COURSE GUIDE

BHM 777
OPERATIONS AND QUALITY MANAGEMENT

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Introduction

BHM 777: Operations and Quality Management is a two credit semester course. It will be available to all students taking the MBA programme in the School of Business and Human Resources Management.

The course consists of 20 units involving Operations and Quality Management. It will illustrate how operations management is put into practice, operations functions in an organisation, giving you a real inside look at all aspects of operations management and the importance of Quality Management to the growth of business organisation.

Course Contents

The course contents are Introduction to Operations Management, Designing Operations, Managing Operations, Quantitative Modules, quality Approach to Quality Management, Quality and Global Competitiveness, Strategic Management, Quality Management, Ethics and Corporate Social Responsibility, Partnering and Strategic Alliances, Quality Culture Customer Satisfaction, Retention and Loyalty, Employee Empowerment, Leadership and Change, Team Building and Teamwork, Effective Communication, Education and Training, Overcoming Politics, Negativity and Confliction in the Workplace, and finally ISO 9000 and Total Quality.

Course Aim

The aim of the course is to help expose you to Operations and Quality Management, to modern-day techniques in Operations Management, Quality Management for production, processing and services.

The course is also aimed at making you appreciate the importance of Operations and Quality Management to modern-day global competitiveness.

The aims will be achieved by:

1. explaining operations and quality management
2. identifying the importance of operations and quality management
3. explaining the approaches to operation and quality management
4. discussing the major contributors to operation and quality management
5. citing examples where operations and quality management have been employed to the good of such organizations.

Course Objectives

At the end of this course, you will be able to:

1. explain the meaning of operations and Quality Management
2. distinguish between Staff Management and Operations Management in their various organisations
3. explain the various approaches to Operations and Quality Management
4. appreciate the importance of Quality Management to the Growth and Global Competitiveness of their various organisations
5. be equipped with the Tools and Techniques of Operations and Quality Management
6. solve problems and make decisions using the skills acquired on the course
7. establish a Quality Management Department in their organisation.

Course Materials

1. Course guide
2. Study Units
3. Textbooks
4. Assignment Guide

Study Units

There are 20 units of this course, and they are divided into four modules which should be studied carefully.

Module 1

Unit 1 Operations and Productivity
Unit 2 Operations Strategy in a Global Environment
Unit 3 Project Management
Unit 4 Forecasting

Module 2

Unit 1 Designing of Goods and Services
Unit 2 Managing Quality
Unit 3 Process Strategy
Unit 4 Capacity Planning
Unit 5 Location Strategy
Unit 6 Layout Strategy
Unit 7 Human Resources and Job Design
Unit 8 Work Measurement

Module 3

Unit 1 Supply-Chain Management
Unit 2 E-Commerce and Operations Management
Unit 3 Inventory Management
Unit 4 Aggregate Planning
Unit 5 Material Requirements Planning (MRP) and Enterprise Resource Planning (ERP)
Unit 6 Short-Term Scheduling
Unit 7 Just-in-Time and Loan Production System
Unit 8 Maintenance and Reliability

Each study unit will take at least two hours and it includes the Introduction, Objectives, Main Content, Exercise, Conclusion, Summary and References. Others are the tutor marked questions.

6. You are expected to study the materials, reflect on them and do the exercises. Some of the exercises will necessitate visiting some business organisations. You are advised to do so in order to appreciate the importance of Operations and Quality Management to the Growth and Global Competitiveness of an organisation in modern-day economy.

7. There are also textbooks, under references for further reading. They are to give you additional information. Practice the tutor-marked assignment for additional and greater understanding and by so doing the stated learning objectives will be achieved.

The Modules

The course is divided into 3 modules:

The first module has four units; the second module has eight units while the third has eight units also.

The first module treats Introduction to Operational Management. The second module covers Designing Operation and Managing Quality. The third links the second, covering Managing Operation.

Schedule of Assignment

There will be five assignments and you are expected to do all the assignments by following the schedule presented below:

1. Introduction to Operational Management (Units 1, 2, 3 and 4)
2. Managing Quality (Module 2, Units 1 and 2)
3. Designing Operations and Quality (Module 2, Units 3, 4, 5, 6, 7 and 8)
4. Managing Operation (Module 3, Units 1, 2, 3, 4, 5, 6, 7 and 8)

Tutor-Marked Assignment

In doing the Tutor-Marked Assignment, you are expected to apply what you have learnt in the contents of the study units. These assignments, which are five in number, are expected to be submitted in to your tutor for grading. They constitute 40% of the total score.

Final Examination and Grading

At the end of the course, you will write the final examination. This will attract the remaining 60%. This makes a total final score of 100%.

Summary

Course BHM 777 (Operations and Quality Management) will equip you with an indepth knowledge and appreciation of the importance of Operations and Quality Management to the success of modern-day Production, Processing and Services Organisations. On completion of the course, you would have been armed with all the necessary skills in this field to effectively manage any business organisation.

Course Code BHM 777

Course Title Operations and Quality Management

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MODULE 1

UNIT 1 INTRODUCTION TO OPERATIONS MANAGEMENT

CONTENTS

1.0 INTRODUCTION

Operations Management (OM) is a discipline that applies to restaurants like Tantalizers as well as to factories like Sony, Ford and Maytag. The techniques of OM apply throughout the world to virtually all productive enterprises. It doesn’t matter if the application is in an office, a hospital, a restaurant, a department store, or a factory – the production of goods and services requires effective application of the concepts, tools, and techniques of OM that we have introduced in this course.

2.0 OBJECTIVES

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

Identify or define:

- production and Productivity
- operations Management OM
- what Operations Managers do
- services.

3.0 MAIN CONTENT

3.1 Introduction to Operations Management

3.2 What is Operations Management?

Production is the creation of goods and services. Operations **Management (OM) is a set of activities that creates value in the form of** goods and services by transforming inputs into outputs. Activities creating goods and services take place in all organizations. In manufacturing firms, the production activities that create goods are usually quite obvious. In them we can see the creation of a tangible product such as Sony TV or a Harley Davidson motorcycle.

In organizations that do not create physical products, the production function may be less obvious. It may be "hidden" from the public and even from the customer. Examples are the transformations that take place at a bank, hospital, airline office, or college.

Often when services are performed, no tangible goods are produced. Instead, the products may take such forms as the transfer of funds from a savings account to a current account, the transplant of a liver, the filling of an empty seat on an airline, or the education of a student. Regardless of whether the end product is a good or service, the production activities that go on in the organization are often referred to as operations or *operations management.*

3.3 Organising to Produce Goods and Services

To create goods and services, all organisations perform three functions. These functions are the necessary ingredients not only for production but also for an organisation's survival. They are:

1. Marketing, which generates the demand or at least takes the order for a product or service (nothing happens until there is a sale).
2. Production/operations, which creates product.
3. Finance/accounting, which cracks how well the organization is doing, pays the bills, and collects money. Universities, churches or mosques, and businesses all perform these functions. Even a volunteer group such as the Boy Scouts of Nigeria is organized to perform these three basic functions.

3.4 Why Study Operations Management?

We study OM for four reasons:

1. OM is one of the three major functions of any organization, and it is integrally related to all the other business functions. All organizations market (sell), finance (account), and produce (operate), and it is important to know how the OM activity functions. Therefore, we study how people organize themselves for productive *enterprise.*
2. We study OM because we want to know how goods and services are *produced. The production function is the segment of our society that* creates the products we use.
3. We study OM to understand what operations managers do. By understanding what these managers do, you can develop the skills necessary to become such a manager. This will help you explore the numerous and lucrative career opportunities in OM.
4. We study because it is such a costly part of an organization. A large percentage of the revenue of most firms is spent in the OM function. Indeed, OM provides a major opportunity for an organization to improve its profitability and enhance its services to society. It considers how a firm might increase its profitability via the production function.

3.5 What Operations Managers Do?

All good Operations Managers perform the basic functions of the management process. The management process consists of planning, *organizing, leading, and controlling. Operations managers apply this* management process to the decision they make in the operations managers function. The 10 major decisions of operations managers are shown in the table below. Successfully addressing each of these decisions requires planning, organizing, staffing, leading and controlling.

Ten Critical Decisions of Operations Management

Ten Decision Areas	**Issues**
Service and product design	What good or service should we offer? How should we design these products?
Quality management	How do we define the quality? Who is responsible for quality?
Process and capacity design	What process and what capacity will these products require? What equipment and technology is necessary for these processes?
Location	Where should we put the facility? On what criteria should we base the location decision?
Layout design	How should we arrange the facility? How large must the facility be to meet our plan?
Human resources and work design	How do we provide a reasonable and job environment? How much can we expect our employees to produce?
Supply-chain Management	Should we make or buy this component? Who are our suppliers and who can integrate into our e-commerce programme?
Inventory, material requirement planning and JIT (just-in-time)	How much inventory of each item should we have? When do we reorder?
Intermediate and short-term Scheduling	Are we better off keeping people on the payroll during slowdowns? Which job do we perform next?
Maintenance	Who is responsible for maintenance? When do we do maintenance?

3.6 The Heritage of Operations Management

The field of OM is relatively young, but its history is rich and interesting. Our lives and the OM discipline have been enhanced by the innovations and contributions of numerous individuals. We will now introduce a few of these people, and we provide summary of significant events in operations management.

Eli Whitney (1800) is credited for the early popularization of interchangeable parts, which was achieved through standardization and quality control. Through a contract he signed with the United States government for 10,000 muskets, he was able to command a premium price because of their interchangeable parts.

Frederic W. Taylor (1881), known as the father of scientific management, contributed to personnel selection, planning and scheduling, motion study and the now popular field of Ergonomics.

One of his major contributions was his belief that management should be much more resourceful and aggressive in the improvement of work methods. Taylor and his colleagues, Henry L. Grantt, Frank and Lillian Gilbert, were among the first to systematically seek the best way to produce.

Another of Taylor's contributions was the belief that management should assume more responsibility for:

1. Matching employees to the right job.
2. Providing the proper training.
3. Providing proper work methods and tools.
4. Establishing legitimate incentives for work to be accomplished.

3.7 Operations in the Service Sector

Manufacturers produce tangible products, whereas service products are often intangible. But many products are a combination of a good and a service which complicates the definition of a service. Because definitions vary, much of the data and statistics generated about the service sector are inconsistent. However, we will define services as including repair and maintenance, government, food and lodging, transportation, insurance, trade, financial, real estate, education, legal, medical, entertainment, and other professional occupations.

Differences between Goods and Services

Lets examine some of the differences between goods and services:

- Services are usually intangible (for example, your purchase of a ride in an empty airline seat between two cities) as opposed to a tangible goods.
- Services are often produced and consumed simultaneously; there is no stored inventory. For instance, the beauty salon produces a haircut that is "consumed" simultaneously, or the doctor produces an operation that is "consumed" as it is produced. We have not yet figured out how to take inventory of haircuts or appendectomies.
- Services are often unique. Your mix of financial coverage, such as investments and insurance policies, may not be the same as anyone else's, just as the medical procedure or a haircut produced for you is not exactly like anyone else's.

•Services have high customer interaction. Services are often difficult to standardize, automate or made as efficient as we would like because customer interaction demands uniqueness.

•Services have inconsistent product definition. Product definition may be rigorous, as in the case of an auto insurance policy, but inconsistent because policyholders change cars and mature.

•Services are often knowledge-based, as in the case of educational, medical and legal services and therefore hard to automate.

•Services are frequently dispersed. Dispersion occurs because services are frequently brought to the client/customer via a local office, a retail outlet or even a house call.

3.8 Exciting New Trends in Operations Management

One of the reasons OM is such an exciting discipline is that the operations manager is confronted with an ever-changing world. Both the approach to and the results of the 10 OM decisions in Trade 1.2 are subject to change. These dynamics are the result of a variety of forces, from globalization of world trade to the transfer of ideas, products, and money at electronic speeds.

•Global focus: The rapid decline in communication and transportation costs has made markets global. At the same time, resources in the form of materials, talent and labour have also become global. Contributing to this rapid globalization are countries throughout the world that are vying for economic growth and industrialization. Operations managers are responding with innovations that generate and move ideas, parts and finished goods rapidly, wherever needed.

•Just-in-time performance: vast financial resources are committed to inventory, making it costly. Inventory also impedes response to rapid changes in the marketplace. Operations managers are viciously cutting inventories at every level, from raw-materials to finished goods.

•Supply-chain partnering: shorter product life cycles, driven by demanding customers, as well as rapid changes in material and processes, require suppliers to be more in tune with the needs of end users. And because suppliers usually supply over half of the value of products, operations managers are building long-term partnerships with critical players in the supply chain.

• Rapid product development: rapid international communication of news, entertainment, and lifestyles is dramatically chopping away at life span on products. Operations managers are responding with management structures and technology that are faster and alliances (partners) that are more effective.

•Mass customization: once managers begin to recognize the world as a marketplace, then the individual differences become quite obvious. Cultural differences, in a world where customers are increasingly aware of options, places substantial pressure on firms to respond. Operations managers are responding with production processes that are flexible enough to cater for individual whims of customers. The goal is to produce customized products, whenever and wherever needed.

•Empowered employees: The knowledge explosion and a more technical workplace have combined to require more competence at the workplace. Operations managers are responding by moving more decisions making to the individual worker.

•Environmentally sensitive production: The Operation manager's continuing battle to improve productivity is increasingly concerned with designing product and processes that are environmentally friendly. That means designing products that are biodegradable or automobile components that can be re-used or recycled or making packaging more efficient.

•Ethics: Operations managers are taking their place in the continuing challenge to enhance ethical behavior.

3.9 The Productivity Challenge

The creation of goods and services requires changing resources into goods and services. The more efficiently we make this change, the more productive we are and the more value is added to the good or service provided. Productivity is the ratio of outputs (goods and services) divided by the inputs (resources, such as labour and capital). The operations manager's job is to enhance (improve) this ratio of outputs to inputs. Improving productivity means improving efficiency.

3.9.1 Productivity Measurement

The measurement of productivity can be quite direct. Such is the case when productivity is measured by labour-hours per ton of a specific type of steel. Although labour-hours is a common measure of input, other measures such as capital (nairas invested), materials (tons of ore), or energy (kilo-watts of electricity) can be used. An example of this can be summarized in the following equation:

$$\text{Productivity} = \frac{\text{Units produced}}{\text{Input used}}$$

For example, if units produced = 1,000 and labour-hours used is 250, then:

$$\text{Productivity} = \frac{\text{Units produced}}{\text{Labour-hours used}} = \frac{1{,}000}{250} = 4 \text{ units per labour-hour}$$

The use of just one resource input to measure productivity, as shown in the Equation, is known as single-factor productivity. However, a broader view of productivity is multifactor productivity, which includes all inputs (e.g., capital, labour, material, energy). Multifactor productivity is also known as total factor productivity. Multifactor productivity is calculated by combining the input units, as shown below:

$$\text{Productivity} = \frac{\text{Output}}{\text{Labour + Material + Energy + Miscellaneous}}.$$

Use of productivity measures aids managers in determining how well they are doing. The multifactor productivity measures provide better information about the trade-offs among factors, substantial measurement problems remain. Some of these measurement problems are listed here.

1. **Quality may change while the quantity of inputs and outputs** remains constant. Compare a radio set of this decade with one of the 1940s. Both are radios, but few people will deny that the quality has improved. The unit of measure of a radio is the same, but the quality has changed.

2. **External elements may cause an increase or decrease in** productivity of which the system under study may not be directly responsible. A more reliable electric power service may greatly improve production, thereby improving the firm's productivity because of the support system rather than because of managerial decisions made within the firm.

3. **Precise units of measure may be lacking. Not all automobile** require the same inputs: some cars are subcompacts, others are 911 Turbo Porsches.

Productivity measurement is particularly difficult in the service sector, whereby the end product can be hard to define. For example, economic statistics ignore the quality of your haircut, the outcome of a court case or service at a retail store. In some cases, adjustments are made for the quality of the product sold but not the quality of the sales presentation or the advantage of a broader product selection. Productivity measurements require specific inputs and outputs, but a free economy is producing what people want which includes convenience, speed and safety.

Traditional measures of outputs may be a very poor measure of these other measures of worth. Note the quality-measurement problems in a law office, where each case is different, altering the accuracy of the measure "cases per labour hour" or "cases per employee."

3.9.2 Productivity Variables

Productivity increases are dependent on three productivity variables:

1. Labour, which contributes about 10% of the annual increase.
2. Capital, which contributes about 38% of the annual increase.
3. Management, which contributes about 52% of the annual increase.

These three factors are critical to improved productivity. They represent the broad areas in which managers can take action to improve productivity.

1. **Labour: Improvement in the contribution of labour to** productivity is the result of a healthier, better-educated and better nourished labour force. Some increase may also be attributed to a shorter work week. Historically, about 10% of the annual improvement in productivity is attributed to improvement in the quality of labour. Three key variables for improved labour productivity are:

a) Basic education appropriate for an effective labour force.
b) Diet of labour force.
c) Social overhead that makes labour available, such as transportation and sanitation.

In developed nations, a forth challenge to management is maintaining and enhancing the skill of labour in the midst of rapidly expanding technology and knowledge.

Overcoming shortcomings in the quality of labour while other countries have a better labour force is a major challenge. Perhaps improvements can be found not only through increasing competence of labour but also via a fifth item, better utilized labour with a stronger commitment. Training, motivation, team building and the human resource strategies, as well as improved education, may be among the many techniques that will contribute to increased labour productivity. Improvements in

labour productivity are possible: however, they can be expected to be increasingly difficult and expensive.

2. **Capital: Human beings are tool using animals. Capital** investment provides those tools. Inflation and taxes increase the cost of capital, making capital investment increasingly expensive. When the capital invested per employee drops, we can expect a drop in productivity. Using labour rather than capital may reduce unemployment in the short run, but it also make economies less productive and therefore lowers wages in the long run. Capital investment is often a necessity, but seldom a sufficient ingredient in the battle for increased productivity.

The trade-off between capital and labour is continually in flux. The higher the interest rate, the more projects requiring capital are "squeezed out": They are not pursued because the potential return on investment for a given risk has been reduced. Managers adjust their investment plans to changes in capital cost.

3. **Management: Management is a factor of production and an** economic resource. Management is responsible for ensuring that labour and capital are effectively used to increase productivity. Management accounts for over half of the annual increase in productivity. It includes improvements made through the use of knowledge and the application of technology.

Using knowledge and technology are critical in postindustrial societies. Consequently, postindustrial societies are known as knowledge societies. Knowledge societies are those in which much of the labour force has migrated from manual work to technical and information processing-tasks requiring ongoing education. The required education and training are important high-cost items that are the responsibility of operations managers as they build workforces and organizations. The expanding knowledge base of contemporary society requires that managers use technology and knowledge effectively.

More effective use of capital also contributes to productivity. It falls on the operations manager, as a productivity catalyst, to select the best new capital investments as well as to improve the productivity of existing investments.

The productivity challenge is difficult. A country cannot be a world-class competitor with second-class inputs. Poorly educated labour, inadequate capital and outdated technology are second-class inputs. High productivity and high-quality outputs require high-quality inputs, including good operations managers.

3.9.3 Productivity and the Service Sector

The service sector provides a special challenge to the accurate measurement of productivity improvement. The traditional analytical framework of economic theory is based primarily on goods producing activities. Consequently, most published economic data relate to goods production. But the data do indicate that as our contemporary service economy has increased in size, we have had slower growth in productivity.

Productivity of the service sector has proven difficult to improve because service-sector work is

1. Typically labour-intensive (for example, counseling, teaching).
2. Frequently focused on unique individual attributes or desires (for example, investment advice).
3. Often an intellectual task performed by professionals (for example, medical diagnosis).
4. Often difficult to mechanize and automate (for example, a haircut).
5. Often difficult to evaluate for quality (for example, performance of a law firm).

The more intellectual and personal the task, the more difficult it is to achieve increases in productivity. Low-productivity improvement in the service sector is also attributable to the growth of low-productivity activities in the service sector. These include activities not previously a part of the measured economy, such as child care, food preparation, house cleaning and laundry service. These activities have moved out of the home and into the measured economy as more and more women have joined the workforce. Inclusion of these activities has probably resulted in lower measured productivity for the service sector, although, in fact actual productivity has probably increase because these activities are now more efficiently produces than previously.

However, in spite of the difficulty of improving productivity in the service sector, improvements are being made. And this text presents a multitude of ways to do it. Indeed, an article in the Harvard Business *Review on the concept that managers can improve service productivity,* the authors argue that "the primary reason why the productivity growth rate has stagnated in the service sector is management" and they find astonishing what can be done when management pays attention to how work actually gets done.
Although the evidence indicates that all industrialized countries have the same problem with service productivity, the U.S. remains the world leader in overall productivity and service productivity. Retailing is twice as productive in the U.S. as in Japan, where law protects shopkeepers from discount chains. The U.S. telephone industry is at least twice as

productive as Germany's. The U.S. banking system is also 33% more efficient than Germany's banking oligopolies.

However, because productivity is central to the operations manager's job and because the service sector is so large, we take special note in this text of how to improve productivity in the service sector.

3.10 Ethics and Social Responsibility

Operations managers are subjected to constant changes and challenges. The system they build to convert resources into good services are complex. The physical and social environment changes, as do laws and values. These changes present a variety of challenges that come from the conflicting perspectives of stakeholders such as customers, distribution, suppliers, owners, lenders, and employees. These stakeholders, as well as government agencies at various levels, require constant monitoring and thoughtful responses.

Identifying ethical and socially responsible responses is not always clear-cut. Among the many ethical challenges facing operations manager are:

- developing safe quality products;
- maintaining a clean environment;
- providing a safe workplace;
- honouring community commitments.

Managers must do all of this in an ethical and socially responsible way while meeting the demands of the market place. If operations managers have a moral awareness and focus on increasing productivity in a system where all stakeholders have a voice, then many of the ethical challenges will be successfully addressed. The organization will use fewer resources, the employees will be committed, the market will be satisfied, and the ethical climate will be enhanced.

SELF ASSESSMENT EXERCISE

1. Why should one study Operations Management?
2. Name the 10 decision areas of Operations Management.

4.0 CONCLUSION

Operations, marketing, and finance/accounting are the three functions basic to all organizations. The operations function creates goods and services. Much of the progress of operations management has been made in the twentieth century, but since the beginning of time, humankind has been attempting to improve its material well-being. Operations managers are key players in the battle for improved productivity.

5.0 SUMMARY

However, as societies become increasingly affluent, more of their resources are devoted to services. In the U.S., more than three quarters of the workforce are employed in the service sector. Productivity improvements are difficult to achieve, but operations managers are the primary vehicle for making improvements.

6.0 TUTOR-MARKED ASSIGNMENT

Productivity can be measured in a variety of ways, such as by labour, capital, energy, material usage, and so on. At Modern Lumber Inc., Art Binley, president and producer of apple crates sold to growers, has been able, with his current equipment, to produce 240 crates per 100 logs. He currently purchases 100 logs per day, and each log requires 3 labour-hours to process. He believes that he can hire a professional buyer who can buy a better quality log at the same cost. If this is the case, he can increase his production to 260 crates per 100 logs. His labour-hours will increase by 8 hours per day.

What will be the impact on productivity (measured in crates per labour-hour) if the buyer is hired?

7.0 REFERENCES/FURTHER READINGS

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UNIT 2 OPERATIONS STRATEGY IN A GLOBAL ENVIRONMENT

CONTENTS

1.0 INTRODUCTION

Today's operations manager must have a global view of operations strategy. Rapid growth in world trade and emerging markets like China and Eastern Europe means that many organizations must extend their operations globally. Making a product only in Nigeria and then exporting it, no longer guarantees success or even survival.

There are new standards of global competitiveness that include quality, variety, customization, convenience, timelines, and cost. This globalization of strategy contributes efficiency and adds value to products and services offered the world, but it also complicates the operations manager's job.

Companies today respond to the global environment with strategies and speeds unheard of in the past.

2.0 OBJECTIVES

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

Identify or Define

- mission
- strategy
- ten division of OM
- multinational corporation.

3.0 MAIN CONTENT

3.1 Operations Strategy in a Global Environment

3.1.1 A Global View of Operations

There are many reasons why a domestic business operation will decide to change to some form of international operation. These can be viewed as a continuum ranging from one tangible reason to another.

3.1.2 Reduce Costs

Many international operations seek to take advantage of the tangible opportunities to reduce their costs. Foreign locations with lower wages can help lower both direct and indirect costs. Less stringent government regulations on a wide variety of operation practices (e.g., environmental control, health and safety, etc.) reduce costs. Opportunities to cut the cost of taxes and tariffs also encourage foreign operations.

Shifting low-skilled jobs to another country has several potential advantages. First, and most obviously, the firm may reduce costs. Second, moving the lower skilled jobs to a lower cost location, frees higher cost workers for more valuable tasks. Third, reducing wage costs allows the savings to be invested in improved products and facilities (and the retraining of existing workers if necessary) at the home location.

3.1.3 Improve the Supply Chain

The supply chain can often be improved by locating facilities in countries where unique resources are available. These resources may be expertise, labour, or raw material. For example, auto-styling studios from throughout the world are migrating to the auto-mecca of southern California to ensure the necessary expertise in contemporary auto-design. Similarly, world athletic shoe production has migrated from South Korea to Guangzhou, China: This location takes advantage of the low-cost labour and production competence in a city where 40,000 people work making athletic shoes for the world. A perfume essence manufacturer wants a presence in Grasse, France, where much of the world's perfume essences are prepared from the flowers of the Mediterranean.

3.1.4 Provide Better Goods and Services

Although the characteristics of goods and services can be objective and measurable (e.g., number of on-time deliveries) they can also be subjective and less measurable (e.g., sensitivity to culture). We need an even better understanding of differences in culture and of the way business is handled in different countries. Improved understanding as the result of local presence permits firms to customize products and services to meet unique cultural needs in foreign markets.

Another reason for international operations is to reduce response time to meet customers' changing product and service requirements. Customers who purchase goods and services from U.S. firms are increasingly located in foreign countries. Providing them with quick and adequate service is often improved by locating facilities in their home countries.

3.1.5 Understand Market

Because international operations require interaction with foreign customers, suppliers, and other competitive businesses, international firms inevitably learn about opportunities for new products and services. Europe led the way with cell phone innovations, and now the Japanese lead with the latest cell phone fads. Knowledge of these markets not only helps firms diversify from their customer base, add production flexibility, and smoothen the business cycle.

3.1.6 Learn to Improve Operations

Learning does not take place in isolation. Firms serve themselves and their customers well when they remain open to the free flow ideas. For example, General Motors found that it could improve operations by jointly building and running with the Japanese, an auto assembly plant in San Jose, California. This strategy allows GM to contribute to production and inventory ideas. GM also used its employees and experts from Japan to help design its U.S. Saturn plant around production ideas from Japan. Similarly, operations managers have improved equipment and layout by learning from the ergonomic competence of the Scandinavians.

3.1.7 Attract and Retain Global Talent

Global organisations can attract and retain better employees by offering more employment opportunities. They need people in all functional areas and areas of expertise worldwide. Global firms can recruit and retain good employees because they provide both greater growth opportunities and insulation against unemployment during times of economic downturn. During economic downturns in one country or continent, a global firm has the means to relocate unneeded personnel to more prosperous locations. Global organizations also provide incentives for people who like to travel or take vacations in foreign countries.

3.2 Developing Missions and Strategies

An effective operations management effort must have a mission so it knows where it is going and a strategy to guide it to get there. This is the case for a small or domestic organization, as well as a large international organization.

3.2.1 Mission

Economic success, indeed survival is the result of identifying missions to satisfy a customer's needs and wants. We define the organisation's mission as its purpose – what it will contribute to society. Mission statements provide boundaries and focus for organizations and the concept around which the firm can rally. The mission states the rationale for the organisation's existence.

Developing a good strategy is difficult, but it is much easier if the mission has been well defined. Once an organisation's mission has been decided, each functional area within the firm determines its supporting missions. By functional area we mean the major disciplines required by the firm such as marketing, finance/accounting, and production/operations. Missions for each function are developed to support the firms overall mission. Then within that function, lower-level supporting missions are established for the OM functions.

3.2.2 Strategy

With the mission established, strategy and its implementation can begin. Strategy is an organisation's action plan to achieve the mission. Each functional area has a strategy for achieving its mission and for helping the organization reach the overall mission. These strategies exploit opportunities and strengths, neutralize threats, and avoid weaknesses. In the following sections we will describe how strategies are developed and implemented.
Firms achieve missions in three conceptual ways: (1) differentiation (2) cost leadership and (3) response. This means operations managers

are called on to deliver goods and services that are (1) better, or at least different (2) cheaper and (3) more responsive. Operations managers translate these strategic concepts into tangible tasks to be accomplished. Any one or combination of these strategic concepts can generate a system that has a unique advantage over competitors.

3.3 Achieving Competitive Advantage

Each of the three strategies provides an opportunity for operations managers to achieve competitive advantage. Competitive advantage implies the creation of a system that has a unique advantage over competitors. The idea is to create customers value in an efficient and sustainable way. Pure forms of these strategies may exist, but operation managers will more likely be called on to implement some combination of them. Let us briefly look at how managers achieve competitive advantage via differentiation, low cost, and response.

3.3.1 Competing on Differentiation

Differentiation is concerned with providing uniqueness. A firm's opportunities for creating uniqueness are not located within a particular function or activity but can arise in virtually everything that the firm does. Moreover, because most products include some services and most services include some products, the opportunities for creating uniqueness are limited only by imagination. Indeed, differentiation should be thought of as going beyond both physical characteristics and service attributes to encompass everything about the product or service that influences the value that the customer derives from it.

Therefore, effective operations managers assist in defining everything about a product or service that will influence the potential value to the customer. This may be the convenience of a broad product line, product features or a service related to the product. Such services can manifest themselves through convenience (location of distribution centres or stores), training, product delivery and installation, or repair and maintenance services.

3.3.2 Competing on Cost

Low-cost leadership entails achieving maximum value as defined by your customer. It requires examining each of the 10 OM decisions in a relentless effort to drive down costs while meeting customers' expectation of value. A low-cost strategy does not imply low value or low quality.

3.3.3 Competing on Response

The third strategy option is response. Response is often thought of as flexible response, but it also refers to reliable and quick response. Indeed, we define response as including the entire range of values related to timely product development and delivery, as well as reliable scheduling and flexible performance.

Flexible performance may be thought of as the ability to match changes in a marketplace where design innovations and volume fluctuate substantially.

3.4 Ten Strategic on Decisions

Differentiation, low-cost and response can be achieved when managers make effective decisions in 10 areas of OM. These are collectively known as operations decision. The 10 decisions of OM that support mission and implement strategies are as follows:

1. **Goods and Service Design: Designing goods and services** defines much of the transformation process. Cost, quality and human resource decisions are often determined by design decisions. Designs usually determine the lower limits of cost and the upper limits of quality.

2. **Quality: The customer's quality expectations must be determined** and policies and procedures established to identify and achieve that quality.

3. **Process and Capacity Design: Process options are available for** products and services. Process decisions commit management to specific technology, quality, human resource use, maintenance. These expenses and capital commitments will determine much of the firm's basic cot structure.

4. **Location Selection: Facility location decisions for both** manufacturing and service organizations may determine the firm's ultimate success. Errors made at this juncture may overwhelm other efficiencies.

5. **Layout Design: Material flows, capacity needs, personnel levels,** technology decisions, and inventory requirements influence layout.

6. **Human Resources and Job Design: People are an integral and** an expensive part of the total system design. Therefore, the

quality of work life provided, the talent and skills required, and their costs must be determined.

7. Supply-Chain Management: These decisions determine what is to be made and what is to be purchased. Consideration is also given to quality, delivery, and innovation, all at a satisfactory price. Mutual trust between buyer and supplier is necessary for effective purchasing.

8. Inventory: Inventory decisions can be optimized only when customer satisfaction, suppliers, production schedules, and human resource planning are considered.

9. Scheduling: Feasible and efficient schedules of production must be developed; the demands on human resources and facilities must be determined and controlled.

10. Maintenance: Decisions must be made regarding desired levels of reliability and stability, and systems must be established to maintain that reliability and stability.

3.5 Issues in Operations Strategy

Once a firm has formed a mission, developing and implementing specific strategy requires that the operations manager considers a number of issues. We will examine these issues in three ways. First, we look at what research tells us about effective operations management strategies. Second, we identify some of the preconditions to developing effective OM strategy. Third, we look at the dynamics of OM strategy development.

3.6 Strategy Development and Implementation

Once firms understand the issue involved in developing an effective strategy, they evaluate their internal strengths and weaknesses as well as the opportunities and threats of the environment. This is known as SWOT analysis (for Strength, Weakness, Opportunities, and Threats). Beginning with SWOT analysis, firms position themselves, through their strategy, to have a competitive advantage.

The firm may have excellent design skills or great talent at identifying outstanding locations. However, the firm may recognize limitations of its manufacturing process or in finding good suppliers. The idea is to maximize opportunities and minimize threats in the environment while maximizing the advantages of the organisation’s strengths and minimizing the weaknesses.

Any preconceived ideas about mission are then reevaluated to ensure they are consistent with the SWOT analysis. Subsequently, a strategy for achieving the mission is developed. The strategy is continually evaluated against the value provided, customers, and competitive realities.

3.7 Global Operation Strategy Options

As we suggested earlier in this unit, many operations strategies now require an international dimension. We tend to call a firm with an international dimension, an international business or a multinational corporation. An international business is any firm that engages in international trade or investment. This is a very broad category and is the opposite of a domestic or local firm.

A Multi-National Corporation (MNC) is a firm with extensive international business involvement. MNCs buy resources, create goods or services, and sell good or services in a variety of countries. The term *multinational corporation applies to most of the world's large,* well-known businesses.

SELF ASSESSMENT EXERCISE

Define the following:

1. Mission
2. Strategy.

4.0 CONCLUSION

Effective use of resources, whether domestic or international, is the responsibility of the professional manager, and professional managers are among the few in our society who can achieve this performance. The challenge is great and the rewards to the manager and to society is substantial.

5.0 SUMMARY

Global operations provide an increase in both the challenges and opportunities for operations managers. Although, the task is challenging, operations managers can improve productivity in a competitive, dynamic global economy. They can build and manage OM functions that contribute in a significant way to competitiveness.
Organisations identify their strengths and weaknesses. They then develop effective missions and strategies that account for these strengths

and weaknesses and complement the opportunities and threats in the environment. If this procedure is performed well, the organization can have competitive advantage through some combination of product differentiation, low cost, and response. This competitive advantage is often achieved via a move to international, multidomestic, global, or transnational strategies.

6.0 TUTOR-MARKED ASSIGNMENT

The global tyre industry continues to consolidate. Michelin buys Goodsrich and Uniroyal and builds plants throughout the world. Bridgestone buys Firestone, expands its research budget, and focuses on world markets. Goodyear spends almost 4% of its sales revenue on research. These three aggressive firms have come to dominate the world tyre market with a 15% to 20% market share each.

