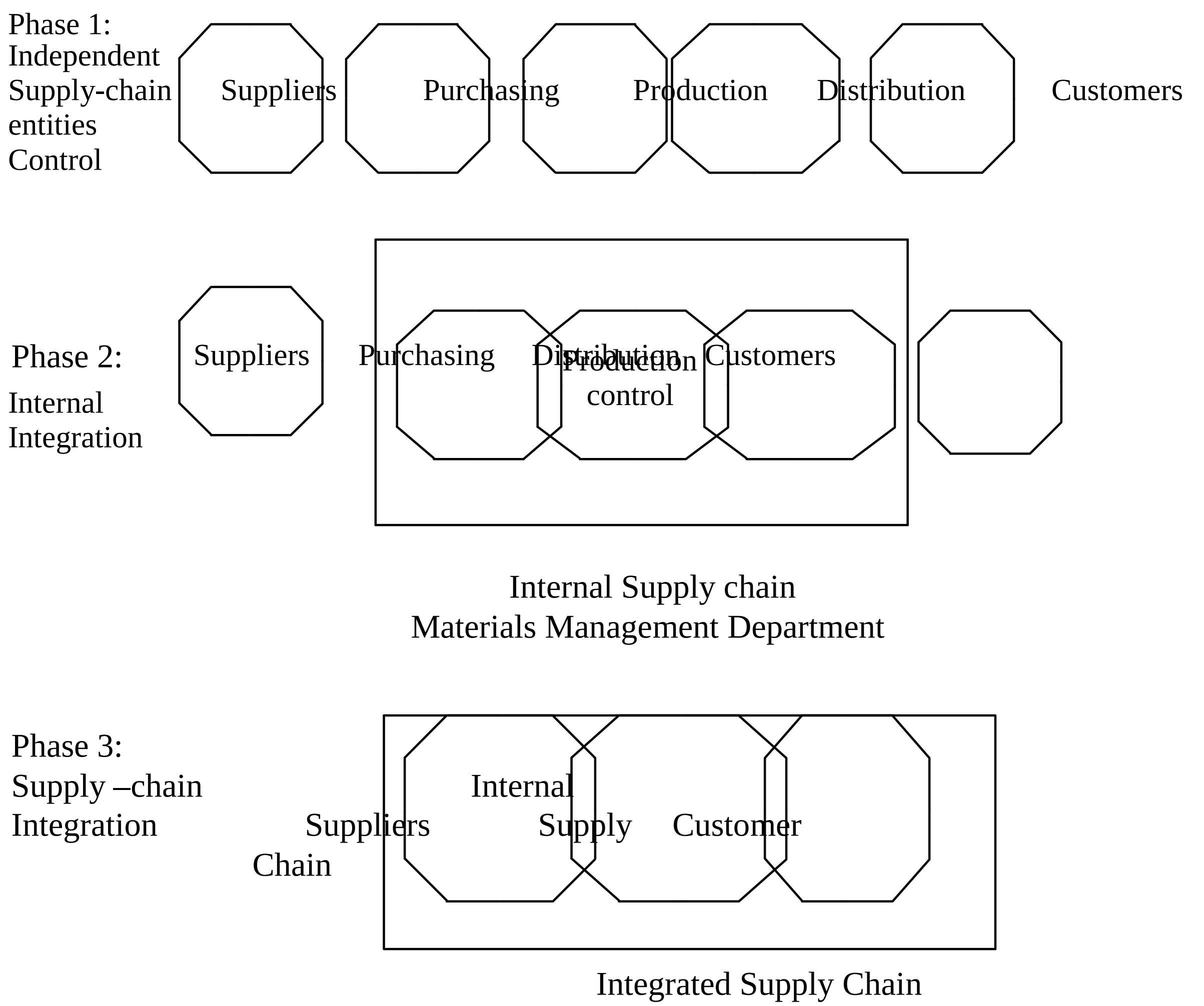


Most importantly, if demand drops, the firm can't simply reduce the amount of materials purchased from the supplier to reduce costs since the supplier's fixed costs remain unchanged. Another approach of controlling suppliers is to enter into some agreements with the first-tier suppliers, such that these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

3.1.3 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 with those of other entities. The existence of organizational and functional boundaries often leads 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 are emphasized, the firm still considers its suppliers and customers to be independent entities, thus focusing on 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 not under the direct 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.

3.2 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.

3.2.1 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 materials or 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 to appraise 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 have already 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 a supplier.

(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 of customer goodwill as well as future sales.

(v) **Receive the order: This is the last step. Here, the in-coming shipments** are normally checked for quantity and quality, with notices going to purchasing department, the unit placing the purchase requisition, inventory control and accounting. In a situation where the shipment is not satisfactory, the purchasing department should decide whether to return it to the supplier. It is also very important to keep a track of punctuality, quality and quantity deviations and price. Furthermore, the purchasing department should coordinate closely with account department to ensure that supplies are paid accurately and punctually too.

3.2.2 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 market segments 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 pries. However, low prices should not be made to overshadow quality, since this should equally be given an important consideration. 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 maintaining acceptable 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, certification involves 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.

3.2.3 Types and Effects of Supplier Relations

The nature and type of relations maintained with suppliers can affect the quality, delivery and price of a firm’s products and services. There are tow major types of relationships a firm may develop with its suppliers: competitive and cooperative.

3.2.3.1 Competitive 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 he lowest level. The buyer may also push demand to high levels during 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 have purchasing power when its purchasing volume represents a significant share of the supplier's sales or the purchased item or service is standardized and many substitutes are available.

3.2.3.2 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 interesting feature of the cooperative relationship is that he buyer shares 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, and may 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.

3.3 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. These are:

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

3.3.1 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 or retailer. 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 the manufacturing 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 in one 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 is based 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 distribution centre to another can be minimized.

3.3.2 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 can be 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 pickup and delivery rehandling. Water transportation provides high capacity at low unit cost, but its transit times are low. 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 in slurry 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.

3.3.3 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.

3.4 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.

3.3.3 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 can not 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

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

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 how much of a firm's assets are tied in inventory. T ypically, manufacturing firms have about 25 percent of their total assets in inventory, whereas wholesalers and 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 turn over (or turns), which is obtained by dividing annual sales at cost by the average aggregate inventory value maintained during the year. T he 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, how many weeks of supply were held in inventory? What was the inventory turnover?

Solution

(a)

$$\text{Weeks of Supply} = \frac{\text{N2m}}{\text{(N10m) / (52 weeks)}}$$

$$= 10.4 \text{ weeks}$$

(b)

$$\text{Inventory turns} = \frac{\text{N10m}}{\text{N2m}} = 5\text{turns / year}$$

4.0 CONCLUSION

In this unit, you have learned that a careful management of the materials and services from the suppliers to production to the customer allows organisations to operate more efficiently than competitors. You were also thought that supply-chain management involves the coordination of key functions in the firm such as marketing, finance, engineering, information systems, operations and logistics.

5.0 SUMMARY

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

6.0 TUTOR – MARKED ASSIGNMENT

A firm's cost of goods sold last year was N3, 410,000 and the firm operates 52 weeks per year. It carries items in inventory: three raw materials, two work-in-process items, and two finished goods. The following table contains last year's average inventory level for each item, along with its value.

(a) What is the average aggregate inventory value?
(b) What weeks of supply does the firm maintain?
(c) What was the inventory turnover last year?

Category	Part Number	Average Level	Unit value
Raw materials	1	15,000	3.00
	2	2,500	5.00
	3	3,000	1.00
Work-in-process	4	5,000	14.00
	5	4,000	18.00
Finished goods	6	2,000	48.00
	7	1,000	62.00

7.0 REFERENCES/FURTHER READINGS

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UNIT 4 INVENTORY MANAGEMENT

CONTENTS

1.0 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 foods etc. To test your understanding of inventory, try to identify the different types of inventories carried in the following organizations: Banks, Laboratory, clothing store and petrol station.

2.0 OBJECTIVES

After completing this unit you should be able to:

1) Define the term inventory and list the major reasons for holding inventories.
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 typical problems.
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 be appropriate.
12) Solve typical problems that involve shortage costs and excess costs.

3.0 MAIN CONTENT

3.1 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 keep inventory of birds until festival periods when they will be sold. Can you think of examples of firms that keep seasonal inventories?.
3. 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 while the 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.

4. 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?
5. To allow economic production and purchase or to take advantage 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 inventory storage 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 order cycles. 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.
6. 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.
7. To permit operations. The fact that production operations take a certain amount of time (i.e. they are not instantaneous) means that there will generally 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 ware houses, - 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?

3.2 Inventory Cost Structures

One of the most important prerequisites for effective inventory management is an understanding of the cost structure. Inventory cost structures incorporate the following four types of costs:

3.2.1 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.

3.2.2 Ordering (or set up) costs

These are costs of ordering and receiving inventory. They include typing purchase 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.

3.2.3 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 15 kobo to hold N1 of inventory for a year or in Naira per unit.

The carrying cost usually consists of three components:

3.2.3.1 Cost of capital

When items are carried in inventory, the capital invested is not available for other purposes. This represents a cost of foregone opportunities for other investments, which is assigned to inventory as an opportunity cost.

3.2.3.2 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

3.2.3.3 Costs of obsolescence, deterioration, and loss

Obsolescence costs should be assigned to items which have a high risk of becoming 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 on the concept of foregone profits.

3.3 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. A classic 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. More materials or ordered only as required by the need for other higher-level or end items.
The sections that follow focus on independent demand items.

3.4 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 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.

Let's take a close look at each of these requirements.

3.4.1 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 to make a decision on order quantities at each review.

A perpetual inventory system (also known as a continual system) keeps tracks of removal from inventory on a continuous basis, so when the system can provide 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). The disadvantages include added cost of record keeping and also a physical count shall be performed.

Bank transactions such as customer deposit and withdrawals are examples of continuous 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 periodically and entered into the system. In on-line system the transactions are recorded instantaneously. The advantage of latter over the former is that they are always up to date.

3.4.2 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 between submitting an order and receiving it) might vary.

3.4.3 Classification System

Since items held in inventory are not of equal importance in terms of naira invested, 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- C approach which classifies inventory items according to some 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 an inventory. In most instances A items account for large share of the value or cost associated with an inventory; and they should receive a relatively greater share of control efforts. The C items should receive only loose control and B items should have controls that lie between the two extremes.

The A. B. C concept is used by managers in many different settings to improve 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 C based on annual naira value.

Item	Annual **Demand**	Unit × **Cost**	Annual Naira Value
1	1,000	N4,300	N4,300,000
2	5,000	720	N3,600,000
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 seems reasonable 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 especially during 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.

3.5 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.

3.5.1 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 is reasonably 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, even though 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

$$\text{cost} = \frac{Q}{2}H \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Annual ordering cost is a function of the number of orders per year and the ordering cost per order

$$\text{Annual ordering Cost} = \frac{DS}{Q}$$

Where

S = ordering cost
D = annual demand
Q = order size

The equation shows that annual ordering cost varies inversely with respect to order sizes.

The total cost associated with carrying and ordering inventory when Q units are ordered 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

$$Q0 = \sqrt{\frac{2DS}{H}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

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 next year. 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 tires per year
H = N16 per unit per year
S = N75

Having determined these values, answers to those questions are thus: (a) Qo =

$$\sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(9600)\ 75}{16}} = 300 \text{ tires}$$

(b) Number of order per year

$$D/Q0 = \frac{9.600 \text{ tires}}{300 \text{ tires}} = 32$$

(c) (length of order cycle:

$$Q0/D = \frac{300 \text{ tires}}{9,600 \text{ tires}} =$$

1/32 of a year, which is 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 N 65 each. Ordering costs are N 31, and annual carrying costs are 20 percentage of the purchase price. Compute the optimal quantity and the total annual cost of ordering and carrying the inventory

Solution

D= 3,600 picture tubes per year
S= N 31
H= 20 (N65) = N13 (since this can be done, Q0 expression is therefore appropriate)

$$Q0=\sqrt{\frac{2DS}{H}}=\sqrt{\frac{2\,(3{,}600\,(31)}{13}} = 131 \text{ picture tubes}$$

TC = carrying costs + ordering costs
= (Q0/2) H + (D/Q0) S
= (131/2) 13 + (3.600/13)31
= N852 + N852 = N1, 704

3.5.2 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 in time 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 the number of runs per year times the setup cost per run: (D/Qo)S
Total cost is

TCmh = carrying cost + setup cost

$$= \left(\frac{Imax}{2}\right) H + (D/Q0)S \quad \text{-----------------} \ (4)$$

Where

Imax = maximum inventory
The economic run quantity is

$$Q0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where

P = production or delivery rate

U= usage rate

The maximum and average inventories are

$I_{max} = \frac{Q0}{p}(P-U)$ and $I_{average} = \frac{I_{max}}{2}$

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:

$\text{Cycle time} = \frac{Q0}{U}$

Similarly, the run time (the production phase of the cycle) is dependent on the run size and the production rate:

$\text{Run time} = \frac{Q0}{P}$

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 days per 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= N 1 per wheel per year

P= 800 wheels per day

U = 48,00 wheels per 240 days or 200 wheel per day

$$Q0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}} = \sqrt{\frac{2(48000)\ 45}{1}}\sqrt{\frac{800}{800-200}} = 2400 \text{ wheels}$$

(b) Tcmin = carrying cost + set up cost =

$$\left(\frac{I_{max}}{2}\right)H + (D/Q0)S$$

Thus you must first compute Imax

$I_{max} = \frac{Q0}{P}(P-U) = \frac{2,400}{800}(800-200) = 1,800$ wheels

$$TC = \frac{N1,800}{2} \times \frac{N1}{2,400} + 48,000 \times N45 = N900 + N900 = N1,800$$

(c) Cycle time = $\frac{Q0}{U} = \frac{2,400 \text{ wheels}}{200 \text{ wheels per day}}$ = 12 days.

Thus, a run of wheel will be made every 12 days

(d) Run time = $\frac{Q0}{P} = \frac{2,400 \text{ wheel}}{800 \text{ wheels per day}}$ = 13days

Thus, each run will require 3 days to complete.

3.5.3 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 of purchasing

$$= \left(\frac{Q}{2}\right) H + \left(\frac{Q}{D}\right) S + PD$$

Where

P = unit price

Recall that in the basic 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. N20 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, the procedure is as follows:

(1) Compute the common EOQ
(2) Only one of the unit price will have the EOQ in its feasible range since the ranges do not overlap. Identify that range

(a) if the feasible EOQ is on the lowest price range, that is the optimum order 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 liquid cleaner 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 per case, 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 =

$$= \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2\ (2\ (816)12}{4}} = 70\text{cases}$$

2. The 70 cases can be bough 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

TC70,= carrying cost + order cost + purchase cost
= (Q/2)H + (D/Q)S + PD
= (70/2) 4 + (816/70)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) = N14,154.

To obtain a cost of 16 per case, at least 100 cases per order are required and the total const 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 toggle switches 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 ₦18 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 = ₦18 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 more	0.82	0.18 (0.82) = 0.1476

(a) Find the EOQ for each price, starting with the lowest price until a feasible EOQ is located.

$$EOQ_{0.82} = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(4,00)\ 18}{0.1476}} = 988 \text{ switches}$$

Since 988 stitches will cost ₦0.85 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 ₦0.85 range of 500 to 999.

(b) Compute TC for 970, and compare it to the total cost at the minimum quantity 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.

3.5.4 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 latter is the function of models that identity the reorder point (ROP) in terms of a quantity: the reorder 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 day
Lead 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 desire amount 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 that demand 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 percent implies a probability of 95 percent that demand will not exceed supply during lead time.
An equivalent statement that demand will be satisfied in 95 percent of such instance 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 on the 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 be needed 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 might simply 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. The first 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 a strict 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 with an example:

Suppose that the manager of a construction supply house determined from historical records that the lead time demand for sand averaged 50 tons. In addition, 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 tons
dLT = 5 tons
Risk = 3 percent

(a) From normal deviate table, using a service level of 1 – 0.3 =.9700 you obtain 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 standard deviation. For those situations, one of the following formulae can be used.

If only demand is variable, then d LT =

$\sqrt{\ }$ 1LT d and the reorder point is

ROP = $\bar{d} \times LT + Z \sqrt{LT}\, \sigma_d$ ---------------------------- *(1)*

Where

$\bar{d}$ = Average daily or weekly demand

σ_d = standard deviation of demand per day or week

LT = lead time in days or weeks if only lead time is variable, than $\sigma_{dLT} = d\, \sigma_{LT}$

and the reorder point is ROP = d x LT + Z dLT ---------- 2)

Where

$\bar{d}$ = Daily or weekly demand

$\overline{LT}$ = Average lead time in days or week

σ_{LT} = Standard deviation of lead-time in days or weeks.

If both demand and lead-time are variables, then.

$$\sigma_{dLT} = \sqrt{\overline{LT}\, \sigma_d^2 + \bar{d}^2\, \sigma_{LT}^2}$$

and the reorder point is

ROP = $\bar{d} \times \overline{LT} + Z \sqrt{\overline{LT}\, \sigma_d^2 + \bar{d}^2\, \sigma_{LT}^2}$ …………………. (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 is willing 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

$\bar{d}$ = 50 jars per week

LT = 2 weeks

σ_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, you obtain Z = + 1.28.

(c) ROP = d X LT + Z $\sqrt{LT}$ d

= 50 X 2 + 1.28 $2\sqrt{(3)}$
= 100 + 5.43
= 105.43.

3.6 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).

3.6.1 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.

3.6.2 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 time only, or in both demand and lead time. However, for the sake of simplicity ad because it is perhaps the most frequently encountered situation, the discussion here will focus on variable demand and constant lead time.

Order size in the fixed-interval model is determined by the following computation:

Amount = Expected demand during protection interval + safe stock – Amount on hand at reorder time

= d (OI + LT) + Z d $\sqrt{OI + LT}$ - 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 interval is 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

$$\text{Amount} = \bar{d}\,(01 + LT) + Z\,d\,\sqrt{01 + LT} - A$$

$$= 30\,(7+2) + 2.33\,(3)\,\sqrt{7+2} - 71 = 220 \text{ units}$$

3.6.2 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 safely stock for a given risk of stock-out because of the need to protect against shortage during an entire order interval plus lead time (instead of lead time only) and this increases the carrying cost. Also, there are the costs of the periodic reviews.

3.7 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 not typically 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 over seafood 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, then shortage cost refer to the actual cost of production. Excess cost pertains to items left over at the end of 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 can be approximated using 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 continuous scale, thus lending itself to description by a continuous distribution. Demand for tractors cars and computer is expressed in terms of the number of units demanded and lends itself to description by a discrete distribution.

3.7.1 Continuous Stocking Levels

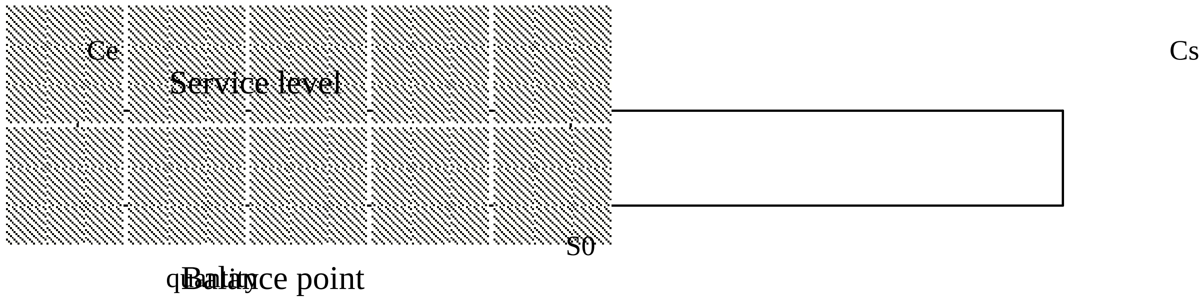
The concept of identifying an optimal stocking level is perhaps easiest to visualize when demand is uniform. Choosing the stocking level is similar to balancing a seesaw, but instead of a person on each end of the see saw, we have excess cost per unit (Ce) on one and of the distribution and shortage cost per unit (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

$$\text{Service level} = \frac{Cs}{Cs + Ce}$$

Where

Cs = shortage cost per unit
Ce = Excess cost per unit



So = 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.

Ce = cost per unit – Salvage Value per Unit

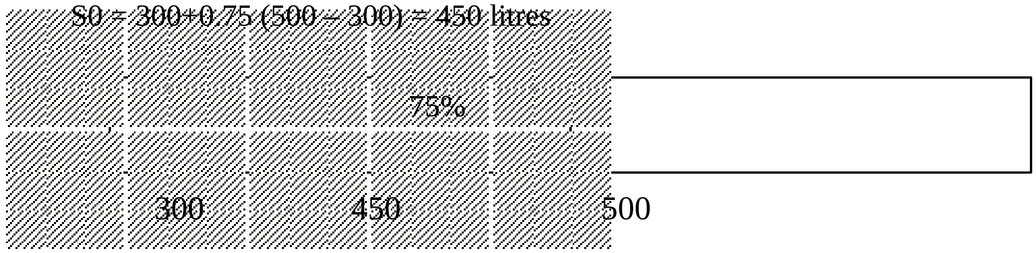
= ₦0.20 - - ₦0

= ₦0.20 per unit

$$SL = \frac{Cs}{Cs + Ce} = \frac{₦0.06}{₦0.06 + ₦0.20} = .75$$

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

S0 = 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. Cs = 60 kobo per litre, and Ce = 20 kobo per litre find the optimal stocking level for the apple cherry blend.

$$SL = \frac{Cs}{Cs + Ce} = \frac{N\ 0.60}{N\ 0.60 + N\ 0.20} = .75$$

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.

Thus, S0 = 200 litres + 0.675 (10 litres)
= 206.75 litres

3.7.2 Discrete Stocking Level.

When stocking level are indiscrete rather than continuous, the service level computed using the ratio Cs / (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 **N4, 200 per unit short. Spares cost N 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	

Cs = N 4,200 Ce = N 800

$$SL = \frac{Cs}{Ce + Cs} = \frac{N\ 4,200}{N\ 800 + N\ 4,200} = 0.90$$

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?

Cs = N 3 Ce = N 2 $\quad SL = \dfrac{Cs}{Cs + Ce} = \dfrac{N\,3}{N\,3 + N\,2} = .60$

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 a service level of at least .60 it is necessary to stock four dozens.

3.8 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.

4.0 CONCLUSION

In this unit you have learnt the management of finished goods, raw materials, purchased parts and retail items. You have also learnt the different functions of inventories, requirements for effective inventory management, objective of inventory control, and the techniques for determining how much to order and when to order.

5.0 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 of holding inventory and the cost of providing reasonable levels of customer 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 lead time. 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 is used for items that have a “shelf life” of one period.

6.0 TUTOR MARKED ASSIGNMENT

1. a. Does inventory control increase profitability? Explain your answer
   b. The Dangobell Corporation produces water heating unit in a number of types and sizes. Most of the parts for these units are made by the company and stored for later use during assembly of the heaters.