Against this formidable array the old-line Italian tyre company Pirelli responded but with two mistakes: the purchase of Armstrong Tyre and a disastrous bid to take over the German tire marker Continental AG. Pirelli still had only 5% of the market and was losing $500 million a year while the competition was getting stronger. Tyres are tough, competitive business that rewards companies with strong market shares and long production runs. Use SWOT analysis to establish a feasible strategy for Pirelli.

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 PROJECT MANAGEMENT

CONTENTS

1.0 INTRODUCTION

Scheduling project is a difficult challenge to operations managers. The stakes in project management are high. Cost overruns and unnecessary delays occur due to poor scheduling and controls.

Projects that take months or years to complete are usually developed outside the normal production system. Project organizations within the firm may be set up to handle such jobs and are often disbanded when the project is complete. On other occasions, managers find projects just like a part of their job. The management of projects involves three phases:

1. **Planning: This phase includes goal setting, defining the** project, and team organization.

2. **Scheduling: This phase relates people, money, and supplies** to specific activities and relates activities to each other.

3. **Controlling: Here the firm monitors resources, costs,** quality, and budgets. It also revises or changes plans and shifts resources to meet time and cost demands.

2.0 OBJECTIVES

When you complete this unit, you should be able to:

Identify or define

•work breakdown structure
•critical part
•AOA and AON networks
•forward and backward passes
•variability in activity times.

Describe or explain

•the role of the project manager
•project evaluation and review technique PERT
•Critical Part Method (CPM).

3.0 MAIN CONTENT

3.1 Project Management

3.2 Project Planning

Projects can be defined as a series of related tasks directed toward a major output. In some firms a project organization is developed to make sure existing programs continue to run smoothly on a day-to-day basis while new projects are successfully completed.

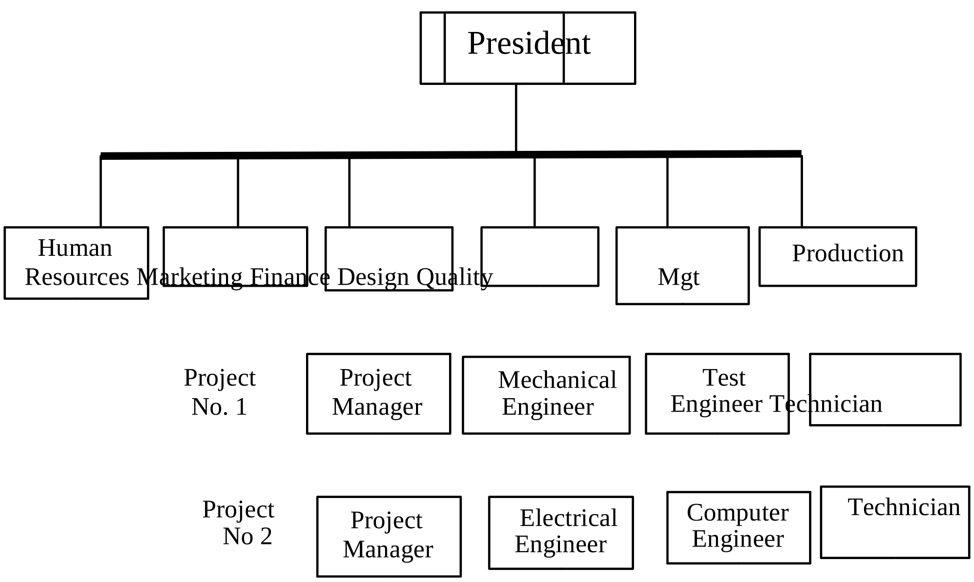
For companies with multiple large projects, such as construction firms, a project organization is an effective way of assigning the people and physical resources needed. It is a rare organization structure designed to achieve results by using specialists from throughout the firm. NASA and many other organizations use the project approach. You may recall Project Gemini and Project Apollo. These terms were used to describe teams that NASA organizes to reach space exploration objectives.

The project organization works best when:

1. Work can be defined with a specific goal and deadline.
2. The job is unique or somewhat unfamiliar to the existing organization.
3. The work contains complex interrelated tasks requiring specialized skills.
4. The project is temporary but critical to the organization
5. The project cuts across organizational lines.

3.2.1 The Project Manager

An example of a project organization is shown in the diagram below. Project team members are temporarily assigned to a project and report to the project manager. The manager heading the project coordinates activities with other departments and reports directly to top management. Project managers receive high visibility in a firm and are responsible for making sure that (1) all necessary activities are finished in proper sequence and on time; (2) the project comes in within budget; (3) the project meets its quality goals; and (4) the people assigned to the project receive the motivation, direction, and information needed to do the jobs. This means that project managers should be good coaches and communicators, and be able to organize activities from a variety of disciplines.



3.2.2 Ethical Issues Faced in Project Management

Project managers not only have high visibility but they also face ethical decisions on a daily basis. How they act, establishes the code of conduct for everyone on their project. On the personal level, project managers often deal with (1) offers of gifts from contractors, (2) pressure to alter status reports to mask the reality of delays, (3) false report for charges of time and expenses, and (4) pressures to compromise quality to meet bonus or penalty schedules.

Other major problems in projects large and small are:

•Bid rigging-divulging confidential information to some bidders to give them an unfair advantage.
•"Lowballing" contractors-who try to "buy" the project by bidding low with the hope of recovering costs later by contract renegotiations or by simply cutting corners.
•Bribery-particularly on international projects
•Expenses account padding, use of substandard materials, compromising health/safety standards, withholding needed information.
•Failure to admit project failure at the close of the project.

3.2.3 Work Breakdown Structure

The project management team begins its task well in advance of project execution so that a plan can be developed. One of its first steps is to carefully establish the project's objectives, then break the project down into manageable parts. This work breakdown structure (WBS) defines the project by dividing it into 15 major subcomponents (or tasks), which are then subdivided into more detailed components, and finally into a set of activities and their related costs. The division of the project into smaller and smaller tasks can be difficult, but is critical to managing the project and to scheduling success. Gross requirement for people, supplies, and equipment are also estimated in this planning phase.

The work breakdown structure typically decreases in size from top to bottom and is intended like this:

Level

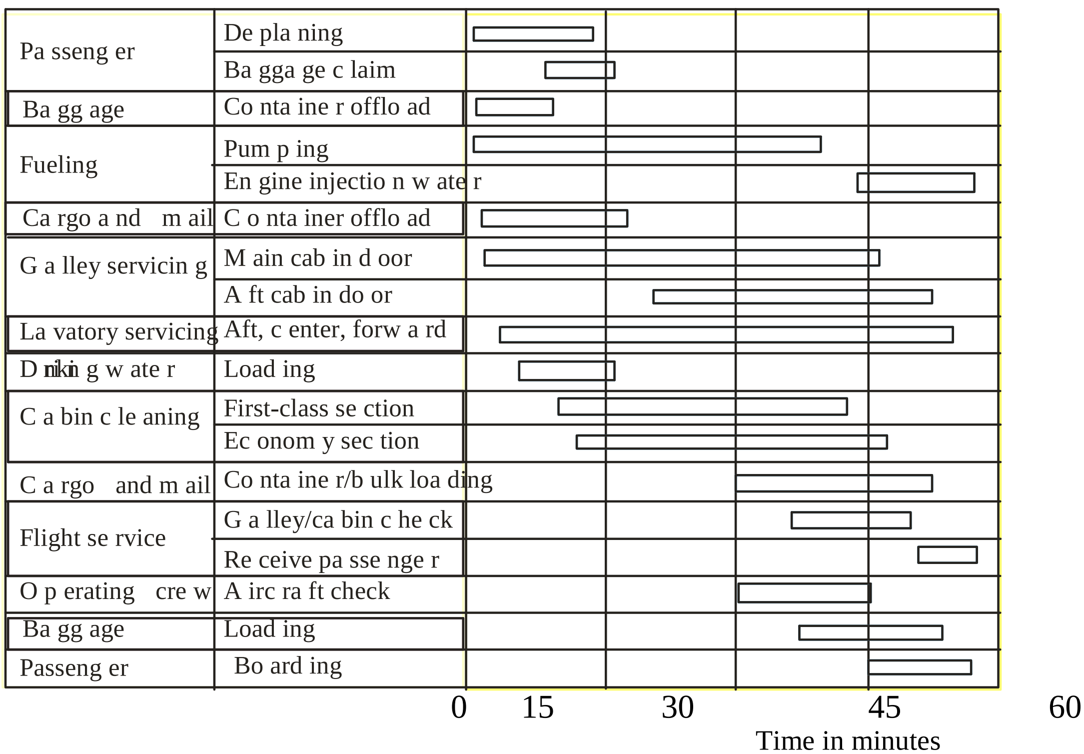
1. Project
2. Major tasks in the project
3. Subtasks in major tasks
4. Activities (or "work packages") to be completed

3.3 Project Scheduling

Project scheduling involves sequencing and allotting time to all project activities. At this stage, managers decide how long each activity will take and compute how many people and materials will be needed at each stage of production. Managers also chart separate schedules for personnel needs by type of skill (management, engineering, or pouring concrete, for example). Charts also can be developed for scheduling materials.

One popular project scheduling approach is the Gant chart. Gant charts are low-cost means of helping managers make sure that (1) all activities are planned for, (2) their order of performance is accounted for, (3) the activity time estimates are recorded, and (4) the overall project time is developed. Grant charts are easy to understand. Horizontal bars are drawn for each project activity along a time line. This illustration of a routine servicing of a Delta jetliner during a 60-minute layover shows that Grant charts can be used for scheduling repetitive operations. In this case, the chart points out potential delays.

Grant Chart of Service Activities for a Delta Jet during a 60-minute Layover



On simple projects, scheduling charts such as these can be used alone. They permit managers to observe the progress of each activity and to spot and tackle problem areas. Grant charts, though, do not adequately illustrate the interrelationship between the activities and the resources.

PERT and CPM, the two widely used network techniques that we shall discuss later, do have the ability to consider precedence relationships and interdependency of activities. On complex projects, the scheduling of which is almost always computerized, PERT and CPM thus have an edge over the simpler Grant charts. Even on huge projects, though, Grant charts can be used as summaries of project status and may complement the other network approaches.

To summarize, whatever the approach taken by a project manager, project scheduling serves several purposes:

1. It shows the relationship of each activity to others and to the whole project.
2. It identifies the precedence relationships among activities.
3. It encouraged the setting of realistic time and cost estimates for each activity.
4. It helps make better use of people, money, and material resources by identifying critical bottlenecks in the project.

3.4 Project Controlling

The control of large projects, like the control of any management system, involves close monitoring of resources, costs, quality, and budgets. Control also means using a feedback loop to revise the project plan and having the ability to shift resources to where they are needed most. Computerized PERT/CPM reports and charts are widely available today on personal computers. Some of the more popular of these programs are Primavera (by Primavera System, Inc.) Mac Project (by Apple Computer Corp.), Pertmaster (by Westminster Software, Inc.), VisiSchedule (by Paladin Software Corp.), Time Line (by Symantec Corp.), MS Project (by Microsoft Corp.)

These programs produce a broad variety of reports, including (1) detailed cost breakdown for each task, (2) total program labor curves, (3) cost distribution tables, (4) functional cost and hour summaries, (5) raw material and expenditure forecasts, (6) variance reports, (7) time analysis reports, and (8) work status reports.

3.5 Project Management Techniques: PERT and CPM

Program evaluation and review technique (PERT) and the critical path method (CPM) were both developed in the 1950s to help managers schedule, monitor, and control large and complex projects. CPM arrived first, in 1957, as a tool developed by J.E. Kelly of Remington Rand and M.R. Walker of duPont to assist in the building and maintenance of chemical plants at duPdont. Independently, PERT was developed in 1958 by Booz, Allen and Hamilton for the U.S Navy.

The Framework of PERT and CPM

PERT and CPM both follow six basic steps:

1. Define the project and prepare the work breakdown structure

2. Develop the relationships among the activities. Decide which activities must precede and which must follow others.
3. Draw the network connecting all the activities.
4. Assign time and/or cost estimates to each activity.
5. Compute the longest time path through the network. This is called critical path.
6. Use the network to help plan, schedule, monitor and control the project.

Step 5, finding the critical path, is a major part of controlling a project. The activities on the critical path represent tasks that will delay the entire project unless they are completed on time. Managers can gain the flexibility needed to complete critical tasks by identifying noncritical activities and replanning, rescheduling and reallocating labor and financial resources.

Although, PERT and CPM differ to some extent in terminology and in the construction of the network, their objectives are the same. Furthermore, the analysis used in both techniques is very similar. The major difference is that PERT employs three time estimates for each activity. These time estimates are used to compute expected values and standard deviations for the activity. CPM makes the assumption that activity times are known with certainty and hence requires only one time factor for each activity.

For purpose s of illustration, the rest of this section concentrates on a discussion of PERT, most of the comments and procedures described, however, apply just as well to CPM.

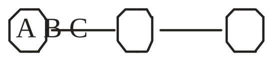
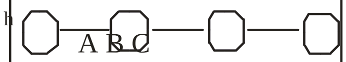
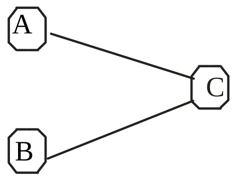
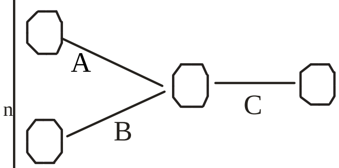
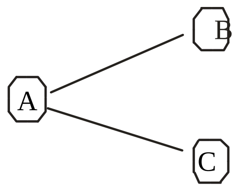
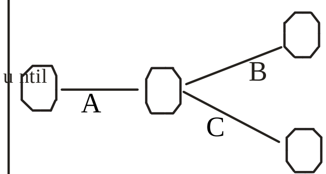
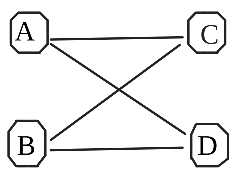
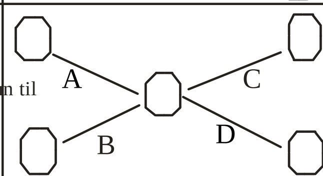
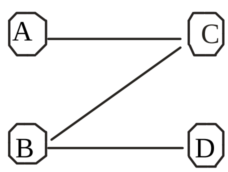
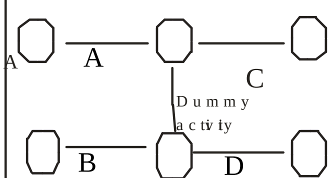
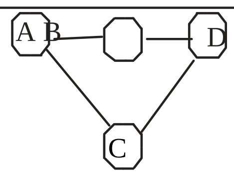
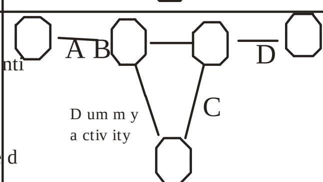
PERT and CPM are important because they can help answer questions such as the following about project with thousands of activities:

1. When will the entire project be completed?
2. What are the critical activities or tasks in the project-=that is, which activities will delay the entire project if they are late?
3. Which are the noncritical activities—the ones that can run late without delaying the whole project's completion?
4. What is the probability that the project will be completed by a specific date?
5. At any particular date, is the project on schedule, behind schedule, or ahead of schedule?
6. On any given date, is the money spent equal to, less than, or greater than the budgeted amount?
7. Are there enough resources available to finish the project on time?

8. If the project is to be finished in a shorter amount of time, what is the best way to accomplish this goal at the least cost?

Network Diagrams and Approaches

The first step in a PERT or CPM network is to divide the entire project into significant activities in accordance with the work breakdown structure. There are two approaches for drawing a project network: activity on node (AON) and activity on arrow (AOA). Under the AON convention, nodes designate activities. Under AOA, arrows represent activities. Activities consume time and resources. The basic difference between AON and AOA is that the nodes in an AON diagram represent activities. In an AOA network, the nodes represent the starting and finishing times of an activity and are also called events. So nodes in AOA consume neither time nor resources.

	Activity on Node (AON)	Activity Meaning	Activity Arrow (AOA)
(A)		A comes before B which comes before C	
(B)		A and B must both be completed before C can	
(C)		A and C cannot begin until A is completed	
(D)		C and D cannot begin until both A and B are	
(E)		C cannot begin until both A and B are complete, D cannot begin until B is completed. A dummy	
(F)		B and C cannot begin until A is completed. D cannot begin until both B and C are completed. A dummy activity is again introduced	

Determining the Project Schedule

Once the project network has been drawn to show all the activities and their precedence relationships, the next step is to determine the project schedule. That is, we need to identify the planned starting and ending time for each activity.

Three Time Estimates in PERT

In PERT, we employ a probability distribution based on three time estimates for each activity, as follows:

Optimistic time (a) = time an activity will take if everything goes as planned. In estimating this value, there should be only a small probability (say, 1/100) that the activity time will be < a.

Pessimistic time (b) = time an activity will take assuming very unfavorable conditions. In estimating this value, there should also be only a small probability (also, 1/100) that the activity time will be > b.

Most likely time (m) = most realistic estimate of the time required to complete an activity.

When using PERT, we often assume that activity time estimates follow the beta probability distribution. This continuous distribution is often appropriate for determining the expected value and variance for activity completion times.

To find the expected activity time t, the beta distribution weights the three time estimates as follows

$$t = (a + 4m + b)/6$$

That is, the most likely time (m) is given four times the weight as the optimistic time (a) and pessimistic time (b). The time estimate t computed using Equation 3-6 for each activity is used in the project network to compute all earliest and latest times.

3.6 Cost-Time Trade-Offs and Project Crashing

While managing a project, it is not uncommon for a project manager to be faced with either (or both) of the following situations: (1) the project is behind schedule, and (2) the scheduled project completion time has been moved forward. In either situation, some or all of the remaining activities need to be speeded up to finish the project by the desired due date. The process by which we shorten the duration of a project in the cheapest manner possible is called project crashing.

As mentioned earlier, CPM is a deterministic technique in which each activity has two sets of times. The first is the normal or standard time that we used in our computation of earliest and latest times. Associated with this normal time is the normal cost of the activity. The second time is the crash time, which is defined as the shortest duration required to complete an activity. Associated with this crash time is the crash cost of the activity. Usually, we can shorten an activity by adding extra resources (e.g., equipment, people) to it. Hence, it is logical for the crash cost of an activity to be higher than its normal cost.

The amount by which an activity can be shortened (i.e., the difference between its normal time and crash time) depends on the activity in question. We may not be able to shorten some activities at all. For example, if a casting needs to be heat-treated in the furnace for 48 hours, adding more resources does not help shorten the time. In contrast, we may be able to shorten some activities significantly (e.g., frame a house in 3 days instead of 10 days by using three times as many workers.)

Likewise, the cost of crashing (or shortening) an activity depends on the nature of the activity. Managers are usually interested in speeding up a project at the least additional cost. Hence, when choosing which activities to crash, and by how much, we need to ensure the following:

•the amount by which an activity is crashed is, in fact, permissible;
•taken together, the shortened activity durations will enable us to finish the project by the due date;
•the total cost of crashing is as small as possible.

Crashing a project involves four steps, as follows:

Step 1: Compute the crash cost per week (or other time period) for each activity in the network. If crash costs are linear over time, the following formula can be used:

$$\text{Crash cost per period} = \frac{(\text{Crash cost} - \text{Normal cost})}{(\text{Normal time} - \text{Crash time})}$$

Step 2: Using the current activity times, find the critical path(s) in the project network. Identify the critical activities.

Step 3: If there is only one critical path, then select the activity on this critical path that (a) can still be crashed and (b) has the smallest crash cost per period. Crash this activity by one period. If there is more than one critical path, then select one activity from each critical path such that (a) each selected activity can still be crashed and (b) the total crash cost per period of all selected activities is the smallest. Crash each activity by one period. Note that the same activity may be common to more than one critical path.

Step 4: Update all activity times. If the desired due date has been reached, stop. If not, return to Step 2.

SELF ASSESSMENT EXERCISE

Give an example of a situation in which project management is needed.

4.0 CONCLUSION

PERT and CPM do not, however solve all the project scheduling and management problems. Good management practices, clear responsibilities for tasks, and straightforward and timely reporting systems are also needed. It is important to remember that the models we described in this unit are only tools to help managers make better decisions.

5.0 SUMMARY

PERT, CPM and other scheduling techniques have proven to be valuable tools in controlling large and complex projects. With these tools, managers understand the status of each activity and know which activities are critical and which have slack: in addition, they know where crashing makes the most sense. Projects are segmented into discrete activities, and specific resources are identified. This allows project managers to respond aggressively to global competition. Effective project management also allows firms to create products and services for global market.

6.0 TUTOR-MARKED ASSIGNMENT

To complete the wing assembly for an experimental aircraft, Jim Gilbert has laid out seven major activities involved. These activities have been labeled A through G in the following table, which also shows their estimated completion times (in weeks) and immediate predecessors. Determine the expected time and variance for each activity.

ACTIVITY	a	m	b	IMMEDIATE PREDECESSORS
A	1	2	3	-
B	2	3	4	-
C	4	5	6	A
D	8	9	10	B
E	2	5	8	C, D
F	4	5	6	D
G	1	2	3	E

7.0 REFERENCES/FURTHER READINGS

Heizer Jay and Render Barry, Operations Management.

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UNIT 4 FORECASTING

CONTENTS

1.0 INTRODUCTION

Every day managers make decisions without knowing what will happen in the future. They order inventory without knowing what sales will be like, purchase new equipment despite uncertainty about demand for products, and make investments without knowing what profit will be like. Managers are always trying to make better estimates of what will happen in the future in the face of uncertainty. Making good estimates is the main purpose of forecasting.

2.0 OBJECTIVES

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

Identify or Define

•forecasting
•types of forecasts
•time horizons
•approaches to forecasts

Describe or Explain

•moving Averages
•exponential Smoothing
•seasonality.

3.0 MAIN CONTENT

3.1 What is Forecasting?

Forecasting is the art and science of predicting future events. It may involve taking historical data and projecting them into the future with some sort of mathematical Model. It may be a subjective or intuitive prediction. Or it may involve a combination of these that is, a mathematical model adjusted by a manager's good judgment.

As we introduce different forecasting techniques in this unit, you will see that there is seldom one superior method. What works best in one firm under one set of conditions may be a complete disaster in another organization, or even in a different department of the same firm. In addition, you will see that there are limits as to what can be expected from forecasts. They are seldom, if ever, perfect. They are also costly and time consuming to prepare and monitor.

Few businesses, however, can afford to avoid the process of forecasting by just waiting to see what happens and then taking their chances. Effective planning in both the short and long run depends on a forecast of demand for the company's products.

3.1.1 Forecasting Time Horizons

A forecast is usually classified by the future time horizon that it covers. Time horizon fall into three categories:

1. Short range forecast: This forecast has a time span of up to 1 year but is generally less than 3 months. It is used for planning purchasing, job scheduling, workforce levels, job assignments and production levels.

2. **Medium-range forecast: A medium-range, or intermediate** forecast generally spans from 3 months to 3 years. It is useful in sales planning, production planning and budgeting, cash and budgeting and analyzing various operating plans.

3. **Long-range forecast: Generally 3 years or more in time span,** long-range forecasts are used in planning for new products, capital expenditures, facility location or expansion and research and development.

Medium and long-range forecasts are distinguished from short-range forecasts by three features:

1. First, intermediate and long-run forecast deal with more comprehensive issues and support Management decisions regarding planning and products, plants and process. Implementing some facility decisions, such as GM's decision to open a new Brazilian manufacturing plant, can take 5 to 8 years from inception to completion.

2. Second, short-term forecasting usually employs different methodologies than longer-term forecasting. Mathematical techniques, such as moving averages, exponential smoothing and Trend extrapolation (all of which we shall examine shortly), are common to short-run projections. Broader, less quantitative methods are useful in predicting such issues as whether a new product, like the optical disk recorder, should be introduced into a company's product line.

3. Finally, as you would expect, short-range forecasts tend to be more accurate than longer-range forecasts. Factors that influence demand change every day. Thus, as the time horizon lengthens, it is likely that forecast accuracy will diminish. It almost goes without saying then, that sales forecasts must be updated regularly to maintain their value and integrity. After each sales period, forecasts should be reviewed and revised.

3.1.2 The Influence of Product Life Cycle

Another factor to consider when developing sales forecasts especially longer ones, is product life cycle. Products, and even services, do not sell at a constant level throughout their lives. Most successful product pass through four stages: (1) introduction, (2) growth, (3) maturity, and (4) decline.

Products in the first two stages of the life cycle need longer forecasts than those in the maturity and decline stages. Forecasts that reflect life cycle are useful in projecting different staffing levels, inventory levels, and factory capacity as the product passes from the first to the last stage

3.2 Types of Forecasts

Organizations use three major types of forecasts in planning future operations:

8. Economic forecasts address the business cycle by preceding inflation rates, money supplies, housing charts, and other planning indicators.

9. Technological forecasts are concerned with rates of technological progress, which can result in the birth of exciting new products, requiring new plants and equipment.

10. Demand forecast are projections of demand for a company's products or services. These forecasts, also called sales forecasts, drive a company's production, capacity, and scheduling systems and serve as inputs to financial, marketing, and personnel planning.

Economic and technological forecasting are specialized techniques that may fall outside the role of the operations manager. The emphasis in this book will therefore be on demand forecasting.

3.3 The Strategic Importance of Forecasting

Good forecasts are of critical importance in all aspect of a business. The forecast is the only estimate of demand until actual demand becomes known. Forecasts of demand therefore drive decisions in many areas. Let's look at the impact of product forecast on three activities: (1) human resources, (2) capacity, and (3) supply-chain management.

3.3.1 Human Resources

Hiring, training, and laying off workers all depend on anticipated demand. If the human resource department must hire additional workers without warning, the amount of training declines and the quality of the workforce suffers. A large Louisiana chemical firm almost lost its biggest customer when a quick expansion to around-the-clock shifts led to a total breakdown in quality control on the second and third shifts.

3.3.2 Capacity

When capacity is inadequate, the resulting shortages can mean undependable delivery, loss of customer, and loss of market share. This is exactly what happen to Nabisco when it underestimated the huge demand for its new low-fat Snackwell Devil's Food Cookies. Even with production lines working overtime, Nabisco could not keep up with demand, and it lost customers. When excess capacity is built, on the other hand, costs can skyrocket.

3.3.3 Supply-Chain Management

Good supplier relations and the ensuing price advantages for materials and parts depend on accurate forecasts. For example, auto manufacturers who want TRW Corp. to guarantee sufficient airbag capacity must provide accurate forecasts to justify TRW plant expansions. In the global marketplace, where expensive components for Boeing 787 jets are manufactured in dozens of countries, coordination driven by forecasts is critical. Scheduling transportation to Seattle for final assembly at the lowest possible cost and no last-minute surprises that can harm already low profit margins.

3.4 Seven Steps in the Forecasting System

Forecasting follows seven basic steps. We use Tupperware Corporation, the focus of this unit's Global Company Profile, as an example of each step.

1. Determine the use of the forecast. Tupperware uses demand forecasts to drive production at each of its 13 plants.

2. Select the items to be forecasted. For Tupperware, there are over 400 products, each with its own SKU (stock-keeping unit). Tupperware, like other firms of this type, does demand forecasts by families (or group) of SKUs.

3. Determine the time horizon of the forecasts. Is it short, medium, or long-term? Tupperware develops forecasts monthly, quarterly, and for 12-month sales projections.

4. Select the forecasting model(s). Tupperware uses a variety of statistical models that we shall discuss, including moving averages, exponential smoothing and regression analysis. It also employs judgmental, or non-quantitative, models.

5. Gather the data needed to make the forecast. Tupperware's world headquarters maintain huge databases to monitor the sale of each product.

6. Make the forecast.

7. Validate and implement the results. At Tupperware, forecasts are reviewed in sales, marketing, finance and production departments to make sure that the model, assumptions and data are valid. Error measures are applied; then the forecasts are to schedule material, equipment and personnel at each plant.

3.5 Forecasting Approach

There are two general approaches to forecasting, just as there are two ways to tackle all decision modeling. One is a quantitative analysis; the other is a qualitative approach. Quantitative forecasts uses a variety of mathematical models that rely on historical data and/or casual variables to forecast demand. Subjective or qualitative forecasts incorporate such factors as the decision maker's intuition, emotions, personal experiences and value system in reaching a forecast. Some firms use one approach and some use the other. In practice, a combination of the two is usually most effective.

3.5.1 Overview of Qualitative Methods

In this section, we consider four different qualitative forecasting techniques:

1. Jury of executive opinion: Under this method, the opinions of a group of high-level experts or managers, often in combination with statistical models, are pooled to arrive at a group estimate of demand. Bristol-Meyers Squibb Company, for example uses 220 well-known research scientists as its jury of executive opinion to get a grasp on future trends in the world of medical research.

2. Delphi method: There are three different types of participants in Delphi method: decision makers, staff personnel and respondents. Decision makers usually consist of a group of 5 to 10 experts who will be making the actual forecast. Staff personnel assist decision makers by preparing, distributing, collecting and summarizing a series of questionnaires and survey results. The respondents are a group of people, often located in different places, whose judgments are valued. This group provides inputs to the decision makers before the forecast is made.

The state of Alaska, for example, has used the Delphi method to develop its long-range economic forecast. An amazing 90% of the state's budget is derived from 1.5 million barrels of oil pumped daily through a pipeline at Prudhoe Bay. The large Delphi panel of experts had to represent all groups and opinions in the state and all geographic areas. Delphi was the perfect forecasting tool because panelist travel could be avoided. It also meant that leading Alaskans could participate because their schedules were not affected by meetings and distances.

3. **Sales force composite: In this approach, each saleperson** estimates what sales will be in his or her region. These forecasts are then reviewed to ensure that they are realistic. Then they are combined at the district and national levels to reach an overall forecast. A variation of this approach occurs at Lexus, where every quarter Lexus dealers have a "make meeting." At this meeting they talk about what is selling, in what colors and with what options, so the factory knows what to build.

4. **Consumer market survey: This method solicits input from** customers or potential customers regarding future purchasing plans. It can help not only in preparing a forecast but also in improving product design and planning for new products. The consumer market survey and sales force composite methods can however, suffer from overly optimistic forecasts that arise from customer input. The 2001 crash of the telecommunication industry was the result of over-expansion to meet "explosive customer demand". Where did these data come from? Oplink Communications, a Nortel Networks supplier, says its "company forecasts over the last few years were based on informal conversations with customers.

3.5.2 Overview of Quantitative Methods

Five quantitative forecasting methods, all of which use historical data, are described in this unit. They fall into two categories:

1. Naive approach]
2. Moving averages] time-series models
3. Exponential smoothing]
4. Trend projection]
5. Linear regression } associative model

Time-series Models: **Time-series models predict on the assumption** that the future is a function of the past. In other words, they look at what has happened over a period of time and use a series of past data to make a forecast. If we are predicting weekly sales of lawn mowers, we use the past weekly sales for the lawn mowers when making the forecasts.

Associative Models: Associative (or casual) models, such as linear regression, incorporate the variables or factors that might influence the quantity being forecast. For example, an associative model for lawn mower sales might include such factors as new housing starts, advertising budget and competitor's prices.

3.6 Time-Series Forecasting

A time series based on a sequence of evenly spaced (weekly, monthly, quarterly and so on) data points. Examples include weekly sales of Nike Air Jordans, quarterly earnings reports of Microsoft stock, daily shipments of Coors beer and annual consumer price indices. Forecasting time-series data implies that future values are predicted only from past value and that other variables, no matter how potentially valuable, may be ignored.

3.6.1 Decomposition of a Time Series

Analyzing time series means breaking down data into components and then projecting them forward. A time series has four components: trend, seasonality, cycles and random variation.

a. Trend is the gradual upward and downward movement of the data over time. Changes in income, population, age distribution or cultural views may account for movement in trend.

b. Seasonality is a data pattern that repeat itself after a period of days, weeks, months, or quarters. There are six common seasonality patterns:

PERIOD OF PATTERN	**"SEASON" LENGTH**	**NUMBER OF "SEASONS" IN PATTERN**

Week	Day	7
Month	Week	4-41/2
Month	Day	28-31
Year	Quarter	4
Year	Month	12
Year	Week	52

c. Restaurants and barber shops, for example, experience weekly seasons, with Saturday being the peak of business. Beer distributors forecast yearly patterns, with monthly seasons. Three "seasons" – May, July and September each contain a big beer drinking holiday.

d. Cycles are patterns in the data that occur every several years. They are usually tied into the business cycle and are of major importance in short-term business analysis and planning. Predicting business cycles is difficult because they may be affected by political events or by international turmoil.

e. Random variations are "blips" in the data caused by chance and unusual situations. They follow no discernible pattern, so they cannot be predicted.

3.6.2 Naive Approach

The simplest way to forecast is to assume that demand in the next period will be equal to demand in the most recent period. In other words, if sales of a product – say, Motorola cellular phones were 68 units in January, we can forecast that February's sales will also be 68 phones. Does this make any sense? It turns out that for some product lines, this naive approach is the most cost-effective and efficient objective forecasting model. At least it provides a starting point against which more sophisticated models that follow can be compared.

3.6.3 Moving Averages

A moving average forecast uses a number of historical actual data values to generate a forecast. Moving averages are useful if we can assume that market demands will stay fairly steady over time. A 4-month moving average is found by simply summing the demand during the past 4 months and dividing by 4. With each passing month, the most recent month's data are added to the sum of the previous 3 month's data, and the earliest month's is dropped. This practice tends to smooth out short-term irregularities in the data series.

Mathematically, the simple moving average (which serves as an estimate of the next period's demand) is expressed as

$$\text{Moving average} = \frac{\text{(Demand in previous n periods)}}{n}$$

Where n is the number of periods in the moving average-for example, 4, 5, or 6 months, respectively, for a 4, 5, or 6-period moving average.

3.6.4 Exponential Smoothing

Exponential smoothing is a sophisticated weighted moving-average forecasting method that is still fairly in use. It involves very little record keeping of past data. The basic exponential smoothing formula can be shown as follows:

New forecast = Last period's forecast
+ a (Last period's actual demand –Last period's forecast)

Where a is a weight, or smoothing constant, chosen by the forecaster, that has a value between 0 and 1. Equation (4-3) can be written mathematically as

$$F_t = F_{t-1} + a(A_{t-1} - F_{t-1})$$

Where F_t = new forecast
F_{t-1} = previous forecast
a = smoothing (or weighting) constant ($0 < a < 1$)
A_{t-1} = previous period's actual demand

The concept is not complex. The latest estimate of demand is equal to the old estimate adjusted by a fraction of the difference between the last period's actual demand and the old estimate.