Since many different items are made and stored, the company wishes to be certain to manufacture these items in the most economical lot size. The formular used to make this determination is:

$$\text{Economic lot} = \sqrt{\frac{2 \times \text{quantity used per year} \times \text{total setup cost}}{\text{Manufacturing cost per piece} \times \text{interest rate}}}$$

The Company recognized that the formular gave only approximate results, but its use was justified because of its simplicity.

Model BY water heater has enjoyed steady sales over the years and an assembly line operating at a fairly uniform rate of 30 units a day has been set up to produce this heater. This model takes a special nozzle that is not used on any other model. The nozzle is produced on a turret lathe that can be set up for the job at a cost of N 300. The combined labour, material and over head cost of producing the nozzle once the machine is set up is N 60.10 each. The company regularly computes inventory carrying charges at 20% of the average investment in the inventory. The plant operates regularly 5 days a week for 50 weeks of the year.

1. What is the economic manufacturing lot size of nozzles for model BY?
2. What other factors in might influence the EOQ or lot size?
3. What types of charges are included in the 20% inventory carrying cost?

7.0 REFERENCES/FURTHER READINGS

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UNIT 5 AGGREGATE PLANNING

CONTENTS

1.0 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 experience seasonal or other fluctuations in demand or capacity. The goal of aggregate planning is to achieve a production plan that will effectively utilize the organisations resources to satisfy expected demand.

2.0 OBJECTIVES

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

i. Explain what aggregate planning is and how it is useful

ii. Identify the variables decision makers have to work with in aggregate planning
iii. Identify some of the possible strategies decision makers use
iv Describe some of the techniques planners use.

3.0 MAIN CONTENT

3.1 Production – Planning Hierarchy

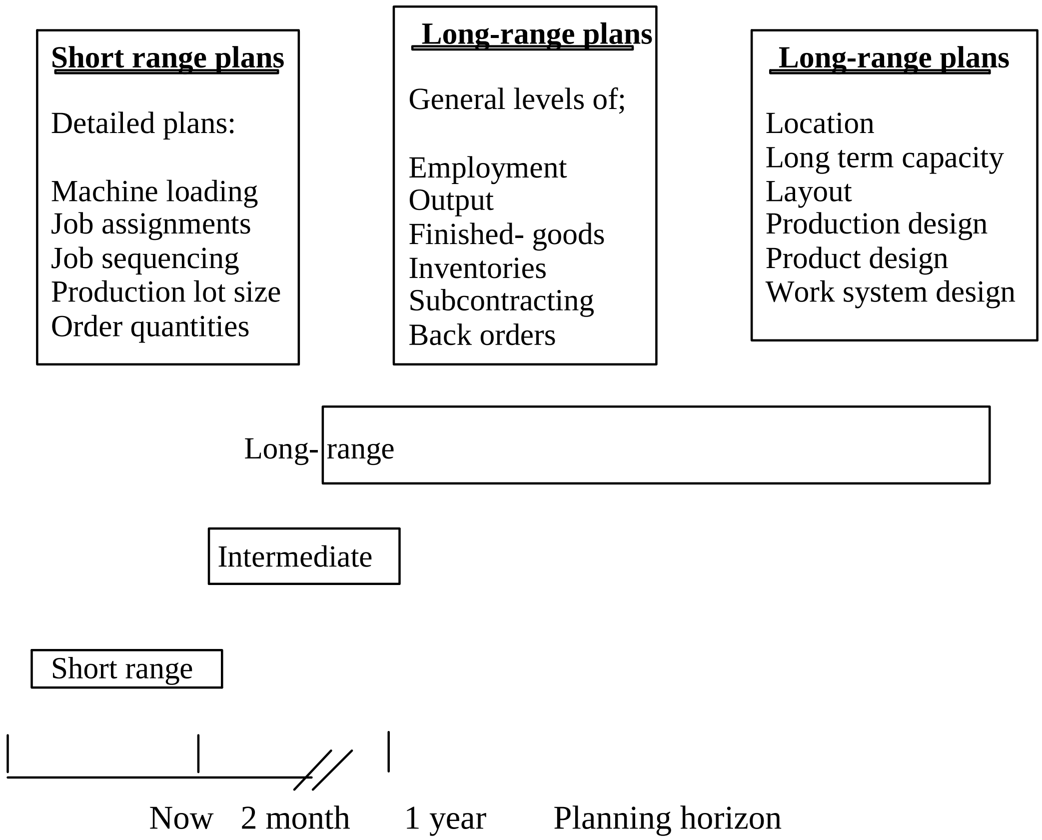
Generally, organisations become involved with capacity decisions on three levels: Long-term, intermediate term, and short-term. Long term decisions usually relate to:

(i) Product and service selection i.e. determining which predicts or services to offer;
(ii) Facilities i.e. plan locations, layout, size send capacities
(iii) Processing plans i.e., new production technology, new production processes, 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 on the 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 Table 10.1

Table 10.1: Overview of planning levels



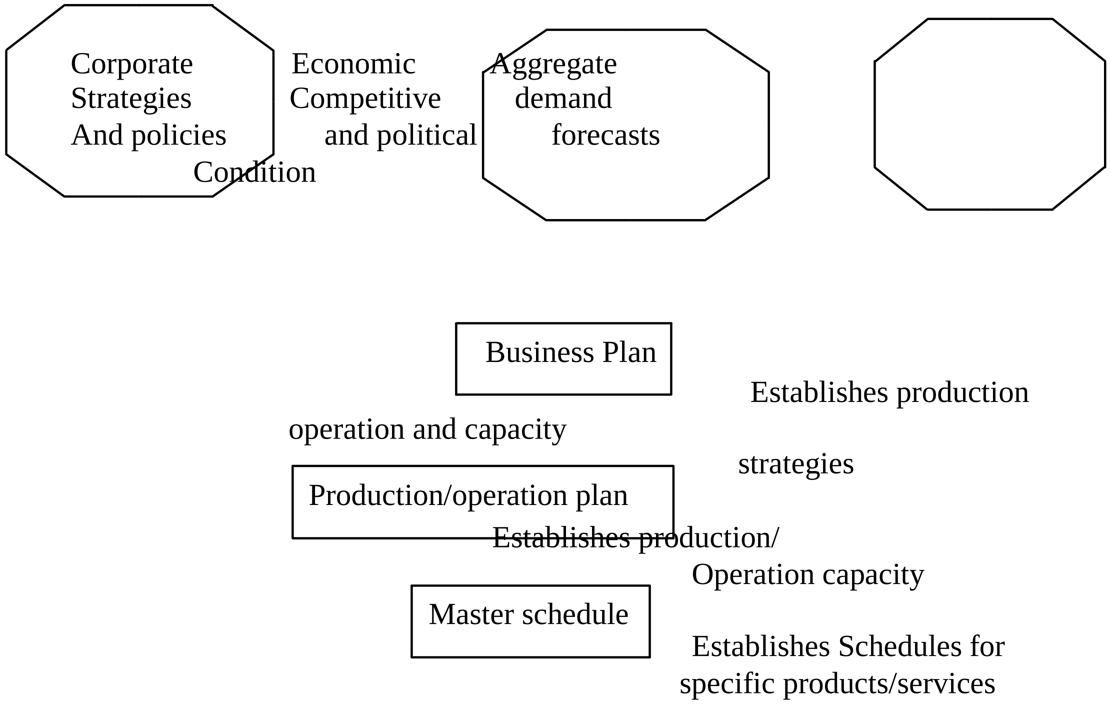
It is usual to find many business organisations developing a business plan that comprises both long-term and intermediate-term planning. This business plan sets guidelines for the organisations, taking into account the organisations strategies and policies; forecasts of demand for the organisation's 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 guides the planning processes of each functional area. For example, in operations functions, a production plan (or operations plan in the services organisation) is usually developed to guide the more detailed planing that eventually leads to a master schedule. The illustration of the planning sequence is given in Figure 10.2.

3.2 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 focussing 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 sets versus 18-inch or 14-inch. Instead, they would lump all models together and deal with them as a simple product. Hence, the term aggregate planning.

(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 item will actually be involved .

The advantage in this approach is that it frees planners to make general decision about the use of resources without having to get into the complexities of individual product or service requirements.

3.3 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.

3.3.1 Demand and Capacity

Aggregate planners are usually pre-occupied with the quantity and timing of expected demand. For instance, it total expected demand for the planning period is much different from available capacity over the particular planning period, the major approach of planners is either to try to increase demand (in case demand is less than capacity) or increase capacity (if 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.

3.3.2 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 Operations Management 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 is important in time of scarce production resources.

3.3.3 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.

3.3.4 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, such as using part-time workers, overtime, and subcontracting represent options that are being used to alter capacity or supply we shall examine these options in the section that follow:

3.3.4.1 Demand Options

There are four basic demand options: pricing, promotion, back-orders and new demand.

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 some of 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 price elasticity 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 is much 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 products or services for peak demand, for instance, demand for public transportation tends to be more intense during the moving and late afternoon rush 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 excess capacity during such slack periods. This way, organisations can achieve a more consistent use of labour, equipment and facilities.

3.3.4.2 Capacity Options

There are five basic options available for altering the capacity (or supply) or production. 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 an organisation can do. Furthermore, since the issue of firing and laying-off can give workers serious problems, some organisations have policies that 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. For instance, hiring costs include recruitment, screening, and training to bring new workers "up to speed". And quality 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 loss of morale for workers who are retained.

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 can generally 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 inventories allows 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 quality problems. 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.

3.4 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 of backlogging). Hence we will be concentrating on the capacity options here, within the ambit of operations (With the inclusion of back orders).

There are a number of strategies open to aggregate planners. Some of the notable 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 may suffer 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.

3.4.1 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 organisation is considering however depends on two important factors: company policy and costs. 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 secrecy about some aspects of the manufacturing of the product.

3.5 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 more widely used.

1. Determine demand for each product
2. Determine capacities (regular time, overtime, subcontracting) for each period
3. Identify company or departmental policies that are pertinent. (e.g. maintain a safety stock of 5 percent of demand, maintain a reasonably stable workforce).
4. Determine unit costs for regular time, overtime, subcontracting, holding inventories, 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/Fire Inventory Back orders						
TOTAL						

3.5.1 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 alternatives are then evaluated on the basis of their overall costs. The major limitation of these techniques is that they do not necessarily result in the optional aggregate plan.

Let us make use of an examples provided by Stevenson (1996). It is based on the 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 function composed 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 and capacity 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 the planning 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 Workers in a Period	=	*Numbers* of workers at end of the previous period	+	Number of new workers at start of the period	–	Number of laid off workers at start of 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 of the previous period	+	Production in the current period	− Amount used to satisfy demand in the current 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 by summing the appropriate costs:

Cost for a period

= Output cost (Regular + Overtime + Subcontract) + Hire / Fire Cost + Inventory cost + Back - order 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	Cost/Fire x Number fired
Fire	Carrying cost/unit x Average inventory
Inventory	Back order cost/unit x Number of back-order
Back order	units

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 cover six 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	= N/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
Forecast	200	200	300	400	500	200	1,800
Output							
Regular	300	300	300	300	300	300	1,800
Overtime	-	-	-	-	-	-	
Subcontract							
Output – Forecast	100	100	0	100	200	100	0
Inventory	0	100	200	200	100	0	
Beginning	100	200	200	100	-	0	
Ending	50	150	200	150	50	0	600
Average	0	0	0	0	100	0	100
Backlog							
Costs							
Output							
Regular	N600	600	600	600	600	600	3600
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 the quantity output-forecast.

3.5.2 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.

3.5.2.1 Linear Programming

These are methods for obtaining optimal solutions involving the allocation of scarce resources in terms of cost minimisation 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.

3.5.2.2 Linear Decision Rule

The Linear decision rule is another optimising technique. It was developed in the 1950s, by Charles Holt, 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 or impractical.

3.5.2.3 Simulation Models

In addition to the first two techniques, some simulation models have been developed for aggregate planning. The essence of simulation is the development of computerized models that can be tested under a variety of conditions in an attempt to identify reasonably acceptable solutions to problems.

3.6 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. What three levels of planning involve operations managers? What kinds of decisions are made at the various levels?
2. Why is there a need for aggregate planning?
3. What are the three phases of aggregate planning?

4.0 CONCLUSION

This unit has taken you though a number of important issues involved in aggregate planning. You have learned that the essence of aggregate planning is the aggregation of products or services into one “products” or “service”

5.0 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 very specific and detailed short-range planning decisions. It begins with overall forecasts for the planning horizon and ends with preparations for applying the plans to specific products and services.

6.0 TUTOR MARKED ASSIGNMENT

Question: Refer to the worked example in the text: After reviewing the plan developed in the worked example, planners have decided to develop an alternative plan. They have learned that one person is about to return from the company, rather than replace him, they would like to stay with the smaller workforce and use overtime to make up for the lost output. The reduced regular-time output is 280 units per period; the maximum amount of overt-time output per period is 40 units. Develop a plan and compare it to the previous one.

7.0 REFERENCES/FURTHER READINGS

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MODULE 3

UNIT 1 LINEAR PROGRAMMING (LP)

CONTENTS

1.0 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.

2.0 OBJECTIVES

After reading this unit you will be able to:

(i) Explain the characteristics and assumption of linear programming model.
(ii) Formulate models for various problems
(iii) Perform graphic analysis for two-variable problems and find the algebraic solution for the corner point found to be optimal.
(iv) Describe the meaning of slack and surplus variables
(v) Discuss the meaning of sensitivity analysis on the objective function co-efficient and right hand side parameters.
(vi) Interpret the computer output of a linear programming solution.

3.0 MAIN CONTENT

3.1 Function and Characteristics of LP

3.1.1 Functions

(i) LP is useful in the specification of optimum organisation of resources in a business organisation such that net returns of maximization of returns is achieved under given condition of resource restriction.
(ii) LP makes long range planning possible in business
(iii) LP gives technical co-efficient based largely on the practices and methods of operation adopted by the manager.
(iv) By-product obtained from results of the LP planning exercises are capable of throwing considerable light on a number of aspects of business management e.g. the surplus or unexhausted resource(s), the rate of interest the manager can justifiably pay on borrowed funds, wages that the manager is willing to pay for labour.

3.1.2 Characteristics

Some assumptions (characteristics) go with the three components of LP outlined in section 3.2, they are:

(i) Linearity:- This implies that the input-output co-efficient are constant and independent of the scale of operation implying constant resource productivity and return to scale.

(ii) Additivity:- This assumption implies that the total quantity of resources used in different activities is equal to the sum of the quantities of different input used in each activity and that the size of any activity is independent of the size of other activities.

(iii) Divisibility:- This means that inputs are infinitely divisible. Thus, an LP solution can specify inputs and outputs in fractional units such as 10.7 units of labour etc.

(iv) Finiteness:- This implies that a limit exists on the number of `activities and resources which can be programmed. This is a practical assumption in the sense that an unlimited number of activities and resources would make an optimum solution impossible to obtain

(v) Single valued expectation:- This characteristics shows that the prices of inputs and outputs, the input-output co-efficient and the levels of resources are known with certainty. Hence, a LP model is deterministic.

(vi) Non -negativity of decision variables:- This is very logical, there is no way you use any negative quantity of any resource, the least you use of any input among series of inputs in a production process is zero i.e. not used at all.

3.2 Components of LP Model

(i) An objective function:- This must be clearly spelt out in mathematical language, and this can take one of several forms e.g. (a) Maximization of net revenue or profit from one or a several combination of enterprises (b) Maximization of production or a transportation cost.

(ii) Competitive enterprises with possible alternative methods of producing each enterprise. This implies that enterprises must be competing for the use of resources and in which case there is a problem of choice among enterprises, (see section under formulation of LP problem).

(iii) Constraint to the attainment of the objective: A linear programming (LP) problem exists only if there are constraints limiting the attainment of an objective

Basically there are 3 types of constraints

(a) Resource constraint:- A manager always have limited levels of such resources as capital, labour, machines, building capacity etc. which limits the scale of his operation.

(b) Institutional constraint: - This is typified by quota system which is a contractual arrangement with say a governmental agency specified minimum or maximum production levels.

(c) Subjective constraint: - The manager imposes this on himself. For example, there may be internal capital rationing due to (i) debt aversion (ii) scale restriction due to skill (iii) consumption habit consideration etc.

3.3 Formulating a LP problem

Linear programming application begins with the formulation of a model of the problem with the general characteristics just described. We illustrate the modeling process here with the product mix problem, a one- period type of aggregate planning problem, the solution of which yields optimal output quantities (or product mix) of a group of product or services, subject to resource capacity and market demand constraints. Formulating a model to represent each unique problem, using the following three-step sequence, is the most creative and perhaps the most difficult part of linear programming.

Step 1: Define the decision variable

Define each decision variable specifically, remembering that the definitions used in the objective function must be equally useful in the constraints. The definitions should be as specific as possible e.g. X, = product 1

or

X, = no of units of product 1 produced and sold at a time.

Step 2: Write out the objective function.

What is to be maximized or minimized? If it is revenue, write out an objective function that makes the revenue a linear function of the decision variables. Identify parameters to go with each decision variable. For example, if each unit of X1 sold yields a revenue of ₦45, the total revenue realizable from X1 equal 45 X1. The objective function often is set to equal to Z, and the goal is to maximize or minimize Z.

What limits the values of the decision variables? Identify the constraints and the parameters for each decision variable in them. To be formally correct, also write out the non-negativity constraints.

Example 1

Lopin factory produces two basic types of plastic pipe. Three resources are taken to be crucial to the output of pipe: extrusion hours, packaging hours, and a special additive to the plastic raw material. The data below represent next production situation.

	Product		
Resource	Type 1	Type 2	Resource availability
Extrusion	4hr	6hr	48hr
Packaging	2hr	2hr	18hr
Additive mix	2kg	l kg	16kg

The contribution of profits and overhead per 100 feet of pipe is N34 for type 1 and N40 for type 2. Formulate a linear programming mode to determine how much of each type of pipe should be produced to maximize contribution to profits and to overhead.

Solution

Step 1: To define the decision variables that determine product mix, we let
X1 = amount of type 1 pipe to be produced and sold after next production. X2 = amount of type 2 pipe to be produced and sold after next production.

Step 2: Next define the objective function. The goal is to maximize the total contribution that the two products make to profits and overhead. Each unit of X1 yields N34 and each unit of X2 yields x N40. For specific values of X1and X2 we find the total profit by multiplying the number of units of each product produced by the profit per unit and adding them. Thus our objective function becomes Maximize N34X1 + N40X2 =Z.

Step 3. The final step is to formulate the constraints. Each unit of X1 and X2 produced consumes some of the critical resources. In the extrusion department, a unit of X1 requires 4 hours and a unit of X2 requires 6 hrs. The total must not exceed the 48hours capacity available, so we use the = sign. Thus the first constraint is 4 X1 + 6 X2 = 48 (extrusion).

Similarly, we can formulate constraints for packaging and raw materials.

2 X1+ 2 X2 = 18 (packaging)
2 X1+ X2 = 16 (additive mix)

These three constraints restrict our choice of values for the decision variables because the values we choose for X1and X2 must satisfy all of them. Negative values for X1and X2 don't make sense, so we add non-negativity restrictions to the model

X1 = 0; X2 = 0

We can now state the entire model, made complete with the definition of variables.

Maximize 1 N3~~4X~~1 + ; N40~~X2~~ = Z

Subject to 4X1 + 6X2 = 48
2X1 + 2X2 = 18
2X1 + X2 = 16
X1, X2 = 0.

3.3.1 Graphic analysis

With the model formulated, we now seek the optimal solution. In practice, most linear programming problems are solved with the computer. However, insight into the meaning of the computer output and linear programming concept in general can be gained by analyzing a two - variable problem with the graphic method of linear programming, even though it isn't a practical techniques for solving problems having three or more decision variables. Five basic steps involved are

(i) Plot the constraint
(ii) Identity the feasible region
(iii) Plot an objective function line
(iv) Find the visual solution
(v) Find the algebraic solution

Each of these five steps are briefly discussed

(1) Plot the constraints:

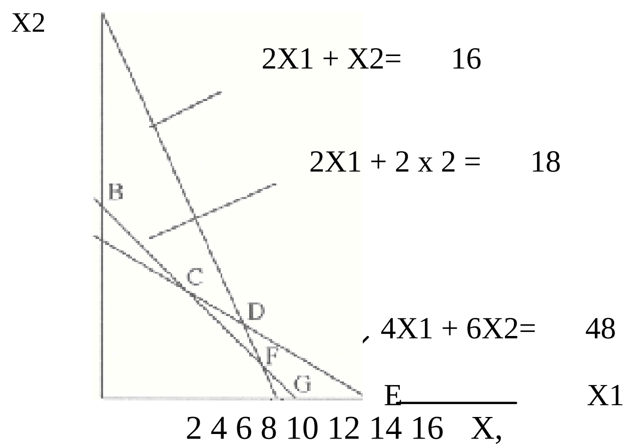
We begin by plotting the constraint equations, disregarding the inequality portion of the constraints. Making each constraint equal converts it to equation for a straight line. The line can be drawn as soon as we identify two points on it. To find the X1 axis intercept, set X2 equal to 0 and solve the equation for X1. For the Lopin factory in example l, the equation of the line for the extrusion process is

4X1 + 6X2 = 48

for the X1 axis intercept, X2 = 0
and so 4X1 + 6(0) = 48
X1 = 12
To find X2 axis intercept, X1 = 0
and so 4(0) + 6(X2) = 48
X2 = 8

We now connect points (0, 8) and (12, 0) as in Figure 11.1 below.

Figure 11.1: Graph of the Three Constraints



The solution for packaging process line

$2X1 + 2X2 = 18$
for X1, $:2X1 + 2(0) = 18$
$X1, = 9$
For X2 : $2(0) + 2(X2) = 18$
$X2 = 9$

We now connect points (9,0) and (0,9) on the same graph behind in fig. 1. The equation for the additive mix line is 2X1, + X2 = 16. To find X1, intercept, set X2 = 0

$2X1, + X2 = 16$
$X1 = 8$
To find X2, set $X1 = 0$
$2(0) + X2 = 16$
$X2 = 16.$

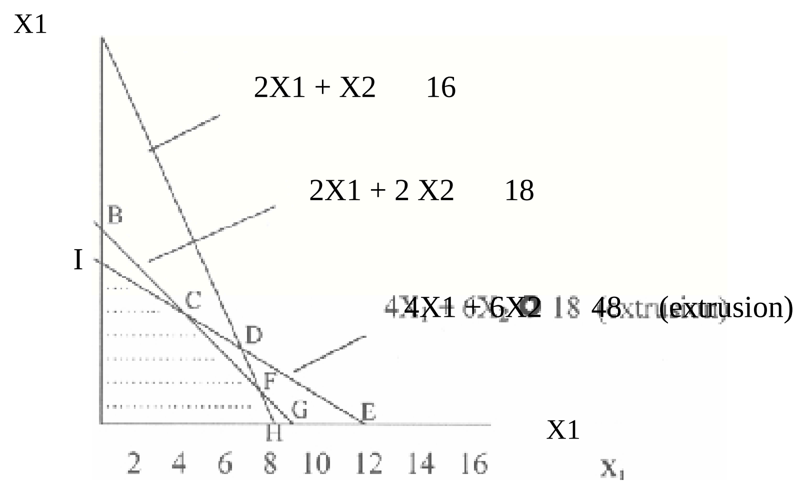
We also connect points (0, 16) and (8, 0) for the additive mix on the same graph of Figure 11.1.

(2) Identify the feasible region

The feasible region is the area on the graph that contains the solutions that satisfy all the constraints simultaneously, including the nonnegative restriction.
The feasible region for a maximization problem as in this case is that area bounded by all the tree curves and so we would have the curve ICFH as our feasible region as shown in Figure 11.2. Having obtained the feasible region we

now seek to locate the point that maximizes the objective function this is achieved by plotting the objective function on the feasible region. The series of lines plotted are called Iso-revenue curves if the objective function is to maximize revenue or Iso-profit curve if the objective is to maximize profit. The optimal point is finally read as the point where the objective function line cuts the tip of the feasible point (farthest point from the origin).

Figure 11.2: The Feasible region



2 X1 + 2 X2 18 (packaging)

(3) Find the visual solution

From the feasible region lCFH we eliminate corner point OH because better points lie above and to the right. The optimal solution is the last point touching the feasible region when series of lines with slope equal to the slope of the objective are plotted within the feasible region. Due to some errors in reading, the value from the graph or gradation, visual solution isn't exact.

(4) Find the Algebraic Solution

To find an exact solution, we must use algebra. We begin by identifying the pair of constraints that define the corner point at their intersection. We then list the constraints as equations and solve them simultaneously to find the coordinates (XI, X2) of the corner point.

Simultaneously equation can be solved several ways. For small problems the easiest way is as follows.

Step 1: Develop an equation with just one unknown. Start by multiplying both sides of one equation by a constant so that the co-efficient for one of the two variables is identical in both equations. Then subtract one equation from the other and solve the resulting equation for its single unknown variable.

Step 2: Insert this decision variable value into either one of the original constraints and solve for the other decision variable. Find the optimal solution algebraically for the Lopin factory. What is the value of Z when the decision variables have optimal values.'?

Solution

Step 1

4X1 + 6X2 = 48 (Extrusion)
2X1 + 2X2 = 18 (Packaging)

Multiply each term in packaging constraint by 2 to give 4X1 + 4X2 = 36. Next, we subtract the packaging constraint from the extrusion constraints.

4X1 + 6X2 = 48
(4X1 + 4 X2 = 36)
2X2 = 12
X2 = 6

Step 2 substituting the values of X2 into the extrusion equation, we get

4 X1 + 6(6) = 48
4X1 = 12
X1 = 3

The optimal point is thus (3, 6) to give an optimal profit of
34(3) + 40 (6) = ₦4342

3.4 Slack and surplus variables.

For a O constraints, the amount by which the left-hand side falls short of the right-hand side is called slack. For a 1:1 constraint, the amount by which the left-hand side exceeds the right-hand side is called surplus. To find the slack for a O constraint algebraically, we add a slack variable to the constraint and convert it to an equality. Then we substitute in the values of the decision variables and solve for the slack. For example the additive mix constraint in Lopin factory is 2X1 + X2 + S1 = 16.

We then find the slack at the optimal solution (3, 6)

2(3) + 6 + S1 = 16
S1 = 4.

The procedure is much the same to find the surplus for a , constraint, except that we subtract a surplus variable from the left-hand side. Suppose that $X_1 + X_2$, 6 was another constraint in the Lopin factory problem, representing a lower bond on the number of units produced. We would then rewrite the constraint by subtracting a surplus variable S_2

$XI + X_2 - S_2 = 6$

The slack at the optimal solution (3,6) would be

$3+6 - S_2 = 6$

$S_2 = 3$

3.5 Sensitivity analysis

The parameters in the objective function and constraints are rarely known with certainty. Sometimes they are just estimates of actual values. For example, the available packaging and extrusion hours for the Lopin factory are estimates that do not reflect the uncertainties associated with absenteeism or personnel transfers, and required time per unit to package and extrude may be work standards that essentially are averages. Likewise, profit contribution used for the objective function coefficients do not reflect uncertainties in selling prices and such variable costs as wages, raw materials, and shipping.

In spite of these uncertainties, initial estimates are needed to solve the problem. Accounting, marketing and work-standard information systems usually often provide these initial estimates. After solving the problem using these estimated values, the analyst can determine how much the optimal value of the decision variables and the objective function value Z would be affected if certain parameters had different values. This type of post solution analysis for answering "what if' question is called sensitivity analysis.

3.5.1 Right - hand - side parameters

Now consider how a change in the right-hand-side parameter for a constraint may affect the feasible region and perhaps cause a change in the optimal solution. Let's return to the Lopin factory problem. Consider adding one more hour to the packaging process, increasing it from 18 to 19 hours; i.e.

$4X_1 + 6X_1, = 48$ (extrusion)

$2X_1, + 2X_2 = 19$ (packaging)

The optimal values are $X_1 = 4.5$ and $X_2 = 5$ and the new Z value is N34 (4.5) + N40 (5) = N353. Because the value of Z was N342 with 18 hours of packaging time, the value of one more hour of packaging is N11 (or N353 - N342).

The change in Z per unit of change in the value of the right-hand side parameter of a constraint is called the shadow price, which is the marginal improvement in Z caused by relaxing the constraint by one unit. Relaxations mean making the constraint or decrease it for an O restrictive, which involves increasing the right-hand-side for an O constraint. The shadow price also is the marginal loss in Z caused by making the constraint more restrictive by one unit.

3.6 Computer Solution

Most real-world linear programming problems are solved on a computer, so we will focus our understanding on the use of computer to solving LP problems and the logic behind its use. The solution procedure in computer codes is some form of the simplex method, an iterative algebraic procedure for solving linear programming problems.

3.6.1 Simplex Method

The graphic analysis gives insight into the logic of the simplex method. One corner point of the feasible region will always be the optimum, even when there are multiple optimal solutions. Thus, the simplex method starts with an initial corner point and then systematically evaluates other corner points in such a way that the objective function improves (or at worst, stays at the same) at each iteration. In the Lopin factory example we have being using for illustration; an improvement would be an increase in profits. When no more improvements are possible, the optimal solution has been found.

3.6.2 Computer Output

Computer programmes diagrammatically reduce the amount of time required to solve linear programming problems. Special - purpose programmes can be developed for applications that must be repeated frequently. Such programmes simplify data input and generate the objective function and constraint for the problem.

Printout 1 shows the input data for the Lopin factory problem. The last half of printout 1 gives the values an the type of constraint (O = or O). The user may choose to enter labels for the objective function, constraint, and right hand side values. Here the extrusion constraint is labelled "Ext" and the right-hand -side values are labelled "RHS" Input data can be stored in file for use during subsequent sessions.

Printout 1

Data entered
Number of variables 2
Number of O constraint 3
Number of = constraint 0
Number of O constant 0

Number of Model	constraint 0 Xl	X2	RHS
Max Z	34	4	
Ext	4	6	O 48
Pac	2	2	O 18
Add	2	1	0 16

Printout 2

Solution

sVariable Label	Variable Value	original coefficient coefficient	sensitivity
X1	3	34	0
X2	6	40	0

Constraint Label	Original RHV	Slack or Surplus	Shadow Price
Ext	48	0	3
Pac	18	0	11
Add	16	4	0

Objective function value: 342

So far we have solved the Lopin factory problem graphically and algebraically, mention was made of the simplex approach but not performed in this section we shall see manually the series of operations being performed within the input-output system of a computer.

Max Z = 34 X1 + 40 X2

S.t 4X1 + 6X2 48

2X1 + 2X2 18

2X1 + X2 16

By converting the inequality to strict equality, we add slack activities to each of the constraints. i.e.

Max Z = 34X1 + 40X2
S.t 4X1 + 6X2 + IS1 = 48
2X1 + 2X2 + IS2 = 18
2X1 + X2 + IS3 = 16
X1 X2 O 0

Simplex table

iteration C Resources/ Resources Real Activities Slack Activities R
Activities Level 34 40 0 0 0
X, X2 S, S2 S3
0 S, 48 4 6 1 0 0 8*
0 S, 18 2 2 0 1 0 9
1 0 S3 16 2 1 0 0 1 16
Z 0 0 0 0 0 0
Z-C - -34 -40 0 0 0
40 X2 8 213 1 '/6 0 0 12
0 S2 2 2/3 0 -1/3 1 0 3*
0 S3 8 11/3 0 -1/6 0 1 6
11
Z 320 262/3 40 62/3 0 0
Z-C - -71/3 0 62/3 0 0
34 X, 3 1 0 -`/2 1 `/2 0
111 40 X2 6 0 1 1/2 -1 0
0 S3 4 0 0 1/2 -2 1
Z 342 34 40 3 11 0
Z-C - 0 0 3 11 0

Critical evaluation of the simplex table would show the last value of Z as N342, just as in the computer printout 2, the values 3, 11, 0, last bottom values are defined as shadow prices, just the same as in computer printout 2. In the third iteration S3 featured with a value of 4, showing us that the third resource was not fully consumed, Just the same as computer printout 2. It may be of necessity to practice one or two examples on simplex table, this then call for the need to explain the table.

1. In the first iteration, all resources to be used in the production process are treated as surplus
2. Anything surplus would have a shadow price of zero i.e. how much you are willing to pay to have an additional unit.
3. Consider the resource level column, the level you have would be the total amount you have in store to use in production process.
4. The real activities column would have the co-efficient of the constraint.
5. Slack activities column would have diagonal values as 1 and all off diagonal values as 0, i.e. and identity matrix.
6. Having inputted all these values, underline every column and introduce a Z row

7. To fill the Z row, multiply the cost values corresponding to any entry by the quantity and sum throughout the row.
8. Designate another Z-C row and subtract C, note that C attached to X, and XZ is the coefficient in its objective form as 34 and 40 respectively and C corresponding to Si. SZ and S3 are all zeros, meaning that whatever is surplus would not command a value from a consumer.
9. Looking at the Z-C row under the real activity column, observe any highest negative value, trace it up and call this the pivot column (incoming activity)
10. Next, divide all resource levels by their pivot column equivalent and fill this in the R column
11. Observe the lowest of all the Rs and trace this sideways (outgoing activity); this is the pivot row.
12. There is a place where the pivot column and pivot row intersect, call this the pivot. That is the end of the first iteration.
13. In the second iteration, first input the incoming activity (XZ in this case)
14. To know the levels of X2 in each cell divide the values of the outgoing activity by its pivot all through.
15. Now, observe something special, just as the pivot divide itself to give 1, observe the two other values under it to be zero. This must be, and so would be helpful when the levels of the other two resources are to be deduced.
16. For the level of S2, we wont just copy the levels iteration 1, but we have to use adjusted levels (observe what was said in point 15 above).
17. To go about that where we peg S2 = 0 under the location where pivot divide itself to give 1 and other values under = 0, we say we want to look for a multiplier effect. This is calculated as initial - multiplier (outgoing) = 0.
18. Look back at iteration 1 and see that the value of S2 directly under pivot value is 2 (that value represents initial).
19. Back in iteration II, the value of S2 under same column was traced down to zero. The outgoing value for that column was 6 (the pivot).
20. Let us now use this combination to find out multiplier as

    2 - Multiplier (6) = 0

    Let multiplier be x

    So that 2-x (6) = 0

    x = 1/3
21. To calculate resource level for S2 in iteration II we say 18 which is initial value from iteration I less the product of multiplier and what is going out under same column i.e. 18 - 1/3 (48) = 2.

Similarly to calculate the value of S2 under real activity X1, we say
2-1/3 (4) = 2/3, until the whole array is filled up.

22. We also have to look for multiplier S3.
23. Underline and evaluate Z and Z-C and observe if negative exists in the real activity column of Z-C row.

24. If negative exists, the highest negative connotes the incoming activity in the next iteration. If not an optimal solution has been reached.

3.7 Dual

The objective of any LP process is called the primal, the process of reversing or transpose of the primal process is called the dual. If the primal is to maximize then the dual is to minimize, whether the primal function is solved or its dual function is used to establish the solution, the answer remain unchanged

3.7.1 Procedure for a dual process

1. Observe the objective function of the primal problem
2. Write out the co-efficients of the constraints of the primal problem in form of matrix.
3. Transpose the matrix of co-efficients of the constraints.
4. Total requirement of each of the constraints of the primal problem now turn coefficients of the objective function of the dual.
5. Co-efficients of the objective function of the primal problem become the resource constraints.
6. The inequality sign is reversed for the dual problem.

4.0 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.

5.0 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.

6.0 TUTOR MARKED ASSIGNMENT

(1) Maximize Z = 2X1 + 3X2

S.t X1 + 2X2 O 30

3X1 + X2 O 60
6X1 + 3X2 O 200
5X1 + 4X2 O 200

(2) Maximize Z = 2X1 + X2
S.t. X1 + X2 O 5
X1 + 3X2 O 9

In each case find maximum Z, the slack resources, and the shadow prices.

7.0 REFERENCES/FURTHER READINGS

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UNIT 2 MATERIAL REQUIREMENTS PLANNING

CONTENTS

1.0 INTRODUCTION

Material requirements planning (MRP) is a computer-based information system for ordering and scheduling of dependent-demand inventories (e.g. raw materials, component parts, and subassemblies). (Recall that dependent-demand is the demand for items that are subassemblies or component parts to be 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 to produce 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) a master 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 determine the planning horizon.

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.

2.0 OBJECTIVES

After completing this unit, you should be able to:

(i) Describe the conditions under which MRP is most appropriate.
(ii) Describe the input, outputs and nature of MRP processing.
(iii) Explain how requirements in a master production schedule are translated into material requirements for lower-level items.
(iv) Discuss the benefits and requirements of MRP.
(v) Explain how an MRP system is useful in capacity requirements planning.
(vi) Outline the potential benefits and some of the difficulties users have encountered with MRP.
(vii) Describe MRP II and how it relates to MRP.

3.0 MAIN CONTENT

3.1 MRP Inputs

As already mentioned in proceeding section, an MRP 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.

3.1.1 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 planning horizon. 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 up seasonal 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 lead time 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 8 weeks, the plan is fixed, but small charges may be allowed; and the plan is frozen out to the four-week fence.

3.1.2 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 a finished 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 Tree

Chair

Leg Seat Assembly
Assembly Back

Legs (2) Cross bar Side Cross bar
Back rails (2)
Supports

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

0
X
1. B(2)
C

2. D(3) E
F(2)

3. E(4)

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

Solution

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

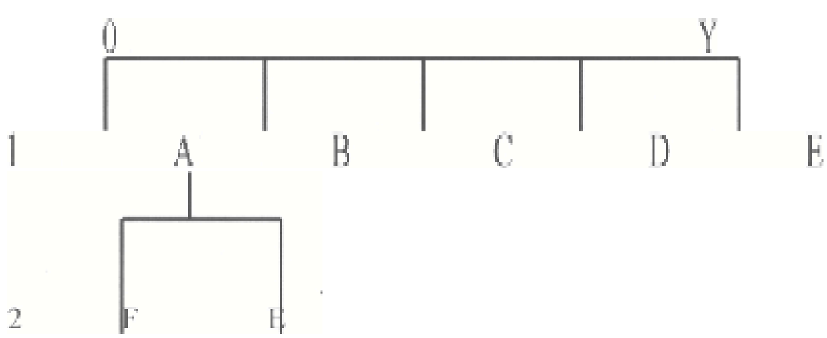
Note that E appears in three separate places. Its total requirements can be determined by summing the separate amounts, which yields 28.

(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 at only one level.

Figure 12.4: Low-level coding for component E.

Level



3 E E E

3.1.3 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 are recorded in this file.

3.2 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 inventory from 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 next time period.

Planned-order releases: - Indicates a planned amount to 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 two orders 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 scheduled receipt 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 delivery requirements 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 as follows:

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 100 shutters. Therefore planned receipts for week 4 equals 100 shutters. Some shutters are assembled during week 7 in order to be available 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 1. Similarly, the planned-order release of 150 shutters at week 7 generates gross net requirement 300 frames for week 7 as well as planned receipts for that time. The two-week lead time means frames must be ordered at the 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 70 wood 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 gross requirements 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 advantage of the net-change system is that management can have up-to-date information for planning and control purposes.

3.3 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.

3.3.1 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 future orders.
(2) Order releases, authorizing the execution of planned orders.
(3) Changes to planned orders, including revisions of due dates or order quantities and cancellations of orders.

3.3.2 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 used to assess cost performance.

(2) Planning reports are useful in forecasting future inventory requirements. They include purchase commitments and other data that can be used to assess 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.

3.3.3 Safety Stock

Theoretically, inventory systems with dependent demand should not require safety 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 downstream operations. 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 safety time 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 those items. Frequently, managers elect to carry safety stock for end items, which are subject to random demand and for selected lower-level operations when safety time is not feasible.

3.3.4 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 called lot 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. This would 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 be very complex at times. Let's consider some of the methods used to handle lot sizing.

3.3.4.1 Lot-for-lot ordering

The order or run size for each period is set equal to demand for that period. This method was demonstrated in the example in section 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.

3.3.4.2 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.

3.3.4.3 Fixed - 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 them both with the 80 units and order 85 units.

Figure 12.5: Demand of part

Period

	1	**2**	**3**	**4**	**5**
Demand	70	50	1	80	4
Cumulative	70	120	121	01	205

Demand

3.3.4.4 Part-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:

$$EPP = \frac{\text{Setup Cost}}{\text{Unit holding cost per period.}}$$

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 order sizes 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 demand schedule: set cost is N80 per run for this item, and unit-holding cost is N95 per period.

Solution

Period	1	2			3	4	5
Demand	60	40	20	2	30	70	50
Cumulative demand	60	100	120	122	152	2 222	272

(1) First compute the EPP: EPP = N80/=N95 = 84.21 which rounds to 84 part period.

(2) Next, try the cumulative lot sizes beginning with 60, until the port periods approximate the EPP. Continue this process for the planning horizon. This leads to the following:

	Lot Extra Period Size		Period inventory X	Part cumulative carried =	period	part periods	carried
	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	50	0
0	0		0 0	0		0	
0							

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).

3.4 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 resources requirements 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 and availability of components.

The capacity planning begins with a proposed or tentative master production schedule 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 requirements per unit. For instance, if 100 units of product A are scheduled in the fabrication department, and each unit 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. For example, 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.

$$\frac{\text{Required}}{\text{Available}} \times 100 = \frac{\text{150hours}}{\text{200 hours}} \times 100 = 75 \text{ percent.}$$

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.

3.5 Benefits and Requirements of MRP

3.5.1 Benefits

MRP offers a number of benefits for the typical manufacturing or assembly type 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 given master 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 on MRP 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.

3.5.2 Requirements

In order to implement and operate an effective MRP system, it is necessary to have:

(1) A computer and the necessary software programs to handle computations 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 in scheduling and inventory management but it has not proved to be the cure-all that many hoped it would be. Consequently, manufacturers are beginning to take a much broader approach to resource planning one such approach is referred to as MRP 11.

3.6 MRP II

MRP II refers to manufacturing resources planning. It represents an effort to expand 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 begins with 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 works and with which everyone can live. Moreover, because each of these functional areas has been involved 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 amount and 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. Once these 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 these more specific requirements can be met. Again some adjustment in the master production schedule 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 to keep 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. the master production schedule).

Finally, it should be noted that most MRP 11 systems have the capability of performing simulation, enabling managers to answer a variety of "what if” questions so they can gain a better appreciation of available options and their consequences.

4.0 CONCLUSION

In this unit, you have learnt the meaning of MRP and the conditions under which it is appropriate; its inputs and outputs as well as the nature of MRP processing; the benefits, requirements and the difficulties encountered with its use.

5.0 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 and quantity 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 links business planning, production planning, and the master production schedule.

6.0 TUTOR MARKED ASSIGNMENT

Compare and contrast MRP with MRP II and state the advantage MRP offers as also compared to “Order Point” control.

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 JUST-IN-TIME SYSTEM

CONTENTS

1.0 INTRODUCTION

The term just-in-time (JIT) is used to refer to a production system in which both the movement of goods 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 of Japan by Taiichi 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 a philosophy 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. It must 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.

2.0 OBJECTIVES

After completing this unit, you should be able to:

(i) Explain what is meant by the term just-in time (JIT) production system.
(ii) List each of the goals of JIT and explain its importance.
(iii) List and briefly describe the building blocks of JIT.
(iv) List the benefits of the JIT systems.

3.0 MAIN CONTENT

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. It should 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.

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 four building blocks:

1. Product design
2. Process design
3. Personnel/organizational elements
4. Manufacturing planning and control.

Let us discuss these blocks in turn.

3.2.1 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 the bill 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 system can 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.

3.2.2 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 these are 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 valuable part of the process.

One characteristic of many JIT systems is multiple manufacturing cells. The cells 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 manufacturing cells are reduced changeover times, high utilization of equipment, and ease of cross-training operators. The combination of high cell efficiency and small lot sizes results in very little work-in-process inventory.

JIT systems sometimes minimize defects through the use of autonomation (note the 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 is taken 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 breakdowns and 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 or subtract capacity.
5. Use off-line buffers. Store infrequently used safety stock away from the production area to decrease congestion and to avoid continually turning it 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 space needed, 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 opportunities may be lost if the system is unable to respond quickly enough.

3.2.3 Personnel Organizational Elements

There are five elements of personnel and organizational that are particularly important 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 for quality 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 members of 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 of overhead by different jobs.

One alternative method of allocating overhead is activity-based costing. This method is designed to more closely reflect the actual amount of overhead consumed by particular job or activity. Activity-based costing first identifies traceable 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 JIT systems relates to leadership. Managers are expected to be leaders and facilitators, not order givers. Two-way communication between workers and managers is encouraged.

Project managers are often given full authority over all phases of a project. They remain with the project from beginning to end; in the more traditional forms of project management, the project manger often has to rely on the cooperation of other managers to accomplish project goals.

3.2.4 Manufacturing Planning and Control

Five elements of manufacturing planning and control are particularly important for 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 production time for a container of parts
X = Policy variable set by management that reflects possible inefficiency in the system (the closer to 0. the more efficient the system
C = Capacity of a standard container (should be no more than 10 percent of daily 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 day
T = 12day
C = 25 parts per container
X = 20
N = 300(12)(1 +20)(25) = 1,890,000 containers

Close Vendor Relationships: JIT systems typically have close relationship with 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 be able to certify a vendor 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. Buyers take 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 a tiered approach for suppliers. They use relatively few first-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 from dealing with large numbers of suppliers.

A good example of this situation is found in the automotive industry. Suppose a certain 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 the personnel involve in these and supporting activities.