Example 1

In January, a car dealer predicted February demand for 142 Ford Mustangs. Actual February demand was 153 autos. Using a smoothing constant chosen by management of a = .20, we can forecast March demand using the exponential smoothing model. Substituting the sample data into the formula, we obtain

New forecast (for March demand) = 142+.2(153-142) =142+2.2
= 144.2

Thus, the March demand forecast for Ford Mustang is rounded to 144.

The smoothing constant, a is generally in the range from .05 to .50 for business applications. It can be changed to give weight to recent data (when a is high) or more weight to past data (when a is low). When a reaches the extreme of 1.0, then in Equation (4-4), Ft = 1.0 At-1. All the older values drop out, and the forecast becomes identical to the naive model mentioned earlier in the unit. That is, forecast for the next period is just the same as this period's demand.

Selecting the Smoothing Constant

The exponential smoothing approach is easy to use, and it has been successfully applied in virtually every type of business. However, the appropriate value of the smoothing constant, a, can make the difference between an accurate forecast and an inaccurate forecast. High values of a are chosen when the underlying average is likely to change. Low values of a are used when the underlying average is fairly stable. In picking a value for the smoothing constant, the objective is to obtain the most accurate forecast.

3.6.5 Measuring Forecast Error

The overall accuracy of any forecasting model moving average, exponential smoothing, or other can be determined by comparing the forecasted values with the actual or observed values. If Ft denotes the forecast in period t, and At denotes the actual demand in period t, the forecast error (or deviation) is defined as

Forecast error = Actual demand – Forecast value
= At – Ft

Several measures are used in practice to calculate the overall forecast error. These measures can be used to compare different forecasting models, as well as to monitor forecast and to ensure they are performing well. Three of the most popular measures are mean absolute deviation (MAD), mean squared error (MSE), and mean absolute percent error (MAPE).

a. Mean Absolute Deviation: The first measure of the overall forecast error for a model is the mean absolute deviation (MAD). This value is computed by taking the sum of the values of the individual forecast errors and dividing by the number of periods of data (n).

MAD = [!Actual – Forecast!]
n

Example 2

During the past 8 quarters, the Port of Baltimore has unloaded large quantities of grain from ships. The port's manager wants to test the use of exponential smoothing to see how well the technique works in predicting tonnage unloaded. He guesses that the forecast of grain unloaded in the first quarter was 175 tons. Two values of a are examined: a = .10 and a = .50. The following table shows the detailed calculations for a = .10 only:

Quarter	Actual Tonnage Unloaded	Rounded Forecast with a = .10a	Rounded Forecast with a = .50a
1	180	175	175
2	168	176 = 175.00+.10(180-175)	178
3	159	175 = 175.50+ .10(168-175.50)	173
4	175	173 = 174.75+ .10(159-174.75)	166
5	190	173 = 173.18+ .10(175-173.18)	170
6	205	175 = 173.36+ .10(190-173.36)	180
7	180	178 = 175.02+ .10(205-175.02)	193
8	182	178 = 178.02+ .10(180-178.02)	186
9	?	179 = 178.22+ .10(182-178.22)	184

*forecast rounded to the nearest ton.

b. Mean Square Error: The mean square error (MSE) is a second way of measuring overall forecast error. MSE is the average of the squared differences between the forecasted and observed values. Its formula is

MSE = [(Forecast errors)2
n

Example 3

MSE for the port of Baltimore introduced in Example 2

Quarter	Actual tonnage unloaded	Forecast for a = .10	(Error)2
1	180	175	5 = 25
2	168	176	(-8)2 = 64
3	159	175	(-16)2 = 256
4	175	173	2 = 4

5	190	173	17 = 289
6	205	175	30 = 900
7	180	178	2 =
4 8	182	178	4 =
16		sum of error squared = 1,558	

c. Mean Absolute Percent Error: A problem with both the MAD and MSE is that their values depend on the magnitude of the item being forecast. If the forecast item measured in thousands, the MAD and MSE values can be large. To avoid this problem, we can use the mean absolute percent error (MAPE). This is computed as the average of the absolute difference between the forecasted and actual values, expressed as a percentage of the actual values. That is, if we have forecasted and actual values for n periods, the MAPE is calculate as

MAPE = 100! Actuali – Forecasti!/Actuali
n

3.7 Associative Forecasting Methods: Regression and Correlation Analysis

Unlike time-series forecasting, associative forecasting models usually consider several variables that are related to the quantity being predicted. Once these related variables have been found, a statistical model is built and used to forecast the item of interest. This approach is more powerful than the time-series methods that use only the historical values for the forecast variable.

Many factors can be considered in an associative analysis. For example, the sales of Dell PCs may be related to Dell's advertising budget, the company's prices, competitors' prices and promotional strategies, and even the nation's economy and unemployment rates. In this case PC sales would be called the dependent variable, and the other variables would be called independent variables. The manager's job is to develop the best statistical relationship between PC sales and the independent variables. The most common quantitative associative forecasting model is linear-regression analysis.

3.7.1 Using Regression Analysis to Forecast

We can use the mathematical model that we employed in the least squares method of trend projection to perform a linear-regression analysis. The dependent variables that we want to forecast will still be

y. But now the independent variable, x, need no longer be time. We use the equation

where y = value of the dependent variable (in our example, sales)
a = y-axis intercept
b = slope of the regression line
x = independent variable

SELF ASSESSMENT EXERCISE

What is Qualitative Forecasting and when is it appropriate.

4.0 CONCLUSION

Forecasts are a critical part of the operations manager's function. Demand forecasts drive a firm's production, capacity, and scheduling systems and affect the financial, marketing, and personnel planning functions.

5.0 SUMMARY

There are a variety of qualitative and quantitative forecasting techniques.

Qualitative approaches employ judgment, experience, intuition, and a host of other factors that are difficult to quantify. Quantitative forecasting use historical data and casual, or associative, relations to project future demands.

6.0 TUTOR-MARKED ASSIGNMENT

Sales of Volkswagen's popular Beetle have grown steadily at auto dealership in Nevada during the past 5 years. The sales manager had predicted in 2000 that 2001 sales would be 410 VWs. Using exponential smoothing with a weight of a = .30, develop forecasts for 2002 through 2006.

7.0 REFERENCES/FURTHER READINGS

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MODULE 2

UNIT 1 DESIGN OF GOODS AND SERVICES

CONTENTS

1.0 INTRODUCTION

The basis for an organization’s existence is the good or services it provides for society. Great products are the keys to success. Anything less than excellent product strategy can be devastating to a firm. To maximize the potential for success, top companies focus on only a few products and then concentrate on those products. For instance, Honda's focus is engines. Virtually all of Honda's sales (autos, motorcycles, generators, lawn mowers) are based on its outstanding engine technology. Likewise, Intel's focus is on chips and Microsoft's is PC software. However, because most products have a limited and even predictable life cycle, companies must constantly be looking for new products to design, develop and take to market. Good operations managers insist on strong communication among customer, product, processes and suppliers that results in a high success rate for their new products.

2.0 OBJECTIVES

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

Identify or Define

•product life cycle
•product development
•manufacturability and value engineering
•robust design
•time based competition

Explain

•attiames
•concurrent engineering.

3.0 MAIN CONTENT

3.1 Goods and Services Selection

3.1.1 Product Strategy Options Support Competitive Advantage

A world of options exists in the selection, definition and design of products. Product selection is choosing the good or services to provide for customers or clients. For instance, hospitals specialize in various types of patients and various types of medical procedures. A hospital's management may decide to operate a general purpose hospital or a maternity hospital or, as in the case of the Canadian hospital Shouldice, to specialize in hernias. Hospitals select their products when they decide what kind of hospital to be. Numerous other options exist for hospitals, just as they exist for McDonald's or General Motors.

3.1.2 Product Life Cycle

Products are born. They live and they die. They are cast aside by a changing society. It may be helpful to think of a product's life as divided into four phases. Those phases are introduction, growth, maturity and decline.

Product life cycles may be a matter of a few hours (a newspaper), months (seasonal fashions and personal computers), years (video cassette tapes) or decades (Volkswagen Beetle). Regardless of the length of the cycle, the task for the operations manager is the same: to design a system that helps introduce new products successfully. If the operations function cannot perform effectively at this stage, the firm may be saddled with losers-products that cannot be produced efficiently and perhaps not at all.

3.1.3 Introductory Phase

Because products in the introductory phase are still being "fine-tuned" for the market, as are their production techniques, they may warrant unusual expenditures for (1) research, (2) product development, (3) process modification and enhancement and (4) supplier development. For example, when cellular phones were first introduced, the features desired by the public were still being determined. At the same time, operations managers were still groping for the best manufacturing techniques.

3.1.4 Growth Phase

In the growth phase, product design has begun to stabilize, and effective forecasting of capacity requirements is necessary. Adding capacity or enhancing existing capacity to accommodate the increase in product demand may be necessary.

3.1.5 Maturity Phase

By the time a product is matured, competitors are established. So high-volume innovative production may be appropriate. Improved cost control, reduction in options, and a paring down of the product line may be effective or necessary for profitability and market share.

3.1.6 Decline Phase

Management may need to be ruthless with those products whose life cycle is at an end. Dying products are typically poor products in which to invest resources and managerial talent. Unless dying products make some unique contribution to the firm's reputation or its product line or can be sold with an unusually high contribution, their production should be terminated.

3.2 Generating New Ideas

Because products die; because products must be weeded out and replaced; because firms generate most of their revenue and profit from new products – product selection, definition and design take place on a continuing basis. Knowing how to successfully find and develop new products is a requirement.

3.2.1 New Product Opportunities

One technique to generate new product ideas is brainstorming. Brainstorming is a technique in which a diverse group of people share, without criticism ideas on a particular topic. The goal in this application is to generate an open discussion that will yield creative ideas about possible products and product improvements. Although firms may include brainstorming in various stages of new-product development, directly and energetically focusing on the specific opportunities, as noted below, is often rewarding.

1. Understanding the customer is the premier issue in new-product development. Many commercially important products are initially thought of and even prototyped by users rather than producers. Such products tend to be developed by “lead users”- companies, organizations or individuals that are well ahead of market trends and have needs that go far beyond those of average users.

2. Economic change brings increasing levels of affluence in the long run but economic cycles and price changes in the short run. In the long run, for instance, more and more people can afford automobiles, but in the short run, a recession may weaken the demand for automobiles.

3. Sociological and demographic change may appear in such factors decreasing family size. This trend alters the size preference for homes, apartments and automobiles.

4. Technological change makes possible everything from hand-held computers to cellular phones to artificial hearts.

5. Political/legal change brings about new trade agreements, tariffs and government contract requirements.

6. Other changes may be brought about through market practice, professional standards, suppliers and distributors.

Operations managers must be aware of these factors and be able to anticipate changes in product opportunities, the products themselves, product volume and product mix.

3.2.2 Importance of New Products

The importance of new products cannot be overestimated. Leading companies usually generate a substantial portion of their sales from products less than 5 years old.

Despite constant efforts to introduce viable new products, many new products do not succeed. Indeed, for General Mills to come up with a winner in the breakfast cereal market defined as a cereal that gets a scant half of 1% of the market it isn't easy. Among the top 10 brands of cereal, the youngest, Honey Nut Cheerios, was created in 1979. DuPont estimates that it takes 250 ideas to yield one marketable product.

As one can see, product selection, definition and design occur frequently-perhaps hundreds of times for each financially successful product. Operations managers and their organizations must be able to accept risk and tolerate failure. They must accommodate a high volume of new product ideas while maintaining the activities to which they are already committed.

3.3 Product Development

3.3.1 Product Development System

An effective product strategy links product decisions with cash flow, market dynamics, product life cycle and the organization's capabilities.
A firm must have the cash for product development, understand the changes constantly taking place in the marketplace, and have the necessary talents and resources available. The product development system may well determine not only product success but also the firm's future. In this system, product options go through a series of steps, each having its own screening and evaluation criteria and providing feedback to prior steps.
The screening process extends to the operations function. Optimum product development depends not only on support from other parts of the firm but also on the successful integration of all 10 of the OM decisions, from product design to maintenance. Identifying products that appear likely to capture market share, be cost effective and profitable,

but are in fact very difficult to produce, may lead to failure rather than success.

3.3.2 Quality Function Deployment (QFD)

Quality function deployment (QFD) refers to both (1) determining what will satisfy the customer and (2) translating those customer desires into the target design. The idea is to capture a rich understanding of customer wants and to identify alternative process solutions. This information is then integrated into the evolving product design. QFD is used early in the design process to help determine what will satisfy the customer and where to deploy quality efforts.

One of the tools of QFD is the house of quality. The house of quality is a graphic technique for defining the relationship between customer desires and product (or service). Only by defining this relationship in a rigorous way can operations managers build products and processes with features desired by customers. Defining this relationship is the first step in building a world-class production system. To build the house of quality, we perform four basic steps.

8. Identify customer wants. (What do prospective customers want in this product?)
9. Identify how the good/service will satisfy customer wants. (Identify specific product characteristics, features or attributes and show how they will satisfy customer wants.)
10. Relate customer wants to product hows.
11. Identify relationship between the firm's hows. (How do our hows tie together?)

3.4 Manufacturability and Value Engineering

Manufacturability and value engineering activities are concerned with improvement of design and specifications at the research, development, design and production stages of product development. In addition to immediate, obvious cost reduction, design for manufacturability and value engineering may produce other benefits. These include:

1. Reduced complexity of the product.
2. Additional standardization of components.
3. Improvement of functional aspects of the product.
4. Improved job design and job safety.
5. Improved maintainability (serviceability) of the product
6. Robust design.

Manufacturability and value engineering activities may be the best cost-avoidance technique available to operations management. They yield value improvement by focusing on achieving the functional specifications necessary to meet customer requirements in an optimal way. Value engineering programs, when effectively managed, typically reduce costs between 15% and 70% without reducing quality. Some studies have indicated that for every naira spent on value engineering, N10 to N25 in savings can be realized.

Product design affects virtually all aspects of operating expenses. Consequently, the development process needs to ensures a thorough evaluation of design prior to a commitment to produce.

3.5 Issues for Product Design

In addition to developing an effective system and organization structure for product development, several techniques are important to the design of product. They are:

1. **Robust Design: Robust design means that the product is designed** so that small variations in production or assembly do not adversely affect the product.

2. **Modular Design: It means that products are designed in easily** segmented components, it offers flexibility to both production and marketing. The production department typically finds modularity helpful because it makes product development, production and subsequent changes easier. Moreover, marketing may like modularity because it adds flexibility to the ways customers can be satisfied.

3. **Computer Aided Design (CAD): This is the use of computers to** interactively design products and prepare engineering documentation. Although the use and variety of CAD software is extensive, most of it is still used for drafting and three-dimensional drawings.

4. **Computer Aided Manufacturing (CAM): This refers to the use of** specialized computer programs to direct and control manufacturing equipment, i.e. the use of information technology to control machinery.
5. **Virtual Reality Technology: This is a visual form of** communication in which images substitute for the real thing but still allow the user to respond interactively.

6. Value Analysis: This is a review of successful products that takes place during the production process. Value analysis seeks improvements that lead to either a better product or a product made more economically.

7. Ethics and Environmentally Friendly Design: An operations manager's most ethical and an environmentally sound activity is to enhance productivity while delivering desired goods and services.

3.6 Defining the Product

Once new goods or services are selected for introduction, they must be defined. First, a good or service is defined in terms of its functions that is, what it is to do. The product is then designed, and the firm determines how the functions are to be achieved. Management typically has a variety of options as to how a product should achieve its functional purpose. For instance, when an alarm clock is produced, aspects of design such as the color, size or location of buttons may make substantial differences in ease of manufacture, quality and market acceptance.

3.7 Documents for Production

Once a product is selected, designed and ready for production, production is assisted by a variety of documents. We will briefly review some of these.

An assembly drawing simply shows an exploded view of the product. An assembly drawing is usually a three-dimensional drawing, known as an isometric drawing: the relative locations of components are drawn in relation to each other to show how to assemble the unit.

The assembly chart shows in schematic form how a product is assembled. This is a graphic means of identifying how components flow into subassemblies and ultimately into a final product.

The route sheet lists the operations necessary to produce the component with the material specified in the bill of material.

The work order is an instruction to make a given quantity of a particular item, usually to a given schedule. The ticket that a waiter writes in your favorite restaurant is a work order.

Engineering change notices (ECNs) is a correction or modification of an engineering drawing or bill of material.

3.8 Service Design

Designing services is challenging because they often have unique characteristics. One reason productivity improvements in services are so low is because both the design and delivery of service products include customer interaction. When the customer participates in the design process, the service supplier may have a menu of services form which the customer selects options. At this point, the customer may even participate in the design of the service. Design specifications may take the form of a contract or a narrative description with photos (such as for cosmetic surgery or a hairstyle). Similarly, the customer may be involved in the delivery of a service or in both design and delivery, a situation that maximizes the product design challenge.

However, like goods, a large part of cost and quality of a service is defined at the design stage. Also as with goods, a number of techniques can both reduce costs and enhance the product. One technique is to design the product so that customization is delayed as late in the process as possible. This is the way a hair salon operates: Although shampoo and rinse are done in a standard way with lower-cost labor, the tint and styling (customizing) are done last. It is also the way most restaurants operate: How would you like that cooked? Which dressing would you prefer with your salad?

The second approach is to modularize the product so that customization takes the form of changing modules. This strategy allows modules to be designed as “fixed,” standard entities. The modular approach to product design has applications in both manufacturing and service. Just as modular design allows you to buy a Harley-Davidson motorcycle or a high fidelity sound system with just the features you want, modular flexibility also lets you buy meals, clothes and insurance on a mix-and-match (modular) basis. Similarly, investment portfolios are put together on a modular basis. Certainly, college curricula are another example of how the modular approach can be used to customize a service.

A third approach to the design of services is to divide the service into small parts and identify those parts that lend themselves to automation or reduced customer interaction. For instance, by isolating check-cashing activity via ATM machines, banks have been very effective at designing a product that both increases customer service and reduces costs.

Because of the high customer interaction in many service industries, a fourth technique is to focus design on the so-called moment of truth. Jan Carlzon, former president of Scandinavian Airways, believes that in the service industry there is a moment of truth when the relationship between the provider and the customer is crucial. At that moment, the customer's satisfaction with the service is defined. The moment of truth is the moment that exemplifies, enhances, or detracts from the customer's expectations. That moment may be as simple as a smile or having the checkout clerk focus on you rather than talking over his shoulder to the clerk at the next counter. Moment of truth can occur when you order at Mr. Biggs's, get a haircut or register for college courses. The operations manager's task is to identify moments of truth and design operations that meet or exceed the customer's expectation.

3.8.1 Documents for Service

Because of the high customer interaction of most services, the documents for moving the product to production area different from those used in goods producing operations. The documentation for a service will often take the form of explicit job instructions that specify what is to happen at the moment of truth. For instance, regardless of how good a bank's products may be in terms of chequing, savings, trusts, loans, mortgages and so forth, if the moment of truth is not done well, the product may be poorly received.

3.8.2 Application of Decision Trees to Product Design

Decision trees can be used for new-product decisions as well as for wide variety management problems. They are particularly helpful when there are a series of decisions and various outcomes that lead to subsequent decisions followed by other outcomes. To form a decision tree we use the following procedure:

1. Be sure that all possible alternatives and states of nature are included in the tree. This includes an alternative of "doing nothing."
2. Payoffs are entered at the end of the appropriate branch. This is the place to develop the payoff achieving this branch.
3. The objective is to determine the expected value of each course of action. We accomplish this by starting at the end of the tree (the right-hand side) and working toward the beginning of the tree (the left), calculating values at each step and "pruning" alternatives that are not as good as others from the same node.

3.9 Transition to Production

Eventually, a product, whether a good or service, has been selected, designed and defined. It has progressed from an idea to a functional definition, and then perhaps to a design. Now, management must take a decision as to further development and production or termination of the product idea. One of the arts of modern management is knowing when to move a product from development to production; this move is known as transition to production. The product development staff tends to see product development as evolutionary, they may never have a completed product, but as we noted earlier, the cost of late product introduction is high. Although these conflicting pressures exist, management must make a decision-more development or production.

SELF ASSESSMENT EXERCISE

1. Why is it necessary to document a product explicitly.
2. What techniques do we use to define a product.

4.0 CONCLUSION

Written specifications, bills of material, and engineering drawings aid in defining products. Similarly, assembly drawings, assembly charts, route sheets, and work orders are often used to assist in the actual production of the product. Once a product is in production, value analysis is appropriate to ensure maximum product value. Engineering change notices and configuration management provide product documentation.

5.0 SUMMARY

Effective product strategy requires selecting, designing and defining a product and then transitioning that product to production. Only when this strategy is carried out effectively can the production function contribute its maximum to the organization. The operations manager must build a product development system that has the ability to conceive, design and produce products that will yield a competitive advantage for the firm. As products move through their life cycle (introduction, growth, maturity and decline), the options that the operations manager should pursue change. Both manufactured and service products have a variety of techniques available to aid in performing this activity efficiently.

6.0 TUTOR-MARKED ASSIGNMENT

Customers who use drive-up teller stations rather than walk-in lobbies require different customer relations techniques. The distance and machinery between you and the customer raises communication barriers.

7.0 REFERENCES/FURTHER READINGS

Heizer Jay and Render Barry, Operations Management.

UNIT 2 MANAGING QUALITY

CONTENTS

1.0 INTRODUCTION

Quality, or lack of quality, affects the entire organization from supplier to customer and from product design to maintenance. Perhaps more importantly, building an organization that can achieve quality also affects the entire organization and it is a demanding task. The diagram (Fig. 6.1) lays out the flow of activities for an organization to use to achieve total quality management (TQM). A successful set of activities begins with an organization environment that fosters quality, followed by an understanding of the principles of quality. When these things are done well, the organization typically satisfies its customers and obtains a competitive advantage. The ultimate goal is to win customers. Because quality causes so many other good things to happen, it is a great place to start.

2.0 OBJECTIVES

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

Identify or Define:

• quality
• ISO International Quality Standard
• Taguchi Concept.

Describe or Explain:

•why quality is important
•total Quality Management
•seven tools of TQM.

3.0 MAIN CONTENT

3.1 Defining Quality

Total quality management systems are driven by identifying and satisfying customer needs. Total quality management takes care of the customer. Consequently, we accept the definition of quality as adopted by the Nigeria Society for Quality: “The totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs.”

Others, however, believe that definitions of quality fall into several categories. Some definitions are user based. They propose that quality “lies in the eyes of the beholder.” Marketing people like this approach and so do customers. To them higher quality means better performance, nicer features and other (sometimes costly) improvements. To production managers, quality is manufacturing based. They believe that quality means conforming to standards and “making it right the first time. Yet a third approach is product based, which views quality as a precise and measurable variable. In this view, for example, really good ice cream has high butterfat levels.

Figure 6.1

3.1.1 Implications of Quality

In addition to being a critical element in operations, quality has other implications. Here are three other reasons why quality is important:

1. **Company reputation: An organization can expect its reputation** for quality, be it good or bad to follow it. Quality will show up in perceptions about the firm's new products, employment practices and supplier relations. Self-promotion is not a substitute for quality products.

2. **Product liability: The courts increasingly hold organizations that** design, produce or distribute faulty products or services liable for damages or injuries resulting from their use. Legislation such as National Administration for Food and Drug Admin and Control (NAFDAC) sets and enforces product standards by banning products that do not reach those standards. Impure food that cause illness, nightgowns that burns, tyres that fall apart or auto fuel tanks that explode on impact can all lead to huge legal expense, large settlements or losses, and terrible publicity.

3. **Global implication: In this technological age, quality is an** international, as well as OM, concern. For both a company and a country to compete effectively in the global economy, Product must meet global quality, design and price expectations. Inferior products harm a firm's profitability and a nation's balance of payments.

3.1.2 Cost of Quality (COQ)

Four major categories of costs are associated with quality. Called the cost of quality (COQ), they are:

•Prevention costs – costs associated with reducing the potential for defective parts or services (e.g., training, quality improvement programs).

•Appraisal costs – costs related to evaluating products, processes, parts and services (e.g., testing, labs, inspectors).

•Internal failure – costs that result from production of defective parts or services before delivery to customers (e.g., rework, scrap, downtime).

•External costs – costs that occur after delivery of defective parts or services (e.g., rework, returned goods, liabilities, lost goodwill, costs to society).

3.1.3 Ethics and Quality Management

For operations managers, one of the most important jobs is to deliver healthy, safe and quality products and services to customers. The development of poor-quality products, because of inadequate design and production processes, results not only in higher production costs but leads to injuries, lawsuits and increased government regulation.

3.2 International Quality Standards (ISO 9000)

Quality is so important globally that the world is uniting around a single quality standard, ISO 9000. ISO 9000 is the only standard with international recognition. In 1987, 91 member nations published a series of quality assurance standards, known collectively as ISO 9000. The focus of the standard is to establish quality management procedures, through leadership, detailed documentation, work instructions and record-keeping. These procedures, we should note, say nothing about the actual quality of the product – they deal entirely with standards to be followed.

To become ISO 900 certified, organizations go through a 9 to 18 month process that involves documenting quality procedures, an on site assessment, and an ongoing series of audits of their products or services. To do business globally and especially in Europe being listed in the ISO directory is critical. As of 2005, there were well over 600,000 certifications awarded to firm's in 152 countries, including Nigeria.

3.3 Total Quality Management

Total quality management (TQM) refers to a quality emphasis that encompasses the entire organization, from supplier to customer. TQM stresses a commitment by management to have a continuing companywide drive towards excellence in all aspects of products and services that are important to the customer.
TQM is important because quality decisions influence each of the 10 decisions made by operations managers. Each of those 10 decisions deals with some aspect of identifying and meeting customer expectations. Meeting those expectations requires an emphasis on TQM if a firm is to compete as a leader in world markets.

Quality expert W. Edwards Deming used 14 points to indicate how he Implemented TQM. We develop these into seven concepts for an effective TQM program: (1) continuous improvement, (2) six sigma, (3) employee empowerment, (4) benchmarking, (5) just-in-time (JIT), (6) Taguchi concepts and (7) knowledge of TQM tools.

3.3.1 Continuous Improvement

Total quality management requires a never-ending process of continuous improvement that covers people, equipment, suppliers, materials and procedures. The basis of the philosophy is that every aspect of an operation can be improved. The end goal is perfection, which is never achieved but always sought.

3.3.2 Six Sigma

The term six sigma, popularized by Motorola, Honeywell and General Electric, has two meanings in TQM. In a statistical sense it describes a process, product or service with an extremely high capability (99.9997% accuracy). For example, if 20,000,000 passengers pass through London's Heathrow Airport with checked baggage each year, a Six Sigma program for baggage handling will result in only 72 passengers with misplaced luggage. The more common three sigma program would result in 2,076 passengers with misplaced bags every week!

The second TQM definition of six sigma is a program designed to reduce defects to help lower costs, save time and improve customer satisfaction. Six sigma is a comprehensive system a strategy, a discipline and a set of tools for achieving and sustaining business success.

3.3.3 Employee Empowerment

Employee empowerment means involving employees in every step of the production process. Consistently, business literature suggests that some 85% of quality problems have to do with materials and processes, not with employee performance. Therefore, the task is to design equipment and processes that produce the desired quality. This is best done with a high degree of involvement by those who understand the shortcomings of the system. Those dealing with the system on a daily basis understand it better than anyone else. One study indicated that TQM programs that delegate responsibility for quality to shop floor employees tend to be twice as likely to succeed as those implement with "top down" directives. When nonconformance occurs, the worker is seldom wrong, either the product was designed wrongly the system that makes the product was designed wrongly or the employee was improperly trained, although the employee may be able to help solve the problem, the employee rarely causes it. Techniques for building employee empowerment include (1) building communication networks that include employees; (2) developing open, supportive supervisors; (3) moving responsibility from both managers and staff to production employees; (4) building high morale organizations; (5) and creating such formal organization structures as teams and quality circles. Teams can be built to address a variety of issues. One popular focus of teams is quality. Such teams are often known as quality circles. A quality circle is a group of employees who meet regularly to solve work related problems. The members receive training in group planning, problem solving, and statistical quality control. They generally meet once a week (usually after work, but sometimes on company time). Although the members are not rewarded financially, they do receive recognition from the firm. A specially trained team member, called the facilitator, usually helps train the members and keeps the meetings running smoothly. Teams with a quality focus have proven to be a cost-effective way to increase productivity as well as quality.

3.3.4 Benchmarking

Benchmarking is another ingredient in an organization's TQM program. Benchmarking involves selecting a demonstrated standard of products, services, costs, or practices that represent the very best performance for processes or activities very similar to your own. The idea is to develop a target at which to shoot and then to develop a standard or benchmark against which to compare your performance. The steps for developing benchmarks are:

• Determine what to benchmark.
• Form a benchmark team.
• Identify benchmarking partners.

• Collect and analyze benchmarking information.
• Take action to match or exceed the benchmark.

3.3.5 Just-in-Time (JIT)

The philosophy behind just-in-time (JIT) is one of continuing improvement and enforced problem solving. JIT systems are designed to produce or deliver goods just as they are needed. JIT is related to quality in three ways.

• JIT cuts the cost of quality. This occurs because scrap, rework, inventory investment, and damage costs are directly related to inventory on hand. Because there is less inventory on hand with JIT, costs are lower. Additionally, inventory hides bad quality, whereas JIT immediately exposes bad quality.

• JIT improves quality. As JIT shrinks lead time it keeps evidence of errors fresh and limits the number of potential sources of error. JIT creates, in effect, an early warning system for quality problems, both within the firm and with vendors.

• Better quality means less inventory and a better, easier to employ JIT system. Often the purpose of keeping inventory is to protect against poor production performance resulting from unreliable quality. If Consistent quality exists, JIT allows firms to reduce all the costs associated with inventory.

3.3.6 Taguchi Concepts

Most quality problems are the result of poor product and process design. Genichi Taguchi has provided us with three concepts aimed at improving both product and process quality. They are: quality robustness, quality loss function, and target-oriented quality.

1. **Quality robust: These are products that are consistently built to** meet customer needs in spite of adverse conditions in the conditions in the production process.

2. **Quality loss function (QLF): This is a mathematical function that** identifies all costs connected with poor quality and shows how these costs increase as product quality moves from what the customer wants.

3. **Target oriented quality: This is a philosophy of continuous** improvement to bring the product exactly on target.

3.4 Knowledge of TQM Tools

To empower employees and implement TQM as a continuing effort, everyone in the organization must be trained in the techniques of TQM.

3.4.1 Tools of TQM

Seven tools that are particularly helpful in the TQM effort are, shown in Figure 6.5. We will now introduce these tools.

3.4.2 Check Sheets

A check sheet is any kind of a form that is designed for recording data. In many cases, the recording is done so the patterns are easily seen while the data are being taken. Check sheets help analysts find the facts or patterns that may aid subsequent analysis. An example might be drawing that shows a tally of the areas where defects are occurring or a check sheet showing the type of customer complaints.

3.4.3 Scatter Diagrams

Scatter diagrams show the relationship between two measurements. An example is the positive relationship between length of a service call and the number of trips the repairperson makes back to the truck for parts. If the two items are closely related, the data points will form a tight band. If a random pattern results, the items are unrelated.

3.4.4 Cause and Effect Diagrams

Another tool for identifying quality issues and inspection points is the cause and effect diagram, also known as an Ishikawa diagram or a **fish-bone chart. Figure 6.2 illustrates a chart (note the shape resembling** the bones of a fish) for an everyday quality control problem dissatisfied airline customer. Each "bone" represents a possible source of error.

Figure 6.2

3.4.5 Pereto Charts

Pareto charts are a method of organizing errors, problems, or defects to help focus on problem solving efforts. They are based on the work of Vilfredo Pareto, a nineteenth century economist. Joseph M. Juran popularized Pareto's work when he suggested that 80% of a firm's problems are as a result of only 20% of the causes Example I indicates that of the five types of complaints identified, the vast majority were of one type, poor room service.

Pareto analysis indicates which problems may yield the greatest payoff. Pacific Bell discovered this when it tried to find a way to reduce damage to buried phone cable, the number one cause of phone outages. Pareto analysis showed that 41% of cable damage was caused by construction work. Armed with this information, Pacific Bell was able to devise a plan to reduce cable cuts by 24% in one year, saving $6 million.

3.4.6 Flowcharts

Flowcharts graphically present a process or system using annotated boxes and interconnected lines. They are a simple, but great tool for trying to make sense of a process or explain a process.

3.4.7 Histograms

Histograms show the range of values of a measurement and the frequency with which each value occurs. They show the most frequently occurring readings as well as the variations in the measurements. Descriptive statistics, such as the average and standard deviation, may be calculated to describe the distribution. However, the data should always be plotted so the shape of the distribution can be "seen." A visual presentation of the distribution may also provide insight into the cause of the variation.

3.4.8 Statistical Process Control (SPC)

Statistical process control monitors standards, makes measurements, and takes corrective action as a product or service is being produced. Samples of process outputs are examined; if they are within acceptable limits, the process is permitted to continue. If they fall outside certain specific ranges, the process is stopped and, typically, the assignable cause located and removed.

Control charts are graphic presentations of data over time that show upper and lower limits for the process we want to control. Control charts are constructed in such a way that new data can be quickly compared with past performance data. We take samples of the process output and plot the average of these samples on a chart that has the limits on it. The upper and lower limits in a control chart can be in units of temperature, pressure, weight, length, and so on.

3.5 The Role of Inspection

To make sure a system is producing at the expected quality level, control of the process is needed. The best processes have little variation from the standard expected. The operations manager's task is to build such systems and to verify often by inspection, that they are performing to standard. This inspection can involve measurement, tasting, touching, weighing, or testing of the product (sometimes even destroying it when doing so). Its goal is to detect a bad process immediately. Inspection does not correct deficiencies in the system or defects in the products; nor does it change a product or increase its value. Inspection only finds deficiencies and defects, and it is expensive. Inspection should be thought of as an audit. Audits do not add value to the product. However, operations managers, like financial managers, need audits, and they need to know when and where to audit. Thus there are two basic issues relating to inspection: (I) when to inspect and (2) where to inspect.

3.5.1 When and Where to Inspect

Deciding when and where to inspect depends on the type of process and the value added at each stage. Inspections (audits) can take place at any of the following points:

1. At your supplier's plant while the supplier is producing
2. At your facility upon receipt of goods from your supplier
3. Before costly or irreversible processes
4. During the step-by-step production process
5. When production or service is complete
6. Before delivery from your facility
7. At the point of customer contact.

3.5.2 Source Inspection

The best inspection can be thought of as no inspection at all; this "inspection" is always done at the source it involves doing the job properly with the operator ensuring that this is so. This may be called source inspection (or source control) and is consistent with the concept of employee empowerment, where individual employees self-check their own work. The idea is that each supplier, process, and employee treats the next step in the process as the customer, ensuring perfect product to the next "customer." This inspection may be assisted by the use of checklists and controls such as a feel-safe device called a poka-yoke, a name borrowed from the Japanese.