Quality transactions:- Include determining and communicating specifications, monitoring, recording, and follow-up activities. Costs relates 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 all transactions.

JIT systems cut transaction costs by reducing the number and frequency of transactions. 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.

3.3 Benefits of JIT Systems

JIT systems have a number of important benefits that are attracting the attention of traditional companies. The main benefits are:

1. Reduced level of in-process inventories, purchased goods, and finished goods.
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 material handlers.

4.0 CONCLUSION

This unit has described the JIT/lean production approach, including the basic elements of these systems, and what it takes to make them work effectively. It has also pointed out the benefits of these systems.

5.0 SUMMARY

Just-in-time (JIT) is a system of lean production used mainly in repetitive manufacturing, 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 ultimate goal of a JIT system is to achieve a balanced, smooth flow of production. 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.

6.0 TUTOR MARKED ASSIGNMENT

"One reason for Japan's high manufacturing productivity is the cost reductions it achieved through its Just-in-Time".

1. Define the conceptual framework of JIT as a philosophy to bring out its fundamental characteristics.
2. Discuss fully the foundations building block of Just-In-Time.

7.0 REFERENCES/FURTHER READINGS

Krajewski, L. J. and L.P Ritzman (1999): Operations Management: Strategy and Analysis, Reading, Massachutes. Addison Wesley

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UNIT 4 PROJECT MANAGEMENT

CONTENTS

1.0 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.

2.0 OBJECTIVES

After completing this unit, you should be able to:

(i) Discuss the behavioral aspects of projects in terms of project personnel and the project manager.
(ii) Discuss the importance of a work breakdown structure in project management
(iii) Give a general description of PERT / CPM techniques
(iv) Construct simple network diagrams.
(v) List the kinds of information that a PERT or CPM analysis can provide.
(vi) Analyse networks with deterministic times.
(vii) Analyze networks with probabilistic times
(viii) Describe activity "crashing" and solve typical problems.

3.0 MAIN CONTENT

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.

3.1.1 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 organisation tend to be involved with project on a regular basis; examples include consulting firms, architects, writers and publishers.

3.1.2 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 effectively managing each of the following:

(i) The work, so that all of the necessary activities are accomplished in the desired sequence.
(ii) The human resource, so that those working on the project have direction and motivation.
(iii) Communications, so that everybody has the information they need to do their 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 successful project, and the personal satisfaction of seeing it through to its conclusion.

3.1.3 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 being replaced 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 new people 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.

3.2 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.

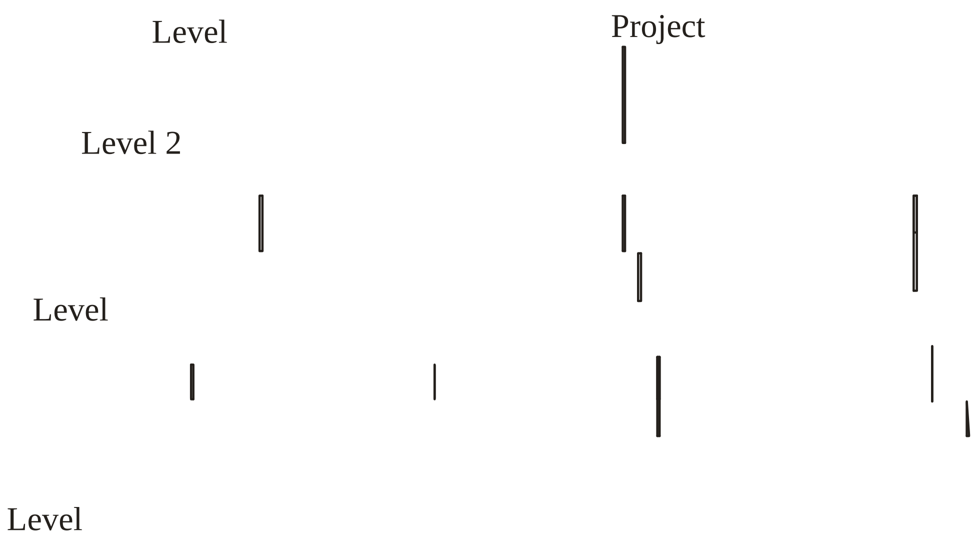
(i) Concept at which point the organisation recognizes the need for a project or responds to a request for a proposal from a potential client.
(ii) Feasibility analysis, which examines the expected costs, benefits and risk of undertaking the project.
(iii) Planning, this spells out the details of the work and provides estimates of 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 be fully completed before the next phase begins. This can reduce the time necessary to move through the life cycle, perhaps generating some competitive advantage and cost saving.

3.3 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. The framework 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



3.4 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 monitor progress over time by comparing planned progress to actual progress. A Gantt chart for a bank's plan to establish a new direct marketing department is given in 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

Activity Weeks after start

Activity	Start	2	4	6	8	10	12	14	16	18	20
Locate new facilities											
Interview prospective staff											
Hire and train staff											
Select and order furniture											
Remodel and install phones											
Furniture received and setup											
More in start up											

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.

3.5 PERT and CPM

PERM (Program Evaluation and Review Technique) and CPM (Critical Path Method) are two of the most widely used techniques for planning and coordinating large -scale projects. By using PERT and CPM, managers are to obtain:

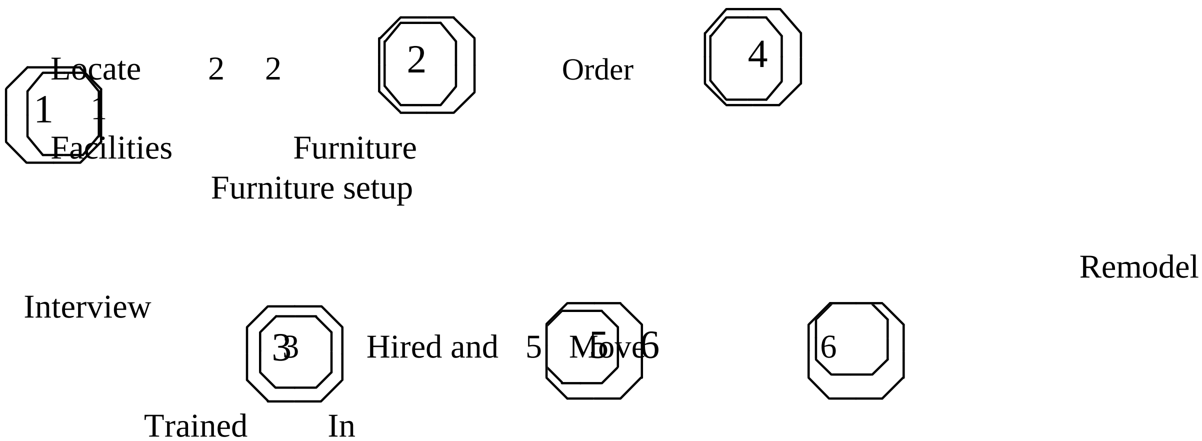
(i) A graphical display of project activities
(ii) An estimate of how long the project will take
(iii) An indication of which activities are the most critical to timely project completion.
(iv) An indication of how long any activities can be delayed without lengthening the project.

3.6 The Network Diagram

One of the main features of PERT and related techniques is their use of a network 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. The diagram 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 network diagram is generally the preferred approach for visual portrayal 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 neither resources 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.

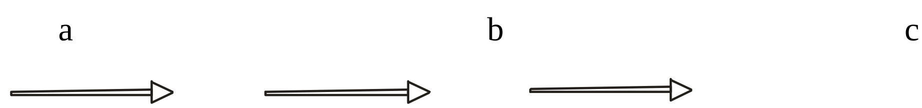
The network diagram describes sequential relationship among major activities on a project. For example activity 2-4 cannot be started, according to the network until activity 1-2 has been completed (Figure 14.3 behind). A path is a sequence of activities that leads from the starting node to the finishing 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.

3.6.1 Network Conventions

Developing and interpreting network diagrams requires some familiarity with networking conventions. Although many could be mentioned, the discussion will only itemize some of the most basic and most common features of network diagrams. This will provide us sufficient background for understanding the basic concepts associated with precedence diagrams and allow us to solve typical problems.

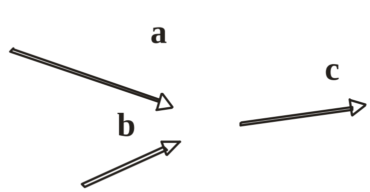
One of the main features of a precedence diagram is that it reveals which activities must be performed in sequence and which can be performed independently of each other. For example, in the following diagram, activity "a" must be completed before activity "b" can begin and activity "b" must be completed before activity "c" can begin (Figure 14.4 below).

Figure 14.4



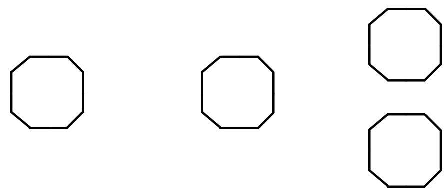
If the diagram had looked like the one below (Figure 14.5), both activities "a" and "b" would have to be completed before activity "c" could begin, but "a" and "b" could be performed simultaneously, performance of "a" is independent of performance of "b".

Figure 14.5



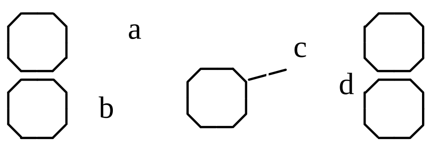
If activity a must precede "b" and "c", the appropriate network would look like this:

Figure 14.6



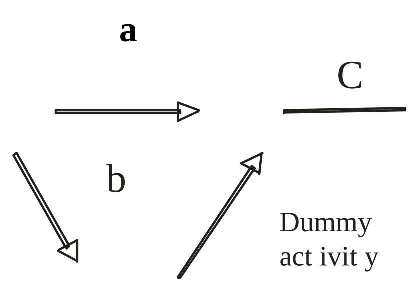
When multiple activities enter a node, this implies that all those activities must be completed before any activity that is to begin at that node can start. Hence, in this next diagram, activities "a" and "b" must both be finished before either activity "c" or activity "d" can start.

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



3.7 Deterministic Time Estimates

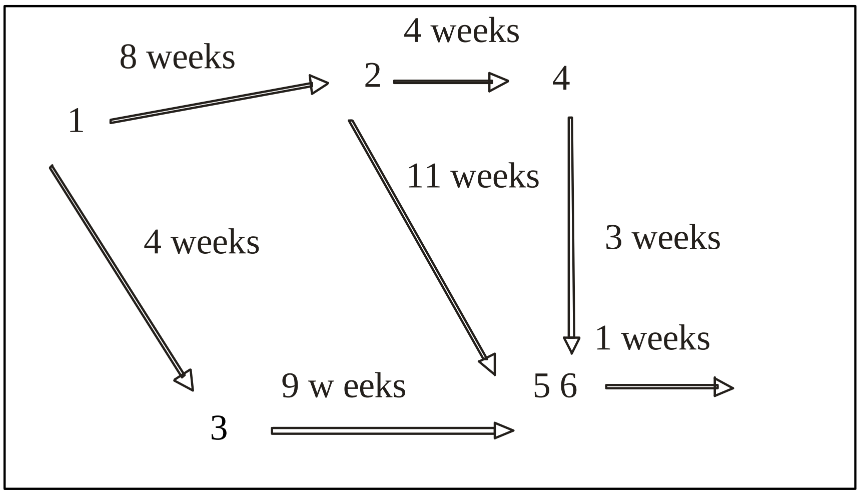
The main determinant of the way PERT and CPM networks are analyzed and interpreted is whether activity time estimates are probabilistic or deterministic. If time estimates can be made with a high degree of confidence the actual times will not differ significantly, we say the estimates are deterministic. 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 critical path (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

3.7.1 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 as early 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 earliest finishing 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.

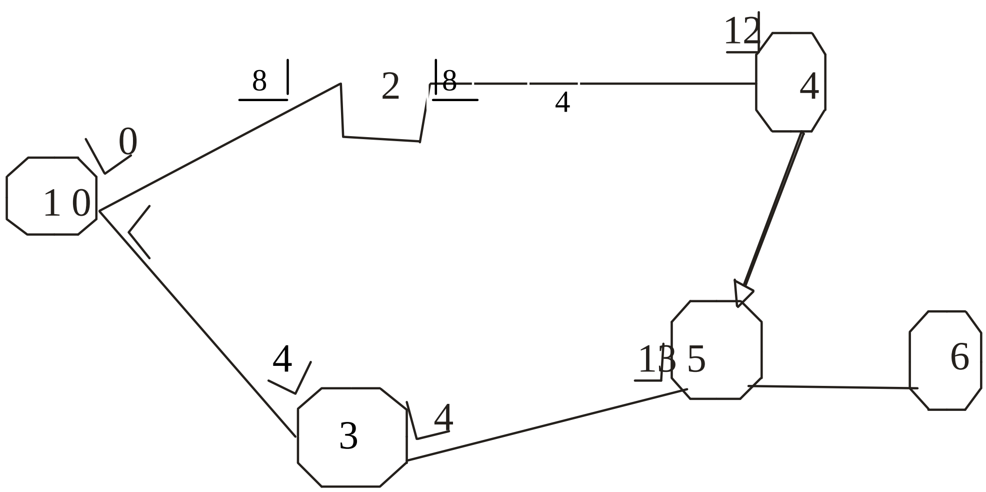
The earliest finishing time is the time taken for an activity added to ES and so,

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:

ES EF

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 origin of the project, but note that ES for activity 2-4 would be the EF of activity 1-2 (8 weeks 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.

3.7.1.1 Computing ES and EF times

Computation of earliest starting and finishing times is aided by two simple rules:

(i) The earliest finish time for any activity is equal to its earliest start time 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.

3.7.1.2 Computing LS and LF Times

Computation of the latest starting and finishing times is aided by the use of two rules:

(i) The latest starting time for each activity is equal to the latest finishing time 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.

3.7.1.3 Computing Slack Times

The slack time can be computed in either of two ways:

Slack = LS - ES
or
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, those situations require a probabilistic approach.

The probabilistic approach involves three time estimates for each activity instead of one:

1. Optimistic time: - The length of time required under optimum conditions; represented by the letter o.
2. Pessimistic time: T he length of time required under the worst conditions: 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 probability surrounding 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.

$$d2 = \left\{\frac{P-0}{6}\right\}^2$$

The size of the variance reflects the level of uncertainty associated with an activity 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 the activities on a path and then taking the square root of that number: that is,

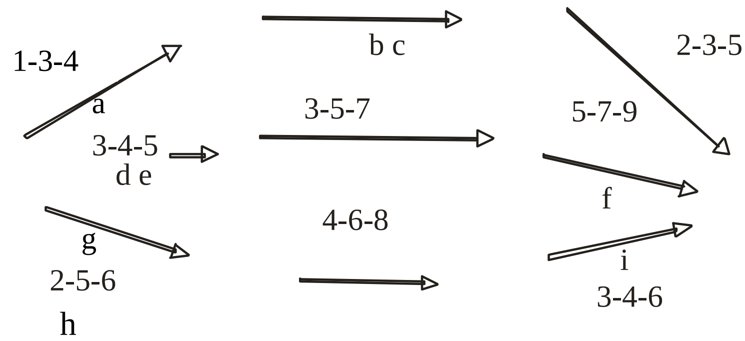
$$\text{Path} = \sqrt{(\text{variances of activities on path}}$$

For simplicity the following example illustrates clearer.

The network diagram for a project is shown in the accompanying figure. With three time estimates for each activity. Activity times are in months.

Do the following:

(a) Compute the expected time for each activity and the expected duration 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

Path	Activity	Times O M P	Te = 0+4m+p / 6	Path total
a-b-c	A	1 3 4	2.83	
	B	2 4 6	4.00	10.00
	C	2 3 5	3.17	
d- e-f	D	3 4 5	4.00	
	E	3 5 7	5.00	16.00
	F	5 7 9	7.00	
g-h-1	9	2 3 6	3.33	
	H	4 6 8	6.00	13.50
	1	3 4 6	4.17	

(a) The path that has the longest expected duration is the critical path. Since path d-e-f has the largest path, it is the critical path.

(b) Path 2path Activity Times 2 act = (P-O) 2 2path

O M P

a-b-c a 1 3 4 (4-1)2/36 =-3-4
b 2 4 6 (6-2) 2/36 36 =0.944 0.97
c 2 3 5 (5-2) 2/36

d-e-f D 3 4 5 (5-3) 2/36 =36

e 3 5 7 (7-3) 2/36 36= 1.00 1.00
f 5 7 9 (9-5) 2/36
g-h-I g 2 3 6 (6-2) 2/36 =41
h 4 6 8 (8-4) 2/36 36 = 1.139 1.07
I 3 4 6 (6-3) 2/36

If we use the information from this preceding example, we may consider the following question.

(a) What is the probability that the project can be completed within 17 month of its start?

(b) What is the probability that the project will be completed within 15 months of its start?

(c) What is the probability that the project will not be completed within 15 months of its start?

Solution

(a) To answer this question, you must first compute the value of Z using the relationship

$$Z = \frac{\text{Specified time} - \text{Expected time}}{\text{Path standard deviation}}$$

In this instance, we have

$$Z = \frac{17-16}{1.00} = 1.00 \text{ for project d-e-f}$$

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 $= \dfrac{15 - \text{Expected path duration}}{\text{Path standard deviation}}$ = probability of completion in 15 months

a-b-c $\dfrac{15 - 10.00}{0.97} = +5.15$ 1.00

d-e-f $\dfrac{15 - 16.00}{1.00} = -1.00$ 0.1587

g-h-i $\dfrac{15 - 13.50}{1.07} = +1.40$ 0.9192

1.00

Months

1.00

0.1587

Months

16.0

0.9192

Months

13.5

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 is for each path. This requires computing Z values; any Z value that is greater than + 2.50 is treated as having 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 to crashing costs: crash those with lowest cost first.

Moreover, crashing should continue as long as the cost to crash is less than the benefits received from crashing.

4.0 CONCLUSION

We have been able to see the need for a manager to be versatile and have creative and imaginative thought to the smooth running of business. The need to be evaluative and analytical has been greatly emphasized. Working round clock has been able to bring his dread a reality.

5.0 SUMMARY

Projects are made up of special activities established to realize a given set of objectives in a short while. The non-routine nature of project activities places a set of demands on the project manager that are different in many respects from those the manager of more routine operations activities require.

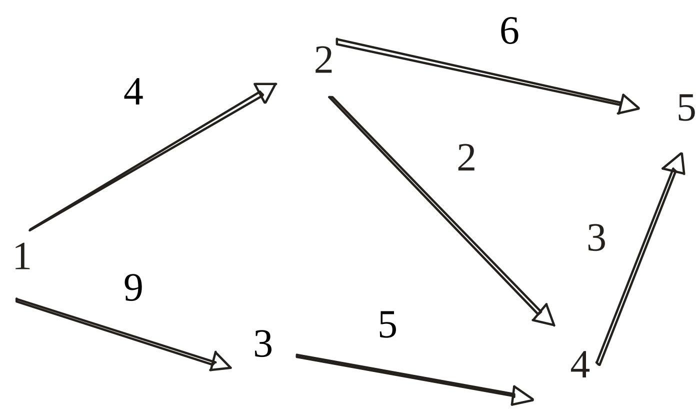
PERT and CPM are two commonly used techniques for developing and monitoring projects. Although each technique was developed independently and for expressly different purposes, time and practice have erased most of the original differences, so that now there is little distinction between the two. Either 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-arrow model.

In some situations, it may be possible to shorten, or crash, the length of a project 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 of additional reduction, or to a specified time.

6.0 TUTOR MARKED ASSIGNMENTS ON PROJECT MANAGEMENT

1. Given the following information



(a) Determine the number of paths by writing them out

(b) Determine the critical path

(c) Expected length of the project (all unit in months)

(d) Amount of slack time for each path. Tabulate your answers.

2. Identify the term being described for each of the following:

(a) A sequence of activities in a project.

(b) The longest time sequence of activities in a project

(c) The difference in time length of any path and the critical path.

(d) Used to denote the beginning or end of an activity.

(e) Shortening an activity by allocating additional resources.

7.0 REFERENCES/FURTHER READINGS

Peterson, R.S. (1984): "The critical issues for manufacturing management" Operations Management Review 2, No. 4 pp.15-20.

Hall, R (1987): Attaining Manufacturing Excellence. Burr Ridge, III: Richard D. Irwin. Sutermesster, R.A (1969) People and Productivity, 2nd ed. New York: McGraw-Hill. Aft, L.S. 1983 (Productivity Measurement and Improvement, Reston, V.A: Reston Publishing.

UNIT 5 PRODUCTIVITY

CONTENTS

1.0 INTRODUCTION

This unit discusses issues concerned with productivity. Productivity itself relates to how effective an organisation is in the use of its resource. Here you will learn how to differentiate between efficiency and productivity. Other things to learn in this unit include the impact of human behaviour on productivity, and how productivity can be measured as well as improved.

2.0 OBJECTIVES

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

i. Define the term productivity
ii. Explain why it is important to organizations
iii. Determine partial, multi-factor and total productivities
iv. Explain how productivity can be improved.

3.0 MAIN CONTENT

3.1 Productivity and Human Behaviour

One of the primary responsibilities of an operations manager is to achieve productive use of an organisations resource. The term "productivity" is used to describe this. Productivity is actually an index that measures output (i.e. goods and services) relative to the input (e.g. labour, materials, energy, cost of equipment, and other appropriate resources) used to produce them. It is usually expressed as the ratio of output to input

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

The ratio can be computed for a single operation, a department, an organisation, or even the whole country productivity measures can be based on single input (i.e. partial productivity) on more than one in (i.e. multi-factor productivity), or on all inputs (i e total productivity) some of these measures are given in Table 1.

The choice of particular measure depends primarily on the purpose of the measurement. For example, if the purpose is to track improvements in labour productivity, then labour becomes the obvious input measurement.

Table 1: Examples of different types of measures of productivity.

TYPE FORMULAR

Partial Output Output Output Output

Measures Labour Machine Capital Energy

Multifactor Output Output

Measures Labour + Machine L abour + Capital + Energy

Total Goods or Services Produced

Measures All inputs used to produce them

Operations managers are more interested in partial measures of productivity Examples of such measure include the following;

(a) Labour Productivity

Units of output per labour hour

Units of output per shift

Value-added per labour hour

Naira value of output per labour hour

(b) Machine productivity

Units of output per machine hour

Naira value of output per machine hour

(c) Capital Productivity

Units of output per Naira input

Naira value of output per Naira input

(d) Energy Productivity

Units of output per kilowatt- hour

Naira value of output per kilowatt -hour

Productivity measures are of prime importance at different levels. For instance, in the case of an individual department or organization, such measures can be used to track performance over time this provides opportunities for operations managers to judge performance, and to decide where improvements are needed.

Productivity can also be used to determine the performance of an entire industry or even the national productivity of country as a whole. In a nutshell, productivity measurements serve as scorecards of the effective use of resources.

Operations manager plays a key role in determining productivity. Their challenge is to increase the value of output, relative to the cost of input. For example, if they can generate more output of better quality by using the same amount of input productivity will definitely increase. Again if they can maintain the same level of output while reducing the use resources productivity will also increase.

At the national level, productivity is usually measured as the naira value of output per unit of labour. This measure depends on the quality of the products and services generated in a nation, as well as the efficiency with which they are produced.

Productivity is actually the prime determinant of a nation's standard of living. If the output per work hour goes up, the nation benefits from higher income levels, since the productivity of human resources determines employee wages. On the other hand, lagging or declining productivity lowers the standard of living. For instance, wage or price increases not accompanied by productivity increases usually lead to inflationary pressures rather real increases in the standard of living.

Examples on the Calculation of Productivity

Calculate the productivity for the following operations:

(a) Three employees processed 600 insurance policies last week. They worked 8 hours per day, 5 days per week.

(b) A team of workers made 400 units of a product, which is valued by its standard cost of 10 each (before markups for other expenses and profit). The accounting department reported that for this job, the actual costs were N400 for labour, N1,000 for materials, and N300 for overhead.

Solutions

(a) Labour productivity = $\dfrac{\text{Policies processed}}{\text{Employee hours}}$

$$= \frac{600}{(3 \text{ employees})(40 \text{ hours/Employee})}$$

= 5 policies/hour

(b) Multi-factor productivity

$$= \frac{\text{Quantity of standard cost}}{\text{Labour Cost + material cost + overhead cost}}$$

$$= \frac{(400 \text{ units})(\text{N}10/\text{unit})}{\textbf{N400+ N1,000+ N300}} = \frac{\textbf{N4,000}}{\textbf{N1,700}}$$

= N2.35

3.2 Labour Productivity

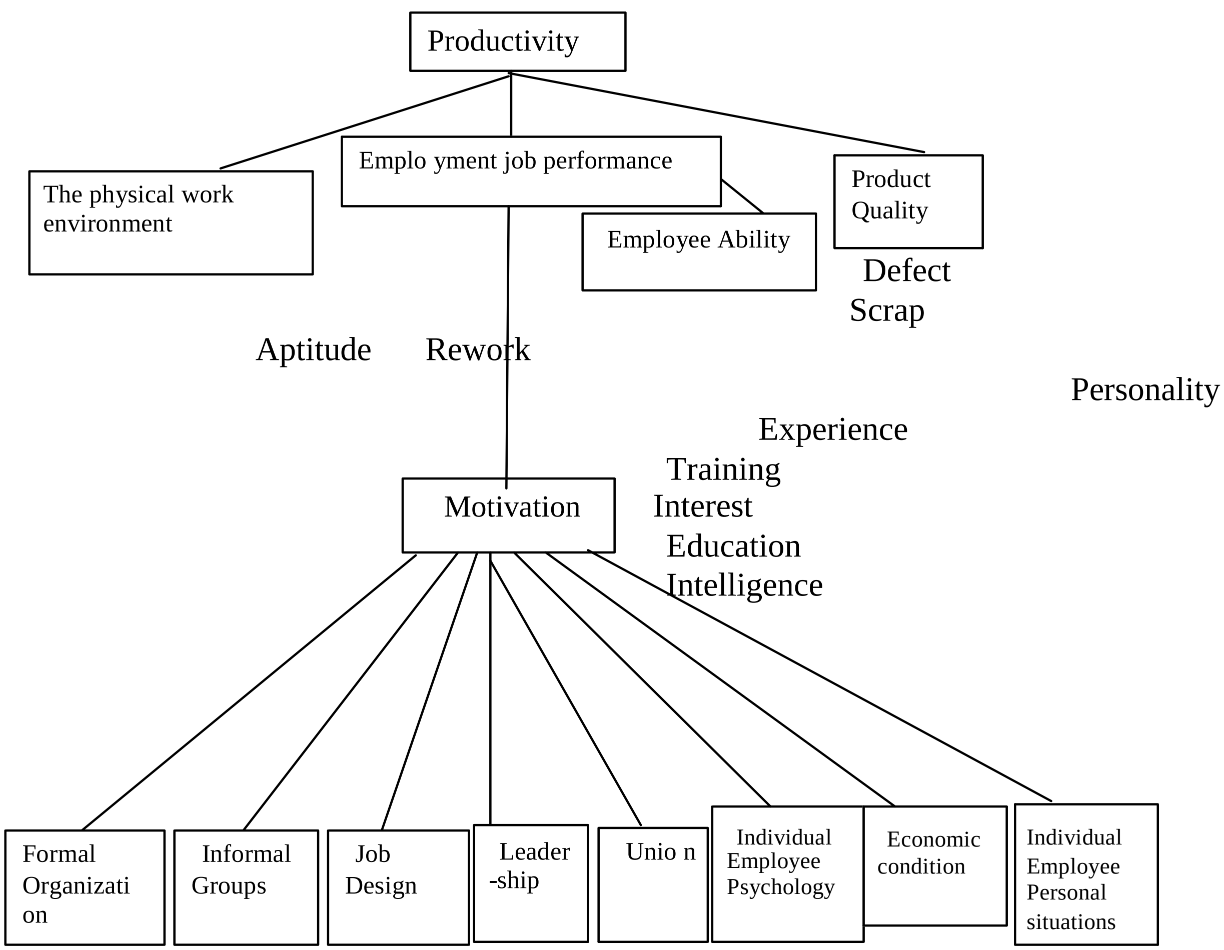
Many companies today are pushing hard to improve their labour productivity. For man of these companies, direct labour cost remains a significant cost. Some manufacturing operations are not yet automated, and never will be because either it is not cost effective or insufficient capital is available. In addition, many services remain direct-labour-intensive. For these reasons, the cost of labour and the need to improve the productivity of labour continues to receive management attention. We are therefore going to focus on labour productivity in this section.

The major factors that affect labour productivity are contained in Figure 15.1. The figure clearly shows that the causes of labour productivity are many. Unfortunately, there are currently no sets of formulars that precisely predict human behaviour, in general and productivity in particular. It is however gratifying to note that we can have enough understanding of employee behaviour, so as to remove some of the uncertainty about why employees are productive.

Another look at Figure 15.1 should reveal to you that three major factors affect labour productivity. These are the physical work environment; employee job performance; and product quality. In this realisation, various staff groups are making efforts such as industrial, process product and systems engineering to develop better automation, machines, tools, and work methods to enhance labour productivity. The belief is their increasing productivity through technology development is at least as important as employee job performance in increasing productivity. The productivity of all factors of production can also be directly increased through reduction in defects, scrap, and re-work.

You need to realise that employee job performance is a complex topic because no two people are exactly the same. Hence, their abilities, personalities, interests, ambitions, energy levels, education, training, and experience are bound to vary considerably. Operations managers often consider these factors since blanket or common approaches to improving job performances may not be effective for all and sundry.

Figure 15.1 Variables Affecting Labour Productivity



Source: Gaither, M. (1996): Production and Operations Management, 7th Ed. Belmont, Duxary Press, p. 608.

It is in recognition of these differences that efforts are being made by personnel, departments to select employees who have the desired abilities to develop training programmes for the improvement of employee skills.

There is a growing importance of employee training and education all over the world. Many organisation are aggressively increasing their employee training programmes for competitive advantage, and this has been off in boosted production and morale.

Motivation has been discovered to be the most complex variable in the equation of productivity. As Berelson and Steiner (1964) have defined the term, a motive "is an inner state that energises, activates, or moves (hence 'motivation'), and that directs or channels behaviour toward goals". In other words, "motivation" is a general term applying to the entire class of drives, desires, needs, wishes, and similar forces.

One of the widely referred-to theories of motivation is the "hierarchy of needs" theory developed by Abraham Maslow. He saw human needs in the form of a hierarchy, starting in an ascending order from the lowest to the highest needs, and concludes that when one set of needs was satisfied, this kind of need ceased to be a motivator. In this sense, therefore, only unsatisfied needs are motivators, or cause people to act.

The basic human needs identified by Maslow in an ascending order of importance are the following:

1. **Physiological needs**
   These are the basic needs for sustaining human life itself - food, water, clothing, shelter, sleep, and sexual satisfaction. Maslow took the position that until these needs are satisfied to the degree necessary to maintain life, other needs will not motivate people.

2. **Security or Safety needs**
   These are the needs to be free from physical danger, and the fear or loss of a job property, food, clothing or shelter.

3. **Affiliation or Acceptance needs**
   Since people are social beings, they need to belong and to be accepted by others. In other words, this means sense of belonging and love.

4. **Esteem needs**
   According to Maslow, once people begin to satisfy their need to belong, they tend to want to be held in esteem both by themselves, and by others. This kind of need produces such satisfactions as power, prestige, status, and self-confidence.

5. **Self-Actualisation needs**
   Maslow regards this as the highest need in his hierarchy. It is the desire to become what one is capable of becoming, i.e. to maximise one's potential and to accomplish something.

In Nigeria today, many employees' lower-level needs (physiological and safety) have been mostly taken care of by the recent minimum wage law. For all workers in the country, Thehigher-level needs (social, esteem and self-actualisation) may therefore hold more promise for managers in their attempt to motivate employees.

To what extent can we use the understanding of employees' needs to design a work environment that encourages productivity?. Using Maslow's theory, if we can determine what class of needs is currently important to our employees, then we can apply the following framework given by Graither (1996).

If productivity is seen by employees as a means of satisfying their needs, high productivity is likely to result. Once employees have their needs satisfied through rewards that have been conditional upon productivity, the process is likely to be repeated.

Labour unions and work groups can influence employees to be either productive or unproductive. For instance, if employees think that their work groups may treat them as outcasts because they have been productive, they may not cooperate with management in this productivity-reward-productivity cycle. This is the reason why operations managers should recognise the influence that work groups have on labour productivity. They therefore need to develop cooperative work groups. The also need to influence group norms through effective cooperation and communication.

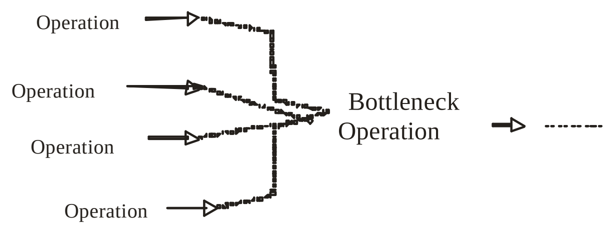
3.3 How Productivity can be Improved

An organisation or a department can take a number of key steps toward improving productivity. Here are some of them as suggested by Stevenson (1996):

l. Develop productivity measures for all operations. This is based on the premise that measurement is the first step in managing and controlling an operation.

2. Look at the system as a whole in deciding which operations are most critical. This is based on the fact that it is the overall productivity that is important. This concept is illustrated by Figure 15.2, which shows several operations feeding their output into a bottle neck operation. The capacity of the bottle neck operation is less than the combined capacities of the operations that provide input, so units queue up waiting to be processed. Productivity improvements to any non-bottleneck operation will not affect the productivity of the system. However, improvement in the bottleneck operation will lead to increases productivity, up to the point where the output rate of the bottleneck equals the output of the operations feeding it.

Figure 15.2: Bottleneck Operation



Source: Stevenson, W.J. (1996): Production/Operations Management, (5th ed), Burr Ridge, Ill.: Richard D. Irwin. p. 45.

3. Develop methods achieving productivity improvements, such as soliciting ideas from workers (e.g. organising teams of workers, engineers, and managers) studying how similar firms have increased productivity, and re-examining the way work is done.

4. Estimate reasonable goods for improvement

5. Make it clear that management supports and encourages productivity improvement. It is also important to consider incentive to reward workers for contributions.

6. Measure improvement and publicise them.

7. Don't confuse productivity with efficiency. This is because efficiency is a narrower concept that pertains to getting the best out of a given set of resources. Productivity, on the other hand, is a broader concept that pertains to effective use of overall resources. For example, an efficiency perspective on mowing a lawn given a hand mower would focus on the best way to use the hand mower; a productivity perspective would include the possibility of using a power mower.

4.0 CONCLUSION

In this unit, you have learned what productivity is and why it is important. You have also learned how organisations can improve productivity. You should now be able to compute partial, multi-factor and total measures of productivity.

5.0 SUMMARY

One basic fact you have learned in this unit is that it is necessary for organisations, especially the operations managers to achieve productive use of resources. This unit has taken you through a general discussion on productivity and human behaviour and labour productivity in particular. The unit that follows is also in line with attempts to increase the efficiency, as well as productivity of organisations.

SELF-ASSESSMENT EXERCISE (SAE)

(1) If labour productivity is low in a company, does it necessarily mean that the labour resource is under performing?

(2) A company that processes fruits and vegetables is able to produce 400 cartoons of canned peaches in one-half hour with two workers. What is labour productivity?

(3) A wrapping paper company produced 2,000 rolls of paper one day. Labour cost was N60, material cost was N50, and overhead was N320. Determine the multi-factor productivity.

6.0 TUTOR-MARKED ASSIGNMENT

(1) Student tuition a university in an oil-rich state is N100 per semester credit hour. The state supplements school revenue by matching student tuition, naira for naira. Average class size for a typical three-credit course is 50 students. Labour costs are N4, 000 per class, material cost are N20 per students per class, and overhead costs are N25, 000 per class.

(a) What is the multi-factor productivity ratio?
(b) If instructors work an average of 14 hours per week for 16 weeks for each three credit class of 50 students, what is the labour productivity ratio?

(2) Natty Dresses makes fashionable garments. During a particular week, employees works 360 hours to produce a batch of 132 garments, of which 52 were "seconds" (meaning that they were flawed). Seconds are sold for N90 each at Natty's Factor outlet store. The remaining 80 garments are sole to retail distributor, at N200 each. What is the labour productivity ratio?

7.0 REFERENCES/FURTHER READINGS

Peterson, R.S. (1984): "The critical issues for manufacturing management" Operations Management Review 2, No. 4 pp. 15-20.

Hall, R (1987): Attaining Manufacturing Excellence. Burr Ridge, III: Richard D. Irwin. Sutermesster, R.A (1969) People and Productivity, 2nd ed. New York: McGraw-Hill. Aft, L.S. 1983 (Productivity Measurement and Improvement, Reston, V.A: Reston Publishing.

MODULE 4

UNIT 1 WORK METHODS

CONTENTS

1.0 INTRODUCTION

In this unit, you will learn that methods analysis and motion study techniques are often used to develop the "efficiency" aspects of job. However they do not directly address their behavioural aspects. Nonetheless, they are important part of job design, as well as the efforts being made to increase productivity through different means.

2.0 OBJECTIVES

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

i. Explain the importance of work methods analysis
ii. Demonstrate the ability to develop a questioning attitude about every aspect of a particular job to be studied
iii. Explain the steps usually followed by job analysis
iv. Explain who a job analyst is
v. Demonstrate how to use motion study in the performance of human activities

vi. Demonstrate the ability to use flow diagrams and process charts.

3.0 MAIN CONTENT

3.1 Introduction to Work Methods Study

It is usual for job design to begin with a methods analysis of an overall operation. It then moves from general to specific details of the job by concentrating on arrangement of the workplace and movements of the worker.

The need for methods analysis can come from a number of different sources, such as:

(a) Changes in tools and equipment
(b) Changes in product design, or new products
(c) Changes in materials or procedures
(d) Government regulations or contractual agreements
(e) Other factors (e.g. accidents, quality problems)

In our treatment of Productivity and Human Behaviour under Unit 15, we referred to Figure 15.1, showing the various variables affecting labour productivity. From that figure, you were able to see that the machines, tools, materials, and work methods used by workers directly affect labour productivity. How do we go about improving work methods? It might be better to start with workers themselves. This is because they are the people who do the jobs daily, and on things related to these jobs. In a way, they are experts in their own rights.

You should note that the main objective of improving work methods is to increase productivity by increasing the production capacity of an operation or group of operations, reducing the cost of the operations, or improving product quality.

One important approach to successful methods analysis is the development of a questioning attitude about every aspect of the job being studied. Such relevant questions will include the following:

i. Why is there a delay or storage at this point?
ii. How can travel distances be shortened or avoided?
iii. Can materials handling be reduced?
iv. Would a re-arrangement of the workplace result in greater efficiency?
v. Can similar activities be grouped?
vi. Would the use of additional or improved equipment be helpful?
vii. Does the worker have any ideas for improvement?
viii. Who else could do it better?

Questions such as these will ensure that analysts accept nothing in an operation as sacred, i.e. everything about the job will be meticulously scrutinized.

3.2 Steps Involved in Conducting Work Methods

Works analysis can be done both for existing jobs and jobs that have not yet been performed. It might seem strange to you that we are talking about analysing methods of nonexisting jobs! Yet, it is important to establish a method for a new job, instead of allowing the job to start and then try to improve it later.

For an existing job, the procedure usually is to have the analyst observe the job as it is currently being performed, and then device improvements. For a new job however, the analyst must rely on a job description and an ability to visualise the operation in advance.

Gaither (1996) lists ten steps that are generally followed by methods analysts:

i. Make an initial investigation of the operation under consideration
ii. Decide what level of analysis is appropriate
iii. Talk with workers, supervisors, and others who are familiar with the operation. Get their suggestions for better ways to do the work.
iv. Study the present method. Use process Charts, time study, and other appropriate techniques of analysis. Thoroughly describe and evaluate the present method
v. Apply the questioning attitude, the principles of motion economy, and the suggestions of others. Device a new proposed method by using process charts and other appropriate techniques of analysis.
vi. Use time study, if necessary. Compare new and proposed methods. Obtain supervisors' approval to proceed.
vii. Modify the proposed method as required after reviewing the details with workers and supervisors.
viii. Train one or more workers to perform the proposed method on a trial basis. Evaluate the proposed method. Modify the method as required.
ix. Train workers and install the proposed method.
x. Check periodically to ensure that the expected savings are being realised.

In performing work methods analysis, certain diagrams and charts can be useful. These include flow-process charts and worker-machine charts.

3.2.1 Flow-Process Charts

Flow diagrams and process charts are about the most versatile techniques available for analysing work methods. They are usually used together to eliminate or reduce delays, eliminate or combine tasks, or reduce travel time or

distance. Table 16.1 shows and describes widely applied flowcharting symbols.
Of the five, only the operation symbol denotes a value-adding activity. The other symbols reflect an addition of cost not value.

Table 16.1: Flow Chart Symbols

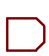
Symbol	Activity	Description
	Operation	Activity that adds value to a workplace or provides a value-adding service to a customer; usually Operation requires a setup
	Transportation	Movement of objects from one work station to another; movement of customer from one operation Transportation to another
	Inspiration	Work is checked for some characteristic of quality; may call for 100 - percent inspection or inspection Inspection by sampling
	Storage	Applies to materials or documents; may be Storage temporary, or permanent V
	Delay	Time, person, materials or documents wait for next operation; In lot delay, wait is for other items in the lot to be processed; In process delay, entire lot waits for workstation or other bottleneck to clear

Figure 16.1 shows how an improvement team might document a company's travel authorisation process. The before version, i.e. part A, has eight value-adding operations, five transportations, two inspections, and three delays. The streamlines version in part B uses personal computer communication by e-mail.
It thus cuts the operations to five, transportation to two, inspections to one (combined with an operation), and delays to one. You should, however, note that the reduction from eight to five does not mean less value, since value-

adding operations also consume costly resources and time. The end result is a simpler process that does the job.

For worked examples on this discussion please refer to Dennis C. Kinlaw (1992) Continuous Improvement and Measurement for Total Quality (Burr Ridge, III, Business One Irwin, 1992), pp. 214-215.

3.2.2 Worker-machine Chart

A worker-machine chart is helpful in visualising the portions of a work cycle during which an operator and equipment are busy or idle. The analyst can easily see when the operator and machine are working independently, and when their work overlaps or is interdependent. One area in which this type of chart is useful is in determining how many machines or how much equipment the operator can manage. An example of a worker machine chart is given in Figure 16.2

Figure 16.2: Worker-Machine Chart

Product; Operator;
Process; Charted b y;

Stop	Employee	time	machine (Seconds)
1	Accept plastic bag from customers and places on scale	0 1	
2	punches in price/b	2 3	
3	calculate and displays total price	4 5	
4	Remo ves bag	6	
5	Note prices and makes on bag	7	
6	Hands bag to customer	8	

Summar y

	Employee Time (Seconds)	%	Machine Time (Second)	%
Work	7	87.5	1	12.5
Idle	1	12.5	7	87.5

Source: Adapted from Schroeder, R.G. (1993): Operations Management Decision Making in the operations function 4th e New York: McGraw-Hill

3.3 Motion Study

Motion study is the systematic study of human motions used during the performance of an operation. The purpose is to eliminate unnecessary motions and to identify the best sequence of motions for maximum efficiency. In this regard therefore, motion study can be an important avenue for productivity improvements. The present practice of motion study can be traced to the work of Frank Gilbreth, who originated the concept in the bricklaying trade in the early 20th century.

There are a number of different techniques that motion study analysts can use to develop efficient procedures. We will only review motion study principles and micromotion study here.

3.3.1 Motion study principles

Gilbreth's work laid the foundation for the development of motion study principles, which are guidelines for designing motion-efficient work procedures. The guidelines are divided into three categories: principles for use of the body, principles for arrangement of the workplace and principles for the design of tools and equipment. These principles are listed in Table 16.2.

Table 16.2: Motion Study Principles

1. Finger motions.
2. Finger and wrist motions.
3. Finger, wrist, and lower arm motions.
4. Finger, wrist, lower arm, and upper arm motions.
5. Finger, wrist, lower arm, upper arm, and body motions.
6. Work done by the feet should be done simultaneously with work done by the hands. However, it is difficult to move the hand and foot simultaneously.
7. The middle finger and the thumb are the strongest. The use of the human body:

(a.) Both hands should begin and end their basic divisions of accomplishment simultaneously and should not be idle at the same instant, except during rest periods.
(b.) The motions made by the hands should be made symmetrically and simultaneously away from and toward the center of the body.
(c.) Momentum should assist workers wherever possible and should be minimized if it must be overcome by muscular effort.
(d.) Continuous curved motions are preferable to straight-line motions involving sudden and sharp changes in direction.
(e.) The least number of basic divisions should be used, and they should be confined to the lowest practicable classifications. These classifications,

summarized in ascending order of the time and fatigue expended in their performance are: working fingers. The index finger, fourth finger, and little finger are not capable of handling heavy loads over extended periods.

8. The feet are not capable of efficiently operating pedals when the operator is in a standing position.
9. Twisting motions should be performed with the elbows bent.
10. To grip tools, workers should use the segments of the fingers closest to the palm of the hand.

The arrangements and conditions of the workplace.

1. Fixed locations for all tools and material should be provided to permit the best sequence and to eliminate or reduce the therbligs search and select.
2. Gravity bins and drop delivery should reduce reach and move times, wherever possible, ejectors should remove finished parts automatically.
3. All materials and tools should be located within the normal working area in both the vertical and the horizontal planes.
4. A comfortable chair for the operator and the workstation's height should be arranged so that the work can be efficiently performed by the operator alternately standing or sitting.
5. Proper illumination, ventilation, and temperature should be provided.
6. The visual requirements of the workplace should be considered so that eye fixation demands are minimized.
7. Rhythm is essential to the smooth and automatic performance of an operation, and the work should be arranged to permit an easy and natural rhythm wherever possible.