3.5.3 Service Industry Inspection

In service-oriented organizations, inspection points can be assigned at a wide range of locations. Again, the operations manager must decide where inspection are justified and may find the seven tools of TQM useful when making these judgments.

3.5.4 Inspection of Attributes versus Variables

When inspections take place, quality characteristics may be measured as either attributes or variables. Attribute inspection classifies items as either good or defective. It does not address the degree of failure. For example, the lightbulb burns or it does not. Variable inspection measures such dimensions as weight, speed, height, or strength to see if an item falls within an acceptable' range. If a piece of electrical wire is supposed to be 0.0 I inch in diameter, a micrometer can be used to see if the product is close enough to pass inspection

Knowing whether attributes or variables are being inspected helps us decide which statistical quality control approach to take, as we will see in the supplement to this chapter.

3.6 TQM in Services

The personal component of services is more difficult to measure than the quality of the tangible component. Generally, the user of a service, like the user of a good, has features in mind that form a basis for comparison among alternatives. Lack of anyone feature may eliminate the service from further consideration. Quality also may be perceived as a bundle of attributes in which many lesser characteristics are superior to those of competitors. This approach to product comparison differs little between goods and services. However, what is very different about the selection of services is the poor definition of the (1) intangible differences between products and (2) the intangible expectations customers have of those products. Indeed, the intangible attributes may not be defined at all. They are often unspoken images in the purchaser's mind. This is why all of those marketing issues such as advertising, image, and promotion can make a difference.

The operations manager plays a significant role in addressing several major aspects of service quality. First, the tangible-component of many services is important. How well the service is designed and produced does make a difference. This might be how accurate, clear, and complete your checkout bill at the hotel is, how warm the food is at Mr. Biggs, or how well your car runs after you pick it up from the repair shop.

SELF ASSESSMENT EXERCISE

1. Explain how higher quality can lead to lower cost
2. List the seven concepts that are necessary for an effective TQM program. How are these related to Deming’s 14 point?

4.0 CONCLUSION

Quality is defined in this unit as “the totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs.” Defining quality expectations is critical to effective and efficient operations.

5.0 SUMMARY

Quality requires building a total quality management (TQM) environment because quality cannot be inspected into a product. This unit also addresses seven TQM concepts: continuous improvement, six sigma, employee empowerment, benchmarking, just-in-time, Taguchi concepts and knowledge of TQM tools. The seven TQM tools introduced in this unit are check sheets, pareto charts, flowcharts, histograms and statistical process control (SPC).

6.0 TUTOR-MARKED ASSIGNMENT

1. Develop a Pareto analysis of the following causes of poor grades on an exam

REASON FOR POOR GRADE	FREQUENCY
Insufficient time to complete	15
Late arrival to exam	7
Difficulty understanding material	25
Insufficient preparation time	2
Studied wrong material	2
Distractions in exam room	9
Calculator batteries died during exam	1
Forgot exam was scheduled	3
Felt ill during exam	4

2. Develop a histogram of the time it took for you or your friends to receive six recent orders at a fast-food restaurant

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 PROCESS STRATEGY

CONTENTS

1.0 INTRODUCTION

In this unit, we address statistical process control also, we introduce acceptance sampling. Statistical process control is the application of statistical techniques to the control of processes. Acceptance sampling is used to determine acceptance or rejection of material evaluated by a sample.

2.0 OBJECTIVES

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

Identify or Define

- natural and assignable causes of variations
- central limit theorem
- attributes and variable inspection
- process control
- x – chart and R – Charts
- acceptance Sampling
- producer's and Consumer's risk

Describe or Explain

- the role of Statistical Quality Control.

3.0 MAIN CONTENT

3.1 Statistical Process Control

Statistical process control (SPC) is a statistical technique that is widely used to ensure that processes meet standards. All processes are subject to a certain degree of variability. While studying process data in the 1920s, Walter Shewhart of Bell Laboratories made the distinction between the common and special causes of variation. Many people now refer to these variations as natural and assignable causes. He developed a simple but powerful tool to separate the two. This tool is called the control chart.

We use statistical process control to measure performance of a process. A process is said to be operating in statistical control when the only source of variation is common (natural) causes. The process must first be brought into statistical control by detecting and eliminating special (assignable) causes of variation.) Then its performance is predictable, and its ability to meet customer expectations can be assessed. The objective of a process control system is to provide a statistical signal when assignable causes of variation are present. Such a signal can quicken appropriate action to eliminate assignable causes.

3.1.1 Natural Variation

Natural variations behave like a constant system of chance causes. Although individual values are all different, as a group they form a pattern that can be described as a distribution. When these distributions are normal, they are characterized by two parameters

- mean, (the measure of central tendency in this case, the average value)
- standard deviation, (the measure of dispersion)

As long as the distribution (output measurements) remains within specified limits, the process is said to be "in control," and natural variations are tolerated.

3.1.2 Assignable Variations

Assignable variation in a process can be traced to a specific reason. Factors such as machine wear, misadjusted equipment, fatigued or untrained workers, or new batches of raw material are all potential sources of assignable variations.

Natural and assignable variations distinguish two tasks for the operations manager. The first is to ensure that the process is capable of operating under control with only natural variation. The second is, of course, to identify and eliminate assignable variations so that the process will remain under control.

3.1.3 Samples

Because of natural and assignable variation, statistical process control uses averages of small samples (often of four to eight items) as opposed to data on individual parts. Individual pieces tend to be too erratic to make trends quickly visible.

3.1.4 Control Charts

The process of building control charts is based on the concepts presented in Figure 6.2. This figure shows three distributions that are the result of outputs from three types of processes. We plot small samples and then examine characteristics of the resulting data to see if the process is within "control limits." The purpose of control charts is to help distinguish between natural variations and variation due to assignable causes.

3.2 Control Charts for Variables

Variables are characteristics that have continuous dimensions. They have an infinite number of possibilities. Examples are weight, speed, length, or strength. Control charts for the mean. x or x-bar, and the range, R, are used to monitor processes that have continuous dimensions. The x -chart tells us whether changes have occurred in the central tendency (the mean, in this case) of a process. These changes might be due to such factors as tool wear, a gradual increase in temperature, a different method used on the second shift, or new and stronger materials. The R-chart values indicate that a gain or loss in dispersion has occurred. Such a change may be due to worn bearings, a loose tool, an erratic flow of lubricants to a machine, or to sloppiness on the part of a machine operator. The two types of charts go hand in hand when monitoring variables because they measure the two critical parameters, central tendency and dispersion.

3.3 The Central Limit Theorem

The theoretical foundation for x-charts is the central limit theorem. This theorem states that regardless of the distribution of the population, the distribution of x s (each of which is a mean of a sample drawn from the population) will tend to follow a normal curve as the number of samples increases. Fortunately, even if the sample (n) is fairly small (say, 4 or 5), the distributions of the averages will still roughly follow a normal curve. The theorem also states that: (1) the mean of the distribution of the x s (called x) will equal the mean of the overall population (called u); and (2) the standard deviation of the sampling distribution, o x, will be the *population standard deviation, o, divided by the square root of the* sample size, n. In other words.

x = u

and

o x = o n

3.4 Setting Mean Chart Limits (x-Charts)

If we know, through past data, the standard deviation of the process population, o, we can set upper and, lower control limits by these formulas

Upper control limit (UCL) = _= + z sx

x

Lower control limit (LCL) = _ = – z sx

X

Where x = mean of the sample means or a target value set for the process

z = number of normal standard deviations (2 for 95.45% confidence, 3 for 99.73%)

o x = standard deviation of the sample means = o n

o = population (process) standard deviation.

n = sample size.

3.5 Setting Range Chart Limits (R-Charts)

In addition to being concerned with the process average, operations managers are interested in the process dispersion, or range. Even though the process average is under control, the dispersion of the process may not be. For example, something may have worked itself loose in a piece of equipment that fills boxes of Oat Flakes. As a result, the average of the samples may remain the same, but the variation within the samples could be entirely too large. For this reason, operations managers use control charts for ranges to monitor the process variability, as well as control charts for averages, which monitor the process central tendency. The theory behind the control charts for ranges is the same as that for process average control charts. Limits are established that contain +3 standard deviations of the distribution for the average range R. We can use the following equations to .set the upper and lower control limits for ranges.

UCL R = D4R

LCL R = D3R

where UCLR = upper control chart limit for the range.
LCLR = lower control chart limit for the range
D 4 and D3 = values from

3.6 Using Mean and Range Charts

The normal distribution is defined by two parameters, the mean and standard deviation. The x (mean)-chart and the R-chart mimic these two parameters. The x-chart is sensitive to shifts in the process mean, whereas the R-chart is sensitive to shifts in the process standard deviation. Consequently, by using both charts we can track changes in the process distribution.

3.6.1 Steps to Follow when Using Control Charts

There are five steps that are generally followed in using x- and R-charts.

1. Collect 20 to 25 samples of n = 4 or n = 5 each from a stable process and compute the mean and range of each.

2. Compute the overall means (x and R), set appropriate control limits, usually at the 99.73% level, and calculate the preliminary upper and lower control limits. If the process is not currently stable, use the desired mean, u, instead of x to calculate limits.

3. Graph the sample means and ranges on their respective control charts and determine whether they fall outside the acceptable limits.

4. Investigate points or patterns that indicate the process is out of control. Try to assign causes for the variation and then resume the process.

5. Collect additional samples and, if necessary, revalidate the control limits using the new data.

3.7 Control Charts for Attributes

Control charts for x and R do not apply when we are sampling *attributes, which are typically classified as defective or nondefective.* Measuring defectives involves counting them (for example, number of bad lightbulbs in a given lot, or number of letters or data entry records typed with errors), whereas variables are usually measured for length or weight. There are two kinds of attribute control charts: (1) those that measure the percent defective in a sample called p-charts-and (2) those that count the number of defects called c-charts.

3.7.1 P-Charts

Using p-charts is the chief way to control attributes. Although attributes that are either good or bad follow the binomial distribution, the normal distribution can be used to calculate p-chart limits when sample sizes are large. The procedure resembles the x -chart approach, which was also based on the central limit theorem

The formulas for p-chart upper and lower control limits follow

UCL p = p + zop

LCL p = p – zop

p = mean fraction defective in the sample.
z = number of standard deviations (z = 2 for 95.45% limits; z = 3 for 99.73% limits).
a p = standard deviation of the sampling distribution
a p is estimated by the formula

p(1-p) op = n
where n = size of each sample.

3.7.2 C-Charts

A defective record was one that was not exactly correct because it contained at least one defect. However, a bad record may contain more than one defect. We use c-charts to control the number of defects per unit of output.

Control charts for defects are helpful for monitoring processes in which a large number of potential errors can occur, but the actual numbers that do occur is relatively small. Defects may be errors in newspaper words, bad circuits in a microchip, blemishes on a table, or missing pickles on a fast food hamburger.

The Poisson probability distribution, which has a variance equal to its mean, is the basis for c-charts. Because c is the mean number of defects per unit, the standard deviation is equal to *. To compute 99.73% control limits for c, we use the formula.

Control limits = c + 3 c

3.8 Process Capability

Statistical process control means we want to keep the process in control. This means that the natural variation of the process must be small (narrow) enough to produce products that meet the standards (quality) required. But a process that is in statistical control may not yield goods or services that meet their design specifications (tolerances). The ability of a process to meet design specifications, which are set by engineering design or customer requirements, is called process capability. Even though that process may be statistically in control (stable), the output of that process may not conform to specifications.

3.8.1 Process Capability Ratio (Cp)

For a process to be capable, its values must fall within upper and lower specifications. This typically means the process capability is within +3 standard deviations from the process mean. Since this range of values is 6 standard deviations, a capable process tolerance, which is the difference between the upper and lower specifications, must be greater than or equal to 6.

The process capability ratio, Cp' is computed as

$$Cp = \frac{\text{Upper Specification - Lower Specification}}{6}$$

3.8.2 Process Capability Index (Cpk)

The process capability index, Cpk measures the difference between the desired and actual dimensions of goods or services produced

The formula for Cpk is

$$\text{Cpk} = \text{minimum of } \left[\frac{\text{Upper Specification Limit} - \bar{X}}{3\sigma}, \frac{\bar{X} - \text{Lower Specification Limit}}{3\sigma} \right]$$

Where X = process mean

o = standard deviation of the process population

3.9 Acceptance Sampling

Acceptance sampling is a form of testing that involves taking random samples of "lots," or batches, of finished products and measuring them against predetermined standards. Sampling is more economical than 100% inspection. The quality of the sample is used to judge the quality of all items in the lot. Although both attributes and variables can be inspected by acceptance sampling, attribute inspection is more commonly used, as illustrated in this section.

Acceptance sampling can be applied either when materials arrive at a plant or at final inspection, but it is usually used to control incoming lots of purchased products. A lot of items rejected, based on an unacceptable level of defects found in the sample, can (1) be returned to the supplier or (2) be 100% inspected to cull out all defects, with the cost of this screening usually billed to the supplier. However, acceptance sampling is not a substitute for adequate process controls. In fact, the current approach is to build statistical quality controls at suppliers so that acceptance sampling can be eliminated.

3.9.1 Operating Characteristic Curve

The operating characteristic (OC) curve describes how well an acceptance plan discriminates between good and bad lots. A curve pertains to a specific plan-that is, to a combination of n (sample size) and c (acceptance level). It is intended to show the probability that the plan will accept lots of various quality levels.

With acceptance sampling, two parties are usually involved: the producer of the product and the consumer of the product. In specifying a sampling plan, each party wants to avoid costly mistakes in accepting or rejecting a lot. The producer usually has the responsibility of replacing all defects in the rejected lot or of paying for a new lot to be shipped to the customer. The producer, therefore, wants to avoid the mistake of having a good lot rejected (producer's risk). On the other hand, the customer or consumer wants to avoid the mistake of accepting a bad lot because defects found in a lot that has already been accepted are usually the responsibility of the customer (consumer's risk). The OC curve shows the features of a particular sampling plan, including the risks of making a wrong decision.

3.9.2 Average Outgoing Quality

In most sampling plans, when a lot is rejected, the entire lot is inspected and all defective items replaced. Use of this replacement technique improves the average outgoing quality in terms of percent defective. In fact, given (1) any sampling plan that replaces all defective items encountered (2) the true incoming percent defective for the lot, it is possible to determine the average outgoing quality (AOQ) in percent defective. The equation for AOQ is

P d = *true percent defective of the lot*
P a = *probability of accepting the lot for a given sample size and* quantity defective
N = *number of items in the lot n = number of items in the* sample

SELF ASSESSMENT EXERCISE

1. Define “in statistical control”.
2. Explain briefly what x-chart and an R-chart do.

4.0 CONCLUSION

Statistical process control is a major statistical tool of quality control. Control charts for SPC help operations managers distinguish between natural and assignable variations.

5.0 SUMMARY

The x –chart and the R – chart are used for variable sampling, and the p-chart and the c – chart for attribute sampling. The Cpk index is a way to express process capability. Operating characteristic (OC) curves facilitate acceptance sampling and provide the manager with tools to evaluate the quality of a production run or shipment.

6.0 TUTOR-MARKED ASSIGNMENT

A manufacturer of precision machine parts produces round shafts for use in the construction of drill presses. The average diameter of a shaft is .

56 inch. Inspection samples contain 6 shafts each. The average range of these samples is .006 inch. Determine the upper and lower x control chart limits.

Use Table to solve the above question.

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UNIT 4 CAPACITY PLANNING

CONTENTS

1.0 INTRODUCTION

After selection of a production process, we need to determine capacity. Capacity is the "throughput," or the numbers of units a facility can hold, receive, store or produce in a period of time. The capacity determines a large portion of fixed cost. Capacity also determines if demand will be satisfied or if facilities will be idle. If the facility is too large, portions of it will sit idle and add cost to existing production. If the facility is too small, customers and perhaps entire markets are lost, so determining facility size, with an objective of achieving high levels of utilization and a high return on investment, is critical.

2.0 OBJECTIVES

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

Identify or Define

- capacity
- design capacity
- effective capacity
- utilization

Describe or Explain

- capacity consideration
- net present value analysis
- break-even analysis
- financial considerations
- Strategy-driven investment.

3.1 Capacity

Capacity planning can be viewed in three time horizons. In Figure 7.1 we noted that long-range capacity (greater than 1 year) is a function of adding facilities and equipment that have a long lead time. In the intermediate range (3 to 18 months) we can add equipment, personnel, and shifts; we can subcontract; and we can build or use inventory. This is the aggregate planning task. In the short run (usually up to 3 months) we are primarily concerned with scheduling jobs and people, and allocating machinery. It is difficult to modify capacity in the short run; we are using capacity that already exists.

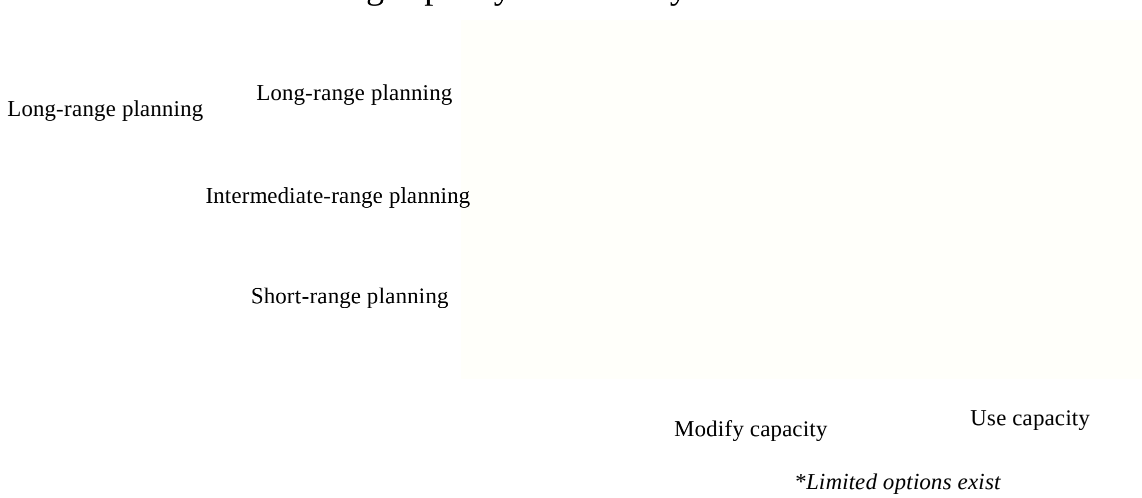

Fig. 7.1

3.2 Design and Effective Capacity

Design capacity is the maximum theoretical output of a system in a given period under ideal conditions. It is normally expressed as a rate, such as the number of tons of steel that can be produced per week, per month, or per year. For many companies, measuring capacity can be straightforward: It is the maximum number of units produced in a specific time. However, for some organizations, determining capacity can be more difficult. Capacity can be measured in terms of beds (a hospital), active members (a church), or classroom size (a school). Other organizations use total work time available as a measure of overall capacity.

Most organizations operate their facilities at a rate less than the design capacity. They do so because they have found that they can operate more efficiently when their resources are not stretched to the limit. Instead, they expect to operate at perhaps 82% of design capacity. This concept is called effective capacity.

Effective capacity is the capacity a firm expects to achieve, given the current operating constraints. Effective capacity is often lower than design capacity because the facility may have been designed for an earlier version of the product or a different product mix than is currently being produced.

Two measures of system performance are particularly useful: utilization and efficiency.

Utilization is simply the percent of design capacity actually achieved. Efficiency is the percent of effective capacity actually achieved. Depending on how facilities are used and managed, it may be difficult or impossible to reach 100% efficiency. Operations managers tend to be evaluated on efficiency. The key to improving efficiency is often found in correcting quality problems and in effective scheduling, training, and maintenance. Utilization and efficiency are computed below

Utilization = Actual output/Design capacity
Efficiency = Actual output/Effective capacity

3.3 Capacity and Strategy

Sustained profits come from building competitive advantage, not just from a good financial return on a specific process. Capacity decisions must be integrated into the organization's mission and strategy. Investments are not to be made as isolated expenditures, but as part of a coordinated plan that will place the firm in an advantageous position.'

The questions to be asked are, Will these investments eventually win customers? And what competitive advantage (such as process flexibility, speed of delivery, improved quality, and so on) do we obtain?

All 10 decisions of operations management we discuss in this text, as well as other organizational elements such as marketing and finance, are affected by changes in capacity. Change in capacity will have sales and cash flow implications, just as capacity changes have quality, supply chain, human resource, and maintenance implications. All must be considered.

3.4 Capacity Considerations

In addition to tight integration of strategy and investments, there are four special considerations for a good capacity decision.

1. Forecast demand accurately. An accurate forecast is paramount to the capacity decision. The new product may be Hard Rock Cafe's nightly live music venue that places added demands on the cafe's food service and retail shop, or the product may be a new maternity capability at Arnold Palmer Hospital, or the new PT Cruiser convertible at DaimlerChrysler. Whatever the new product, its prospects and the life cycle of existing products, must be determined. Management must know which products are being added and which are being dropped, as well as their expected volumes.

2. Understand the technology and capacity increments. The number of initial alternatives may be large, but once the volume is determined, technology decisions may be aided by analysis of cost, human resources required, quality, and reliability. Such a review often reduces the number of alternatives to a few. The technology may dictate the capacity increment. Meeting added demand with a few extra tables in the dining room of a restaurant may not be difficult, but meeting increased demand for a new automobile by adding a new assembly line at BMW may be very difficult-and expensive. But the operations manager is held responsible for the technology and the correct capacity increment.

3. Find the optimum operating level (volume). Technology and capacity increments often dictate an optimal size for a facility. A roadside motel may require 50 rooms to be viable. If smaller, the fixed cost is too burdensome; if larger, the facility becomes more than one manager can supervise.

4. Build for change. In our fast-paced world, change is inevitable. So operations managers build flexibility into the facility and equipment. They evaluate the sensitivity of the decision by testing several revenue projections on both the upside and downside for potential risks. Buildings, and the infrastructure for such things as utilities and parking, can often be built in phases. And buildings and equipment can be designed with modifications in mind to accommodate future changes in product, product mix, and processes.

3.5 Managing Demand

Even with good forecasting and facilities built to that forecast, there may be a poor match between the actual demand that occurs and available capacity. A poor match may mean demand exceeds, capacity, or capacity exceeds demand. However, in both cases firms have options.

3.5.1 Demand Exceeds Capacity

When demand exceeds capacity, the firm may be able to curtail demand simply by raising prices, scheduling long lead times (which may be inevitable), and discouraging marginally profitable business. However, because inadequate facilities reduce revenue below what is possible, the long-term solution is usually to increase capacity.

3.5.2 Capacity Exceeds Demand

When capacity exceeds demand, the firm may want to stimulate demand through price reductions or aggressive marketing, or it may accommodate the market through product changes.

3.5.3 Adjusting to Seasonal Demands

A seasonal or cyclical pattern of demand is another capacity challenge. In such cases, management may find it helpful to offer products with complementary demand patterns-that is, products for which the demand is high for one but low for the other.

3.5.4 Tactics for Matching Capacity to Demand

Various tactics for matching capacity to demand exist. Internal changes include adjusting the process to a given volume through:

1. Making staffing changes (increasing or decreasing the number of employees);
2. Adjusting equipment and processes, which might include purchasing additional machinery or selling or leasing out existing equipment.

3. Improving methods to increase throughput; and/or
4. Redesigning the product to facilitate more throughput.

The foregoing tactics can be used to adjust demand to existing facilities. The strategic issue is, of course, how to have a facility of the correct size

3.6 Capacity Planning

Setting future capacity requirements can be a complicated procedure, one based in large part on future demand. When demand for goods and services can be forecast with a reasonable degree of precision, determining capacity requirements can be straightforward. Determining capacity normally requires two phases. During the first phase, future demand is forecast with traditional models. During the second phase, this forecast is used to determine capacity requirements and the incremental size of each addition to capacity. Interestingly, demand growth is typically gradual in small units, while capacity additions are typically instantaneous in large units. This contradiction often makes the capacity expansion difficult.

Fig. 6.3

3.7 Costs

Fixed costs are costs that continue even if no units are produced. Examples include depreciation, taxes, debt, and mortgage payments. Variable costs are those that vary with the volume of units produced. The major components of variable costs are labor and materials. However, other costs, such as the portion of the utilities that varies with volume, are also variable costs. The difference between selling price and variable cost is contribution. Only when total contribution exceeds total fixed cost will there be profit.

Another element in break-even analysis is the revenue function. As shown in the diagram, revenue begins at the origin and proceeds upward to the right, increasing by the selling price of each unit. Where the revenue function crosses the total cost line (the sum of fixed and variable costs), is the break-even point, with a profit corridor to the right and a loss corridor to the left.

3.7.1 Assumptions

A number of assumptions underlie this basic break-even model. Notably, costs and revenue are shown as straight lines. They are shown to increase linearly that is, in direct proportion to the volume of units being produced. However, neither fixed costs nor variable costs (nor, for that matter, the revenue function) need be a straight line. For example, fixed costs change as more capital equipment or warehouse space is used; labour costs change with overtime or as marginally skilled workers are employed; the revenue function may change with such factors as volume discounts.

3.7.2 Graphic Approach

The first step in the graphic approach to break-even analysis is to define those costs that are fixed and sum them up. The fixed costs are drawn as a horizontal line beginning at that dollar amount on the vertical axis. The variable costs are then estimated by an analysis of labor, materials, and other costs connected with the production of each unit. The variable costs are shown as an incrementally increasing cost, originating at the intersection of the fixed cost on the vertical axis and increasing with each change in volume as we move to the right on the volume (or horizontal) axis. Both fixed and variable cost information is usually available from a firm's cost accounting department, although an industrial engineering department may also maintain cost information.

3.7.3 Algebraic Approach

The respective formulas for the break-even point in units and Nairas are shown below. Let:

BEP = break-even point in units TR = total revenue = PX
BEPN = break-even point in nairas F = fixed costs
P = price per unit (after all discounts) V = variable costs per unit
x = number of units produced TC = total costs = F+Vx

The break-even point occurs where total revenue equals total costs. Therefore,

$$TR = TC \text{ or } Px = F + Vx$$

Solving for x, we get

$$BEPx = \frac{F}{P - V}$$

and

$$BEPN = BEPX\ P = \frac{F}{P} P = \frac{F}{(P - V)/P} = \frac{F}{1 - V/P}$$

$$\begin{aligned}\text{Profit} &= TR - TC \\ &= Px - (F + Vx) = Px - F - Vx \\ &= (P - V)x - F\end{aligned}$$

Using these equations, we can solve directly for break-even point and profitability. The two formulas of particular interest are:

$$\text{Break-even in units} = \frac{\text{Total fixed cost}}{\text{Price - Variable cost}}$$

$$\text{Break-even in nairas} = \frac{\text{Total fixed cost}}{1 - \dfrac{\text{Variable cost}}{\text{Selling price}}}$$

3.8 Multiproduct Case

Most firms, from manufacturers to restaurants (even fast-food restaurants), have a variety of offerings. Each offering may have a different selling price and variable cost. Utilizing break-even analysis, we modify Equation to reflect the proportion of sales for each product. We do this by "weighting" each product's contribution by its proportion of sales. The formula is then

$$BEP_s = \frac{F}{\sum \left[\left(1 - \frac{V_i}{P_i}\right) \times (W_i)\right]}$$

Where V = variable cost per unit
P = price per unit
F = fixed cost
W = percent each product is of total naira sales
i = each product

3.9 Applying Decision Trees to Capacity Decisions

Decision trees require specifying alternatives and various states of nature. For capacity planning situations, the state of nature usually is future demand or market favorability. By assigning probability values to the various states of nature, we can make decisions that maximize the expected value of the alternatives.

3.9.1 Investment, Variable Cost and Cash Flow

Because capacity and process alternatives exist, so do options regarding capital investment and variable cost. Managers must choose from among different financial options as well as capacity and process alternatives. Analysis should show the capital investment, variable cost, and cash flows as well as net present value for each alternative.

3.9.2 Net Present Value

Determining the discount value of a series of future cash receipts is known as the net present value technique. By way of introduction, let us consider the time value of money. Say you invest N100.00 in a bank at 5% for 1 year. Your investment will be worth N100.00 + (N100.00)(.05) = N105.00. If you invest the 'N105.00 for a second year, it will be worth N105.00 + (N105.00)(.05) = N110.25 at the end of the second year. Of course, we could calculate the future value of N100.00 at 5% for as many years -as we wanted by simply extending this analysis. However, there is an easier way to express this relationship mathematically. For the first year:

$$N105 = N100\ (1+.05)$$

For the second year: $N110.25 = N105\ (1+.05) = N100\ (1+.05)^2$

In general,

$$F = P\ (1+i)^N$$

where F = future value (such as N10.25 or N105)
P = present value (such as N100.00)
i = interest rate (such as .05)
N = number of years (such as 1 year or 2 years)

In most investment decisions, however, we are interested in calculating the present value of a series of future cash receipts. Solving for P, we get.

$$P = \frac{F}{(1+i)^N}$$

When the number of years is not too large, the preceding equation is effective. However, when the number of years, N, is large, the formula is cumbersome. For 20 years, you would have to compute $(1+i)^{20}$. Without a sophisticated calculator, this computation would be difficult. Interest-rate tables, such as Table S7.1, alleviate this situation. First, let us restate the present value equation:

$$P = \frac{F}{(1+i)^N} = FX$$

where X = is a factor defined as $=1/(1+i)^N$ and F = future value

Thus, all we have to do is find the factor X and multiply it by F to calculate the present value, P. The factors, of course, are a function of the interest rate, i, and the number of years.

4.0 CONCLUSION

Managers tie equipment selection and capacity decisions to the organisation's missions and strategy. They design their equipment and processes to have capabilities beyond the tolerance required by their customers while ensuring the flexibility needed for adjustments in technology, features and volumes.

Good forecasting, break-even analysis, decision trees, cash flow, and net present value (NPV) techniques are particularly useful to operations managers when making capacity decisions

5.0 SUMMARY

Capacity investments are made effective by ensuring that the investments support a long-term strategy. The criteria for investment decisions are contribution to the overall strategic plan and winning profitable orders, not just return in Investment.

Efficient firms select the correct process and the correct capacity that contributes to their long-term strategy.

6.0 TUTOR-MARKED ASSIGNMENT

1. If a plant was designed to produce 7,000 hammers per day but is limited to making 6,000 hammers per day because of the time needed to change equipment between styles of hammers, what is the utilization?

2. For the past month, the plant in problem 7.1, which has an effective capacity of ,500, has made only 4,500 hammers per day because of material delay, employee absences and other problems. What is its efficiency?

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UNIT 5 LOCATION STRATEGIES

CONTENTS

1.0 INTRODUCTION

One of the most important strategic decisions made by companies like Federal Express, Daimler Chrysler, and Hard Rock is where to locate their operations. The international aspect of these decisions is an indication of the global nature of location decisions. With the opening of the Soviet and Chinese blocs, a great transformation is taking place. World markets have doubled, and the global nature of business is accelerating.

2.0 OBJECTIVES

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

Identify or define

- objectives of Location Strategy
- international location issues
- clustering
- geographic information issues

Describe or explain

Three Methods of Solving the Location Problem:

- Factor-Rating Method
- Location Break-Even Analysis
- Center-of-Gravity Method.

3.0 MAIN CONTENT

3.1 Location Strategies

3.1.1 The Strategic Importance of Location

Firms throughout the world are using the concepts and techniques of this unit to address the location decision because location greatly affects both fixed and variable costs. Location has a major impact on the overall risk and profit of the company. For instance, depending on the product and type of production or service taking place, transportation costs alone can cost as much as 25% of the product's selling price. That is, one-fourth of a firm's total revenue may be needed just to cover freight expenses of the raw materials coming in and finished products going out. Other costs that may be influenced by location include taxes, wages, raw material costs, and rents.

Companies make location decisions relatively infrequently, usually because demand has outgrown the current plant's capacity or because of changes 'in labor productivity, exchange rates, costs, or local attitudes. Companies may also relocate their manufacturing or service facilities because of shifts in demographics and customer demand.

Location options include (I) expanding an existing facility instead of moving, (2) maintaining current sites while adding another facility elsewhere, or (3) closing the existing facility and moving to another location.

The location decision often depends on the type of business. For industrial location decisions, the strategy is usually minimizing costs, although innovation and creativity may also be critical. For retail and professional service organizations, the strategy focuses on maximizing revenue. Warehouse location strategy, however, may be driven by a combination of cost and speed of delivery. The objective of location *strategy is to maximize the benefit of location to the firm.*

3.1.2 Location and Costs

Because location is such a significant cost device, location often has the power to make (or break) a company's business strategy. Key multinationals in every major industry, from automobiles to cellular phones, now have or are planning a presence in each of their major markets. Location decisions based on a low-cost strategy requires careful consideration.

Once management is committed to a specific location, many costs are firmly in place and difficult to reduce. For instance, if a new factory location is in a region with high energy costs, even good management with an outstanding energy strategy is starting at a disadvantage. Management is in a similar bind with its human resource strategy if labour in the selected location is expensive, ill-trained, or has a poor work ethic. Consequently, hard work to determine an optimal facility location is a good investment.

3.1.3 Location and Innovation

When creativity, innovation, and research and development investments are critical to the operations strategy the location criteria may change from a focus on costs. When innovation is the focus, four attributes seem to affect overall competitiveness as well as innovation.

•The presence of high-quality and specialized inputs such as scientific and technical talent.
•An environment that encourages investment and intense local rivalry.
•Pressure and insight gained from a sophisticated local market.
•Local presence of related and supporting industries.

3.2 Factors that Affect Location Decisions

Selecting a facility location is becoming much more complex with the globalization of the workplace. As we saw in Unit 2, globalization has taken place because of the development of (1) market economics; (2) better international communications; (3) more rapid, reliable travel and shipping; (4) ease of capital flow between countries; and (5) high differences in labor costs. Many firms now consider opening new offices, factories. Retail stores or banks outside their home country. Location decisions transcend national borders.

3.2.1 Factors that Affect Location Decision

Selecting a facility location is becoming much more complex with the globalization of the workplace. As we saw in unit 2, globalization has taken place because of the development of (1) market economics; (2) better international communications; (3) more rapid, reliable travel and shipping; (4) ease of capital flow between countries; and (5) high differences in labor costs. Many firms now consider opening new offices, factories, retail stores, or banks outside their home country, location decisions transcend national borders.

3.2.2 Labour Productivity

When deciding on a location, management may be tempted by an area's low wage rates. However, wage rates cannot be considered by themselves, Management must also consider productivity.

Differences exist in productivity in various countries. What management is really interested in, is the combination of productivity and the wage rate.

Employees with poor training, poor education, or poor work habits may not be a good buy even at low wages. By the same token, employees who cannot or will not always reach their places of work are not much good to the organization, even at low wages. (Labor cost per unit is sometimes called the labor content of the product.)

$$\frac{\text{Labor cost per day}}{\text{Productivity (that is, units per day)}} = \text{Cost per unit}$$

3.2.3 Exchange Rates and Currency Risk

Although wage rates and productivity may make a country seem economical, unfavourable exchange rates may negate any savings. Sometimes, though, firms can take advantage of a particularly favourable exchange rate by relocating or exporting to a foreign country.

However, the values of foreign currencies continually rise and fall in most countries. Such changes could well make what was a good location in 2006 a disastrous one in 2010.

3.2.4 Costs

We can divide location costs into two categories, tangible and intangible. Tangible costs are those costs that are readily identifiable and precisely measured. They include utilities, labor, material, taxes, depreciation, and other costs that the accounting department and management can identify. In addition, such costs as transportation of raw materials, transportation of finished goods, and site construction are all factored into the overall cost of a location. Government incentives certainly affect a location's cost.

Intangible costs are less easily quantified. They include quality of education, public transportation facilities, community attitudes toward the industry and the company, and quality and attitude of prospective employees. They also include quality of life variables, such as climate and sports teams, that may influence personnel recruiting.

3.2.5 Ethical Issues

Location decisions based on costs alone may create ethical situations such as the United Airlines case in Indianapolis, United accepted $320 million in incentives to open a facility in that location, only to renege a decade later, leaving residents and government holding the bag.

To what extent do companies owe long-term allegiance to a particular country or state or town if they are losing money or if the firm can make greater profits elsewhere? Is it ethical for developed countries to locate plants in undeveloped countries where sweatshops and child labor are commonly used? Where low wages and poor working conditions are the norm? It has been said that the factory of the future will be a large ship, capable of moving from port to port as costs in one port becomes noncompetitive.

3.2.6 Attitudes

Attitudes of national, state, and local governments towards private and intellectual property, zoning, pollution, and employment stability may be in flux. Governmental attitudes at the time a location decision is made may not be the lasting ones. Moreover, management may find that these attitudes can be influenced by their own leadership.
Worker attitudes may also differ from country to country, region to region, and small town to city. Worker views regarding turnover,

unions, and absenteeism are all relevant factors. In turn, these attitudes can affect a company's decision whether to make offers to current workers if the firm relocates to a new location.

One of the greatest challenges in a global operations decision is dealing with another country's culture. Cultural variations in punctuality by employees and suppliers make a marked difference in production and delivery schedules. Bribery likewise creates substantial economic inefficiency, as well as ethical and legal problems in the global arena. As a result, operations managers face significant challenges when building effective supply chains that include foreign firms.

3.2.7 Proximity to Markets

For many firms it is extremely important to locate near customers. Particularly, service organizations, like drugstores, restaurants, post offices, or barbers, find that proximity to market is the primary location factor. Manufacturing firms find it useful to be close to customers when transporting finished goods as expensive or difficult (perhaps because they are bulky, heavy, or fragile). In addition, with the trend toward just-in-time production, suppliers want to locate near users to speed deliveries. For a firm like Coca-Cola, whose product's primary ingredient is water, it makes sense to have bottling plants in many cities rather than shipping heavy (and sometimes fragile glass) containers cross country.

3.2.8 Proximity to Suppliers

Firms locate near their raw materials and suppliers because of (1) perishability, (2) transportation costs, or (3) bulk. Bakeries, dairy plants, and frozen seafood processors deal with perishable raw materials, so they often locate close to suppliers. Companies dependent on inputs of heavy or bulky raw materials (such as steel producers using coal and iron ore) face expensive inbound transportation costs, so transportation costs become a major factor. And goods for which there is a reduction in bulk during production (such as lumber mills located in the Northwest near timber resources) typically need to be near the raw material.

3.2.9 Proximity to Competitors (Clustering)

Companies also like to locate, somewhat surprisingly, near competitors. This tendency, called clustering, often occurs when a major resource is found in that region. Such resources include natural resources, information resources, venture capital resources, and talent resources. Italy may be the true leader when it comes to clustering, however, with northern zones of that country holding world leadership in such specialties as ceramic tile (Modena), gold jewelry (Vicenza), machine tools (Busto Arsizio), cashmere and wool (Biella), designer eyeglasses (Belluma), and pasta machines (Parma).

3.3 Methods of Evaluating Location Alternatives

Four major methods are used for solving location problems: the factor-rating method, locational break-even analysis, the center-of-gravity method, and the transportation model. This section describes these approaches.

3.3.1 The Factor-Rating Method

There are many factors, both qualitative and quantitative, to consider in choosing a location. Some of these factors are more important than others, so managers can use weightings to make the decision process more objective. The factor-rating method is popular because a wide variety of factors, from education to recreation to labor skills, can be objectively included. The factor rating method has six steps.

1. Develop a list of relevant factors called critical success factors.
2. Assign a weight to each factor to reflect its relative importance in the company's objectives
3. Develop a scale for each factor (for example, I to 10 or I to 100 points).
4. Have management score each location for each factor, using the scale in step 3.
5. Multiply the score by the weights for each factor and total the score for each location.
6. Make a recommendation based on the maximum point score, considering the results of quantitative approaches as well.

When a decision is sensitive to minor changes, further analysis of either the weighting or the points assigned may be appropriate. Alternatively, management may conclude that these intangible factors are not the proper criteria on which to base a location decision. Managers therefore place primary weight on the more quantitative aspects of the decision.

3.3.2 Locational Break-Even Analysis

Locational break-even analysis is the use of cost-volume analysis to make an economic comparison of location alternatives. By identifying fixed and variable costs and graphing them for each location, we can determine which one provides the lowest cost. Locational break-even analysis can be done mathematically or graphically. The graphic approach has the advantage of providing the range of volume over which each location is preferable.

The three steps to locational break-even analysis are as follows:

1. Determine the fixed and variable cost for each location.
2. Plot the costs for each location, with costs on the vertical axis of the graph and annual volume on the horizontal axis.
3. Select the location that has the lowest total cost for the expected production volume.

3.3.3 Centre-of-Gravity Method

The centre-of-gravity method is a mathematical technique used for finding the location of a distribution center that will minimize distribution costs. The method takes into account the location of markets, the volume of goods shipped to those markets, and shipping costs in finding the best location for a distribution centre.

The first step in the centre-of-gravity method is to place the locations on a coordinate system. The origin of the coordinate system and the scale used are arbitrary, just as long as the relative distances are correctly represented. This can be done easily by placing a grid over an ordinary map. The centre of gravity is determined by the following equations:

$$\text{x-coordinate of the center of gravity} = \frac{\sum_i d_{ix} Q_i}{\sum_i Q_i}$$

$$\text{y-coordinate of the center of gravity} = \frac{\sum_i d_{iy} Q_i}{\sum_i Q_i}$$

where d_{ix} = x-coordinate of location i

d_{iy} = y-coordinate of locaction i

Q_i = Quantity of goods moved to or from location i

Note that these equations include the term Q;, the quantity of supplies transferred to or from location i.

Since the number of containers shipped each month affects cost, distance alone should not be the principal criterion. The center-of-gravity method assumes that cost is directly proportional to both distance and volume shipped. The ideal location is that which minimizes the weighted distance between the warehouse and its retail outlets, where the distance is weighted by the number of containers shipped.

3.3.4 Transportation Model

The objective of the transportation model is to determine the best pattern of shipments from several points of supply (sources) to several points of demand (destinations) so as to minimize total production and transportation costs. Every firm with a network of supply and demand points faces such a problem. The complex Volkswagen supply network provides one such illustration. VW Mexico ships vehicles for assembly and parts to VW of Nigeria, sends assemblies to VW of Brazil, and receives parts and assemblies from headquarters in Germany.

Although the linear programming (LP) technique can be used to solve this type of problem, more efficient, special-purpose algorithms have been developed for the transportation application. The transportation model finds an initial feasible solution and then makes step-by-step improvement until an optimal solution is reached.

3.4 Service Location Strategy

While the focus in industrial-sector location analysis is on minimizing cost, the focus in the service sector is on maximizing revenue. This is because manufacturing firms finds that costs tend to vary substantially among locations, while service firms find that location often has more impact on revenue than cost. Therefore, for the service firm, a specific location often influences revenue more than it does cost. This means that the location focus for service firms should be on determining the volume of business and revenue. There are eight major components of volume and revenue for the service firm:

1. Purchasing power of the customer-drawing area.
2. Service and image compatibility with demographics of the customer drawing area.
3. Competition in the area.
4. Quality of the competition.
5. Uniqueness of the firm's and competitors' locations.
6. Physical qualities of facilities and neighboring businesses.
7. Operating policies of the firm.
8. Quality of management

Realistic analysis of these factors can provide a reasonable picture of the revenue expected. The techniques used in the service sector include correlation analysis, traffic counts, demographic analysis, purchasing. power analysis, the factor-rating method, the center-of-gravity method, and geographic information systems.

3.4.1 How Hotel Chains Select Sites

One of the most important decisions in the hospitality industry is location. Hotel chains that pick good sites more accurately and quickly than competitors have a distinct strategic advantage.

The hotel started by testing 35 independent variables, trying to find which of them would have the highest correlation with predicted profitability, the dependent variable. "Competitive" independent variables included the number of hotel rooms in the vicinity and average room rates.

Service/Retail/Professional Location	Goods-Producing Location
Revenue Focus	**Cost Focus**
Volume/revenue Drawing area; purchasing power Competition; advertising/pricing Physical quality Parking/access; security/lighting; Appearance/image **Cost determinants** Rent Management caliber Operation policies (hours, wage rates)	**Tangible costs** Transportation cost of raw material Shipment cost of finished goods Energy and utility cost; labour; raw material; taxes, and so on **Intangible and future costs** Attitude toward union Quality of life Education expenditures by state Quality of state and local government
Techniques	**Techniques**
Regression models to determine importance of various factors Factor-rating method Traffic counts Demographic analysis of area Centre of gravity method Geographic information systems	Transportation method Factor-rating method Locational break-even analysis Crossover charts
Assumptions	**Assumptions**
Location is a major determinant of revenue High customer-contact issues are critical Costs are relatively constant for a given area; therefore, the revenue function is critical	Location is a major determinant of cost Most major costs can be identified explicitly for each site Low customer contact allows focus on the identifiable costs Intangible costs can be evaluated

3.4.2 The Telemarketing Industry

Those industries and office activities that require neither face-to-face contact with the customer nor movement of material broaden location options substantially. A case in point is the telemarketing industry and those selling over the Internet, in which our traditional variables are no longer relevant. Where the electronic movement of information is good, the cost and availability of labor may drive the location decision. For instance, Fidelity Investments relocated many of its employees from

Boston to Covington, Kentucky. Now employees in the low-cost Covington region connect, by inexpensive fiber-optic phone lines, to their colleagues in the Boston office at a cost of less than a penny per minute. That is less than Fidelity spends on local connections.

The changes in location criteria may also affect a number of other businesses. For instance, states with smaller tax burdens and owners of property in fringe suburbs and scenic rural areas should come out ahead. So should e-mail providers, telecommuting software makers, video conferencing firms, makers of office electronic equipment, and delivery firms.

3.4.3 Geographic Information Systems

Geographic information systems (GISs) are an important tool to help firms make successful, analytical decisions with regard to location. Retailers, banks, food chains, gas stations, and print shop franchises can all use geographically coded files from a GIS to conduct demographic analyses. By combining population, age, income, traffic flow, and density figures with geography, a retailer can pinpoint the best location for a new store or restaurant.

Here are some of the geographic databases available in many GISs.

•Census data by block, tract, city, county, congressional district, metropolitan area, state zip code.
•Maps of every street, highway, bridge, and tunnel in the U.S.
•Utilities such as electrical, water, and gas lines.
•All rivers, mountains, lakes, forests.
•All major airports, colleges, hospitals

Airlines, as an example, use GIS to identify airports where ground services are the most effective. This information is then used to help schedule and to decide where to purchase fuel, meals, and other services.

SELF ASSESSMENT EXERCISE

Why do so many U.S. firms build facilities in other countries?

4.0 CONCLUSION

For service, retail, and professional organizations, analysis is typically made of a variety of variables including purchasing power of a drawing area, competition, advertising and promotion, physical qualities of the location, and operating policies of the organization

5.0 SUMMARY

Location may determine up to 10% of the total cost of an industrial firm. Location is also a critical element in determining revenue for the service, retail, or professional firm. Industrial firms need to consider both tangible and intangible costs. Industrial location problems are typically addressed via a factor-rating method, locational break-even analysis, the center-of-gravity method, and the transportation method of linear programming

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the three steps to locate break-even analysis?

2. In Cambodia, six laborers each making the equivalent of N3 per day, can produce 45 units. In Billing, Montana, two laborers making N60 per day, can make 100 units. Based on labor costs only, which location would be most economical to produce the item.

7.0 REFERENCES/FURTHER READINGS

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UNIT 6 LAYOUT STRATEGY

CONTENTS

1.0 INTRODUCTION

Layout is one of the key decisions that determine the long-run efficiency of operations. Layout has numerous strategic implications because it establishes an organization's competitive priorities in regard to capacity, processes, flexibility, and cost, as well as quality of work life, customer contact, and image. An effective layout can help an organization achieve a strategy that supports differentiation, low cost, or response

2.0 OBJECTIVES

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

Identify or define:

- Fixed-Position Layout
- Process-Oriented Layout
- Work cells
- Focused Work Center
- Office Layout
- Warehouse Layout
- Product-Oriented Layout
- Assembly-Line

Describe or explain:

- How to achieve a good layout for the process facility
- How to balance production flow in a repetitive or product-oriented facility.

3.0 MAIN CONTENT

3.1 The Strategic Importance of Layout Decisions

The objective of layout strategy is to develop an economic layout that will meet the firm's competitive requirements.

In all cases, layout' design must consider how to achieve the following:

1. Higher utilization of space, equipment, and people.
2. Improved flow of information, materials, or people.
3. Improved employee morals and safer working conditions.
4. Improved customer/client interaction.
5. Flexibility (whatever the layout is now, it will need to change).

In our increasingly short-life-cycle, mass-customized world, layout designs need to be viewed as dynamic. This means considering small, movable, and flexible equipment. Store displays need to be movable, office desks and partitions modular, and warehouse racks prefabricated. To make quick and easy changes in product models and in production rates, operations managers must design flexibility into layouts. To obtain flexibility in layout, managers cross train their workers, maintain equipment, keep investments low, place work stations close together, and use small, movable equipment. In some cases, equipment on wheels is appropriate, in anticipation of the next change in product, process, or volume.

3.2 Types of Layout

Layout decisions include the best placement of machines (in production settings), offices and desks (in office settings), or service centers (in settings such as hospitals or department stores). An effective layout facilitates the flow of materials, people, and information within and between areas. To achieve these objectives, a variety of approaches has been developed. We will discuss seven of them in this unit.

1. Office layout-positions workers, their equipment, and spaces/offices to provide for movement of information.
2. Retail layout-allocates shelf space and responds to customer behavior.
3. Warehouse layout-addresses trade-offs between space and material handling.
4. Fixed-position layout-addresses the layout requirements of large, bulky projects such as ships and buildings.
5. Process-oriented layout-deals with low-volume, high-variety production (also called "job shop," or intermittent production).
6. Work-cell layout-arranges machinery and equipment to focus on production of a single product or group of related products.
7. Product-oriented layout-seeks the best personnel and machine utilization in repetitive or continuous production.

Because only a few of these seven classes can be modeled mathematically, layout and design of physical facilities are still something of an art. However, we do know that a good layout requires determining the following:

1. Material handling equipment. Managers must decide about equipment to be used, including conveyors, cranes, automated storage and retrieval systems, and automatic carts to deliver and store material.

2. Capacity and space requirements. Only when personnel, machines, and equipment requirements are known can managers proceed with layout and provide space for each component. In the case of office work, operations managers must make judgments about the space requirements for each employee. It may be a 6ft x 6” feet cubicle plus allowance for hallways, aisles, rest rooms, cafeterias, stairways, elevators, and so forth, or it may be spacious executive offices and conference rooms. Management must also consider allowances for safety requirements that address noise, dust, fumes, temperature, and space around equipment and machines.

3. Environment and aesthetics. Layout concerns often require decisions about windows, planters, and height of partitions to facilitate air flow, reduce noise, provide privacy, and so forth.

4. Flows of information. Communication is important to any organization and must be facilitated by the layout. This issue may require decisions about proximity as well as decisions about open spaces versus half-height dividers versus private office.

5. Cost of moving between various work areas. There may be unique considerations related to moving materials or to the importance of having certain areas next to each other. For example, moving molten steel is more difficult than moving cold steel.

3.2.1 Office Layout

Office layouts require the grouping of workers, their equipment, and spaces to provide for comfort, safety, and movement of information. The main distinction of office layouts is the importance placed on the flow of information. Office layouts are in constant flux as the technological change sweeping society alters the way offices function.

Even though the movement of information is increasingly electronic, analysis of office layouts still requires a task-based approach. Paper correspondence, contracts, legal documents, confidential patient records, and hard-copy scripts, artwork, and designs still play a major role in many offices. Managers therefore examine both electronic and conventional communication patterns, separation needs, and other conditions affecting employee effectiveness.

3.2.2 Retail Layout

Retail layouts are based on the idea that sales and profitability vary directly with customer exposure to products. Thus, most retail operations managers try to expose customers to as many products as possible. Studies do show that the greater the rate of exposure, the greater the sales and the higher the return on investment. The operations manager can alter both with the overall arrangement of the store and the allocation of space to various products within that arrangement.

Five ideas are helpful for determining the overall arrangement of many stores:

1. Locate the high-draw items around the periphery of the store. Thus,

we tend to find dairy products on one side of a supermarket and bread and bakery products on another.

2. Use prominent locations for high-impulse and high-margin items such as house wares beauty aids, and shampoos.
3. Distribute what are known in the trade as "power items" items that may dominate a purchasing trip to both sides of an aisle, and disperse them to increase the viewing of other items.
4. Use end-aisle locations because they have a very high exposure rate.
5. Convey the mission of the store by carefully selecting the position of the lead-off department. For instance, if prepared foods are part of the mission, position the bakery and delicacy up front to appeal to convenience-oriented customers.

3.2.2.1 Servicescapes

Although the main objective of retail layout is to maximize profit through product exposure, there are other aspects of the service that managers consider. The term servicescape describes the physical surroundings in which the service is delivered and how the surroundings have a humanistic effect on customers and employees. To provide a good service layout, a firm must consider these three elements:

1. Ambient conditions, which are background characteristics such as lighting, sound, smell, and temperature. All these affect workers and customers and can affect how much is spent and how long a person stays in the building.

2. Spatial layout and functionality, which involve customer circulation path planning, aisle.

3. Signs, symbols, and artifacts, which are characteristics of building design that carry social significance (such as carpeted areas of a department store that encourage shoppers to slow down and browse).

3.2.3 Warehousing and Storage Layouts

The objective of warehouse layout is to find the optimum trade-off between handling cost and costs associated with warehouse space. Consequently, management's task is to maximize the utilization of the total "cube" of the warehouse-that is, utilize its full volume while maintaining low material handling costs. We define material handling costs as all the costs related to the transaction. This consists of incoming transport, storage, and outgoing transport of the materials to be warehoused. These costs include equipment, people, material, supervision, insurance, and depreciation. Effective warehouse layouts do, of course, also minimize the damage and spoilage of material within the warehouse.

3.2.3.1 Cross-Docking

Cross-docking means to avoid placing materials or supplies in storage by processing them as they are received. In a manufacturing facility, product is received directly to the assembly line. In a distribution center, labeled and presorted loads arrive at the shipping dock for immediate rerouting, thereby avoiding formal receiving, stocking/storing, and order-selection activities. Because these activities add no value to the product, their elimination is 100% cost savings.

3.2.3.2 Random Stocking

Automatic identification systems (AISs), usually in the form of bar codes, allow accurate and rapid item identification. When automatic identification systems are combined with effective management information systems, operations managers know the quantity and location of every unit. This information can be used with human operators or with automatic storage and retrieval systems to load units anywhere in the warehouse-randomly. Accurate inventory quantities and locations mean the potential utilization of the whole facility because space does not need to be reserved for certain stock-keeping units (SKUs) or part families. Computerized random stocking systems often include the following tasks:

1. Maintaining a list of "open" locations.
2. Maintaining accurate records of existing inventory and its locations.
3. Sequencing items on orders to minimize the travel time required to "pick" orders.
4. Combining orders to reduce picking time.
5. Assigning certain items or classes of items, such as high-usage items, to particular ware house areas so that the total distance traveled within the warehouse is minimized.

Random stocking systems can increase facility utilization and decrease labor cost, but require accurate records.

3.2.3.3 Customizing

Although we expect warehouses to store as little product as possible and hold it for as short a time as possible, we are now asking warehouses to customize products. Warehouses can be places where value is added through customizing. Warehouse customization is a particularly useful way to generate competitive advantage in markets with rapidly changing products. For instance, a warehouse can be a place where computer components are put together, software loaded, and repairs made. Warehouses may also provide customized labeling and packaging for retailers so items arrive ready for display.

3.2.4 Fixed-Position Layout

In a fixed-position layout, the project remains in one place and workers and equipment come to that one work area. Examples of this type of project are a ship, a highway, a bridge, a house, and an operating table in an operating room of a hospital.

The techniques for addressing the fixed-position layout are not well developed and are complicated by three factors. First, there is limited space at virtually all sites. Second, at different stages of a project, different materials are needed; therefore, different items become critical as the project develops. Third, the volume of materials needed is dynamic. For example, the rate of use of steel panels for the hull of a ship changes as the project progresses.

3.2.5 Process-Oriented Layout

The process-oriented layout can simultaneously handle a wide variety of products or services. This is the traditional way to support a product differentiation strategy. It is most efficient when making products with different requirements or when handling customers, patients, or clients with different needs. A process-oriented layout is typically the low-volume, high-variety strategy. In this job-shop environment, each product or each small group of products undergoes a different sequence of operations. A product or small order is produced by moving it from one department to another in the sequence required for that product. A good example of the process-oriented layout is a hospital or clinic. An inflow of patients, each with his or her own needs, requires routing through admissions, laboratories, operating rooms, radiology, pharmacies, nursing beds, and so on. Equipment, skills, and supervision are organized around these processes.

3.2.5.1 Computer Software for Process-Oriented Layouts

When twenty departments are involved in a layout problem, more than 600 trillion different department configurations are possible. Fortunately, computer programs have been written to handle layouts of up to forty departments. The best-known of these is CRAFT

(Computerized Relative Allocation of Facilities Technique), a program that produces "good" but not always "optimal" solutions. CRAFT is a search technique that systematically examines alternative departmental rearrangements to reduce total "handling" cost. CRAFT has the added advantage of examining not only load and distance but also a third factor, a difficulty rating.4 Other popular process layout packages include the Automated Layout Design program (ALDEP), Computerized Relationship Layout Planning (CORELAP), and Factory Flow.

3.3 Work Cells

A work cell reorganizes people and machines that would ordinarily be dispersed in various departments into a group so that they can focus on making single product or group of related products. Cellular work arrangements are used when volume warrants a special arrangement of machinery and equipment. In a manufacturing environment, group technology identifies products that have similar characteristics and lend themselves to being processed in a particular work cell. Motorola, for instance, forms work cells to build and test engine control systems for John Deere tractors. These work cells are reconfigured as product designs change or volume fluctuates. Although the idea of work cells was first presented by R. E. Flanders in 1925, only with the increasing use of group technology has the technique reasserted itself. The advantages of work cells are:

1. Reduced work-in-process inventory because the work cell is set up to provide one-piece flow from machine to machine.
2. Less floor space required because less space is needed between machines to accommodate work-in-process inventory.
3. Reduced raw material and finished goods inventories because less work-in-process allows more rapid movement of materials through the work cell.
4. Reduced direct labor cost because of improved communication among employees, better material flow, and improved scheduling.
5. Heightened sense of employee participation in the organization and the product: employees accept the added responsibility of product quality because it is directly associated with them and their work cell.
6. Increased use of equipment and machinery because of better scheduling and faster material flow.
7. Reduced investment in machinery and equipment because good facility utilization reduces the number of machines and the amount of equipment and tooling.

3.3.1 Requirements of Work Cells

The requirements of cellular production include

1. Identification of families of products, often through the use of group technology codes or equivalents.
2. A high level of training and flexibility on the part of employees.
3. Either staff support or flexible, imaginative employees to establish work cells initially.
4. Test (poka-yoke) at each station in the cell.

Work cells have at least five advantages over assembly lines and process facilities: (I) because tasks are grouped, inspection is often immediate; (2) fewer workers are needed; (3) workers can reach more of the work area; (4) the work area can be more efficiently balanced; and (5) communication is enhanced.

3.3.2 Staffing and Balancing Work Cells

Once the work cell has the appropriate equipment located in the proper sequence, the next task is to staff and balance the cell. Efficient production in a work cell requires appropriate staffing. This involves two steps. First, determine the task time, which is the pace (frequency) of production units necessary to meet customer orders.

Task time = Total work time available/Units required

Second, determine the number of operators required. This requires dividing the total operation time in the work cell by the task time:

Workers required = Total operation time required/Task time

3.4 The Focused Work Center and the Focused Factory

When a firm has identified a family of similar products that have a large and stable demand, it may organize a focused work center. A focused work center moves production from a general-purpose, process-oriented facility to a large work cell that remains part of the present plant. If the focused work center is in a separate facility, it is often called a focused factory. A fast food restaurant is a focused factory, most of which are easily reconfigured for adjustments to product mix and volume.

3.5 Repetitive and Product-Oriented Layout

Product-oriented layouts are organized around products or families of similar high-volume, low-variety products. Repetitive production and continuous production. The assumptions are that:

1. Volume is adequate for high equipment utilization
2. Product demand is stable enough to justify high investment in specialized equipment
3. Product is standardized or approaching a phase of its life cycle that justifies investment in specialized equipment.
4. Supplies of raw materials and components are adequate and of uniform quality (adequately standardized) to ensure that they will work with the specialized equipment.

The disadvantages of product layout are:

1. The high volume required because of the large investment needed to establish the process.
2. That work stoppage at any one point ties up the whole operation.
3. A lack of flexibility when handling a variety of products or production rates.

3.6 Assembly-Line Balancing

Line balancing is usually undertaken to minimize imbalance between machines or personnel while meeting a required output from the line. To produce at a specified rate, management must know the tools, equipment, and work methods used. Then the time requirements for each assembly task (such as drilling a hole, tightening a nut, or spray-painting a part) must be determined. Management also needs to know the precedence relationship among the activities-that is, the sequence in which various tasks must be performed.

SELF ASSESSMENT EXERCISE

1. What are the seven layout strategies presented in this unit?
2. What are the three factors that complicate a fixed-position layout?

4.0 CONCLUSION

Layouts make a substantial difference in operating efficiency. The seven layout situations discussed in this unit are (I) office, (2) retail, (3) warehouse, (4) fixed-position, (5) process-oriented, (6) work cells, and (7) product-oriented. A variety of techniques have been developed to solve these layout problems. Office layouts often seek to maximize information flows, retail firms focus on product exposure, and warehouses attempt to optimize the trade off between storage space and material handling cost.

5.0 SUMMARY

The fixed-position layout problem attempts to minimize material handling costs within the constraint of limited space at the site. Process layouts minimize travel distance multiplied by times the number of trips. Product layouts focus on reducing waste and the imbalance in an assembly line. Work cells are the result of identifying a family of products that justify a special configuration of machinery and equipment that reduces material travel and adjusts imbalances with cross trained personnel.

Often, the issues in a layout problem are so wide ranging, that finding an optimal solution is not possible. For this reason, layout decisions, although the subject of substantial research effort, remain something of an art.

6.0 TUTOR-MARKED ASSIGNMENT

1. The Temple Toy Company has decided to manufacture's new toy tractor, the production of which is broken into six steps. The deJ11and for the tractor is 4,800 units per 40-hour work week:

a. Draw a precedence diagram of this operation
b. Given the demand, what is the cycle time for this operation?
c. What is the theoretical minimum number of work stations?
d. Assign tasks to work stations.
e. How much total idle time is present each cycle?
f. What is the overall efficiency of the assembly line with four stations; with five stations; and with six stations?

2. South Carolina Furniture, Inc., produces all types of office furniture. The "Executive Secretary" is a chair that has been designed using ergonomics to provide comfort during long work hours. The chair sells for $130. There are 480 minutes available during the day, and the average daily demand has been 50 chairs.
There are eight tasks.

a. Draw a precedence diagram of this operation.
b. What is the cycle time for this operation?
c. What is the theoretical minimum number of work stations?
d. Assign tasks to work stations.
e. How much total idle time is present each day?

f. What is the overall efficiency of the assembly line?

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Adeola A. Kupoluyi, Question and Answer on Operation and Quality *Management.*

UNIT 7 HUMAN RESOURCES AND JOB DESIGN

CONTENTS

1.0 INTRODUCTION

Various work cultures, exist all over the world. How these cultures built and what are are the human resource issues for the operations manager? In this unit, we will examine a variety of human resource issues because 'organizations do not function without people. Moreover, they do not function well without competent, motivated people. The operations manager's human resource strategy determines the talents and skills available to operations.

As many organizations have demonstrated, competitive advantage can be built through human resource strategy. Good human resource strategies are expensive, difficult to achieve, and hard to sustain. However, the payoff potential is substantial because they are hard to copy! So a competitive advantage in this area is particularly beneficial. For these reasons, we now look at the operations manager's human resource options.

2.0 OBJECTIVES

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

Identify and define:

•Job design

- Job specialization
- Job expansion
- Tools of methods analysis
- Ergonomics
- Labour standard
- Andon

Explain or Describe:

- Requirements of good job design
- The visual work place
- Ethical issues in human resources.

3.0 MAIN CONTENT

3.1 Human Resources and Job Design

3.1.1 Human Resource Strategy for Competitive Advantage

The objective of a human resource strategy is to manage labour and design jobs so that people are effectively and efficiently utilized. As we focus on a human resource strategy, we want to ensure that people:

1. Are efficiently utilized within the constraints of other operations and management decisions.
2. Have a reasonable quality of work life in an atmosphere of mutual commitment and trust.

By reasonable quality of work life, we mean a job that is not only reasonably safe and for which the pay is equitable but that also achieves an appropriate level of both physical and psychological requirements. Mutual commitment means that both management and employee strive to meet common objectives. Mutual trust is reflected in reasonable, documented employment policies that are honestly and equitably implemented to the satisfaction of both management and employee. When management has a genuine respect for its employees and their contributions to the firm, establishing a reasonable quality of work life and mutual trust is not particularly difficult.

3.1.2 Constraints on Human Resource Strategy

Many decisions made about people are constrained by other decisions. First, the product mix may determine seasonality and stability of employment. Second, technology, equipment, and processes may have implications for safety and job content. Third, the location decision may have an impact on the ambient environment in which the employee works. Finally, layout decisions, such as assembly line versus work cell, influences job content.

Technology decisions impose substantial constraints. For instance, some of the jobs in steel mills are dirty, noisy, and dangerous; slaughterhouse jobs may be stressful and subject workers to stomach-crunching stench; assembly-line jobs are often boring and mind numbing; and high capital expenditures such as those required for manufacturing semiconductor chips may require 24-hour, 7-day-a-week operation in restrictive clothing.

We are not going to change these jobs without making changes in our other strategic decisions. So, the trade-offs necessary to reach a tolerable quality of work life are difficult. Effective managers consider such decisions simultaneously. The results: an effective, efficient system in which both individual and team performance are enhanced through optimum job design.

Acknowledging the constraints imposed on human resource strategy, we now look at three distinct decision areas of human resource strategy: labour planning, job design, and labour standards

3.2 Labour Planning

Labour planning is determining staffing policies that deals with (1) employment stability and (2) work schedules

3.2.1 Employment-Stability Policies

Employment stability deals with the number of employees maintained by an organization at any given time. There are two very basic policies for dealing with stability

1. Follow demand exactly. Following demand exactly, keeps direct labour costs tied to production but incurs other costs. These other costs include (a) hiring and termination costs, (b) unemployment insurance, and (c) premium wages to entice personnel to accept unstable employment. This policy tends to treat labour as a variable cost.
2. Hold employment constant. Holding employment levels constant maintains a trained workforce and keeps hiring, termination, and unemployment costs to a minimum level. However, with employment held constant, employees may not be utilized fully when demand is low, and the firm may not have the human resources it needs when demand is high. This policy tends to treat labour as a fixed cost.

Maintaining a stable workforce may allow a firm to pay lower wages than a firm that follows demand. This savings may provide a competitive advantage. However, firms with highly seasonal work and little control over demand may be best served by a fluctuating workforce.

However, the firm may find complementary labour demands in other products or operations, such as making cans and labels or repairing and maintaining facilities.

The above policies are only two of many that can be efficient and provide a reasonable quality of work life. Firms must determine policies about employment stability. Employment policies are partly determined by management's view of labour costs-as a variable cost or a fixed cost.

3.2.2 Work Schedules

Although the standard work schedule is still 8 hours daily for five days, many variations exist. A currently popular variation is a work schedule called flex time. Flex time allows employees, within limits, to determine their own schedules. A flextime policy might allow an employee (with proper notification) to be at work at 8.00am plus or minus two hours. This policy allows more autonomy and independence on the part of the employee. Some firms have found flex time a low-cost fringe benefit that enhances job satisfaction. The problem from the OM perspective is that much production work requires full staffing for efficient operations. A machine that requires three people cannot run at all if only two show up. Having a waiter show up to serve lunch at 1.30pm rather than 11.30am is not much help either.

Similarly, some industries find that their process strategies severely constrain their human resource scheduling options. For instance, paper manufacturing, petroleum refining and power stations require around-the-clock staffing except for maintenance and repair shutdown.

Another option is the flexible workweek. This plan often calls for fewer but longer days, such as 10 hours daily for four days or, as in the case of light-assembly plants. 12-hour shifts. 12 hours shifts usually mean working 3 days one week and 4 the next. Such shifts are sometimes called compressed workweeks. These schedules are viable for many operations functions as long as suppliers and customers can be accommodated. Firms that have high process start-up times (say, to get a boiler up to operating temperature) find longer workday options particularly appealing.

Another option is shorter days rather than longer days. This plan often moves employees to part-time status. Such an option is particularly attractive in service industries, where staffing for peak loads is necessary. Banks and restaurants often hire part-time workers. Also, many firms reduce labour costs by reducing fringe benefits for part-time employees.