The design of tools and equipment

1. Multiple cuts should be taken whenever possible by combining two or more tools in one or by arranging simultaneous cuts from both feeding devices, if available (cross slide and hex turret).
2. All levers, handles, wheels, and other control devices should be readily accessible to the operator and designed to give the best possible mechanical advantage and to utilize the strongest available muscle group.
3. Parts should be held in position by fixtures.
4. The use of powered or semi automatic tools, such as power nut and screwdrivers and speed wrenches, should always be investigated.

Source: Adapted from Benjamin W. Niebel, Motion and Time Study (Burr Ridge, III: Richard D. Irwin, Inc., 1993) pp. 206-207.

In developing work methods that are motion-efficient, the analyst tries to:

1. Eliminate unnecessary motions
2. Combine activities
3. Reduce fatigue
4. Improve the arrangement of the workplace
5. Improve the design of tools and equipment

3.3.2 Micromotion Study

Frank Gilbreth and his wife, Lilian (an industrial psychologist) were also responsible for introducing motion pictures for studying motions, called micromotion study.

Apart from its direct application in the industry, micromotion study is now useful in other human endeavours such as sports and health care. The use of video camera and slow-motion replays enable analysts to study motions that would otherwise be too rapid to see. Today, it is a most important tool in sports administration, coaching, and arbitration in disputed competitions. It is also increasingly being used to analyse crimes. One other important advantage of micromotion study is that the resulting films provide a permanent record that can be referred to, not only for training workers and analysts, but also for settling job disputes involving work methods.

4.0 CONCLUSION

The best way to improve work methods is to start with workers. This is because they are the people who do the jobs daily, and on things related to these jobs. The main objective of work methods is to increase productivity by increasing the production capacity of an operation or group of operations, reducing the cost of the operation or improving product quality.

5.0 SUMMARY

Methods analysis and motion study techniques are often used to develop the "efficiency" aspects of jobs. However, they do not address their behaviour aspects. In spite of this, they are some important parts of job design. Working conditions are also important aspects of job design, not only because of the behavioural and efficiency factors, but also because of concern for the health and safety of workers.

6.0 TUTOR MARKED ASSIGNMENT

1. a. Wherever work is been done, methods study is a desirable process. How do you understand:

   i. Work methods
   ii. Motion Study

iii. Mocromotion

2. What would you do in an attempt to develop work methods that are motion efficient?

3. Explain the uses of worker-machine chart.

7.0 REFERENCES/FURTHER READINGS

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UNIT 2 WORK MEASUREMENT

CONTENTS

1.0 INTRODUCTION

In Unit 5, you learned that job design determines the content of a job. This unit is devoted to work measurement, which is the process of creating labour standards based on the judgment of skilled observers. Actually, job times are vital inputs for manpower planning, estimating labour costs, scheduling, budgeting and designing incentive systems.

2.0 OBJECTIVES

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

(i) Define a standard time
(ii) Discuss and compare time study methods
(iii) Describe work sampling and perform calculations
(iv) Compare stopwatch time study and work sampling.

3.0 MAIN CONTENT

3.1 Relevance of Work Measurement

Work measurement refers to the process of estimating the amount of worker time required to generate one unit of output. Its ultimate goal is usually to develop labour standards that will be used for planning and controlling operations, thereby achieving labour productivity.

Job times are important inputs for manpower planning, estimating labour costs, scheduling, budgeting, and designing incentive systems. In addition, from the workers' standpoint time standards provide an indication of expected output. Time standard reflects the amount of time it should take an average worker to do a given job, working under typical conditions. The standards include expected activity time plus allowances for probable delays. Whenever a time standard is developed for a job, it is essential to provide a complete description of the parameters of the job because the actual time to do the job is sensitive to given methods, tools and equipment, raw materials inputs and workplace arrangement. For instance, changes in product design or changes in job performance brought about by a methods study should necessitate a new time study to update the standard time.

3.2 Standard Time as Management Tool.

Managers use Standard Time in the following ways:

(i) Establishing Prices and Costs: Managers can use labour and machine time standards to develop costs for current and new products, create budgets, determine prices and arrive at make or - buy decisions.
(ii) Motivating Workers: Standards can be used to define a day's work or to motivate workers to improve their performance. For example, under an inventive compensation plan, workers can earn a bonus for output that exceeds the standard.
(iii) Comparing alternative process designs: Time standards can also be used to compare different routings for an item and to motivate new work methods and new equipment.
(iv) Scheduling: Managers need time standards to assign task to workers and machines in ways that effectively utilize resources.
(v) Capacity Planning: Managers can use time standards to determine current and projected capacity requirements for given demand requirements. Work-force staffing decisions also, may require time estimates.
(vi) Performance Appraisal: A worker's output can be compared to the standard output over a period of time in order to evaluate worker performance and productivity. A manager's performance can similarly be measured by comparing actual costs to standard costs of a process.

3.3. Methods of Work Measurement

Organisations develop time standard in a number of different ways. The most common methods of work measurements are:

(i) The time study method
(ii) The elemental standard data approach
(iii) The predetermined data approach and
(iv) The work sampling method.

The particular method chosen usually depends on the purpose of the data. For example, if a high degree of precision is needed in comparing actual work method results to standard, a stopwatch study or pre-determined times might be required. On the other hand, an analyst who wants to estimate the percentage of time that an employee is idle while waiting for materials requires a work sampling method. We shall be examining the time study method, elemental standard data approach, and the work sampling method in the sections that follow.

3.3.1 Time Study Method

In this method, analysts use stopwatches to time the operation being performed by workers. These observed times are then converted into labour standards that are expressed in minutes per unit of output for the operation.

A time study usually consists of four steps:

Step 1: Selecting Work Elements

Each work element should have definite starting and stopping points so as to facilitate taking stopwatch readings. It has been suggested that work elements that take less than three seconds to complete should be avoided since they are often difficult to time.

The work element selected should correspond to a standard work method that has been running smoothly for a period of time in a standard work environment. Efforts should also be made to identify and separate incidental operations that are not normally involved in the task from the repetitive work.

Step 2: Timing the Elements

Here, the analyst times a worker trained in the work, in order to get an initial set of observations. The analyst may use either the continuous method, recording the stopwatch reading for each work element upon its completion, or the snap-back method, re-setting the stopwatch to zero upon completion of each worker element.

In the case of the latter, the analyst uses two watches, one for recording the previous work element, and the other for timing the present work elements.

In case that data include a single, isolated time that differs greatly from other times recorded for the same element, it is advisable for the analyst to investigate the cause of the variation. Any irregular occurrence such as a dropped tool or a machine failure, should not be included in calculating the average time for the work element. The average observed time based only on representative times is called the select time (t).

Step 3: Determining Sample Size

It is usual for analysts using the time study method to look for an average time estimate that is very close to the true long range average most of the time. The following formular, based on the normal distribution is used to determine the required sample size, n:

$$n = 2 \qquad (\text{—})\left(\frac{d}{t}\right) \quad \text{—}$$

Where

n = required sample size

P = precision of the estimate as a proportion of the true value

t = select time for a work element

d = standard deviation of representative observed times for a work element.

Z = number of normal standard deviations needed for the desired confidence.

Where = Accuracy or maximum acceptable error

Typical values of Z for these formulars are:

Desired Confidence (%)	Z
90	1.65
95	1.96
96	2.05
97	2.17
98	2.33
99	2.58

For example, a Z value of 1.96 represents ±1.96 standard deviations from the mean, leaving a total of 5 percent in the tails of the standardized normal curve.

The precision of the estimate, P is expressed as a proportion of the true (but unknown) average time for the work element.

Let us make use of an example given by Krajewski and Ritzman (1999) as an illustration of this step.

The example

A coffee cup packaging operation has four work elements. A preliminary study provided the following results:

Work Element	Standard deviation, *d (minutes)*	Select Time, t (minutes)	Sample size
1. Get two cartons	0.0305	0.50	5
2. Put liner in carton	0.0171	0.11	10
3. Place cups in carton	0.0226	0.71	10
4. Seal carton and set	0.0241	1.10	10

Aside

Work element 1 was observed only 5 times because it occurs once every two work cycles. The study covered the packaging of 10 cartons. Determine the appropriate sample size if the estimate for the select time for any work element is to be within 4 percent of the true mean 95 percent of the time.

Solution

For this problem
P= 0.04 and Z = 1.96

The sample size for each work element must be calculated, and the largest must be used for the final study so that all estimates will meet or exceed the desired precision.

Work Element 1: $n = \left[\left(\frac{1.96}{0.04}\right)\left(\frac{0.0305}{0.5000}\right)\right]^2 = 9$

Work Element 2: $n = \left[\left(\frac{1.96}{0.04}\right)\left(\frac{0.0171}{0.11}\right)\right]^2 = 58$

Work Element 3: $n = \left[\left(\frac{1.96}{0.04}\right)\left(\frac{0.0226}{0.71}\right)\right]^2 = 3$

Work Element 4: $n = \left[\left(\frac{1.96}{0.04}\right)\left(\frac{0.0241}{1.10}\right)\right]^2 = 2$

All fractional calculations were rounded to the next largest integer. To be sure that all select times are within 4 percent of the true mean 95 percent of the time, we must have a total of 58 observations because of work element 2. Consequently, we have to observe the packaging of 48 (i.e. 58-10) more cartons.

Step 4: Setting the Standard

This is the final step. Here, the analyst first determines the normal time for each work element by judging the pace of the observed worker. Next, he assesses not only whether the pace is above or below average, but also a performance rating factor (RF) that describes how much above or below average the worker's performance on each element is. Note that setting the performance rating requires the greatest amount of judgment. Usually, only a few workers are observed during a study. If the workers are fast, basing the standard on their average time wouldn't be fair, especially if a wage incentive plan is involved. At the same time, If the workers are slow, basing the standard on their normal time would be unfair to the company. In addition, workers may slow pace when they are being observed in a time study. Ironically, it is important to inform the observed worker about the study, so as to avoid suspicion or misunderstandings.

Workers sometimes feel uneasy about being studied and fear the changes that might result. It is therefore necessary for the analyst to discuss these things with the workers prior to studying the operation to allay such fears, and to enlist the cooperation of the worker. Due to these apparent distractions, the analyst has to make an adjustment in the average observed time to estimate the time required for a trained operator to do the task at a normal pace.

The analyst must also factor in the frequency of occurrence, F, of a particular work element in a work cycle. The normal time (NT) for any work element is calculated by multiplying the select time (t), the frequency (F) of the work element per cycle, and the rating factor, (RF) i.e.:

NT = t (F) (RF)

NOTE: Use F= 1, if the work element is performed every cycle

F= 0.05, if it is performed every other cycle. etc.

To find the normal time for the cycle (NTC) the normal time for each element is summed up. i.e. NTC = ,

Where = sum of

An Example of the determination of the Normal Time

Suppose that 48 additional observations of the coffee packaging operations earlier referred to, were taken and the following data were recorded.

Work Element	t	F	RF
1	0.53	0.50	1.05
2	0.10	1.00	0.95
3	0.75	1.00	1.10
4	1.08	1.00	0.90

Because element 1 occurs only every other cycle, its average time per cycle, must be half its average observed time. That is why Fl = 0.50 for that element. All others occur every cycle. What are the normal times for each work element, and for the complete cycle?

Solution

The normal times are calculated as follows:

Work element 1 NT1 = 0.53(0.50)(1.05) = 0.28 minute
Work element 2 NT2 = 0.10(1.00)(0.95) = 0.10
Work element 3 NT3 = 0.75(1.00)(1.10) = 0.83
Work element 4 NT4 = 1.08 (1.00)(0.90) = 0.97
TOTAL 2.18 minutes

The normal time for the complete cycle is 2.18 minutes.

Note that it is not realistic to use this normal time of 2.18 minutes for the cycle as a standard. Can you guess why? This is because it doesn't allow for fatigue, rest periods, or unavoidable delays that might have occurred during an average work day. Therefore, we need to add some allowance time to the normal time to adjust for these factors. The standard time (ST) therefore becomes.

ST = NTC (1 +A)

Where A = Proportion of the normal time added for allowances.

Most allowances range from 10 to 20 percent of normal time and cover factors that may be difficult to measure. However, work sampling can be used to estimate some of those factors. Below is an example of the determination of Standard Time.

Management needs a standard time for the Coffee package operation. Suppose that A= 0.15 of the normal time. What is the standard time for the coffee cup packaging operation, how many cartons can be expected per eight hour day?

Solution

For A = 0.15 of the normal time,
ST = 2.18 (1+0.15) = 2.51 minutes/carton

For an 8-hour day, this translates into a production standard of 480 minutes/day
2.51 minutes/carton = 191 cartons/day A useful hint
At times, you might not be given the value of the standard deviation, •, but would then compute it from sample data. This you can do, using this formular:

√ i2- (=i) Standard Deviation
n -1

3.3.1.1 An Assessment of Time Study

Time study methods have been observed to have some limitations. Therefore, it is s uggested that they should not be used to set s tandards for jobs in which the nature of the task is different each time.

Examples of the situation above include a student solving a problem, a profes sor preparing a lecture, or an automobile mechanic diagnosing the cause of a non-routine problem. Furthermore, an inexperienced person should not be allowed to conduct time studies because errors in recording information or in selecting the work elements to include can result in unrealistic standards.

Another limitation of the time study is that some workers may object to it because of the "subjectivity" involved.

However, in spite of the above s hortcomings, time studies conducted by an experienced analyst usually provide a satisfactory, although imperfect, tool for setting equitable time standards.

3.3.2 Elemental Standard Data Approach

Standard elemental times are derived from a firm's own historical time study data. For instance, a time study department over the years might have accumulated a file of elemental times that are com mon to many jobs. After a certain point, many elemental times can be simply retrieved from the file, thus eliminating the need for analysts to go through a complete time study to obtain them.

The procedure for using standard elemental times consists of the following steps:

(i) Analyse the job to identify the standard elements

(ii) Check the file for elements that have historical times and record them, use time study to obtain others, if necessary

(iii) Modify the file times if necessary. Let us look at some cases where the file times may not pertain exactly to a specific task. For instance, standard elemental times might be on file on "move the tool 3 centimeters" and "move the tool 9 centimeters", whereas the task in question involves a move of 6 centimeters. What can possibly be done is to interpolate between values on file to obtain the desired time estimate.

(iv) Sum the elemental times to obtain the normal time, and factor in allowances to obtain the standard time.

3.3.2.1 An Assessment of the Elemental Standard Data Approach

An obvious advantage of the elemental standard data approach is the potential savings in cost and effort created by not having to conduct a complete time study for each job.

Secondly, there is less disruption of work, since the analyst does not have to time the worker. Thirdly, performance ratings do not have to be done, since they have been generally averaged in the file times.

However, the elemental standard data approach suffers from a major limitation in that times may not exist for enough standard elements to make it worthwhile. In addition, the file times may be biased or inaccurate.

3.3.3 Work Sampling Method

Work sampling is a work measurement technique that randomly samples the work of one or more employees at periodic intervals to determine the proportion of the total operation that is accounted for in one particular activity.

These types of studies are frequently used to estimate the percentage of employee's time spent in such activities as:

Unavoidable delays, which are commonly called ratio-delay studies;
Repairing finished products from an operation; or
Supplying material to an operation

The results of these studies are commonly used to set allowances used in computing labour standards, in estimating costs of certain activities, and in investigating work methods. Unlike time study, work sampling does not require timing an activity nor does it even involve continuous observation of the activity. Instead, an observer is required to make brief observations of a worker or machine at random intervals over a period of time and simply note the nature of the activity. For example, a machine may be busy or idle; a secretary may be typing, filing, talking on the phone, etc. The resulting data are counts of the number of times each category of activity or non-activity was observed.

Conducting a work sampling study involves the following steps:

(i) Define the activities
(ii) Design the observation form
(iii) Determine the length of the study
(iv) Determine the initial sample size
(v) Select random observation times using a random number table
(vi) Determine the observer table schedule
(vii) Observe the activities and record the data
(viii) Decide whether additional sampling is required.

It is important to note here, that work sampling estimates include some degree of error. For instance, the same number of observations taken at different times during the week will probably produce slightly different estimates, and all estimates will usually differ from the actual (but unknown) values. It is therefore important to treat work sampling estimates as approximations of the actual proportion of time devoted to a given activity.

3.3.3.1 Sample Size

The goal of work sampling is to obtain an estimate that provides a specified confidence not differing from the true value by more than a specified error. That is, we want to take a sample, calculate the sample proportion, and be able to say that the following interval contains the true proportion with a specified degree of precision:

Where, $\hat{}\ -\hat{}e < + \hat{}\ <$

$\hat{}$ = Sample proportion (number of occurrence divided by the sample size)
e = *maximum error in the estimate.*

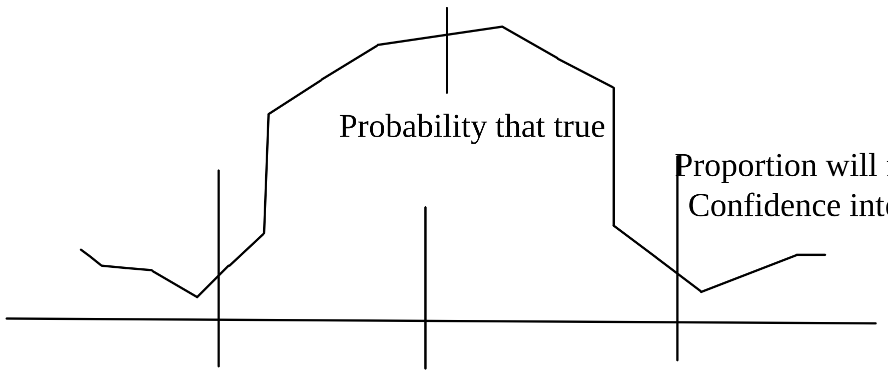
The surface size affects the degree of precision that can be expected from work sampling for any desired level of statistical confidence. Since work sampling involves estimating proportions, its sampling distribution is the binomial distribution. However, it has been found that since large sample sizes are required for this approach, the normal approximation to the binomial distribution can be used to determine the appropriate sample size. Figure 17 shows the confidence interval for a work sampling study. The maximum error can be computed as:

$$e = \sqrt{\frac{\hat{\ }(1 - \hat{\ })}{n}}$$

Where n = sample size

Z = number of standard deviations needed to achieve the desired confidence.

Figure l.l.l: Confidence interval for a Work Study Sampling



An Example of the calculation of Sample Size

The manager of a small supermarket chain wants to estimate the proportion of time stock clerks spend making price changes on previously marked merchandize. The manager wants a 98 percent confidence that the resulting estimate will be within 5 percent of the true value. What sample size should he use?

Solution

e= 0.05(given)

Z = 2.33 (i.e. from z values, 98% confidence interval yields a z-value of 2.33

ˆ is unknown.

When no sample estimate of P is available, a preliminary estimate of sample size can be obtained using ˆ = 0.50. After 20 or so observations, a new estimate of ˆ can be obtained from the observations and a revised value of n computed using the new ˆ It is better to recompute the value of n at two or three points during the study to obtain a better indication of the necessary sample size.

The required sample site for the given information can be computed by the formular:

$$n = \frac{Z^2 \hat{\ }(I - \hat{\ })}{e^2}$$

[ ]

Thus, n = (2.33) [0.05(1-0.05)] $\left[\frac{0.05(1 - 0.05)}{(0.25)^2}\right]$

= 0025 $\frac{5.43(0.0435)}{0.}$ = 543

It follows that the manager should use a sample size of 543.

4.0 CONCLUSION

Through this unit, you have learned that it is important for management to make design of work systems a key element of its operations strategy. Work measurement is the process of estimating the amount of worker time required to generate one unit of output. Its ultimate goal is usually to develop and controlling operations, thereby achieving high labour productivity.

5.0 SUMMARY

As already mentioned above, work measurement is concerned with specifying the length of time needed to complete a job. Such information is vital for personnel planning, cost estimating, budgeting, scheduling, and worker compensation. Commonly used approaches include stopwatch time study and predetermined times.

6.0 TUTOR MARKED ASSIGNMENT

1. How does work measurement contribute to the operation of a modern industrial concern.

2. Comment on suitability of work sampling to set time standards on maintenance operations.

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 LEARNING CURVES

CONTENTS

1.0 INTRODUCTION

This unit is in continuation of our study on productivity improvement. From the previous units, you have learned what productivity means, and how it can be improved. You were also taken through such relevant areas as job design, work methods study, and work measurement. This present topic is on learning curves, which displays the relationship between the total direct labour per unit and the cumulative quantity of a product or service produced. You will find the topic quite interesting and rewarding as specified in the study objectives.

2.0 OBJECTIVES

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

i. Explain the concept of a learning curve and how volume is related to unit costs.
ii. Develop a learning curve, using the arithmetic and logarithmic analyses.
iii. Demonstrate how to use the learning-curve table
iv. Demonstrate the use of learning curves for managerial decision making.

3.0 MAIN CONTENT

3.1 A Soft Background to Learning and the Experience Curve

We are going to open the discussion on learning curve with a soft, or if you like, elementary prologue:

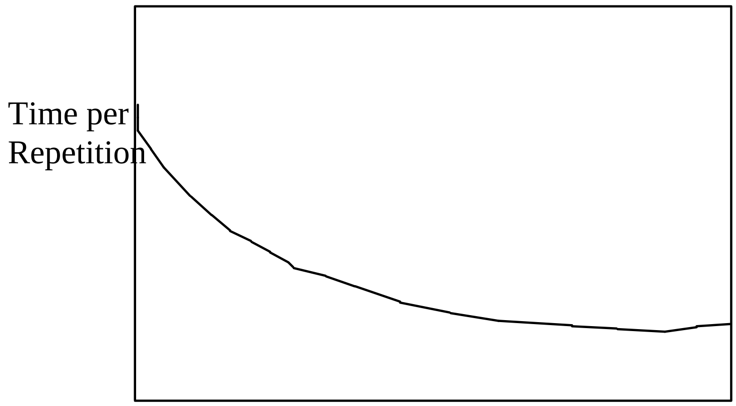
When anybody starts something new, there is a form of learning process before one arrives at one's optimum ability. For instance, in the life cycle, one learns to walk; one learns to talk; one learns to study; one learns in a professional environment, etc. Another fact we should note is that some activities are harder to learn than others, while some individuals are quicker to learn than others.

Let us use some examples to explain the concept of the learning curve: If a company develops a new product, or process, it usually takes time for engineers, operators and/or maintenance personnel to understand the process, as well as the design fully, and thus be efficient regarding all the activities involved. Because of this, the operating and/or product costs at the early stages are higher than at the later periods. Similarly, it takes time for new employees to become full operational in a company that already has established programmes and procedures in place.