3.2.3 Job Classifications and Work Rules

Many organizations have strict job classifications and work rules that specify who can do what, when they can do it, and under what conditions they can do it, often as a result of union pressure. These job classifications and work rules restrict employee flexibility on the job, which in turn reduces the flexibility of the operations function. Yet part of an operations manager's task is to manage the unexpected. Therefore, the more flexibility a firm has when staffing and establishing work schedules, the more efficient and responsive it can be. This is particularly true in service organizations, where extra capacity often resides in extra or flexible staff. Building morale and meeting staffing requirements that result in an efficient, responsive operation are easier if managers have fewer job classifications and work-rule constraints. If the strategy is to achieve a competitive advantage by responding rapidly to the customer. a flexible workforce may be a prerequisite.

3.3 Job Design

Job design specifies the tasks that constitute a job for an individual or a group. We examine seven components of job design: (I) job specialization, (2) job expansion, (3) psychological components, (4) self-directed teams, (5) motivation and incentive systems, (6) ergonomics and work methods, and (7) the visual workplace.

3.3.1 Labour Specialisation

The importance of job design as a management variable is credited to the eighteenth-century economist Adam Smith.2 Smith suggested that a division of labour, also known as labour specialization (or job specialization), would assist in reducing labour costs of multi-skilled artisans. This is accomplished in several ways.

1. Development of dexterity and faster learning by the employee because of repetition.
2. Less loss of time because the employee would not be changing jobs or tools.
3. Development of specialized tools and the reduction of investment because each employee has only a few tools needed for a particular task.

The nineteenth-century British mathematician Charles Babbage determined that a fourth consideration was also important for labour efficiency. Because pay tends to follow skill with a rather high correlation, Babbage suggested, paying exactly the wage needed for the particular skill required. If the entire job consists of only one skill, then we would pay for only that skill. Otherwise, we would tend to pay for the highest skill contributed by the employee. These four advantages of labour specialization are still valid today.

A classic example of labour specialization is the assembly line. Such a system is often very efficient, although it may require employees to do repetitive, mind-numbing jobs. The wage rate for many of these jobs, however, is very good. Given the relatively high wage rate for the modest skills required in many of these jobs, there is often a large pool of employees from which to choose. This is not an incidental consideration for the manager with responsibility for staffing the operations function. It is estimated that 2% to 3% of the workforce in industrialized nations perform highly specialized, repetitive assembly-line jobs. The traditional way of developing and maintaining worker commitment under labour specialization has been good selection (matching people to the job), good wages, and incentive systems.

From the manager's point of view, a major limitation of specialized jobs is their failure to bring the whole person to the job. Job specialization tends to bring only the employee's manual skills to work. In an increasingly sophisticated knowledge based society, managers may want employees to bring their mind to work as well.

3.3.2 Job Expansion

In recent years, there has been an effort to improve the quality of work life by moving from labour specialization toward more varied job design. Driving this effort is the theory that variety makes the job "better" and that the employee therefore enjoys a higher quality of work life. This flexibility thus benefits the employee and the organization.

We modify jobs in a variety of ways. The first approach is job enlargement, which occurs when we add tasks requiring similar skill to an existing job. Job rotation is a version of job enlargement that occurs when the employee is allowed to move from one specialized job to another. Variety has been added to the employee's perspective of the job. Another approach is job enrichment, which adds planning and control to the job. An example is to have the department store's sales people responsible for ordering, as well as selling, their goods. Job enrichment can be thought of as vertical expansion, as opposed to job enlargement, which is horizontal.

A popular extension of job enrichment, employee empowerment is the practice of enriching jobs so employees accept responsibility for a variety of decisions normally associated with staff specialists. Empowering employees helps them take "ownership" of their jobs so they have a personal interest in improving performance.

3.3.3 Psychological Components of Job Design

An effective human resources strategy also requires consideration of the psychological components of job design. These components focus on how to design jobs that meet some minimum psychological requirements

Hawthorne Studies: The Hawthorne studies introduced psychology to the workplace. They were conducted in the late 1920s at Western Electric's Hawthorne plant near Chicago. Publication of the findings in 1939 showed conclusively that there is a dynamic social system in the workplace. Ironically, these studies were initiated to determine the impact of lighting on productivity. Instead, they found the social system and distinct roles played by employees to be more important than the intensity of the lighting. They also found that individual differences may be dominant in what an employee expects from the job and what the employee thinks hers or his contribution to the job should be.

Core Job Characteristics: In the eight decades since the Hawthorne studies, substantial research regarding the psychological components of job design has taken place. Hackman and Oldham have incorporated much of that work into five desirable characteristics of job design 6. Their summary suggests that jobs should include the following characteristics:

1. Skill variety, requiring the worker to use a variety of skills and talents.
2. Job identity, allowing the worker to perceive the job as a whole and recognizing a start and finish.
3. Job significance, providing a sense that the job has an impact on the organization and society.
4. Autonomy, offering freedom, independence, and discretion.
5. Feedback, providing clear, timely information about performance.

Including these five ingredients in job design is consistent with job enlargement, job enrichment, and employee empowerment. We now want to look at some of the ways in which teams can be used to expand jobs and achieve these five job characteristics.

3.3.4 Self-Directed Teams

Many world-class organizations have adopted teams to foster mutual trust and commitment, and provide the core job characteristics. One team concept of particular note is the self-directed team: a group of empowered individuals working together to reach a common goal. These teams may be organized for long or short term objectives. Teams are effective primarily because they can easily provide employee empowerment, ensure core job characteristics, and satisfy many of the psychological needs of individual team members.

Of course, many good job designs can provide these psychological needs. Therefore, to maximize team effectiveness, managers do more than just form "teams." For instance, they (1) ensure that those who have a legitimate contribution are on the team, (2) provide management support, (3) ensure the necessary training, and (4) endorse clear objectives and goals. Successful teams should also receive financial or nonfinancial rewards. Finally, managers must recognize that teams may have a life cycle and that achieving an objective may suggest disbanding the team. However, teams may be renewed with a change in members or new assignments.

Teams and other approaches to job expansion should not only improve the quality of work life and job satisfaction but also motivate employees to achieve strategic objectives. Both managers and employees need to be committed to achieving strategic objectives. However, employee contribution is fostered in a variety of ways, including organizational climate, supervisory action, and job design.

Expanded job designs allow employees to accept more responsibility. For employees who accept this responsibility, we may well expect some enhancement in productivity and product quality. Among the other positive aspects of job expansion are reduced turnover, tardiness, and absenteeism. Managers who expand jobs and build communication systems that elicit suggestions from employees have an added potential for efficiency and flexibility. However, these job designs have a number of limitations.

Limitations of Job Expansion If job designs that enlarge, enrich, empower, and use teams are so good, why are they not universally used? Let us identify some limitations of expanded job designs:

1. Higher capital cost. Job expansion may require facilities that cost more than those with a conventional layout. This extra

expenditure must be generated through savings (greater efficiency) or higher prices.

2. Individual differences. Some studies indicate that many employees opt for the less complex jobs. In a discussion about improving the quality of work life, we cannot forget the importance of individual differences. Differences in individuals provide latitude for the resourceful operations manager when designing jobs.

3. Higher wage rates. People often receive wages for their highest skills, not their lowest. Thus expanded jobs may well require a higher average wage than jobs that are not expanded.

4. Smaller labour pool. Because expanded jobs require more skill and acceptance of more responsibility, job requirements have increased. Depending on the availability of labour, this may be a constraint.

5. Increased accident rates. Expanded jobs may contribute to a higher accident rate. This indirectly increases wages, insurance costs, and worker's compensation. The alternative may be expanding training and safety budgets.

6. Current technology may not lend itself to job expansion. The disassembly jobs at a slaughterhouse and assembly jobs at automobile plants are that way because alternative technologies (if any) are thought to be unacceptable.

These six points provide constraints on job expansion.

In short, job expansion often increases costs. Therefore, for the firm to have a competitive advantage, its savings must be greater than its costs. This is not always the case. The strategic decision may not be an easy one.

Despite the limitations of job expansion, firms are finding ways to make it work. Often the major limitations are not those just listed above, but training budgets and the organization's culture. Training budgets must therefore increase. And supervisors must exercise some control and learn to accept different job responsibilities. Self-directed teams may mean no supervisors on the factory floor.

3.3.5 Motivation and Incentive Systems

Our discussion of the psychological components of job design provides insight into the factors that contribute to job satisfaction and motivation. In addition to these psychological factors, there are monetary factors. Money often serves as a psychological as well as financial motivator. Monetary rewards take the form of bonuses, profit and gain sharing, and incentive systems.

Bonuses, typically in cash or stock options, are often used at executive levels to reward management. Profit-sharing systems provide some part of the profit for distribution to employees. A variation of profit sharing is gain sharing, which rewards employees for improvements made in an organization's performance. The most popular of these is the Scanlon plan, in which any reduction in the cost of labour is shared between management and labour.

Incentive systems based on individual or group productivity are used throughout the world in a wide variety of applications. Production incentives often require employees or crews to produce at or above a predetermined standard. The standard can be based on a "standard time" per task or number of pieces made. Both systems typically guarantee the employee at least a base rate.

With the increasing use of teams, various forms of team-based pay are also being developed. Many are based on traditional pay systems supplemented with some form of bonus or incentive system. However, because many team environments require cross training of enlarged jobs, knowledge-based pay systems have also been developed. Under knowledge-based (or skill-based) pay systems, a portion of the employee's pay depends on demonstrated knowledge or skills possessed.

Knowledge-based pay systems are designed to reward employees for the enlarged scope of their jobs. Some of these pay systems have three dimensions: horizontal skills that reflect the variety of tasks the employee can perform; vertical skills that reflect the planning and control aspects of the job; and depth of skills that reflect quality and productivity.

3.3.6 Ergonomics and Work Methods

As mentioned in unit 1, Frederick W. Taylor began the era of scientific management in the late 1800s. He and his contemporaries began to examine personnel selection, work methods, labour standards, and motivation.

With the foundation provided by Taylor, we have developed a body of knowledge about people's capabilities and limitations. This knowledge is necessary because humans are hand/eye animals possessing exceptional capabilities and some limitations. Because managers must design jobs that can be done, we now introduce a few of the issues related to people's capabilities and limitations.

Ergonomics: The operations manager is interested in building a good interface between human and machine. Studies of this interface are known as ergonomics. Ergonomics means "the study of work." (Ergon is the Greek word for work.) Understanding ergonomics issues helps to improve human performance.

Male and female adults come in limited configurations. Therefore, design of tools and the workplace depends on the study of people to determine what they can and cannot do. Substantial data have been collected that provide basic strength and measurement data needed to design tools and the workplace. The design of the workplace can make the job easier or impossible.

Additionally, we now have the ability, through the use of computer modeling, to analyze human motions and efforts.

Operator Input to Machines: Operator response to machines, be they hand tools, pedals, levers, or buttons, needs to be evaluated. Operations managers need to be sure that operators have the strength, reflexes, perception, and mental capacity to provide necessary control. Such problems as carpal tunnel syndrome may result when a tool as simple as a keyboard is poorly designed.

Feedback to Operators: Feedback to operators is provided by sight, sound, and feel; it should not be left to chance. The mishap at the Three Mile Island nuclear facility, America's worst nuclear experience, was in large part the result of poor feedback to the operators about reactor performance. Nonfunctional groups of large, unclear instruments and inaccessible controls, combined with hundreds of confusing warning lights, contributed to that nuclear failure. Such relatively simple issues make a difference in operator response and, therefore, performance

The Work Environment: The physical environment in which employees work affects their performance, safety, and quality of work life. Illumination, noise and vibration, temperature, humidity, and air quality are work-environment factors under the control of the organization and the operations manager. The manager must approach them as controllable.

Illumination is necessary, but the proper level depends on the work being performed. Table 1. Provides some guidelines. However, other lighting factors are important. These include reflective ability, contrast of the work surface with surroundings, glare, and shadows.

Noise of some form is usually present in the work area, but most employees seem to adjust well. However, high levels of sound will damage hearing. Extended periods of exposure to decibel levels above 85 dB are permanently damaging. The Occupational Safety and Health Administration requires ear protection above this level if exposure equals or exceeds 8 hours. Even at low levels, noise and vibration can be distracting. Therefore, most managers make substantial effort to reduce noise and vibration through good machine design, enclosures, or segregation of sources of noise and vibration.

Temperature and humidity parameters have been well established. Managers with activities operating outside the established comfort 'zone should expect adverse effect on performance.

Methods Analysis: Methods analysis focuses on how a task is accomplished. Whether controlling a machine or making or assembling components, how a task is done makes a difference in performance, safety, and quality. Using knowledge from ergonomics and methods analysis, methods engineers are charged with ensuring that quality and quantity standards are achieved efficiently and safely. Methods analysis and related techniques are useful in office environments as well as in the factory. Methods techniques are used to analyze.

1. Movement of individuals or material. The analysis is performed using flow diagrams and process charts with varying amounts of detail.

2. Activity of human and machine and crew activity. This analysis is performed using activity charts (also known as man-machine charts and crew charts).

3. Body movement (primarily arms and hands). This analysis is performed using micro motion charts.

Process charts use symbols, as to help us understand the movement of people or material. In this way, movement and delays can be reduced and operations made more efficient.

Activity charts are used to study and improve the utilization of an operator and a machine or some combination of operators (a "crew") and machines. The typical approach is for the analyst to record the present method through direct observation and then propose the improvement on a second chart.

Body movement is analyzed by an operations chart. It is designed to show economy of motion by pointing out wasted motion and idle time (delay). The operations chart (also known as a right-hand/left-hand chart).

3.4 The Visual Workplace

A visual workplace uses low-cost visual devices to share information quickly and accurately. Well-designed displays and graphs root out confusion and replace difficult-to-understand printouts and paperwork. Because workplace data change quickly and often, operations managers need to share accurate and up-to-date information. Workplace dynamics, with changing customer requirements, specifications, schedules, and other details on which an enterprise depends, must be rapidly communicated.

All visual systems should focus on improvement, because progress almost always has motivational benefits. An assortment of visual signals and charts is an excellent tool for communication not only among people doing the work but also among support staff, management, visitors, and suppliers. All these stakeholders deserve feedback on the organization. Management reports, if held only in the hands of management, are often useless and perhaps counterproductive. Visual management is a way of communicating to those who can make things happen.

Visual signals in the workplace can take many forms.

Present the big picture

- Visual systems can communicate the larger picture, helping employees understand the link between their day-to-day activities and the organization's overall performance. At Baldor Electric Co. in Fort Smith, Arkansas, the prior day's closing price of Baldor's stock is posted for all to see. The stock price is to remind employees that a portion of their pay is based on profit sharing and stock options and to encourage them to keep looking for ways to increase productivity.

• Missouri's Springfield Manufacturing Corp. has developed a concept called open book management," where every employee is trained to understand the importance of financial measure

Performance

• Details of quality, accidents, service levels, delivery performance, costs, and such traditional variables as attendance and tardiness can all be presented, often in the form of statistical process control (SPC) charts.

• Kanbans are a type of visual signal indicating the need for more production.

• The 30 minute clocks found in Burger Kings are a type of visual standard indicating the acceptable wait for service.

• Some organizations have found it helpful to show performance standards against cycle time or hourly quotas.

Housekeeping

• Shadow boards and foot printing: Painted symbols indicating the place for tools and the position of machinery and equipment are visual ways to aid housekeeping.

• Labeling: Proper identification of parts, bins, and tools is a basic, but substantial, aid to reducing waste.

• Color-coded signs and lights: Andon lights are another visual signal. An andon is a signal that there is a problem. Andons can be manually initiated by employees when they notice a problem or defect. They can also be triggered automatically when machine performance drops below a certain pace or when the number of cycles indicates that it is time for maintenance.

The purpose of the visual workplace is to eliminate non-value-added activities by making problems, abnormalities, and standards visual. This concept enhances communication and feedback by providing immediate information. The visual workplace needs less supervision because employees understand the standard, see the results, and know what to do.

3.5 Ethics and the Work Environment

Ethics in the workplace presents some interesting challenges. As we have suggested in this chapter, many constraints influence job design. The issues of fairness, equity, and ethics are pervasive. Whether the issue is equal opportunity, equal pay for equal work, or safe working conditions, the operations manager is often the one responsible Ethics in the workplace presents some interesting challenges. As we have suggested in this chapter, many constraints influence job design. The issues of fairness, equity, and ethics are pervasive. Whether the issue is equal opportunity, equal pay for equal work, or safe working conditions, the operations manager is often the one responsible.

Managers do have some guidelines. By knowing the law, working with state agencies, unions, trade associations, insurers, and employees, managers can often determine the parameters of their decisions. Human resource and legal departments are also available for help and guidance.

Jobs can be hot, difficult, and dangerous. Indeed, many jobs have been found to be very dangerous even years after they were successfully accomplished by thousands of people. For instance, asbestos, once known as the "magic mineral" for its insulation and ability to withstand flames, is now a notorious and feared killer. The issue may be what is known about jobs and their inherent dangers. In some cases, management and society were ignorant of the dangers, whether they were keyboards, a noisy environment, or materials in the workplace such as asbestos. In other cases, the risks are well known, and appropriate action must be taken promptly. (Many firms failed to take prompt action in the case of asbestos, and all the stakeholders paid the price when bankruptcy was declared.

Insurance companies can provide good estimates of how many people will die in certain occupations each year. Nevertheless, society doesn't stop building skyscrapers or stop making cast-iron pipe even though we can document that ironworkers and foundry workers have dangerous jobs. Management's job is to mitigate the danger and take timely action once the dangers are known.

3.6 Labour Standards

So far in this unit, we have discussed labour planning and job design. The third requirement of an effective human resource strategy is the establishment of labour standards. Effective manpower planning is dependent on a knowledge of the labour required.

Labour standards are the amount of time required to perform a job or part of a job. Every firm has labour standards, although they may vary from those established via informal methods to those established by professionals. Only when accurate labour standards exist can management know what its labour requirements are, what its costs should be, and what constitutes a fair day's work.

SELF ASSESSMENT EXERCISE

1. How would you define a good quality work life?
2. What are some of the worst jobs you know about? Why are they bad jobs? Why do people want these jobs?

4.0 CONCLUSION

Management's role is to educate the employee, even when employees think it is "macho" not to wear safety equipment. Management's role is to define the necessary equipment, work rules, and work environment and to enforce those requirements. We began this chapter with a discussion of mutual trust and commitment, and that is the environment that managers should foster. Ethical management requires no less.

5.0 SUMMARY

Outstanding firms know the importance of an effective and efficient human resource strategy. Often a large percentage of employees and a large part of labour costs are under the direction of OM. Consequently, the operations manager usually has a large role to play in achieving human resource objectives. A prerequisite is to build an environment with mutual respect and commitment and a reasonable quality of work life. Outstanding organizations have designed jobs that use both the mental and physical capabilities of their employees. Regardless of the strategy chosen, the skill with which a firm manages its human resources ultimately determines its success.

6.0 TUTOR-MARKED ASSIGNMENT

1. Make a process chart for changing the right rear tyre on an automobile.
2. Draw an activity chart for a machine operator with the following operation.

The relevant times are as follows:

Prepare mill for loading (cleaning, and so on)	.50 min.

Load mill	1.75 min.
Mill Operating (cutting material)	2.25 min.
Unload mill	.75 min.

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UNIT 8 WORK MEASUREMENT

CONTENTS

1.0 INTRODUCTION

Modern labour standards originated with the works of Frederick Taylor and Frank and Lillian Gilbreth at the beginning of the twentieth century. At that time, a large proportion of work was manual, and the resulting labour content of products was high. Little was known about what constituted a fair day's work, so managers initiated studies to improve work methods and understand human effort. These efforts continue to this day. Although we are now at the beginning of the 21st century, and labour costs are often less than 10% of sales, labour standards remain important and continue to play a major role in both service and manufacturing organizations. They are often a beginning point for determining staffing requirements. With over half of the manufacturing plants in America using some form of labour incentive system, good labour standards are a requirement.

2.0 OBJECTIVES

At the end of this unit, you will be able to

Identify or define:

- four Ways Of Establishing Labour Standards

Describe or explain:

- requirements for Good Labour Standards
- time Study
- predetermined Time Standards
- work Sampling.

3.0 MAIN CONTENT

3.1 Work Measurement

3.1.1 Labour Standards and Work Measurement

Effective operations management requires meaningful standards that can help a firm determine the following:

1. Labour content of items produced (the labour cost).
2. Staffing needs (how many people it will take to meet required production).
3. Cost and time estimates prior to production (to assist in a variety of decisions, from cost estimates to make-or-buy decisions).
4. Crew size and work balance (who does what in a group activity or on an assembly line).
5. Expected production (so that both manager and worker know what constitutes a fair day's work).
6. Basis of wage-incentive plans (what provides a reasonable incentive).
7. Efficiency of employees and supervision (a standard is necessary against whatever determines efficiency).

Properly set labour standards represent the amount of time that it should take an average employee to perform specific job activities under normal working conditions. Labour standards are set in four ways:

1. Historical experience.
2. Time studies.
3. Predetermined time standards
4. Work sampling

3.2 Historical Experience

Labour standards can be estimated based on historical experience-that is, how many labour-hours were required to do a task the last time it was performed. Historical standards have the advantage of being relatively easy and inexpensive to obtain. They are usually available from employee time cards or production records. However, they are not objective, and we do not know their accuracy, whether they represent a reasonable or a poor work pace, and whether unusual occurrences are included. Because these variables are unknown, their use is not recommended. Instead, time studies, predetermined time standards, and work sampling are preferred.

3.3 Time Studies

The classical stopwatch study, or time study, originally proposed by

Frederick W. Taylor in 1881, is still the most widely used time-study method.) A time-study procedure involves timing a sample of a worker's performance and using it to set a standard. A trained and experienced person can establish a standard by following these eight steps.

1. Define the task to be studied (after methods analysis has been conducted).
2. Divide the task into precise elements (parts of a task that often take no more than a few seconds).
3. Decide how many times to measure the task (the number of job cycles or samples needed).
4. Time and record elemental times and ratings of performance.
5. Compute the average observed (actual) time. The average observed time is the arithmetic mean of the times for each element measured, adjusted for unusual influence for each element:

$$\text{Average observed time} = \frac{\text{Sum of the times recorded to perform each element}}{\text{Number of observations}}$$

6. Determine performance rating (work pace) and then compute the normal time for each element.

Normal time = (Average observed time) x (Performance rating factor)

The performance rating adjusts the observed time to what a normal worker could expect to accomplish. For example, a normal worker should be able to walk 3 miles per hour. He or she should also be able to deal a deck of 52 cards into 4 equal piles in 30 seconds. A performance rating of 1.05 would indicate that the observed worker performs the task slightly faster than average. Numerous videos specify work pace on which professionals agree, and benchmarks have been established by the Society for the Advancement of Management Performance rating, however, it is still something of an art.

7. Add the normal times for each element to develop a total normal time for the task.
8. Compute the standard time. This adjustment to the total normal time provides for allowances such as personal needs, unavoidable work delays, and workers fatigue.

$$\text{Standard time} = \frac{\text{Total normal time}}{1 - \text{allowance factor}}$$

Personal time allowances are often established in the range of 4% to 7% of total time, depending on nearness to rest rooms; water fountains, and other facilities. Delay allowances are often set as a result of the actual studies of the delay that occurs. Fatigue allowances are based on our growing knowledge of human energy expenditure under various physical and environmental conditions. Example 1 illustrates the computation of standard time.

Example 1

The time study of a work operation yielded an average observed time of 4.0 minutes. The analyst rated the observed worker at 85%. This means the worker performed at 85% of normal when the study was made. The firm uses a 13% allowance factor. We want to compute the standard time.

Solution

Average observed time = 4.0 min.
Normal time = (Average observed time) x (Performance rating factor)

= (4.0)(.85)

= 3.4 min

$$\text{Standard time} = \frac{\text{Normal time}}{1 - \text{allowance factor}} = \frac{3.4}{1-.13} = \frac{3.4}{.87}$$

= 3.9 min.

Management Science Associates promotes its management development seminars by mailing thousands of individually composed and typed letters to various firms. A time study has been conducted on the task of preparing letters for mailing. On the basis of the following observations, Management Science Associates wants to develop a time standard for this task. The firm's personal, delay, and fatigue allowance factor is 5%.

Observations (in Minutes)

JOB ELEMENT	1	2	3	4	5	PERFORMANCE RATING
(A) Compose and type letter	8	10	9	21	11	120%
(B) Type envelope address	2	3	2	1	3	105%
(C) Stuff, stamp, seal, and Sort envelopes	2	1	5	2	1	110%

Solution

Once the data have been collected, the procedure is as follows:

1. Delete unusual or nonrecurring observations such as those

marked with an asterisk (*). (These may be due to business Interruptions, conferences with the boss, or mistakes of an unusual nature; they are not part of the job element, but may be personal or delay time.).

2. Compute the average time for each job element

$$\text{Average time for A} = \frac{8 + 10 + 9 + 11}{4} = 9.5 \text{ min.}$$

$$\text{Average time for B} = \frac{2 + 3 + 2 + 1 + 3}{5} = 2.2 \text{ min.}$$

$$\text{Average time for C} = \frac{2 + 1 + 2 + 1}{4} = 1.5 \text{ min}$$

3. Compute the normal time for each job element

Normal time for A = (Average observed time) x (Performance rating)
= (9.5) (1.2)
= 11.4 min.

Normal time for B = (2.2) (1.05)
= 2.31 min.

Normal time for C = (1.5)(1.1 0)
= 1.65 min.

Note: Normal times are computed for each element because the performance rating factor (work pace) may vary for each element, as it did in this case.

4. Add the normal times for each element to find the total normal time (the normal time for the whole job):

Total normal time = 11.40 + 2.31 + 1.65.
= 15.36 min.

5. Compute the standard time for the job:

$$\text{Standard time} = \frac{\text{Total normal time}}{1 - \text{allowance factor}} = 18.07 \text{ min}$$

Thus, 18.07 minutes is the time standard for this job.

Note: When observed times are not consistent they need to be reviewed. Abnormally short times may be the result of an observational error and are usually discarded. Abnormally long times need to be analyzed to determine if they, too, are an error. However, they may include a seldom occurring but legitimate activity for the element (such as a machine adjustment) or may be personal, delay, or fatigue time.

Time study requires a sampling process; so the question of sampling error in the average observed time naturally arises. In statistics, error varies inversely with sample size. Thus, to determine just how many cycles we should time, we must consider the variability of each element in the study.

To determine an adequate sample size, three items must be considered:

1. How accurate we want to be (for example, is :t5% of observed time close enough?)
2. The desired level of confidence (for example, the z value; is 95% adequate or is 99% required?).
3. How much variation exists within the job elements (for example, if the variation is large, a larger sample will be required)

The formula for finding the appropriate sample size given these three variables is:

Required sample size = n = (zs)2 $\frac{}{(hx)}$

Where h = accuracy level desired in percent of the job element, expressed as a decimal (5% = .05)
z = number of standard deviations required for desired level of confidence
90% confidence = 1.65; see Table S 10.1 or Appendix I (for the more common z-values)
s = standard deviation of the initial sample
x = mean of the initial sample
n = required sample size

DESIRED CONFIDENCE (%)	**z- VALUE (STANDARD DEVIATION REQUIRED FOR DESIRED LEVEL OF CONFIDENCE)**
90.0	1.65
95.0	1.96
95.44	2.00
99.0	2.58
99.73	3.00

We demonstrate with Example S3.

Thomas W. Jones Manufacturing Co. has asked you to check a labour standard prepared by a recently terminated analyst. Your first task is to determine the correct sample size. Your accuracy is to be within 5% and your confidence level at 95%. The standard deviation of the sample is 1.0 and the mean 3.00

Solution

h = .05
x = 3.00
s = 1.0
z = 1.96 (from Table S 10.1 or Appendix I)

$$n = \left(\frac{zs}{hx}\right)^2$$

$$n = \left(\frac{1.96 \times 1.0}{.05 \times 3}\right)^2 = 170.74 = 171$$

Therefore, you recommend a sample size of 171.

Now let's look at two variations of Example S3.

First, if h, the desired accuracy, is expressed as an absolute amount of error (say, I minute of error is acceptable), then substitute e for hi, and the appropriate formula is

$$n = \left(\frac{zs}{e}\right)^2$$

where e is the absolute amount of acceptable error.
Second, for those cases when s, the standard deviation of the sample, is not provided (which is typically the case outside the classroom), it must be computed. The formula for doing so is given in Equation (S I 0-6):

L (each sample observation – i)2 number in sample – I

$$\frac{\sum (x_i - \bar{x})^2}{n - 1}$$

where Xi = value of each observation
i = mean of the observations.
n = number of observations in the sample.

Although time studies provide accuracy in setting labour standards, they have two disadvantages. First, they require a trained staff of analysts. Second, labour standards cannot be set before tasks are actually performed. This leads us to two alternative work measurement techniques that we discuss next.

3.4. Predetermined Time Standards

In addition to historical experience and time studies, we can set production standards by using predetermined time standards. Predetermined time standards divide manual work into small basic elements that already have established times (based on very large samples of workers). To estimate the time for a particular task, the time factors for each basic element of that task are added together. Developing a comprehensive system of predetermined time standards would be prohibitively expensive for any given firm. Consequently, a number of systems are commercially available. The most common predetermined time standard is methods time measurement (MTM), which is a product of the MTM Association.

Predetermined time standards are an outgrowth of basic motions called *therbligs.*

The term therblig was coined by Frank Gilbreth (Gilbreth spelled backwards with the t and h reversed). Therbligs include such activities as select, grasp, position, assemble, reach, hold, rest, and inspect. These activities are stated in terms of time measurement units (TMUs), which are equal to only .00001 hour, or .0006 minute each. MTM values for various therbligs are specified in very detailed tables. Example below provides the set of time standards for the motion GET and PLACE. To use GET and PLACE, one must know what is "gotten," its approximate weight, and where and how far it is supposed to be placed.

Pouring a tube specimen in a hospital lab is a repetitive task for which the MTM data in Table S 10.2 may be used to develop standard times. The sample tube is in a rack and the centrifuge tubes in a nearby box. A technician removes the sample tube from the rack, uncaps it, gets the centrifuge tube, pours, and places both tubes in the rack.

The first work element involves getting the tube from the rack. Suppose the conditions for GETTING the tube and PLACING it in front of the technician are:

- Weight: (less than 2 pounds)
- Conditions of GET: (easy).
- Place accuracy: (approximate).
- Distance range: (8 to 20 inches)

Then the MTM element for this activity is AA2 (as seen from Figure S 10.2). The rest of Table S 10.2 is developed from similar MTM tables. Most MTM calculations, by the way, are computerized, so the user need only key in the appropriate MTM codes, such as AA2 in this example.

Table 2: MTM-HC Analysis: Pouring Tube Specimen

ELEMENT DESCRIPTION	ELEMENT	TIME
Get tube from rack	AA2	35
Get stopper, place on counter	AA2	35
Get centrifuge tube, place at	AD2	45
sample tube Pour (3 sec.)	PT	83
Place tubes in rack (simo)	PC2	40
		TOTAL TMU 238
0006 x 238 = Total standard minutes = .14		

Predetermined time standards have several advantages over direct time studies. First, they may be established in a labouratory environment, where the procedure will not upset actual production activities (which time studies tend to do). Second, because the standard can be set before a task is actually performed, it can be used for planning. Third, no performance ratings are necessary. Fourth, unions tend to accept this method as a fair means of setting standards. Finally, predetermined time standards are particularly effective in firms that do substantial numbers of studies of similar tasks. To ensure accurate labour standards, some firms use both time studies and predetermined time standards.

3.5 Work Sampling

The fourth method of developing labour or production standards, work sampling, was developed in England by L. Tippet in the 1930s. Work sampling estimates the percent of the time that a worker spends on various tasks. It requires random observations to record the activity that a worker is performing. The results are primarily used to determine how employees allocate their time among various activities. Knowledge of this allocation may lead to staffing changes, reassignment of duties, estimates of activity cost, and the setting of delay allowances for labour standards. When work sampling is done to establish delay allowances, it is sometimes called a ratio delay study.

The work-sampling procedure can be summarized in five steps:

1. Take a preliminary sample to obtain an estimate of the parameter value (such as percent of time a worker is busy).
2. Compute the sample size required
3. Prepare a schedule for observing the worker at appropriate times. The concept of random numbers is used to provide for random observation. For example, let's say we draw the following five random numbers from a table: 07, 12, 22, 25, and 49. These can then be used to create an observation schedule of 9:07 A.M., 9:12, 9:22, 9:25, 9:49.
4. Observe and record worker activities.
5. Determine how workers spend their time (usually as a percent).

To determine the number of observations required, management must decide on the desired confidence level and accuracy. First, however, the analyst must select a preliminary value for the parameter under study (step I above). The choice is usually based on a small sample of perhaps 50 observations. The following formula then gives the sample size for a desired confidence and accuracy:

$$n = \frac{z^2 p(1 - p)}{h^2}$$

Where n = required sample size

z = number of standard normal deviations for the desired confidence level *(z = I for 68% confidence, z = 2 for 95.45% confidence,* and *z = 3 for 99.73% confidence-these values are obtained* from Table S 10.1 or the Normal Table in Appendix I)

p = estimated value of sample proportion (of time worker is observed busy or idle)

h = acceptable error level, in percent.

Example 5 shows how to apply this formula.

The manager of Wilson County's welfare office, Madeline Thimmes, estimates her employees are idle 25% of the time. She would like to take a work sample that is accurate within 3% and wants to have 95.45% confidence in the results.

Solution

To determine how many observations should be taken, Madeline applies the following equation:

$$n = \frac{z^2 p(1-p)}{h^2}$$

where n = required sample size

z = 2 for 95.45% confidence level

p = estimate of idle proportion = 25% = .25

h = acceptable error of 3% = .03

She finds that

$$n = \frac{(2)^2 (.25)(.75)}{(.03)^2} = 833 \text{ observation}$$

Thus, 833 observations should be taken. If the percent of idle time observed is not close to 25% as the study progresses, then the number of observations may have to be recalculated and increased or decreased as appropriate.

The focus of work sampling is to determine how workers allocate their time among various activities. This is accomplished by establishing the percent of time individuals spend on these activities rather than the exact amount of time spent on specific tasks. The analyst simply records in a random, nonbiased way the occurrence of each activity. Example S6 shows the procedure for evaluating employees at the state welfare office introduced in Example 5.

Madeline Thimmes, the operations manager of Wilson County's state welfare office, wants to be sure her employees have adequate time to provide prompt, helpful service. She believes that service to welfare clients who phone or walk in without an appointment deteriorates rapidly when employees are busy more than 75% of the time. Consequently, she does not want her employees to be occupied with client service activities more than 75% of the time.

The study requires several things: First, based on the calculations in Example 5, 833 observations are needed. Second, observations are to be made in a random, nonbiased way over a period of 2 weeks to ensure a true sample. Third, the analyst must define the activities that are "work." In this case, work is defined as all the activities necessary to take care of the client (filing, meetings, data entry, discussions with the supervisor, etc.). Fourth, personal time is to be included in the 25% of non work time. Fifth, the observations are made in a non intrusive way so as not to distort the normal work patterns. At the end of the 2 weeks, the 833 observations yield the following results.

No. of Observation	Activity
485	On the phone or meeting with a
126	welfare client
62	Idle ""
23	Personal time
137	Discussions with supervisor
833	Filing, meeting, and computer data
	entry

The analyst concludes that all but 188 observations (126 idle and 62 personal) are work related. Since 22.6% (= 188/833) is less idle time than Madeline believes necessary to ensure a high client service level, she needs to find a way to reduce current workloads. This could be done through a reassignment of duties or the hiring of additional personnel.

SELF ASSESSMENT EXERCISE

1. Identify four ways in which labour standards are set.
2. Define Normal Time
3. What are some of the uses to which labour standards are put.

4.0 CONCLUSION

Work sampling offers several advantages over time-study methods. First, because a single observer can observe several workers simultaneously, it is less expensive. Second, observers usually do not require much training, and no timing devices are needed. Third, the study can be temporarily delayed at any time with little impact on the results. Fourth, because work sampling uses instantaneous observations over a long period, the worker has little chance of affecting the study's outcome. Fifth, the procedure is less intrusive and therefore less likely to generate objections.

The disadvantages of work sampling are (1) it does not divide work elements as completely as time studies, (2) it can yield biased or incorrect results if the observer does not follow random routes of travel and observation, and (3) because it is less intrusive, it tends to be less accurate; this is particularly true when job element times are short.

5.0 SUMMARY

Labour standards are required for an efficient operations system. They are needed for production planning, labour planning, costing, and evaluating performance. They can also be used as a basis for incentive systems. They are used in both the factory and the office. Standards may be established via historical data, time studies, predetermined time standards, and work sampling.

6.0 TUTOR-MARKED ASSIGNMENT

1. A work operation consisting of three elements has been subjected to a stopwatch time study. The recorded observations are shown in the following table. By union contract, the allowance time for the operation is personal time 5%, delay 5%, and fatigue 10%. Determine the standard time for the work operation.

OBSERVATIONS (MINUTES)

JOB ELEMENT	1	2	3	4	5	6	PERFORMANCE RATING (%)
A	.1	.3	.2	.9	.2	.1	90
B	.8	.6	.8	.5	3.2	.7	110
C	.5	.5	.4	.5	.6	.5	80

2. The preliminary work sample of an operation indicates the following:

Number of times operator working 60
Number of times operator idle 40
Total number of preliminary observations 100

What is the required sample size for a 99.73% confidence level with: t4% precision?

3. Amor Manufacturing Co. of Geneva, Switzerland, has just studied a job in its laboratory in anticipation of releasing the job to the factory for production. The firm wants rather good accuracy for costing and labour forecasting. Specifically, it wants to provide a 99% confidence level and a cycle time that is within 3% of the true value. How many observations should it make? The data collected so far are as follows:

OBSEVATION	**TIME**
1	1.7
2	1.6
3	1.4
4	1.4
5	1.4

4. At Maggard Micro Manufacturing, Inc., workers press semiconductors into predrilled slots on printed-circuit boards. The elemental motions for normal time used by the company are as follows:

Reach 6 inches for semiconductors 10.5 TMU
Grasp the semiconductor 8.0 TMU
Move semiconductor to printed-circuit board 9.5 TMU
Position semiconductor 20.1 TMU
Press semiconductor into slots 20.3 TMU
Move board aside 15.8 TMU

Each time measurement unit is equal to .0006 min.) Determine the normal time for this operation in minutes and in seconds.

5. To obtain the random sample needed for work sampling, a manager divides a typical workday into 480 minutes. Using a random-number table to decide what time to go to an area to sample work occurrences, the manager records observations on a tally sheet like the following:

STATUS	**TALLY**
Productively working	*~~1111~~ ~~1111~~ ~~1111~~ 1*
Idle	*1111*

7.0 REFERENCES/FURTHER READINGS

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MODULE 3

UNIT 1 SUPPLY-CHAIN MANAGEMENT

CONTENTS

1.0 INTRODUCTION

Most firms, like VW, spend more than 50% of their sales dollars on purchases. Because such high percentage of an organization's costs are determined by purchasing, relationships with suppliers are becoming increasingly integrated and long-term. Joint efforts that improve innovation, speed design, and reduce costs are common. Such efforts, when part of an integrated strategy, dramatically improve both partners' competitiveness. This changing focus places added emphasis on procurement and supplier relationships which must be managed. The discipline that manages these relationships is known as supply-chain management.

2.0 OBJECTIVES

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

Identify or define:

- supply chain management
- purchasing
- outsourcing
- e-procurement
- material management
- keiretsu
- virtual Companies

Describe or explain:

- supply Chain Strategies
- approaches to Negotiations.

3.0 MAIN CONTENT

3.1 The Strategic Importance of the Supply Chain

Supply chain management is the integration of the activities that procure materials and services, transform them into intermediate goods and final products, and deliver them to customers. The activities include purchasing and outsourcing activities, plus many other functions that are important to the relationship with suppliers and distributors. Supply-chain management includes determining (1) transportation vendors, (2) credit and cash transfers, (3) suppliers, (4) distributors and banks, (5) accounts payable and receivable, (6) warehousing and inventory levels, (7) order fulfillment, and (8) sharing customer, forecasting, and production information. The objective is to build a chain of suppliers that focuses on maximizing value to the ultimate customer.

Competition is no longer between companies; it is between supply chains. And those supply chains are often global.

As firms strive to increase their competitiveness via product customization, high quality, cost reductions, and speed to market they place added emphasis on the supply chain. The key to effective supply-chain management is to make the suppliers "partners" in the firm's strategy to satisfy; ever-changing marketplace. A competitive advantage may depend on a close long-term strategic relationship with a few suppliers.

Table 1: How Supply-Chain Decisions Affect Strategy

	Low-Cost Strategy	**Response Strategy**	**Differentiation Strategy**
Supplier's goal	Supply demand at lowest possible cost (e.g., Emerson Electric, Taco Bell)	Respond quickly to changing requirements and demand to minimize stockouts (e.g., Dell Computers)	Share market research: jointly develop products and options (e.g., Benetton)
Primary Selection Criteria	Select primarily for cost	Select primarily for capacity, speed, and flexibility	Select primarily for product development skills
Process characteristics	Maintain high average utilization	Invest in excess capacity and flexible processes	Use modular processes that lend themselves to mass customization
Inventory characteristics	Minimize inventory throughout the chain to hold down cost	Develop responsive system, with buffer stocks positioned to ensure supply	Minimize inventory in the chain to avoid obsolescence
Lead-time characteristics	Shorten lead time as long as it does not increase cost	Invest aggressively to reduce production lead time	Invest aggressively to reduce development lead time
Product-design characteristics	Maximize performance and minimize cost	Use product designs that lead to low setup time and rapid production ramp-up	Use modular design to postpone product differentiation for as long as possible

To ensure that the supply chain supports the firm's strategy, managers need to consider the supply-chain issues shown in Table 1. Activities of supply-chain managers cut across accounting, finance, marketing, and the operations discipline. Just as the OM function supports the firm's overall strategy, the supply chain must support the OM strategy. Strategies of low cost or rapid response demand different things from a supply chain than a strategy of differentiation. For instance, a low-cost strategy, as Table 1 indicates, requires suppliers be selected based primarily on cost. Such suppliers should have the ability to design low-cost products that meet the functional requirements, minimize inventory, and drive down lead times. The firm must achieve integration of its selected strategy up and down the supply chain, and must expect that strategy to be different for different products and change as products move through their life cycle.

3.1.1 Global Supply-Chain Issues

When companies enter growing global markets such as Eastern Europe, China, South America, or even Mexico, expanding their supply chains becomes a strategic challenge. Quality production in those areas may be a challenge, just as distribution systems may be less reliable, suggesting higher inventory levels than would be needed in one's home country. Also, tariffs and quotas may block non-local companies from doing business. Moreover, both political and currency risk remain high in most part of the world.

Thus, the development of a successful strategic plan for supply-chain management requires innovative planning and careful research. Supply chains in a global environment must be able to:

1. React to sudden changes in parts availability, distribution or shipping channels, import duties, and currency rates.
2. Use the latest computer and transmission technologies to schedule and manage the shipment of parts in and finished products out.
3. Staff with local specialists who handle duties, freight, customs, and political issues.

Firms like Ford and Boeing also face global procurement decisions. Ford's Mercury has only 227 suppliers worldwide, a small number compared with the 700 involved in previous models. Ford has set a trend to develop a global network of fewer suppliers who provide the lowest cost and highest quality regardless of home country. So global is the production of the Boeing 787 that 75% to 80% of the plane will be built by non-Boeing companies, with most of that figure outside the U.S.

3.2 Supply-Chain Economics

The supply chain receives such attention because it is an integral part of a firm's strategy and the most costly activity in most firms. For both goods and services, supply-chain costs as a percent of sales are often substantial (see Table 11.2). Because such a huge portion of revenue is devoted to the supply chain, an effective strategy is vital. The supply chain provides a major opportunity to reduce costs and increase contribution margins.

Table 2 illustrates the amount of leverage available to the operations manager through the supply chain. Firms spending 50% of their sales dollar in the supply chain and having a net profit of 6% would require N3.57 worth of sales to equal the savings that accrues to the company from a N1 savings in procurement. These numbers indicate the strong role that procurement can play in profitability.

3.2.1 Make-or-Buy Decisions

A wholesaler or retailer buys everything that it sells; a manufacturing operation hardly ever does. Manufacturers, restaurants, and assemblers of products buy components and subassemblies that go into final products. As we saw in Unit 5, choosing products and services that can be advantageously obtained externally as opposed to produced internally is known as the make-or-buy decision. Supply-chain personnel evaluate alternative suppliers and provide current, accurate, complete data relevant to the buy alternative. Table 2 lists a variety of considerations in the make-or-buy decision. Regardless of the decision, supply-chain performance should be reviewed periodically. Vendor competence and costs change, as do a firm's own strategy, production capabilities, and costs.

Table 2

	PERCENT OF SALES SPENT IN THE SUPPLY CHAIN						
PERCENT NET PROFIT OF FIRM	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
2	N2.78	N3.23	N3.85	N4.76	N6.25	N9.09	N16.67
4	N2.70	N3.13	N3.70	N4.55	N5.88	N8.33	N14.29
6	N2.63	N3.03	N3.57	N4.35	N5.56	N7.69	N12.50
8	N2.56	N2.94	N3.45	N4.17	N5.26	N7.14	N11.11
10	N2.50	N2.86	N3.33	N4.00	N5.00	N6.67	N10.00

"The required increase in sales assumes that 50% of the costs other than purchases are variable and that half the remaining costs (less profit) are fixed. Therefore at sales of N100 (50% purchases and 2% margin). N50 are purchases. N24 are other variable costs. N24 are fixed costs. and N2 profit. Increasing sales by N3.85 yields the following.

Purchases at 50% N51.93
Other Variable Costs 24.92
Fixed Cost 24.00
Profit 3.00 ______

N103.85

Through N3.85 of additional sales, we have increased profit by N1 from N2 to N3. The same increase in margin could have been obtained by reducing supply chain costs by N1.

3.3 Outsourcing

Outsourcing transfers some of what are traditional internal activities and resources of a firm to outside vendors, making it slightly different from the traditional make-or-buy decision. Outsourcing is part of the continuing trend towards utilizing the efficiency that comes with specialization. The vendor performing the outsourced service is an expert in that particular specialty. This leaves the outsourcing firm to focus on its critical success factors, that is, its core competencies that yield a competitive advantage.

With outsourcing, there need not be a tangible product or transfer of title. The contracting firm may even provide the resources necessary for accomplishing the activities. The resources transferred to the supplying firm may include facilities, people, and equipment. Many firms outsource their information technology requirements, accounting work, legal functions, logistics, and even product assembly. Because of low-cost electronic data transfer throughout the world, those activities that can be transferred electronically are prime candidates for outsourcing. We find "call centers" for the French in Angola (a former French colony in Africa) and for the U.S. and England in India. We see Microsoft customer email queries and Proctor & Gamble's management, finance, and accounting services routed to the Philippines. Within the U.S., Electronic Data Systems (EDS) provides information technology outsourcing for many firms, including Delphi Automotive and Nextel. Similarly, Automatic Data Processing (ADP) provides payroll services for thousands of firms.

Outsourced manufacturing is becoming standard practice in many industries from computers to automobiles. Much of IBM's computer assembly work is outsourced to a specialist in electronic assembly, Solectron. And production of the Chrysler Crossfire, Audi A4 Convertible, and Mercedes CLK convertible is outsourced to Wilheim Karmann in Osnabruck, Germany.

Table 3

REASONS FOR MAKING	**REASONS FOR BUYING**
1. Maintain core competence.	1. Frees management to deal

	with its primary business
2. Lower production cost.	2. Lower acquisition cost.
3. Unsuitable suppliers.	3. Preserve supplier commitment.
4. Assure adequate supply (quantity or delivery)	4. Obtain technical or management ability
5. Utilize surplus labour or facilities and make a marginal contribution.	5. Inadequate capacity.
6. Obtain desired quality.	6. Reduce inventory costs.
7. Remove supplier collusion.	
8. Obtain unique item that would entail a prohibitive commitment for a supplier.	7. Ensure alternative sources.
9. Protect personnel from a layoff.	8. Inadequate managerial or technical resources.
10. Protect proprietary design or quality	9. Reciprocity.
11. Increase or maintain size of the company (management preference)	10. Item is protected by a patent or trade secret.

3.4 Ethics in the Supply Chain

As we have stressed throughout this text, ethical decisions are critical to the long-term success of any organization. However, the supply chain is particularly susceptible to lapses, as the opportunities for unethical behavior are enormous. With sales personnel anxious to sell, and purchasing agents spending huge sums, the temptation for unethical behavior is substantial. Many salespeople become friends with customers, do favors for them, take them to lunch, or present small (or large) gifts. Determining when tokens of friendship become a bribe can be a challenge. Many companies have strict rules and codes of conduct that limit what is acceptable. Recognizing these issues, the Institute for Supply Management has developed principles and standards to be used as guidelines for ethical behavior. These are shown in Table 4.

As the supply chain becomes international, operations managers need to expect an additional set of ethical issues to manifest themselves as they deal with labour laws, culture, and a whole new set of values. For instance, in 2004, Gap Inc. reported that of its 3,000 plus factories worldwide, about 90% failed their initial evaluation? The report indicated that between 10% and 25% of its Chinese factories engaged in psychological or verbal abuse, and more than 50% of the factories visited in sub-Saharan Africa operate without proper safety devices. The challenge of ethics in the supply chain is significant, but responsible firms such as Gap are finding ways to deal with a difficult issue.

LOYALTY TO YOUR ORGANIZATION
JUSTICE TO THOSE WITH WHOM YOU DEAL
FAITH IN YOUR PROFESSION

From these principles are derived the ISM standards of supply management conduct. (Global)

1. Avoid the intent and appearance of unethical or compromising practice in relationships, actions and communications.

2. Demonstrate loyalty to the employer by diligently following the lawful instructions of the employer using reasonable care and granted authority.

3. Avoid any personal business or professional activity that would create a conflict between personal interests and the interests of the employer.

4. Avoid soliciting or accepting money, loans, credits, or preferential discounts, and the acceptance of gifts, entertainment, favors, or services from present or potential suppliers that might influence, or appear to influence, supply management decisions.

5. Handle confidential or proprietary information with due care and proper consideration of ethical and legal ramifications and governmental regulations.

6. Promote positive supplier relationships through courtesy and impartiality.

7. Avoid improper reciprocal agreements.

8. Know and obey the letter and spirit of laws applicable to supply management.

9. Encourage support for small, disadvantaged, and minority-owned businesses.

10. Acquire and maintain professional competence.
11. Conduct supply management activities in accordance with national and international laws, customs, and practices, your organization's policies, and these ethical principles and standards of conduct.

12. Enhance the stature of the supply management profession.

3.5 Supply-Chain Strategies

For goods and services to be obtained from outside sources, the firm must decide on a supply-chain strategy. One such strategy is the approach of negotiating with many suppliers and playing one supplier against another. A second strategy is to develop long-term "partnering" relationships with a few suppliers to satisfy the end customer. A third strategy is vertical integration, in which a firm decides to use vertical backward integration by actually buying the supplier. A fourth variation is a combination of few suppliers and vertical integration, known as a keiretsu. In a keiretsu, suppliers become part of a company coalition. Finally, a fifth strategy is to develop virtual companies that use suppliers on an as-needed basis. We will now discuss each of these strategies.

3.5.1 Many Suppliers

With the many suppliers strategy, a supplier responds to the demands and specifications of a "request for quotation," with the order usually going to the low bidder. This is a common strategy when products are commodities. This strategy plays one supplier against another and places the burden of meeting the buyer's demands on the supplier. Suppliers aggressively compete with one another. Although many approaches to negotiations can be used with this strategy, long term "partnering" relationships are not the goal. This approach holds the supplier responsible for maintaining the necessary technology, expertise, and forecasting abilities, as well as cost, quality, and delivery competencies.

3.5.2 Few Suppliers

A strategy of few suppliers implies that rather than looking for short-term attributes, such as low cost, a buyer is better off forming a long-term relationship with a few dedicated suppliers. Long-term suppliers are more likely to understand the broad objectives of the procuring firm and the end customer. Using few suppliers can create value by allowing suppliers to have economies of scale and a learning curve that yields both lower transaction costs and lower production costs.

Few suppliers, each with a large commitment to the buyer, may also be more willing to participate in JIT systems as well as provide design innovations and technological expertise. Many firms have moved aggressively to incorporate suppliers into their supply systems. DaimlerChrysler, for one, now seeks to choose suppliers even before parts are designed. Motorola also evaluates suppliers on rigorous criteria, but in many instances has eliminated traditional supplier bidding, placing added emphasis on quality and reliability. On occasion these relationships yield contracts that extend through the product's life cycle. The expectation is that both the purchaser and supplier collaborate, becoming more efficient and reducing prices over time. The natural outcome of such relationships is fewer suppliers, but those that remain have long-term relationships.

Service companies like Marks and Spencer, a British retailer, have also demonstrated that cooperation with suppliers can yield cost savings for customers and suppliers alike. This strategy has resulted in suppliers that develop new products, winning customers for Marks and Spencer and the supplier. The move towards tight integration of the suppliers and purchasers is occurring in both manufacturing and services.

Like all strategies, a downside exists. With few suppliers, the cost of changing partners is huge, so both buyer and supplier run the risk of becoming captives of the other. Poor supplier performance is only one risk the purchaser faces. The purchaser must also be concerned about trade secrets and suppliers that make other alliances or venture out on their own. This happened when the U.S. Schwinn Bicycle Co., needing additional capacity, taught Taiwan's Giant Manufacturing Company to make and sell bicycles. Giant Manufacturing is now the largest bicycle manufacturer in the world, and Schwinn was acquired by Pacific Cycle LLC out of bankruptcy.

3.5.3 Vertical Integration

Purchasing can be extended to take the form of vertical integration. By vertical integration, we mean developing the ability to produce goods or services previously purchased or actually buying over a supplier or a distributor. Vertical integration can take the form of forward or backward integration.

Backward integration suggests a firm purchases its suppliers, as in the case of Ford Motor Company deciding to manufacture its own car radios. Forward integration, on the other hand, suggests that a manufacturer of components make the finished product. An example is Texas Instruments, a manufacturer of integrated circuits that also makes calculators and flat-screen TV's containing integrated circuits Vertical integration can offer a strategic opportunity for the operations manager. For firms with the capital, managerial talent, and required demand, vertical integration may provide substantial opportunities for cost reduction, quality adherence, and timely delivery. Other advantages, such as inventory reduction and scheduling can accrue to the company that effectively manages vertical integration or close, mutually beneficial relationships with suppliers.

Because purchased items represent such a large part of the costs of sales, it is obvious why so many organizations find interest in vertical integration. Vertical integration appears to work best when the organization has large market share and the management talent to operate an acquired vendor successfully.

The relentless march of specialization continues, meaning that a model of "doing everything" or "vertical integration" is increasingly difficult. Backward integration may be particularly dangerous for firms in industries undergoing technological change if management cannot keep abreast of those changes or invest the financial resources necessary for the next wave of technology. The alternative, particularly in high-tech industries, is to establish close-relationship suppliers. This allows partners to focus on their specific contribution. Research and development costs are too high and technology changes too rapid for one company to sustain leadership in every component in many product lines. Most organizations are better served concentrating on their specialty and leveraging the partners' contributions. Exceptions do exist. Where capital, management talent, and technology are available and the components are also highly integrated, as at Sanford Corporation shown in the photo, vertical integration may make sense. On the other hand, it made no sense for Jaguar to make commodity components for its autos as it did until it was purchased by Ford.

3.5.4 Keiretsu Networks

Many large Japanese manufacturers have found a middle ground between purchasing from few suppliers and vertical integration. These manufacturers are often financial supporters of suppliers through ownership or loans. The supplier then becomes part of a company coalition known as a keiretsu. Members of the keiretsu are assured long-term relationships and are therefore expected to function as partners, providing technical expertise and stable quality production to the manufacturer. Members of the keiretsu can also have suppliers farther down the chain, making second and even third-tier suppliers part of the coalition.

3.5.5 Virtual Companies

As noted before, the limitations to vertical integration are severe. Our technological society continually demands more specialization, which further complicates vertical integration. Moreover, a firm that has a department or division of its own for everything may be too bureaucratic to be world-class. So rather than letting vertical integration lock an organization into businesses that it may not understand or be able to manage, another approach is to find good flexible suppliers. Virtual companies rely on a variety of supplier relationships to provide services on demand. Virtual companies have fluid, moving organizational boundaries that allow them to create a unique enterprise to meet changing market demands. Suppliers may provide a variety of services that include doing the payroll, hiring personnel, designing products, providing consulting services, manufacturing components, conducting tests, or distributing products. The relationship may be short or long-term and may include true partners, collaborators, or simply, able suppliers and subcontractors. Whatever the formal relationship, the result can be an exceptionally lean performance. The advantages of virtual companies include specialized management expertise, low capital investment, flexibility, and speed. The result is efficiency.

The apparel business provides a traditional example of virtual organizations. The designers of clothes seldom manufacture their designs; rather, they license the manufacturer. The manufacturer may then rent a loft, lease sewing machines, and contract for labor. The result is an organization that has low overhead, remains flexible, and can respond rapidly to the market.

A contemporary example is the semiconductor industry, exemplified by Visioneer in Palo Alto. This California firm subcontracts almost everything: Software is written by several partners, hardware is manufactured by a subcontractor in Silicon Valley, printed circuit boards are made in Singapore, and plastic cases are made in Boston, where units are also tested and packed for shipment. In the virtual company, the purchasing function is demanding and dynamic.

3.6 Managing the Supply Chain

As managers move towards integration of the supply chain, substantial efficiencies are possible. The cycle of materials as they flow from suppliers, to production, to warehousing, to distribution, to the customer-takes place among separate and often very independent organizations. Therefore, there are significant management issues that may result in serious inefficiencies. Success begins with mutual agreement on goals, followed by mutual trust, and continues with compatible organizational cultures.

Mutual Agreement on Goals: An integrated supply chain requires more than just agreement on the contractual terms of a buy/sell relationship. Partners in the chain must appreciate that the only entity that puts money into a supply chain is the end customer. Therefore, establishing a mutual understanding of the mission, strategy, and goals of participating organizations is essential. The integrated supply chain is about adding economic value and maximizing the total content of the product.

Trust: Trust is critical to an effective and efficient supply chain. Members of the chain must enter into a relationship that shares information-a relationship built on mutual trust. Supplier relationships are more likely to be successful if risk and cost savings are shared and activities such as end-customer research, sales analysis, forecasting, and production planning are joint activities.

Compatible Organizational Cultures: A positive relationship between the purchasing and supplying organizations that comes with compatible organizational cultures can be a real advantage in making a supply chain hum. A champion within one of the two firms promotes both formal and informal contacts, and those contacts contribute to the alignment of the organizational cultures, further strengthening the relationship.

The operations manager is dealing with a supply chain that is made up of independent specialists, each trying to satisfy its own customers at a profit. This leads to actions that may not optimize the entire chain. On the other hand, the supply chain is replete with opportunities to reduce waste and enhance value. We now look at some of the significant issues and opportunities.

3.6.1 Issues in an Integrated Supply Chain

Three issues complicate development of an efficient, integrated supply chain: local optimization, incentives, and large lots.

Local Optimization: Members of the chain are inclined to focus on maximizing local profit or minimizing immediate cost based on their limited knowledge. Slight upturns in demand are overcompensated for, because no one wants to be caught short. Similarly, slight downturns are overcompensated for, because no one wants to be caught holding excess inventory. So fluctuations are magnified. For instance, a pasta distributor does not want to run out of pasta for its retail customers; the natural response to an extra large order is to compensate with an even larger order to the manufacturer on the assumption that sales are picking up. Neither the distributor nor the manufacturer knows that the retailer had a major one time promotion that moved a lot of pasta. This is exactly the issue that complicated the implementation of efficient distribution at the Italian pasta maker Barilla.

Incentives (Sales Incentives, Quantity Discounts, Quotas, and Promotions) Incentives push merchandise into the chain for sales that have not occurred. This generates fluctuations that are ultimately expensive to all members of the chain.

Large Lots There is often a bias towards large lots because large lots tend to reduce unit costs. The logistics manager wants to ship large lots, preferably in full trucks, and the production manager wants long production runs. Both actions drive down unit cost, but fail to reflect actual sales.

These three common occurrences (local optimization, incentives, and large lots) contribute to distortions of information about what is really occurring in the supply chain. A well-running supply system needs to be based on accurate information about how many products are truly being pulled through the chain. The inaccurate information is unintentional, but it results in distortions and fluctuations in the supply chain and causes what is known as the bullwhip effect.

The bullwhip effect occurs as orders are relayed from retailers, to wholesalers, to manufacturers, with fluctuations increasing at each step in the sequence. The "bullwhip" fluctuations in the supply chain increase the costs associated with inventory, transportation, shipping, and receiving while decreasing customer service and profitability. Procter & Gamble found that although the use of Pampers diapers was steady and the retail-store orders had little fluctuation, as orders moved through the supply chain, fluctuations increased. By the time orders were initiated for raw material, the variability was substantial. 3 Similar behavior has been observed and documented at many companies, including Campbell Soup, Hewlett Packard, and Applied Materials. A number of opportunities exist for reducing the bullwhip effect and improving opportunities in the supply chain. These are discussed in the following section.

3.6.2 Opportunities in an Integrated Supply Chain

Opportunities for effective management in the supply chain include the following 10 items.

Accurate "Pull" Data: Generate accurate pull data by sharing (1) point-of-sales (POS) information so that each member of the chain can schedule effectively, and (2) computer-assisted ordering (CAO). This implies using P~S systems that collect sales data and then adjusting that data for market factors, inventory on hand, and outstanding orders. Then a net order is sent directly to the supplier who is responsible for maintaining the finished goods inventory.

Lot Size Reduction: Reduce lot sizes by aggressive management. This may include (1) developing economical shipments of less than truckload lots; (2) providing discounts based on total annual volume rather than size of individual shipments; and (3) reducing the cost of ordering through techniques such as standing orders and various forms of electronic purchasing.

Single Stage Control of Replenishment: Single stage control of replenishment means designating a member in the chain as responsible for monitoring and managing inventory in the supply chain based on the "pull" from the end user. This approach removes distorted information and multiple forecasts that create the bullwhip effect. Control may be in the hands of

- A sophisticated retailer who understands demand patterns. How Wal-Mart does this for some of its inventory with radio frequency (RF) tags is shown in the, "Radio Frequency Tags: Keeping the Shelves Stocked."

- A distributor who manages the inventory for a particular distribution area. Distributors who handle grocery items, beer, and soft drinks may do this. Anheuser-Busch manages beer inventory and delivery for many of its customers.

- A manufacturer who has a well-managed forecasting, manufacturing, and distribution system. TAL Apparel Ltd., "Penney's Supply Chain for Dress Shirts," does this for Penney's

Vendor Managed Inventory: Vendor managed inventory (VMI) means the use of a local supplier (usually a distributor) to maintain inventory for the manufacturer or retailer. The supplier delivers directly to the purchaser's using department rather than to a receiving dock or stockroom. If the supplier can maintain the stock of inventory for a variety of customers who use the same product.

Postponement: Postponement withholds any modification or customization to the product (keeping it generic) as long as possible. For instance, after analyzing the supply chain for its printers, Hewlett-Packard (H-P) determined that if the printer's power supply was moved out of the printer itself and into a power cord, H-P could ship the basic printer anywhere in the world. H-P modified the printer, its power cord, its packaging, and its documentation so that only the power cord and documentation needed to be added at the final distribution point. This modification allowed the firm to manufacture and hold centralized inventories of the generic printer for shipment as demand changed. Only the unique power system and documentation had to be held in each country. This understanding of the entire supply chain reduced both risk and investment in inventory.

Channel Assembly: Channel assembly is a variation of postponement. Channel assembly sends individual components and modules, rather than finished products, to the distributor. The distributor then assembles, tests, and ships. Channel assembly treats distributors more as manufacturing partners than as distributors. This technique has proven successful in industries where products are undergoing rapid change, such as personal computers. With this strategy, finished-goods inventory is reduced because units are built to a shorter, more accurate forecast. Consequently, market response is better, with lower investment, a nice combination.

Drop Shipping and Special Packaging Drop shipping means the supplier will ship directly to the end consumer, rather than to the seller, saving both time and reshipping costs. Other cost-saving measures include the use of special packaging, labels, and optimal placement of labels and bar codes on containers. The final location down to the department and number of units in each shipping container can also be indicated. Substantial savings can be obtained through management techniques such as these. Some of these techniques can be of particular benefit to wholesalers and retailers by reducing shrinkage (lost, damaged, or stolen merchandise) and handling cost.

For instance, Dell Computer has decided that its core competence is not in stocking peripherals, but in assembling PCs. So if you order a PC from Dell, with a printer and perhaps other components, the computer comes from Dell, but the printer and many of the other components will be drop shipped from the manufacturer.

Blanket Orders: Blanket orders are unfilled orders with vendors. A blanket order is a contract to purchase certain items from the vendor. It is not an authorization to ship anything. Shipment is made only on receipt of an agreed on document, perhaps a shipping requisition or shipment release.

Standardization: The purchasing department should make special efforts to increase levels of standardization: That is, rather than obtaining a variety of similar components with labeling, coloring, packaging, or perhaps even slightly different engineering specifications, the purchasing agent should try to have those components standardized.

Electronic Ordering and Funds Transfer: Electronic ordering and funds transfer reduces paper transactions. Paper transactions consist of a purchase order, a purchase release, a receiving document, authorization to pay an invoice (which is matched with the approved receiving report), and finally the issuance of a check. Purchasing departments can reduce this barrage of paperwork by electronic ordering, acceptance of all parts as 100% good, and electronic funds transfer to pay for units received. Not only can electronic ordering reduce paperwork, but it also speeds up the traditionally long procurement cycle.

Transactions between firms often use electronic data interchange. Electronic data interchange (EDI) is a standardized data-transmittal format for computerized communications between organizations. EDI provides data transfer for virtually any business application, including purchasing. Under EDI, for instance, data for a purchase order, such as order date, due date, quantity, part number, purchase order number, address, and so forth, are fitted into the standard EDI format.

3.7 Internet Purchasing

State-of-the-art supply-chain systems combine many of the preceding techniques within automated purchasing systems. Internet purchasing or as it is sometimes called, e-procurement, has many variations. Let's look at four of them.

First, Internet purchasing may just imply that the Internet is used to communicate order releases to suppliers. This would occur for those items for which a blanket purchase order exists. In this application, the Internet replaces more traditional EDI with an order release to the supplier via the Internet.

Secondly, for nonstandard items, for which there is no blanket order, catalog ordering may enhance the communication features of the Internet. In this application of Internet purchasing, long-term master agreements with approved vendors result in placement of catalogs online for the buying organization's use. In such systems, ordering lead time is reduced and purchasing costs are controlled. San Diego State University (SDSU), for example, uses software to check order status, receive invoices and acknowledgments, and generate activity reports. SDSU's supply catalog content is real-time and supplier-managed. Purchasing transactions are integrated with the university's financial software, which is supplied by Oracle. Texas Instruments (TI) has installed a similar system to drive down its purchasing costs while improving item availability. TI employees worldwide now order directly from their desktops, and the transaction data are interfaced with SAP's Enterprise Resource Planning (ERP) software. (SAP and

Third, the Internet lends itself to auctions. Many commodities, for which long-term contracts do not exist, are now being economically purchased via Internet auction sites. The supplement to this unit, HE-Commerce and Operations Management, discusses Internet purchasing and auctions further.
Regardless of the form e-procurement systems take, suppliers like them because online selling means suppliers are getting closer to their customers. The supplier's cash flow may also improve because total cycle time (time from order to delivery to receipt of payment) is cut. As an added sweetener, the capital investment for e-procurement systems is low. Buyers like e-procurement because it lends itself to comparison shopping, rapid ordering, reduced transaction costs, and lower inventory.

Internet purchasing may be a part of an Enterprise Resource Planning (ERP) system with Internet communication among units of the supply chain. In such systems, the "order release" not only tells the shipper to ship but also updates the appropriate portions of the ERP system. Other, less integrated, Internet purchasing systems may not be part of a fully integrated ERP system. But even in these systems, purchases are usually posted automatically to the financial and inventory system of the purchasing firm, thus reducing internal transaction costs.

3.8 Vendor Selection

For those goods and services a firm buys, vendors must be selected. Vendor selection considers numerous factors, such as strategic fit, vendor competence, delivery, and quality performance. Because a firm may have some competence in all areas and exceptional competence in only a few, selection can be challenging. We now examine vendor selection as a three-stage process. Those stages are (1) vendor evaluation, (2) vendor development, and (3) negotiations.

3.8.1 Vendor Evaluation

The first stage, vendor evaluation, involves finding potential vendors and determining the likelihood of their becoming good suppliers. This phase requires the development of evaluation criteria such as those in Example 2. Both the criteria and the weights selected depend on the supply-chain strategy to be achieved.

The selection of competent suppliers is critical. If good suppliers are not selected, then all other supply-chain efforts are wasted. As firms move toward fewer longer-term suppliers, the issues of financial strength, quality, management, research, technical ability, and potential for a close long-term relationship play an increasingly important role. These attributes should be noted in the evaluation process.