The point being made is that human performance of activities typically shows improvement when the activities are done on a repetitive basis. That is, the time required to perform a task decreases with increasing repetitions. Learning curves seem to summarise this phenomenon. However, the degree of improvement and the number of tasks needed to realise the major portion of the improvement is a function of the task being done. For instance, if the task is short and somewhat routine, only a modest amount of improvement is likely to occur, and it generally occurs during the first few repetitions. If the task is fairly complex and has a longer duration, improvements will occur over a longer interval (i.e, larger number of repetitions). Hence learning factors have little relevance for planning or scheduling routine activities, but they do have relevance for complex repetitive activities.

Figure 18.1 illustrates the basic relationship between increasing repetitions and a decreasing time per repetition. You should note that the curve will never touch the horizontal axis, i.e., the time per unit will never be zero.

Figure 18.1: The Learning Effect: Time per Repetition Decreases as the Number of Repetitions increase



3.2 The Learning Curve

The experience, or learning curve, sometimes called the manufacturing progress function, is a mathematical relationship between the cumulative production output and its cost, expressed either in financial terms or in production. The learning curve was first developed in the aircraft industry prior to World War II, when analysts discovered that the direct labour input per airplane decline with considerable regularity as the cumulative number of planes produced increased. Subsequent survey of major airplane manufacturers revealed that a series of learning curves could be developed to represent the average experience for various categories of airframes (e.g. fighters, bombers, etc), despite the different amount of time required to produce the first unit of each type of airframe. It was found that once production started, this direct labour for the eight unit was only 80 percent of that for the fourth unit, the direct labour for the twelfth was only 80 percent of that for the sixth etc. In each case, each doubling of the quantity reduced production time by 20 percent. It was thus concluded that the aircraft industry's rate of learning was 80 percent between doubled quantities of airframe due to the consistency in the observed rate of improvement.

In other words, the labour-hours required to assemble an aircraft is reduced by a factor of 0.8 as the production quantity is doubled. Figure 18.2 shows how the learning of workers causes the labour-hours per unit to fall as the number of unit produced increases. For example, if the first aircraft assembled requires 100 labour-hours, the second aircraft would require 0.8 x 100 = 80 labour-hours, the fourth would require 0.8 x 80 = 64 labour-hours, the eight would require 0.8 x 64 = 51.2 labour-hours etc.

3.3 Mathematical Representation of Learning Curve

A mathematical learning curve can be developed by plotting production labour-hours against the quantity of products produced. You will observe that the curve decreases exponentially, showing that when a new production starts, as the number of units produced increases, the labour-hours per unit decreases as operators become more familiar with the task. Learning curves are presented according to the learning rate, for example 75, 80, 85, or 90 percent. Thus, an 80 percent learning means that, as the quantity produced is doubled, the labour-hours per unit decreases by 80 percent.

The mathematical relationship has the exponential form: T n = T 1 (n b),

Where

T n = labour-hours/unit when n units are manufactured,
T1 = labour-hours to produce the first unit;
n = the unit number produced;
b = a constant representing the slope of the curve.

Where the learning rate was found to be 80 percent. In that example, to assemble the first aircraft required 100 labour-hours. Then at 80 percent learning rate, the time to produce the second unit was 80 labour-hours (i.e. 0.8 x 100). The time to produce the fourth unit = 64 labour-hours (i.e. 0. 8 x 80). Table 18.1 gives the progress, while Figure 18.2 earlier referred to, shows the relationship graphically.

Figure 18.2: Aircraft Assembly 80 Percent Curve

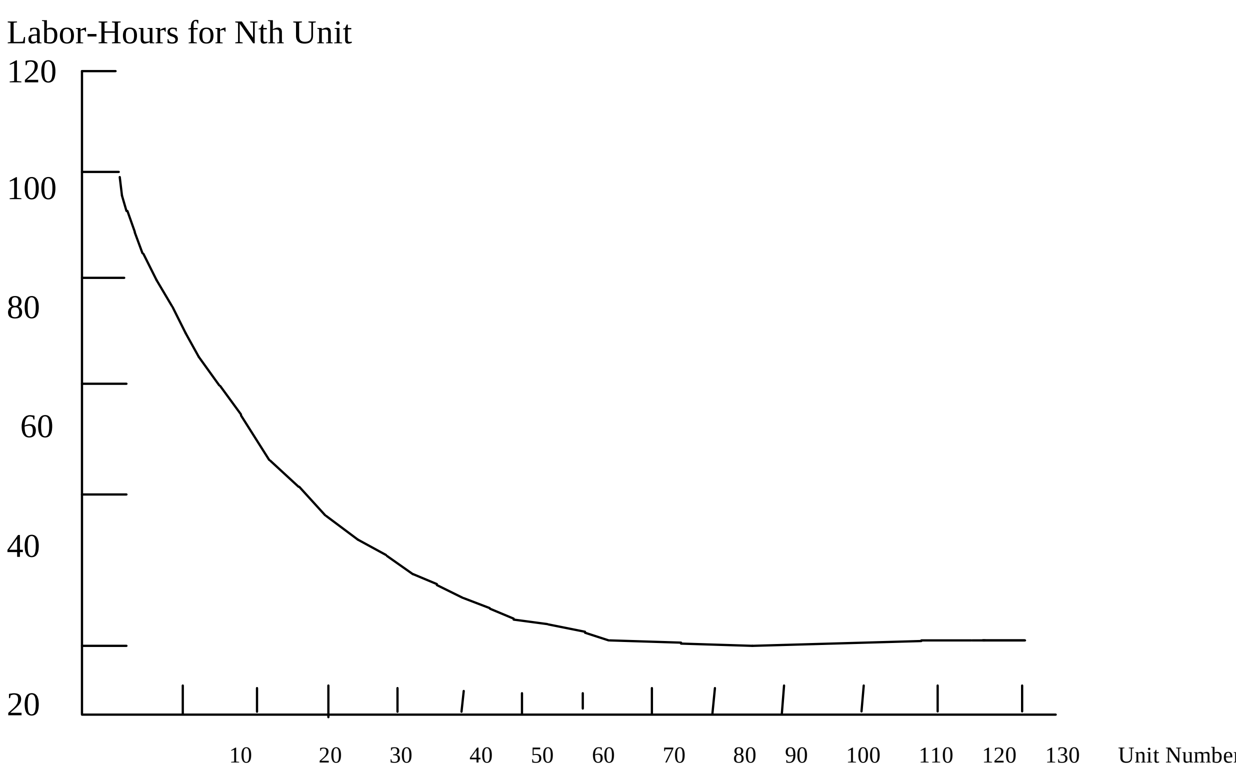


Table 18.1; Relationship between Units produced and Labour-Hour for 80 percent leaning curve.

nth Units Produced	Labour-Hours for nth Unit
1	100.0
2	80.0
4	64.0
8	51.2
16	41.0
32	32.8
64	26.2
128	21.0

There are three approaches to learning-curve problems. These are: arithmetic analysis, logarithmic analysis, and learning-curve tables. We shall make attempts to examine each of these.

3.3.1 Arithmetic Analysis

Arithmetic analysis is the simplest approach to learning-curve problems because it is based on this fundamental concept: As the number of units doubles, the labour-hours per unit decline by a constant factor. You are already familiar with this idea. From our previous example, if we know that the learning rate is 80 percent of a particular operation and that the first unit of production took 100 labour-hours, the labour-hours to produce the eight unit is:

nth Units Produced	Labour-Hours for nth Unit
1	100.0
2	80.0
4	64.0
8	51.2

Carefully observe that as long as we wish to find the labour-hours required to produce n units, and n just happens to be a number that is one of the doubled values, then this arithmetic approach works. Would this approach be useful if we want to find the labour-hours required to produce the seventh unit?. This is where the arithmetic analysis breaks down: it does not let us address such odd cases with precision. The logarithmic analysis tackles such problems.

3.3.2 Logarithmic Analysis

In Logarithmic analysis, this relationship allows us to compare Tn which is the labour hours required to produce the nth unit:

$$Tn = T1\ (n^b) \text{ and } b = \frac{\log r}{\text{Log } 2}$$

Where T1 = labour-hours to produce the first unit;

b = slope or me learning curve; ana

r = learning rate percentage

The values of b are found in Table 2 below labour-hours to produce the first unit;

Table 18.2: Learning-curve values of b

Learning rate	b
70%	-0.515
75%	-0.415
80%	-0.322
85%	-0.234
90%	-0.152

It is also possible to compute the values of b manually. This is by making use of the formular for b:

$$b = \frac{\log r}{\log 2}$$

Where r = learning rate percentage

For example, for an 80 percent learning rate, r = 0.80, hence the value of b is:

$$b = \frac{\log r}{\log 2} = \frac{\log 0.80}{\log 2} = \frac{-0.2231}{+0.6931}$$

:. b = -0.3219

The negative slope indicates that the time decreases as the number of units increases. Example

If we know that the learning rate for a particular operation is 80 percent, and that the first unit of production took 100 labour-hours, the labour-hours required to produce the seventh unit is:

$Tn = T\ 1(n^b)$

T7 = 100 (7-°322) = 53.4 labour-hours

We can also calculate the cumulative average number of hours per unit for the first n units with the help of Table 18.3. The table contains conversion factors that, when multiplied by the direct labour-hours for the first unit, yield the average time per unit for selected cumulative production quantities.

Table 18.3:Conversion Factors for the Cumulative Average Number of Direct Labor Hours per Unit

80% Learning Rate 90% Learning Rate

N	N	N	N	n	n	
1	1.0000019	0.5317837	0.439761	1.0000019	0.7354537	0.67091
2	0.9000020	0.5242538	0.436342	0.9500020	0.7303938	0.66839
3	0.8340321	0.5171539	0.433043	0.9154021	0.7255939	0.66595
4	0.7855322	0.5104540	0.429844	0.8890522	0.7210240	0.66357
5	0.7475523	0.5041064	0.373825	0.8678423	0.7166664	0.62043
6	0.7165724	0.49808128	0.302696	0.8501324	0.71251128	0.56069
7	0.6905625	0.49234256	0.244057	0.8349625	0.70853256	0.50586
8	0.6682426	0.48688512	0.196228	0.8217226	0.70472512	0.45594
9	0.6487627	0.48167600	0.186619	0.8099827	0.80106600	0.44519
10	0.6315428	0.47668700	0.1777110	0.7994528	0.69754700	0.43496
11	0.6161329	0.47191800	0.1703411	0.7899129	0.69416800	0.42629
12	0.6022430	0.46733900	0.1640812	0.7812030	0.69090900	0.41878
13	0.5896031	0.4629310000.1586713		0.7732031	0.6877510000.1217	
14	0.5780232	0.4587112000.1497214		0.7658032	0.6847112000.40097	
15	0.5673733	0.4546414000.1425415		0.7589133	0.6817714000.39173	
16	0.5575134	0.4507216000.1366016		0.7524934	0.6789316000.38390	
17	0.5483435	0.4469418000.1315517		0.7464635	0.6761718000.37711	
18	0.5397936	0.4432920000.1272018		0.7408036	0.6735020000.37114	

Example

A manufacturer of ships needs 50,000 labour-hours to produce the first unit. Based on past experience in the ship-building industry, you know that the rate of learning is 80 percent.

(a) Use the logarithmic model to estimate the direct labour required for the 40th ship and the cumulative average number of labour hours per unit for the first 40 units.

(b) Draw a learning curve for this situation

Solution

(i) The estimated number of direct labour-hours required to produce the

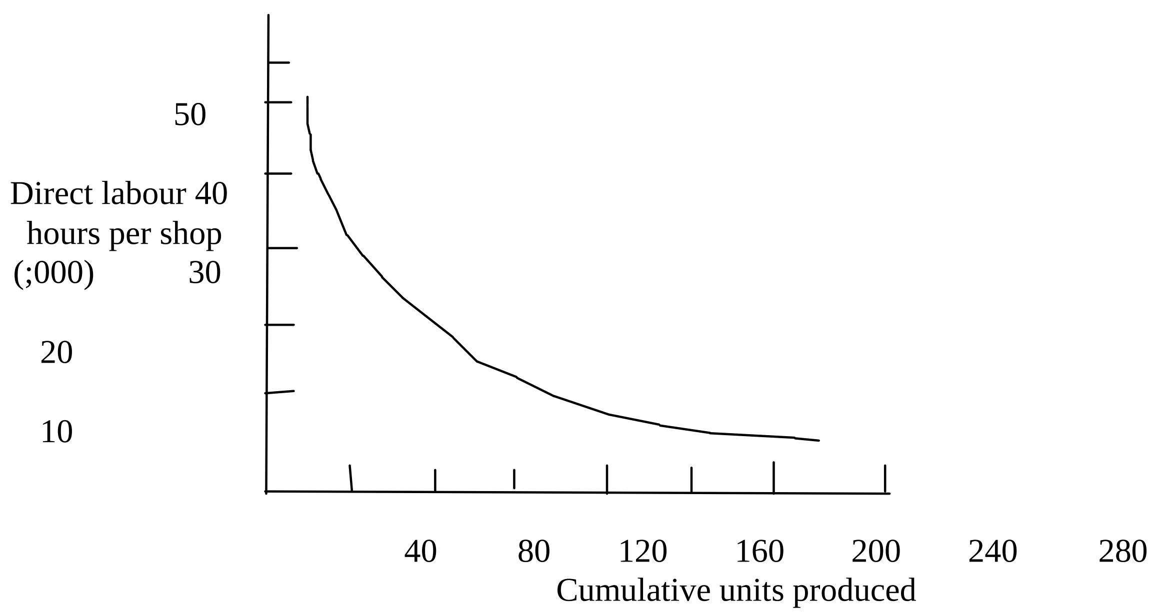
40th unit is: T40 = 50,000 (40)10'0 .8/log 2)
= 50,000 (40)_0.32 = 50,000 (0.30488)
= 15,244 hours

i) We calculate the cumulative average number of direct labour-hours per unit for the first 40 units with the help of Table 18.3. For a cumulative production of 40 units and an 80 percent learning rate, the factor is 0.42984. Therefore, the cumulative average direct labour hour per unit is:

50,000 (0.42984) = 21,492 labour-hours

(b) Plot the first point at (1, 50,000). The second unit's labour time is 80 percent of the first, so you need to multiply 50,000 by 0.80, which should give 40,000 labour-hours. Then use to plot the second point at (2, 40,000). The fourth is 80 percent of the second, so multiply 40,000 by 0.80 to obtain 32,000 labour hours. Plot the third point at (4, 32,000). The result is shown in Figure 18.3.

Figure 18.3: The 80 percent Learning Curve



3.3.3 Learning-Curve Tables

The third approach to learning-curve problems is to use a 'learning factor' obtained from a table containing learning curve coefficients. The table shows two things: One is a unit value of each of the outputs listed - this enables us to easily determine how long any unit will take to produce. The second is a cumulative value, which enables us to complete any given number of repetitions. The computation for both is a relatively simple operation. It just entails multiplying the table value by the time required for the first unit. Table 18.4 contains the learning curve coefficient.

Table 18.4: Learning –Curve Coefficients

					85%		90%	
Unit No.	Unit Time	Total Time	Unit Time	Total Time	Unit Time	Total Time	Unit Time	Total Time
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	.750	1.750	.800	1.800	.850	1.850	.900	1.900
3	.634	2.384	.702	2.502	.773	2.623	.846	2.746
4	.562	2.946	.642	3.142	.723	3.345	.810	3.556
5	.513	3.459	.596	3.738	.686	4.031	.783	4.339
6	.475	3.934	.562	4.229	.657	4.688	.762	5.101
7	.446	4.380	.534	4.834	.634	5.322	.744	5.845
8	.422	4.802	.512	5.346	.614	5.936	.729	6.574
9	.402	5.204	.493	5.839	.597	6.533	.716	7.290
10	.385	5.589	.477	6.315	.583	7.116	.705	7.994
11	.370	5.958	.462	6.777	.570	7.686	.695	8.689
12	.357	6.315	.449	7.227	.558	8.244	.685	6.374
13	.345	6.660	.438	7.665	.548	8.792	.677	10.05
14	.334	6.994	.428	8.092	.539	9.331	.670	10.72
15	.325	7.319	.418	8.511	.530	9.861	.663	11.38
16	.316	7.635	.410	8.920	.522	10.38	.656	12.04
17	.309	7.944	.402	9.322	.515	10.90	.650	12.69
18	.301	8.255	.394	9.716	.508	11.41	.644	13.33
19	.295	8.540	.387	10.10	.501	11.91	.639	13.97
20	.288	8.828	.381	10.49	.495	12.40	.634	14.61
21	.283	9.111	.375	10.86	.490	12.89	.630	15.24
22	.277	9.388	.370	11.23	.484	13.38	.625	15.86
23	.272	9.660	.364	11.59	.479	13.86	.621	16.48
24	.267	9.928	.359	11.95	.475	14.33	.617	17.10
25	.263	10.19	.355	12.31	.470	14.80	.613	17.71
30	.244	11.45	.335	14.02	.450	17.09	.596	20.73
35	.229	12.62	.318	15.64	.434	19.29	.583	23.67
40	.216	13.72	.305	17.19	.421	21.43	.571	26.54
45	.206	14.77	.294	18.68	.410	23.50	.561	29.37
50	.197	15.78	.284	20.12	.400	25.51	.552	32.14
60	.183	71.67	.268	22.89	.383	29.41	.537	37.57
70	.172	19.43	.255	25.47	.369	33.17	.524	42.87
80	.162	21.09	.244	27.96	.358	36.80	.514	48.05
90	.155	22.67	.235	30.35	.348	40.32	.505	53.14
100	.148	24.18	.227	32.65	.340	43.75	.497	58.14
120	.137	27.02	.214	37.05	.326	50.39	.483	67.93
140	.129	29.67	.204	41.22	.314	56.78	.472	77.46
160	.122	32.17	.195	45.20	.304	62.95	.462	86.80
180	.116	34.54	.188	49.03	.296	68.95	.454	95.96
200	.111	36.80	.182	52.72	.289	74.79	.447	105.0
250	.101	42.08	.169	61.47	.274	88.83	.432	126.9
300	.094	46.94	.159	69.66	.263	102.2	.420	148.2
350	.088	51.48	.152	77.43	.253	115.1	.411	169.0
400	.083	55.75	.145	84.85	.245	127.6	.402	189.3
450	.079	59.80	.140	91.97	.239	139.7	.395	209.2
500	.076	63.68	.135	98.85	.233	151.5	.389	228.8

600	.070	70.97	.128	112.0	.223	174.2	.378	267.1
700	.066	77.77	.121	124.4	.215	196.1	.369	304.5
800	.062	84.18	.116	136.3	.209	217.3	.362	341.0
900	.059	90.26	.112	147.7	.203	237.9	.356	376.9
1,000	.057	96.07	.108	158.7	.198	257.9	.350	412.2
1,200	.053	107.0	.102	179.7	.190	296.6	.340	481.2
1,400	.050	117.2	.097	199.6	.183	333.9	.333	548.4
1,600	.047	126.8	.093	218.6	.177	369.9	.326	614.2
1,800	.045	135.9	.090	236.8	.173	404.9	.320	678.8
2,000	.043	144.7	.087	254.4	.168	438.9	.315	742.3
2,500	.039	165.0	.081	296.1	.160	520.8	.304	897.0
3,000	.036	183.7	.076	335.2	.153	598.9	.296	1.047

Example 1

Alexander Airlines is negotiating a contract for the production of 20 small aircraft. The initial jet requires the equivalent of 400 days of direct labour. Estimate the expected number of days of direct labour for:

(a) The 20th jet
(b) All 20 jets
(c) The average time for 20 jets. Solution

From Table 18.4 n = 20 and an 80 percent learning percentage, the following factors are extracted:

Unit time = 0.3 81
Total time = 10.485

Solution

(a) Expected time for 20th jet: 400 (0.381) = 152.4 labour days
(b) Expected total time for all 20: 400 (10.485) = 4,194 labour days.
(c) Average time for 20: 4,194 20 = 209.7

3.3.3.1 Using the Table to Obtain an Estimate of the Initial Time

The use of Table 18.4 requires a time for the first unit. For instance, if the completion time of the first unit is not available, or if the manager believes the completion time for some later unit is more reliable, the table can be used to obtain an estimate of the initial time, and that value can be used in conjunction with the table.

Example

The manger in our immediate past example believes that some unused problems were encountered in producing the first jet, and would like to revise that estimate based on a completion time of 276 days for the third jet.

Solution

From Table 18.4, with n = 3 and an 80 percent learning percentage a coefficient of 0.702 is obtained. Divide the actual time for unit 3 by the table value to obtain the revised estimate for unit l's time:

276 days 0.702 = 393.2 labour days.

3.4 Uses and Applications of Learning Curves

We now know that as production personnel gain experience with a new product/service or operation, the labour-hours per unit fall. Consequently, labour standards are expected to decline on many products and operations, and cost standards, budgets, production, scheduling, staffing plans, and prices are necessarily affected.

In job shops and custom service operations, the learning-curve theory has been found to be important due to the following factors:

(a) Products and services tend to be custom designs that require workers to start near the beginning of small batches
(b) Batches tend to be small; thus labour-hours per unit improves dramatically from the first to the last unit
(c) Product/service designs tend to be complex; thus labour -hours per unit improve quickly. You should note that the application of learning curves to mass production and standard service operations is less significant because entirely new products or services are rare, and long production runs and simplified tasks combine to cause labour-hours per unit to improve only slightly.

Staff specialists have been found to routinely use learning-curve theory to develop labour cost for new products and services. This use allows companies to prepare cost estimates and product prices for bidding purposes.

The learning-curve approach has certain limitations:

(i) It maybe impossible either to develop precise labour-hour estimates for the first unit, or to determine the appropriate learning rate. Large unique projects often exhibit both at these difficulties.

(ii) Different workers have different learning rates. In a pure sense therefore, learning theory applies only to individual workers, but little difficulty is encountered in applying learning curves to groups of workers by applying an average learning rate.

(iii) Few products are completely unique. Workers usually will trained in the completion of tasks within their skill classifications. Past performance on related tasks therefore results in latent learning that is transferred to new products and services.

SELF ASSESSMENT EXERCISE (SAE)

An assembly operation has a 90 percent learning curve. The line has just begun with on a new item; the initial unit requires 28 hours. Estimate the time that will be needed to complete:

(a) The first 5 units
(b) Units 20 through 25

2. A manager wants to determine an appropriate learning rate for a new type of work his firm will undertake. He has obtained completion times for the initial six repetitions of a job of this type:

Unit	Completion Time (hours)
1	15.9
2	12.0
3	10.1
4	9.,1
5	8.4
6	7.5

What learning rater is appropriate?

3. The manager of a custom manufacturer has just received a production schedule for an order for 30 large turbines. Over the next five months, the company is to produce 2, 3, 5, 8, and 12 large turbines, respectively. The first unit took 30,000 direct labour hours, and experience on past projects indicates that a 90 percent learning curve is appropriate; therefore the second unit will require only 27,000 hours. Each employee works an average of 150 hours per month. E stimate the total number of full-time employees needed each month for the next five months.

4.0 CONCLUSION

A basic consideration in the design of work systems relates to the fact that learning is usually present when humans are involved. Consequently, it can be highly desirable to be able to predict how learning will affect task times and costs. You have learned in this unit that the time required to perform a task decreases with increasing repetitions. This is what the learning curves try to summarise.

5.0 SUMMARY

This unit has widened your knowledge to the extent that you can explain the concept of a learning curve, and how volume is related to unit costs. You have also learned how to develop a learning curve by making use of arithmetic and logarithmic analyses. In addition you have been able to demonstrate how to use the learning curve table, as well as use the concept of the learning curves for managerial decision making.

6.0 TUTOR-MARKED ASSIGNMENT

Company A has just been given the following production schedule for model XT cars. The model is considerably different from any others the company has produced. Historically, the company's learning rate has been 80 percent on large projects. The first unit took 1000 hours to produce.

Month	Units	Cumulative Units
1	3	3
2	7	10
3	10	20
4	12	32
5	4	36
6	2	38

(a) Estimate how many hours would be required to complete the 38th unit.

(b) If the budget only provides for a maximum of 30 direct labour employees in any month and a total of 15,000 direct labour hours for the entire schedule, will the budget be adequate?. Assume that each direct labour employee is productive for 150 work hours each month.

7.0 REFERENCES/FURTHER READINGS

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UNIT 4 TOTAL QUALITY MANAGEMENT

CONTENTS

1.0 INTRODUCTION

The challenge for business today is to produce quality products or services efficiently. 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 of the 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.

2.0 OBJECTIVES

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

(i) Define quality from the customer's perspective.
(ii) Describe the principles of a TQM program and how the elements fit together to make improvements in quality and productivity
(iii) Identify
(iv) Discuss how TQM programs improve quality through benchmarking, product and service design, quality function deployment, and quality conscious purchasing
(v) Distinguish among the various tools for improving quality and explain how each should be used.
(vi) Discuss the nature and benefits of NAFDAC and international standards for quality programs and environmental management programs.

3.0 MAIN CONTENT

3.1 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.

3.1.1 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 your apartment.

(e) Psychological Impression

People often evaluate the quality of a product or service on the basis of psychological 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.

3.1.2 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 for second-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.

3.2 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.

3.2.1 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 people or 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 directly with 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 his customer.

The binder will have similar perception of quality as final consumer. All employees have to do a good job of serving their internal customers for ultimate 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 all parts 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. This philosophy 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.

3.2.2 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 skills to train others in quality improvement practices.

3.2.3 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 quality improvements.

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.

3.3 Continuous Improvement

Continuous improvement, based on a Japanese concept called "Kaizen", is the philosophy of continually seeking way to improve operations. It is also applicable 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.

3.3.1 Getting Started with Continuous Improvement.

Instilling the philosophy of continuous improvement involves the following processes:

(a) Train employees in the methods of statistical process control (SPC) and other 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 continuous improvement. The last two steps are crucial if the philosophy is to become part of everyday operations. Problem solving addresses the aspects of operations that need 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.

3.3.2 Problem-solving process

Firms that are actively involved in continuous improvement train their work teams 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 quantifiable measures 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 find out 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.

3.4 The Cost of Poor Quality

Defective and unsatisfactory product may cost a company up to 20 to 30 percent of its gross sales. For instance, a high electric power surge may damage all electrical appliances of a company as low current supply may delay operations. Four major categories of cost are associated with quality management: prevention, appraisal, internal failure, and external failure.

3.4.1 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.

3.4.2 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 improve quality, appraisal costs decrease due to quality inspections.

3.4.3 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.

3.4.4 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 burnt one 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 the customer'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.

3.5 Improving Quality through TQM

Employee involvement and continuous improvement generally improve quality. But, TQM often focuses on benchmarking, product and service design, process design and purchasing.

3.5.1 Benchmarking

Benchmarking is a continuous systematic procedure that measures a firm's products, 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 per unit, return on investment, and customer satisfaction levels. Benchmarking consists of four basic steps"

(i) 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

(ii) Analysis - Determine the difference between the firm's current performance and that of the benchmark firm (s) and identify the causes of significant gaps.

(iii) Integration - Establishing goals and obtaining the support of managers who must provide the resources for achieving the goals.

(iv) 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 organisational unit with superior performance as the benchmark for other units. All forms of benchmarking are applied when there is a need for continuous improvement.

3.5.2 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 potential to 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 are exchanged 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 component depends 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 be operating 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 not fail to work when you put it on.

3.5.3 Process Design

Process designs greatly affect product quality. Wema Bank PLC may observe that 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 one cashier 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 which operation'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.

3.5.4 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 on product quality. QFD encourages inter functional communication for the purpose of improving product quality.

3.5.5 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.

3.5.6 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 of certain product or service characteristics related to quality. The characteristics may be measurable on continuous scale (e.g. weight or 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 data characteristics 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 few of its factors. In a restaurant quality problem, the activity could be customer complaints and the factor could be "discourteous waiter".

Pareto's concept, called the 80-20 rule, is that 80 per cent of the activity is 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 quality problem.

A Pareto chart is a bar chart on which the factors are plotted in decreasing 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 managerial attention.

(d) Scatter diagram

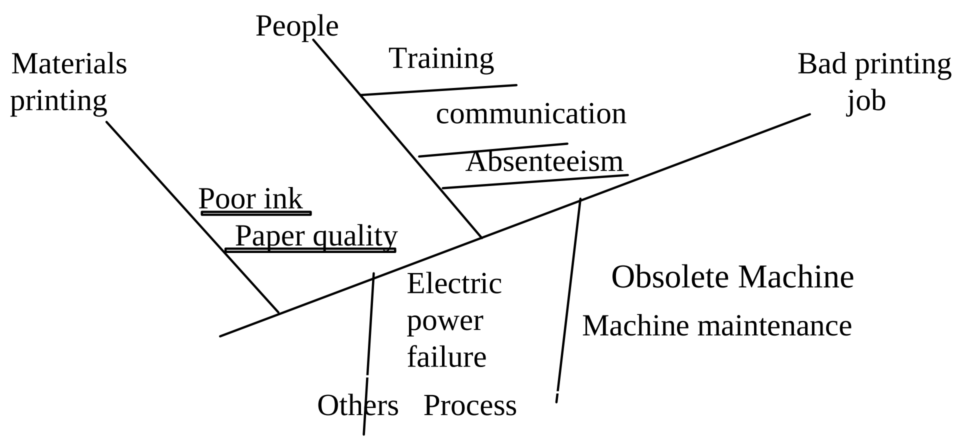
A scatter diagram is a plot of two variables showing whether they are related or not and can be used to clear doubt about a factor causing one quality problem. Each point on the scatter diagram represents a data observation.

(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. Pie charts represent quality factors as slices of a pie, the size of each slice is in proportion to the number of occurrence of the factor.

3.5.7 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.

3.6 National and International Quality Standards

3.6.1 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.

3.6.2 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 standardization devised a set of standards called ISO 9000 for companies doing business in the European Union. Also, a new set of standards, ISO14000, were devised for environmental management systems.

(a) The ISO 9000 standards is a set of standards governing documentation of a quality programme. Companies become certified buy proving to a qualified external examiner that they have complied with all the 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

4.0 CONCLUSION

Total quality management is a big challenge for all modern businesses. Products and services will meet customers' expectations for satisfaction if they have good quality for their money value. Good quality is not a thing to be inspected for in a product after final production but a thing that is built into the product from the beginning of the production process. Everyone in the firm-management, employees and all the units need to be carried along in quality management. Contacts have to be maintained with customers too as their perception of quality changes over time.

5.0 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 service support, and aesthetic reasons. One TQM responsibility 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.

Tow sets of standard, governing the documentation of quality programmes at the global level are ISO 9000 and ISO 14000.

6.0 TUTOR MARKED ASSIGNMENTS

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

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UNIT 5 MAINTENANCE AND RELIABILITY

CONTENTS

1.0 INTRODUCTION

This unit is on maintenance, which encompasses all these activities that relate to keeping facilities and equipment in good working order and makes necessary repairs when breakdowns occur, so that the system can perform as intended. The general objectives for the unit are set below.

2.0 OBJECTIVES

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

(i) Explain the importance of maintenance in production systems.
(ii) Describe the range of maintenance activities
(iii) Describe and differentiate between reactive and proactive approaches to maintenance.
(iv) State how the pareto phenomenon pertains to maintenance decisions.

3.0 MAIN CONTENT

3.1 An Overview of Maintenance

Maintaining the production capability of an organization is an important function in any production system. It is through this that production equipment are adjusted, repaired and kept in good operating conditions. The reasons for keeping equipment and facilities in perfect operating condition are not only to avoid interruption to production, but also to keep production cost low, keep product quantity high, maintain safe working conditions, and avoid late on late shipments to customers.

When equipments malfunction in both manufacturing and service industries, the consequences have a direct impact on:

(i) **Production capacity: Naturally, equipment sidelined by breakdown** cannot produce. This way, the capacity of the system is reduced.

(ii) **Production costs: Since machines are not functioning, workers too** would be made idle. This situation cause labour costs per unit to increase. Apart from this, when machine malfunction causes scrap products to be produced, unit labour and material costs increase. Furthermore, maintenance department budgets include such costs as the costs of providing repair facilities, repair crew, preventive maintenance inspections, standby machines, and spare parts.

(iii) **Product and service quality: Usually, poorly maintained equipment** produces low -quality products.

(iv) **Employee or customer safety: Worn-out equipment is most likely to** fail at any moment while in operation. These failures can cause injuries to workers, as well as to customers (especially in the services sector)

(v) **Customers satisfaction: Whenever production equipment breaks down,** the initial after math is that products cannot be produced according to the master production schedules. In essence, customers may not receive products when promised.

For better maintenance management, maintenance department are usually developed within organizations. A maintenance manager is usually a plant engineer, who reports to either a plant manager or a manufacturing manager. Generally, the organizational level of the department depends on the importance of maintenance to a particular organization.

Maintenance activities are often organized into two categories:

(1) buildings and grounds, and

(2) equipment maintenance. Buildings and grounds is responsible for the appearance and functioning of buildings, parking lots, Lawns, fences, etc. The buildings and grounds workers include electricians, welders, pipe fitters, steamfitters, painters, glaziers, carpenters, janitors, and grounds keepers.

The equipment maintenance group is responsible for maintaining machinery and equipment in good working condition, and making all necessary repairs.

This group can include such workers as machineries, mechanics, welders, oilers, electricians, instrument calibrators, and electronic technicians.
The degree of technology of the production processes, the amount of

investment in plant and equipments, the age of the buildings and equipment, and other factors will affect how maintenance departments are organized, the required workers skills, and the overall mission of maintenance departments.

3.2 Approaches to Maintenance

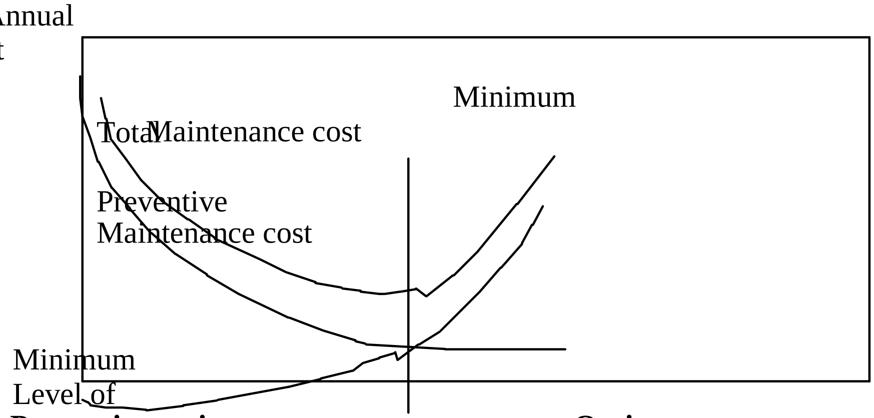
Decision makers have two basic options with respect to maintenance. The first is option reactive and this is to deal with breakdowns or other problems when they occur. This is commonly referred to as breakdown maintenance (B M). The second option is proactive, the purpose of which is to reduce breakdowns through a programme of lubrication, adjustment, cleaning, inspecting, and replacement of worn parts. This is generally knows as preventive maintenance (PM).

Usually a trade-off is made between these two basic options that will minimize their combined cost. For instance, with no preventive maintenance, breakdown and repair costs would be tremendous. In addition, hidden costs, such as cost production and the loss of wages while the equipment is not in service must be considered. Cost injury and damage to other equipment and facilities or to other units in production must also be taken into consideration.

However, beyond a certain point, the cost of preventive maintenance activities exceeds the benefit. The best approach really, is to seek a balance between preventive maintenance costs and breakdown maintenance costs. This concept is illustrated in Figure 20.1

Figure 20.1

Minimum Annual
Cost



Preventive maintenance **Optimum**

Amount of Preventive Maintenance

As figure 20.1 shows, some minimum amount of PM is necessary to provide the mini mal amount of lubrication and adjustment to avoid a complete and imminent collapse of the production system. At this minimal level of PM, the cost of breakdowns, interruption to production, and repairs is so high that total production, and repair is so high that the production cost is beyond practical limits. This is mainly a remedial policy, i.e., fix the machines only when they breakdown or will not operate any longer. As the PM effort is increased, breakdown and repair cost is reduced. Note that the total maintenance cost is the sum of the PM and the breakdown and repair costs. Also observe that at some point, for each piece of equipment, addition spending for PM is uneconomical because PM costs rise faster than breakdown and repair costs fall. Conceptually, operations managers seek to find the optimal level of PM where total maintenance costs are at a minimum both for each piece of equipment and the entire production system. Let us examine both the PM and BM into some detail.

3.2.1 Preventive Maintenance (PM)

As you must be aware by now, the goal of PM is to reduce the incidence of breakdowns or failures in the plant or equipment in order to avoid the associated costs. These can include loss of output, idle workers, schedule reduction; damage to other equipment, products, or facilities, and repairs, which may involve maintaining inventories of spare parts, repair tools and equipment, and repair specialists.

In particular, PM can be an important factor in achieving operation's strategies. For example, a PM program can be essential to the success of a product-focused positioning strategy. In product-focused positioning strategies, standardized product designs are produced along production lines where these are little, if any in-process inventories between adjacent operations. Hence, if a machine breakdown at one operation, all other downstream operations will soon run out of parts of work on. Therefore, an extensive PM programme in such system will reduce the frequency and severity of machine breakdowns.

PM programmes are similarly essential in automated factories, where systems of automated machines operate continuously without the need for production workers (i.e. workless factories). In such an environment, a large number of maintenance workers would be needed to keep the machines adjusted, lubricated, and in good operating condition.

Very often, PM is periodic, and it can be programmed according to the availability of maintenance personnel as well as to avoid interference with operating schedules. PM is generally programmed using some combination of the following three options.

(i) The result of planned inspections that reveal a need for maintenance
(ii) According to the calendar (passage of time)
(iii) After a pre-determined number of operating hours.

Normally, PM is performed just prior to a breakdown or failure because this will result in the longest possible use of equipment of facilities without a breakdown. Predictive maintenance is an attempt to determine when to perform PM activities. It is generally based on historical records and analysis of technical data to predict when a piece of equipment or part is about to fail. The effectiveness of PM often depends on how good the predictions of failures are. A good PM effort relies on complete records for each piece of equipment. Such records must include information like date of installation, operating hours, dates and types of maintenance and dates and types of repairs.

A new concept, known as Total Preventive Maintenance (TPM) is being practiced in Japan. Companies operating TPM usually have their workers Perform PM on the machines they operate, rather than use separate maintenance personnel for that task. The TPM is consistent with Just-In-Time (JIT) systems and lean production, where employees are given greater responsibility for quality, productivity, and the general functioning of the system.

3.2.2 Breakdown Maintenance (BM)

Though the risk of a breakdown can be drastically reduced on by an effective PM programme, occasional breakdowns may still occur. Actually, firms with good preventive practices have some need for breakdown programmes. It is obvious that organisations that rely less on PM have an even greater need for effective ways of dealing with breakdowns.

Very much unlike PM, breakdowns cannot be scheduled. Rather they must be dealt with on an irregular basis (i.e. as they occur). The following approaches are being used to deal with breakdowns:

(i) Standby or backup equipment that can be quickly pressed into service

(ii) Inventories of spare parts that can be installed as needed, thereby avoiding lead times involved in ordering parts, and buffer inventories, so that other equipment will be less likely to be affected by short-term downtime of a particular piece of equipment.

(iii) Operators who are able to perform at least minor repairs on their equipment.

(iv) Repair people who are well trained and readily available to diagnose and correct problems with equipment.

The extent to which any organisation pursues any or all of these approaches depends on how important a particular piece of equipment is to the overall production system. At one extreme is the equipment that is the focal point of a system (e.g. vital operating parts of a car, such as brakes, transmission, ignition and engines or printing presses for a publishing house). At the other extreme is the equipment that is rarely used since it does not perform any important function in the system, and equipment for which substitutes are readily available. What is the implication of this? Usually, breakdown programmes are most effective when they take into account, the degree of importance a piece of equipment has in the production system, as well as the ability of the system to do without it for a period of time. For these types of situations, the Pareto phenomenon exists: A relatively few pieces of equipment will be extremely important to the functioning of the system, thereby justifying considerable effort and/or expense; some will require moderate effort or expense; some will require moderate effort or expense and many will justify little effort or expense.

3.3 Replacement Decisions

These are situations when breakdowns become frequent and/or costly. The manager is thus faced with a trade-off decision in which costs are important consideration. What is the cost of replacement compared with the cost of continued maintenance? At times, a question like this is difficult to resolve, most especially if future breakdowns cannot be readily predicted. The manager may thus, need to examine historical records in order to project future experience.

Another important factor is technological change. For instance, newer equipment may have some features that favour replacement over either preventive or breakdown maintenance. At the same time, the removal of old equipment and the installation of new equipment may cause disruptions to the system, which may actually be greater than the disruptions caused by breakdowns. In addition, employees may have to be trained to operate the new equipment. Finally, forecasts of future demand for the use of the present or new equipment must be taken into account.

3.4 Machine Reliability

It is necessary for you to know the concepts of reliability and their relationship to maintenance management. Machine reliability is the likelihood of a machine breaking down, malfunctioning, or needing repairs in a given time period or number of hours of use. If machine reliability can be increased, the incidence of machine breakdowns and the cost of the havoc caused in production by breakdowns can also be reduced.

There are three approaches to improving machine reliability: over-design, design simplification, and redundant components. All these take place by the time a machine is designed. Over design means enhancing a design to avoid a particular type of failure. For instance, if a machine has only a few independent critical interacting parts, then over design may be an effective way of increasing machine reliability.

Design simplification implies a reduction in the number of interacting parts in a machine. Since there are now fever parts that can fail, machine reliability increases when the number of interacting part s is reduced. Redundant components are the building of backup components right into the machine so that if one part fails, its backing is automatically substituted. These three approaches can be sued together or separately to design more reliable machines.

3.5 Secondary Maintenance Responsibilities

As earlier mentioned, all maintenance departments are responsible for the repair of buildings and equipment and for performing certain preventive maintenance inspections, repairs, lubrication, and adjustments.

Additionally, some particular responsibilities have traditionally been added to these departments. For instance, housekeeping, janitorial, window cleaning, ground keeping and painting services are now usually performed by maintenance departments. These activities often embrace all areas of the facility, from restrooms to offices to production departments to warehouses. Within some plants, it is usual to find the area around each production worker's immediate workplace being cleaned by the worker, while the appearance and cleanliness of all other areas are the responsibility of the maintenance department.

Again, in some organisations, additional activities such as new construction, remodeling, safety equipment maintenance, loss prevention, security, public hazard control. Waste disposal and recycling and pollution control responsibilities have been assigned to their maintenance departments.

3.6 Current Trends in Maintenance Management

There is no doubt that production machinery today is far more complex than it was some years ago. For instance, computerised controls, robotic (especially in developed countries) new technology in metallurgy, more sophisticated electronic controls, new methods in lubrication technology and other developments have resulted in the way complex machines are maintained.

Consequently, special training programmes are being mounted to give maintenance workers the skills necessary to service and repair today's specialised equipment. In addition, subcontracting service firms have evolved to supply specialised maintenance services. It is now common to see computers, automobiles, office machines, and other equipment and facilities being serviced by outside subcontracting firms. In particular, their specialised training and fee structure, which is usually based on an as needed basis, combine to offer competent service at reasonable cost.

Furthermore, other technologies that reduce the cost of maintenance while improving the performance of production machines are now available. An example here is the network of computerized temperature - sensing probes connected to all key bearings in a machine system. When bearings being to fail, they overheat and vibrate, thus causing these sensing systems to indicate that a failure is imminent. Consequently, the massive damage to machines that could happen when bearings fail can therefore be avoided.

Another modern trend is the application of computers to maintenance management. There are at least five general areas in maintenance that commonly use computer assistance. These are:

(i) Scheduling maintenance projects

(ii) Maintenance cost reports by production department, cost category and other classifications

(iii) Inventory status reports for maintenance parts and supplies

(iv) Parts failure data, and

(v) Operations analysis studies, which may include computer simulation, waiting lines (queuing theory), and other analytical programmes.

In spite of the fact that computers, robots, and high-tech machinery are important concerns in maintenance management today, people concerns may actually be at the heart of better maintenance. Hence, one important trend is the involvement of production workers in repairing their own machines and performing PM on their own machines. In this regard, widening the scope of workers' jobs to include maintenance of their machines, would not only improve maintenance, but may actually result in numerous side benefits.

From this discussion, it is very clear that maintenance today in production and operations management (POM) means more than simply maintaining the machines of production. Since POM has broadened its perspectives from minimizing short range costs to other, long-range performance measures such as customer service, return on investment, product quality, and providing for workers' needs, maintenance too, has broadened its own perspectives. Hence, maintenance in the present day means that the prompt supply of quality products and services is what is maintained, not merely machines.

4.0 CONCLUSION

You have learned in this unit, the importance of keeping production equipment adjusted, repaired, and in good operating condition. You also learned the direct impacts of equipment malfunctioning on both manufacturing and service industries. You were again thought that maintenance today means more than simply maintaining the machines of production. In addition, prompt supply of quality products and services is also maintained.

5.0 SUMMARY

Maintaining the productive capability of an organisation is an important function. Maintenance includes all of the activities related to keeping facilities and equipment in good operating order and maintaining the appearance of buildings and grounds.

SELF ASSESSMENT EXERCISE (SAE)

1. List the costs associated with equipment breakdown
2. What are three different ways preventive maintenance is scheduled?
3. Explain the term predictive maintenance and the importance of good records.

6.0 TUTOR - MARKED ASSIGNMENT QUESTION

1. What are the current trends in maintenance management?
2. Discuss the approaches being used to deal with breakdowns

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