3.8.2 Vendor Development

The second stage is vendor development. Assuming a firm wants to proceed with a particular vendor, how does it integrate this supplier into its system? The buyer makes sure the vendor has an appreciation of quality requirements, engineering changes, schedules and delivery, the purchaser's payment system, and procurement policies. Vendor development may include everything from training, to engineering and production help, to procedures for information transfer. Procurement policies also need to be established. Those might address issues such as percent of business done with anyone supplier or with minority businesses

3.8.3 Negotiations

Regardless of the supply-chain strategy adopted, negotiations regarding the critical elements of the contractual relationship must take place. These negotiations often focus on quality, delivery, payment, and cost. We will look at three classic types of negotiation strategies: the cost-based model, the market-based price model, and competitive bidding.

Cost-Based Price Model: The cost-based price model requires that the supplier open its books to the purchaser. The contract price is then based on time and materials or on a fixed cost with an escalation clause to accommodate changes in the vendor's labor and materials cost.

Market-Based Price Model: In the market-based price model, price is based on a published, auction, or index price. Many commodities (agriculture products, paper, metal, etc.) are priced this way.

Competitive Bidding: When suppliers are not willing to discuss costs or where near-perfect markets do not exist, competitive bidding is often appropriate. Infrequent work (such as construction, tooling, and dyes) is usually purchased based on a bid. Bidding may take place via mail, fax, or an Internet auction. Competitive bidding is the typical policy in many firms for the majority of their purchases. Bidding policies usually require that the purchasing agent have several potential suppliers of the product (or its equivalent) and quotations from each. The major disadvantage of this method, as mentioned earlier, is that the development of long-term relations between buyer and seller are hindered. Competitive bidding may effectively determine initial cost.

However, it may also make difficult the communication and performance that are vital for engineering changes, quality, and delivery.

Yet a fourth approach is to combine one or more of the preceding negotiation techniques. The supplier and purchaser may agree on review of certain cost data, accept some form of market data for raw material costs, or agree that the supplier will "remain competitive." In any case, a good supplier relationship is one in which both partners have established a degree of mutual trust and a belief in each other's competence.

3.9 Logistics Management

Procurement activities may be combined with various shipping, warehousing, and inventory activities to form a logistics system. The purpose of logistics management is to obtain efficiency of operations through the integration of all material acquisition, movement, and storage activities. When transportation and inventory costs are substantial on both the input and output sides of the production process, an emphasis on logistics may be appropriate. When logistics issues are significant or expensive, many firms opt for outsourcing the logistics function. Logistics specialists can often bring expertise not available in-house. For instance, logistics companies often have tracking technology that reduces transportation losses and supports delivery schedules that adhere to precise delivery windows. The potential for competitive advantage is found via both reduced costs and improved customer service.

3.9.1 Cost of Shipping Alternatives

The longer a product is in transit, the longer the firm has its money invested. But faster shipping is usually more expensive than slow shipping. A simple way to obtain some insight into this trade-off is to evaluate carrying cost against shipping options. We do this in Example 3

Example 3

A shipment of new connectors for semiconductors needs to go from San Jose to Singapore for assembly. The value of the connectors is N1,750.00 and holding cost is 40% per year. One airfreight carrier can ship the connectors 1 day faster than its competitor, at an extra cost of N20.00.

First we determine the daily holding cost

Daily cost of holding the product = (annual holding cost x product value)/365 = (.40 x N1,750.00)/365 = N1.92

Since the cost of saving one day is N20.00, which is much more than the daily holding cost of N1.92, we decide on the less costly of the carriers and take the extra day to make the shipment. This saves N18.08 (N20.00 - N1.92).

Example 3 looks only at holding costs versus shipping cost. For the operations or logistics manager there are many other considerations, including coordinating shipments to maintain a schedule, getting a new product to market, and keeping a customer happy. There is no reason why estimates of these other costs cannot be added to the estimate of daily holding cost. Determining the impact and cost of these many other considerations is what makes the evaluation of shipping alternatives interesting.

3.9.2 Logistics, Security, and JIT

There is probably no society more open than the U.S. This includes its borders and ports. With removal of the last constraints on the North American Free Trade Agreement (NAFTA), expanding globalization, and increased use of JIT deliveries, U.S. borders and ports are swamped. About 12 million containers enter U.S. ports each year, along with thousands of planes, cars, and trucks each day. Even under the best of conditions, some 5% of the container movements are misrouted, stolen, damaged, or excessively delayed.

Since the September 11, 2001, terrorist attacks, supply chains have gotten more complex and can be expected to become even more so. However, technological innovations in the supply chain are improving logistics, security, and JIT. Technology is now capable of knowing truck and container location, content, and condition. New devices can detect whether someone has broken into a sealed container and can communicate that information to the shipper or receiver via satellite or radio. Motion detectors can also be installed inside containers. Other sensors can record interior data including temperature, shock, radioactivity, and whether a container is moving. Tracking lost containers, identifying delays, or just reminding individuals in the supply chain that a shipment is on its way will help expedite shipments. Improvements in security may aid JIT, and improvements in JIT may aid security-both of which can improve supply-chain logistics.

3.10 Benchmarking Supply-Chain Management

Well-managed supply-chain relationships result in world-class benchmarks set by firms. Benchmark firms have driven down costs, lead times, late deliveries, and shortages, all while improving quality. Effective supply-chain management provides a competitive advantage by aiding firms in their response to a demanding global marketplace. Wal-Mart, for example, has developed a competitive edge through effective supply-chain management. With its own fleet of 2,000 trucks, 19 distribution centers, and a satellite communication system, Wal-Mart (with the help of its suppliers) replenishes store shelves an average of twice per week. Competitors re-supply every other week. Economical and speedy re-supply means high levels of product availability and reductions in inventory investment.

SELF ASSESSMENT EXERCISE

1. Define Supply-chain Management.
2. What are the objectives of Supply-chain.
3. What is the objective of logistics management.
4. How do we distinguish between supply-chain management, purchasing and logistics management.

4.0 CONCLUSION

A substantial portion of the cost and quality of the products of many firms, including most manufacturing, restaurant, wholesale, and retail firms, is determined by how well they manage the supply chain. Supply-chain management provides a great opportunity for firms to develop a competitive advantage, often using e-commerce.

5.0 SUMMARY

Supply-chain management is an approach to working with suppliers that includes not only purchasing but also a comprehensive approach to developing maximum value from the supply chain. Five supply-chain strategies have been identified. They are (1) many suppliers, (2) few suppliers, (3) vertical integration, (4) keiretsu networks, and (5) virtual companies. Leading companies determine the right supply-chain strategy and often develop a logistics management organization to ensure effective warehousing and distribution.

6.0 TUTOR-MARKED ASSIGNMENT

1. Choose a local establishment that is a member of a relatively large chain. From interviews with workers and information from the Internet, identify the elements of the supply chain. Determine whether the supply chain represents a low-cost, rapid response, or differentiation strategy (refer to unit 2). Are the supply-chain

characteristics significantly different from one product to another?

2. As purchasing agent for Woolsey Enterprises in Golden, Colorado, you ask your buyer to provide you with a ranking of "excellent," "good," "fair," or "poor" for a variety of characteristics for two potential vendors. You suggest that "Products" be weighted 40% and the other three categories be weighted 20% each. The buyer has returned the following ranking.

7.0 REFERENCES/FURTHER READINGS

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UNIT 2 E-COMMERCE AND OPERATIONS AND QUALITY MANAGEMENT

1.0 INTRODUCTION

The Internet is a revolutionary development for managing a firm's operations. This international computer network connects hundreds of millions of companies and people around the world. Although the Internet's impact on our lives is only in its infancy, the impact on OM is already significant. Internet technology enables integration of traditional internal information systems as well as enhancement of communication among organizations. Internet-based systems tie together global design, manufacturing, delivery, sales, and after-services activities.

2.0 OBJECTIVES

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

Identify or Define:

- e-Commerce
- B2b, B2C, C2C, C2B
- online catalogs
- outsourcing
- e-Procurement

Describe or Explain:

- how E-Commerce is changing the supply chain
- online auctions
- internet trading exchanges
- inventory tracking

•pass-through warehouses.

3.0 MAIN CONTENT

3.1 The Internet

The Internet has reshaped how business thinks about delivering value to its customer, interacting with suppliers, and managing its employees. A prime benefit is speed, with managers able to make decisions with better information much more quickly than in the past. Here are just a few examples of its applications.

•Customers visiting www.dell.com can configure, price, and order computer systems 24 hours a day, 7 days a week. They can get current order status and delivery information and have online access to the same technical reference materials used by Dell telephone-support teams.

•Integrated Technologies Ltd., a British manufacturer of medical diagnostic equipment, exchanges 3-D design models in real time with clients in Europe through a password-secured site on the Internet. This practice allows customers not only to review the technical aspects of products but also to do more sophisticated analysis-like simulations of stress, or flow through a valve.

•Multinational robotics manufacturer NSK. RHP has built a Web-enabled factory (calling it a "cyberfactory") in which all machining centers are linked to the Internet. Machine operators use Microsoft Explorer's Internet search engine to access plant setup information and operating procedures, to take training, and to leave shift-to-shift-messages.

•Fast-food restaurants, like Burger King, are installing remote tracking systems. Managers can now check the time clock, review cash-register sales, or monitor refrigerator temperatures over the Internet.

In a similar vein, Hallmark cards uses an in-house Internet, known as an intranet, to view images of previous popular cards, share artwork, and even route new cards to production. Hallmark is joining those business processes together so that there is never a handoff until design goes to manufacturing, where a plate is created for the printing press.
In-house use, technical collaboration, and transfer of information to and from the customer are making the Internet a powerful operations tool. Detailed global accessibility to engineering data/drawings, to inventory and suppliers, to ordering and order status, and to procedure and documentation are the new tools of the Internet age.

The Internet is proving a tremendous vehicle for OM change. The range of applications for the Internet seems limited only by our imagination and creativity. This high-speed network that spans most of the globe is available at a very reasonable cost, and its use is growing daily, with over 350 million domains registered worldwide.

Are companies that use the Internet more efficient? The answer is yes, as you will see throughout this supplement.

3.2 Electronic Commerce

E-commerce (or its synonym, e-business) is the use of computer networks, primarily the internet, to buy and sell products and services. The result of e-commerce is a great range of fast, low-cost electronic services. Although e-commerce implies information between businesses, the technology is equally applicable between business and consumers and indeed between consumers themselves. The business applications are evident across business activities, from tracking consumer behavior in marketing functions, to collaboration on product design in production functions, to speeding transactions in accounting functions. Former IBM chairman Louis Gerstner believes e-commerce is a whole new way of doing business and describes it as "all about cycle time, speed, globalization, enhanced productivity, reaching new customers, and sharing knowledge across institutions for competitive advantage. We begin with some definitions within e-commerce.

3.2.1 E-commerce Definitions

Within the popular term e-commerce, four definitions are frequently used. They are based on the type of transaction taking place.

Business-la-business (B2B). This implies that both sides of the transaction are businesses nonprofit organizations, or governments.

Business-la-consumer (B2C). These are e-commerce transactions in which buyers are individual consumers.

Consumer-la-consumer (C2C). Here consumers sell directly to each other by electronic classified advertisements or auction sites.
Consumer-la-business (C2B). In this category individuals sell services or goods to businesses.

Our focus in this supplement is business-to-business e-commerce. The B2B segment of e-commerce has grown to over $1 trillion in the U.S. and constitutes about 80% of the e-commerce market.

3.3 Economics of E-Commerce

E-commerce is revolutionizing operations management because it reduces costs so effectively. It reduces costs by improving communication and disseminating economically valuable information. The new middleman driving down transaction costs is the e-commerce provider. This middleman is cheaper and faster than the traditional broker. E-commerce increases economic efficiencies by matching buyers and sellers. It facilitates the exchange of information, goods, and services. These added efficiencies reduce costs for everyone; they also reduce barriers to entry. E-commerce opens both large and small organizations to economies not previously available. Perfect information is a big contributor to efficiency, and e-commerce is moving us a bit closer to what economists call perfect markets.

In addition, the time constraints inherent in many transactions all but disappear. The firm or individual at the other end of the transaction need not always be immediately available. The convenience to both parties is improved because cheap electronic storage is built into e-commerce systems. Information, transactions, and creativity in the way we communicate have never been easier or cheaper.

Honeywell's Consumer Products Group, for example, used to have 28 employees who took orders by phone or fax. As 4,000 corporate customers shifted to online ordering, the employees were reassigned to other jobs such as outside sales, increasing labor productivity enormously. This is but one of the benefits of e-commerce. This is but one of the benefits of e-commerce listed in Table 2.

Table 1

•Product-drawings, specifications, video, or simulation demonstrations, prices.
•Production Processes--capacities, commitments, product plans.
•Transportation--carrier availability, lead times, costs.
•Inventory-inventory tracking, levels, costs, and location Suppliers-product catalog, quality history, lead times, terms, and conditions.
•Suppliers-product catalog, quality history, lead times, terms and conditions
•Supply Chain Alliances-key contact, partners' roles and responsibilities, schedules.
•Supply Chain Process and Performance-process descriptions, performance measures such as quality and delivery.
•Competitor-benchmarking, product offerings, market share.
•Sales and Marketing-point-of-sale (POS) data entry, promotions, pricing, discounts.
•Customer-sales history and forecasts.

•Costs-market indexes, auction results

Table 2

Benefits of E-Commerce

- Improved, lower-cost information that makes buyers and sellers more knowledgeable has an inherent power to drive down costs.
- Lower entry costs increase information sharing.
- Available 24 hours a day, virtually any place in the world, enabling convenient transactions for those concerned.
- Availability expands the market for both buyers and sellers.
- Decreases the cost of creating, processing, distributing, storing, and retrieving paper-based information.
- Reduces the cost of communication.
- Richer communication than traditional paper and telephone communication because of video clips, voice, and demonstrations
- Fast delivery of digitized products such as drawings, documents, and software.
- Increased flexibility of locations. (That is, it allows some processes to be located anywhere electronic communication can be established, and allows people to shop and work from home.)

Limitations of E-Commerce

- Lack of system security, reliability, and standards.
- Lack of privacy.
- Some transactions are still rather slow.
- Integrating e-commerce software with existing software and databases is still a challenge.
- Lack of trust in (1) unknowns about the integrity of those on the other end of a transaction, (2) integrity of the transaction itself, and (3) electronic money that is only bits and bytes.

3.4 Product Design

Shorter life cycles require faster product development cycles and lead to time-based competition (a topic we addressed in Unit 5). E-commerce is accelerating time-based competition even more. However, the operations manager is finding that e-commerce collaboration in product and process design by virtual teams not only may be cheaper but may also yield better and quicker decisions. Members of product teams in different locations can now easily share knowledge at low cost. At General Electric, for example, engineers in 100 countries now share ideas and information, and work on projects simultaneously. Based on 600 projects completed so far using the Web, GI;: estimates the time it takes to develop a new product has been cut 20%.

Operations managers are also addressing this acceleration by managing product data over the Internet. New communication and collaboration tools allow engineering changes and configuration management to extend to the supply chain. Accurate data to suppliers, subcontractors, and strategic partners become more important with globalization and extended supply chains. The complexity of managing product development and product definition increases as design responsibilities shift away from a central team to dispersed product development teams worldwide. E-commerce, with the rapid transfer of specifications, three-dimensional drawings, and speedy collaboration, eases the task.

General Motors, as an example, is tying thousands of suppliers into its electronic engineering and design network. The Web-based network will let GM's suppliers work online in real time with its designers, creating and editing 3-D CAD models. In the past, suppliers worked from static blueprints and engineering schematics and waited for printed updates. Now they get real-time updates to designs online.

3.4.1 Collaborative Project Management

The use of the Internet to speed collaboration in product design has also been extended to information-sharing opportunities in project management (the topic of unit 3). Microsoft Project software allows users to create an intranet website at which they can share documents and maintain project status and notes. Livelink, a groupware program, permits creation of an intranet document management library

3.5 E-Procurement

Modem procurement is often e-procurement. E-procurement, as we saw in Unit 13, is purchasing or order release communicated over the Internet or via approved online vendor catalogs.

3.5.1 Online Catalogs

Online catalogs are information about products in electronic form via the Internet. They are quickly improving cost comparison and bidding processes. These electronic catalogs can enrich traditional catalogs by incorporating voice and video clips, much as does the CD-ROM that accompanies this text. Online catalogs are available in three versions: (1) those provided by vendors, (2) those developed by intermediaries, and (3) those provided by buyers. We now discuss each.

Online Catalog Provided by Vendor

Among those catalogs provided by vendors is that of W. W. Grainger. W. W. Grainger (www.Grainger.com) is probably the world's largest seller of MRO item (items for maintenance, repair, and operations). Grainger needed to take care of frequent, relatively low dollar, purchases by buyers looking for very specific ways to fill their needs. Rather than treat its Web site as just another toll-free line, Grainger rethought its business model and moved its 4,000-page catalog online. The online catalog is integrated into the company's sales and service agenda, making it easy to use and informative, with relevant pricing and product availability. Customized versions reflect discounts applicable to each customer. Moreover, the system takes orders 24 hours a day rather than just when Grainger's stores are open. These catalogs are a win-win for the operations manager (the customer) and for Grainger. Operations personnel find the online catalog easier to use and available whenever they need it. Moreover, the average order size is up almost 50%.

Online catalogs are often available on every employee's desktop computer. Once approved and established, each employee can do his or her own purchasing. In many process industries, maintenance, repair, and operations items account for a substantial portion of the sales dollar. Many of these purchases are individually small dollar value, and as such fail to receive the attention of other "normal" purchases. The result is a huge inefficiency. Online e-commerce provides an opportunity for substantial savings; plus, paper trails related to ordering become less-expensive electronic trails. Operations managers obtain convenience while purchasing department costs decrease.

Online Catalog Provided by Intermediaries

Intermediaries are companies that run a site where business buyers and sellers can meet. Typical of these is ProcureNet (www.procurenet.com). ProcureNet has combined 30 seller sites with over 100,000 parts for the electronics industry. Qualified buyers can place orders with selling companies. Boeing Aircraft, for example, maintains an intermediary site for its customers. On this Web site, called Boeing PART (Part Analysis and Requirements Tracking), 500 Boeing customers can place orders for replacement parts, many of which are drop shipped from suppliers. The cost is significantly less than with traditional faxes, telephone calls, and purchase orders.

Online Exchange Provided by Buyer

Several mega-online Internet trading exchanges have changed the way businesses buy virtually everything from paper clips to presses to desks.

The first, GlobalNetXchange (GNX), has equity partners such as Sears and Kroger (both U.S.), Carrafour and Pinault (both French), Coles Myer (Australian), Karstadt and Metro (both German), and J. Sainsbury (British). Since its start, GNX stores have reported 32% decrease in excess inventory, 25% improvement in lead times, and a 10% reduction in in-stock inventory levels. Virtually every other industry has followed GNX.

Retail goods-set up by Sears and France's Carrefour; called GlobalNetXchange for retailers (gnx.com). Health care products-set up by Johnson & Johnson, GE Medical Systems, Baxter International, Abbott.

Laboratories, and Medtronic Inc; called the Global Health Care Exchange (ghx.com).

Defense and aerospace products-created by Boeing, Raytheon, Lockheed-Martin, and Britain's BAE Systems; called the Aerospace and Defense Industry Trading Exchange (exostar.com).

Food, beverage, consumer products-set up by 49 leading food and beverage firms; called Transora (transora.com).

Steel and metal products-such as New View Technologies (exchange. e-steel.com) and Metal-Site (metalsite.com).

Hotels-created by Marriott and Hyatt, and later joined by Fairmont, Six Continents, and Club Corp: called.

Avendra (avendra.com) buys for 2,800 hotels.

3.5.2 RFQs and Bid Packaging

The cost of preparing requests for quotes (RFQs) can be substantial; consequently, e-commerce has found another area ripe for improvement. General Electric, for example, has been able to make major advances in this aspect of its procurement process. Purchasing personnel now have access to an extensive database of vendor, delivery, and quality data. With this extensive history. supplier selection for obtaining quotes has improved. Electronic files containing engineering drawings are also available. The combination allows purchasing agents to attach electronic copies of the necessary drawings to RFQs and send the entire electronic-encrypted package to vendors in a matter of hours rather than days. The system is both faster, by about 3 weeks, and less expensive.

3.5.3 Internet Outsourcing

Creative organizations are proving the Internet's versatility by supplying business processes such as payroll, accounting, and human resource services via the Internet. Internet outsourcing transfers an organization's activities that have traditionally been internal to Internet suppliers. Firms that want to outsource their noncore human resource function can find organizations such as Employease (Employease.com), which will provide the service via the Internet. Other companies handle employee benefits (www.OnlineBenefits.com). These and similar firms duplicate some or all of an internal human resource function on a Web site. With various restrictions, supervisors, employees, and human resource personnel have access to appropriate information. Other outsourcing possibilities include travel (TheTrip.com), document management (CyLex.com), and shipping FedEx.com).

Figure 1: The Medical Supply Chain Goes Online

3.5.4 Online Auctions

Online auction sites can also be maintained by sellers, buyers, or intermediaries. General Motors' approach to selling excess steel is to post it on the Web and expect its own suppliers who need steel to buy it from GM. This is a forerunner of business-to-business (B2B) auctions that every industry can be expected to pursue. Operations managers find online auctions a fertile area for disposing of excess raw material and discontinued or excess inventory.

The key for auction firms such as Ariba is to find and build a huge base of potential bidders-indeed, many of Ariba's employees spend their time not running electronic auctions, but qualifying new suppliers. For the operations manager, the implications of this approach to procurement are significant and the supply chain now requires a new set of skills.

From our discussion of supply chains in Unit 11, you may recall that many firms spend over half of their sales dollar on purchases. Preliminary estimates of 10% savings in procurement through these e-commerce options may be conservative. Recently, Honeywell's avionics group saved $400,000, or 19.5%, on the purchase of $1.7 million in parts. Carrier Corp. saved 16% on airconditioner motors, using Asian suppliers. Sun Microsystems claims savings of over $1 billion a year using its in-house reverse auction system (called Dynamic Bidding): The firm now spends 1 hour pricing out items that used to take weeks or months to negotiate.

3.6 Inventory Tracking

FedEx's pioneering efforts at tracking packages from pickup to delivery have shown the way for operations managers to do the same for their shipments and inventory. Surely if FedEx can track millions of documents each day worldwide, operations managers in other firms can also do so. The tools of e-commerce, including the discipline of data collection, bar-code technology, radio frequency, and electronic communications to track inventory in transit, on the shop floor, and in the warehouse are now perfected and available to the resourceful operations manager.

Ford has hired UPS to track vehicles as they move from factory to dealers. Tracking cars and trucks has been an embarrassingly inexact science for years. Ford's tracking system is expected to track more than 4 million Ford cars and trucks each year. Using bar codes and the Internet, dealers are able to log onto the Web site and find out exactly where the vehicles they have ordered are in the distribution system. As operations managers move to an era of mass customization, with each customer ordering exactly the car he or she wants, customers will expect to know where their car is and exactly when they can pick it up. The Internet and e-commerce can provide this service and do so economically.

3.7 Just-in-Time Delivery for E-Commerce

Just-in-time systems in manufacturing (see Unit 16) are based on the premise that parts and materials will be delivered exactly on time.

Electronic commerce can support this goal by coordinating the supplier's inventory system with the service capabilities of the delivery firm.

FedEx has a short but successful history of using the Internet for online tracking in the world of e-commerce. In 1996 the firm launched FedEx InterNetShip, which within 18 months had 75,000 customers. A FedEx.com customer today can compute shipping costs, print labels, adjust invoices, and track package status all on the same Web site. (FedEx, by the way, saves $3 for each inquiry made via the web compared with a phone call). FedEx also plays a core role in other firms' logistics processes. In some cases, FedEx runs the server for retailer Web sites. In other cases, such as for Dell Computer, it operates warehouses that pick, pack, test, and assemble products, then handle delivery and even customs clearance. FedEx's B2B service, called "Virtual Order," integrates different companies' Web catalogs and customer orders for Dell. FedEx then fulfills orders and delivers them via its fleet of trucks and planes. FedEx is effectively demonstrating that an e-commerce service company can economically manage complex transactions for other companies.

SELF ASSESSMENT EXERCISE

1. Define e-commerce
2. Explain the differences between B2B, B2C, C2C and C2B e-commerce. Provide an example of each.
3. Why is e-commerce important in product design?
4. Explain each of the three versions of online catalogs.

4.0 CONCLUSION

The opportunity for Operations Managers to use e-commerce technology to reduce logistics cost is substantial. E-Commerce is revolutionizing the way operations managers achieve greater efficiencies.

5.0 SUMMARY

Economical collaboration can improve decision making and reduce costs. Cost reduction can occur in transaction processing, purchasing efficiencies, inventory reduction, scheduling, and logistics. The opportunities are amazing. Getting up to e-commerce speed is not an option. Stragglers won't just be left behind-they will be eliminated. Operations personnel who use e-commerce to their advantage will overpower their rivals.

6.0 TUTOR-MARKED ASSIGNMENT

1. Using the Internet, find a consultant or software company that helps firms better manages their supply chains using e-commerce. Prepare a short report on the company, including the benefits it provides and the names of its clients.

2. Use the Internet to find and explore the L.L. Bean Web site. What role does delivery logistics play in the firm's operations strategy? Does it have the added advantage of aiding Bean's marketing effort?

7.0 REFERENCES/FURTHER READINGS

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UNIT 3 INVENTORY MANAGEMENT

CONTENTS

1.0 INTRODUCTION

Operations managers around the globe have long recognized that good inventory management is crucial. On the one hand, a firm can reduce costs by reducing inventory. On the other hand, production may stop and customers become dissatisfied when an item is out of stock. Thus, companies must strike a balance between inventory investment and customer service. You can never achieve a low-cost strategy without good inventory management.

All organizations have some type of inventory planning and control system. A bank has methods to control its inventory of cash. A hospital has methods to control blood supplies and pharmaceuticals. Government agencies, schools, and, of course, virtually every manufacturing and production organization are concerned with inventory planning and control.

In cases of physical products, the organization must determine whether to produce goods or to purchase them. Once this decision has been made, the next step is to forecast demand. Then operations managers determine the inventory necessary to service that demand. In this unit we discuss the functions, types, and management of inventory. We then address two basic inventory issues: how much to order and when to order.

2.0 OBJECTIVES

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

Identify and Define:

- ABC Analysis
- Record Accuracy
- Cycle Counting
- Independent And Dependent Demand
- Holding, Ordering and Setup Costs.

Describe or Explain

- The Functions of inventory and basic inventory models.

3.0 MAIN CONTENT

3.1 Functions of Inventory

Inventory can serve several functions that add flexibility to a firm's operations. The four functions of inventory are:

1. To "decouple" or separate various parts of the production process. For example, if a firm's supplies fluctuate, extra inventory may be necessary to decouple the production process from suppliers.
2. To decouple the firm from fluctuations in demand and provide a stock of goods that will provide a selection for customers. Such inventories are typical in retail establishments.
3. To take advantage of quantity discounts, because purchases in larger quantities may reduce the cost of goods or their delivery.
4. To hedge against inflation and upward price changes.

3.1.1 Types of Inventory

To accommodate the functions of inventory, firms maintain four types of inventories: (1) raw material inventory, (2) work-in-process inventory, (3) maintenance/repair/operating supply (MRO) inventory, and (4) finished-goods inventory.

Raw material inventory has been purchased but not processed. This inventory can be used to decouple (i.e., separate) suppliers from the production process. However, the preferred approach is to eliminate supplier variability in quality, quantity, or delivery time so that separation is not needed.

Work-in-process (WIP) inventory is components or raw materials that have undergone some change but are not completed. WIP exists because of the time it takes for a product to be made (called cycle time). Reducing cycle time reduces inventory. Often this task is not difficult: During most of the time a product is "being made," it is in fact sitting idle.

MROs are inventories devoted to maintenance/repair/operating supplies necessary to keep machinery and processes productive. They exist because the need and timing for maintenance and repair of equipment are unknown. Although the demand for MRO inventories is often a function of maintenance schedules, other unscheduled MRO demands must be anticipated. Finished goods inventory is completed product awaiting shipment. Finished goods may be inventoried because future customer demands are unknown.

3.2 Inventory Management

Operations managers establish systems for managing inventory. In this section, we briefly examine two ingredients of such systems: (1) how inventory items can be classified (called ABC analysis) and (2) how accurate inventory records can be maintained. We will then look at inventory control in the service sector.

3.2.1 ABC Analysis

ABC analysis divides on-hand inventory into three classifications on the basis of annual volume. ABC analysis is an inventory application of what is known as the Pareto principle. The Pareto principle states that there are a "critical few and trivial many. The idea is to establish inventory policies that focus resources on the few critical inventory parts and not the many trivial ones. It is not realistic to monitor inexpensive items with the same intensity as very expensive items.

To determine annual naira volume for ABC analysis, we measure the annual demand of each inventory item by the cost per unit. Class A items are those on which the annual naira volume is high. Although such item may represent only about 15 % of the total inventory items, they represent 70 to 80% of the total naira usage. Class B items are those inventory items of medium annual naira volume. These items may represent about 30% of inventory items and 15% to 25% of the total value. Those with low annual naira volume are Class C, which may represent only 5% of the annual naira volume but about 55% of the total inventory items.

Graphically, the inventory of many organizations would appear as presented in Figure 1. An example of the use of ABC analysis is shown in Example1.

Figure 1.

Example 1: Silicon Chips, Inc., maker of superfast DRAM chips, has organized its 10 inventory items on an annual dollar-volume basis. Shown below are the items (identified by stock number), their annual demand, unit cost, annual dollar volume, and the percentage of the total represented by each item. In the following table we show these items grouped into ABC classifications.

Item Stock Number	**Percent of Number of Items Stocked**	**Annual Volume (Unit) X**	**Unit Cost =**	**Annual Naira Volume**	**Percent of Annual Naira Volume**		**Class**
#10286	20% 1,000		N90.00	N90,000	38.8%	72%	A
#11526		500	154.00	77,000	33.2%		A
#12760		1,550	17.00	26,350	11.3%		B
#10867	30%	350	42.86	15,001	6.4%	23%	B
#10500		1,000	12.50	12,500	5.4%		B
#12572		600	N14.17	8,502	3.7%		C
#14075		2,000	.60	1,200	.5%		C
#01036	50%	100	8.50	850	.4%	5%	C
#01307		1,200	.42	540	.2%		C
#10572		250	.60	150	.1%		C
		8,550		N232,057	100.0%		

Criteria other than annual dollar volume can determine item classification. For instance, anticipated engineering changes, delivery problems, quality problems, or high unit cost may dictate upgrading items to a higher classification. The advantage of dividing inventory items into classes allows policies and controls to be established for each class.

Policies that may be based on ABC analysis include the following:

1. Purchasing resources expended on supplier development should be much higher for individual A items than for C items.
2. A items, as opposed to B and C items, should have tighter physical inventory control; perhaps they belong in a more secure area, and perhaps the accuracy of inventory records for A items should be verified more frequently.
3. Forecasting A items may warrant more care than forecasting other items.

Better forecasting, physical control, supplier reliability, and an ultimate reduction in safety stock can all result from appropriate inventory management policies. ABC analysis guides the development of those policies.

3.2.2 Record Accuracy

Good inventory policies are meaningless if management does not know what inventory is on hand. Accuracy of records is a critical ingredient in production and inventory systems. Record accuracy allows organizations to focus on those items that are needed, rather than settling for being sure that "some of everything" is in inventory. Only when an organization can determine accurately what it has on hand can it make precise decisions about ordering, scheduling, and shipping.

To ensure accuracy, incoming and outgoing record keeping must be good, as must be stockroom security. A well-organized stockroom will have limited access, good housekeeping, and storage areas that hold fixed amounts of inventory. Bins, shelf space, and parts will be labeled accurately.

3.2.3 Cycle Counting

Even though an organization may have made substantial efforts to record inventory accurately, these records must be verified through a continuing audit. Such audits are known as cycle counting. Historically, many firms performed annual physical inventories. This practice often meant shutting down the facility and having inexperienced people count parts and material. Inventory records should instead be verified via cycle counting. Cycle counting uses inventory classifications developed through ABC analysis. With cycle counting procedures, items are counted, records are verified, and inaccuracies are periodically documented. The cause of inaccuracies is then traced and appropriate remedial action taken to ensure integrity of the inventory system. A items will be counted frequently, perhaps once a month; B items will be counted less frequently, perhaps once a quarter; and C items will be counted perhaps once every 6 months. Example 2 illustrates how to compute the number of items of each classification to be counted each day.

Example 2: Cole's Trucks, Inc., a builder of high-quality refuse trucks, has about 5,000 items in its inventory. After hiring Matt Clark, a bright young OM student, for the summer, the firm determined that it has 500 A items, 1,750 B items, and 2,750 C items. Company policy is to count all A items every month (every 20 working days), all B items every quarter (every 60 working days), and all C items every 6 months (every 120 working days). How many items should be counted each day.

ITEM CLASS	QUANTITY	CYCLE COUNTING POLICY	NUMBER OF ITEMS COUNTED PER DAY
A	500	Each month (20 working days)	500/20 = 25/day
B	1,750	Each quarter (60 working days)	1,750/60 = 29/day
C	2,750	Every 6 months (120 working days)	2,750/120= 23/day
			77/day

Seventy-seven items are counted each day.

In Example 2, the particular items to be cycle-counted can be sequentially or randomly selected each day. Another option is to cycle-count items when they are reordered.

Cycle counting also has the following advantages:

1. Eliminates the shutdown and interruption of production necessary for annual physical inventories.
2. Eliminates annual inventory adjustments.
3. Trained personnel audit the accuracy of inventory.
4. Allows the cause of the errors to be identified and remedial action to be taken.
5. Maintains accurate inventory records.

3.2.4 Control of Service Inventories

Management of service inventories deserves special consideration. Although we may think of the service sector of our economy as not having inventory, that is not the case. For instance, extensive inventory is held in wholesale and retail businesses, making inventory management crucial and often a factor in a manager's advancement. In the food-service business, for example, control of inventory can make the difference between success and failure. Moreover, inventory that is in transit or idle in a warehouse is lost value. Similarly, inventory damaged or stolen prior to sale is a loss. In retailing, inventory that is unaccounted for between receipt and time of sale is known as shrinkage. Shrinkage occurs from damage and theft as well as from sloppy paperwork. Inventory theft is also known as pilferage. Retail inventory loss of I % of sales is considered good, with losses in many stores exceeding 3%. Because the impact on profitability is substantial, inventory accuracy and control are critical. Applicable techniques include the following.

1. Good personnel selection, training, and discipline. These are never easy but very necessary in food-service, wholesale, and retail operations, where employees have access to directly consumable merchandise.

2. Tight control of incoming shipments. This task is being addressed by many firms through the use of bar-code and radio frequency ID systems that read every incoming shipment and automatically check tallies against purchase orders. When properly designed, these systems are very hard to defeat. Each item has its own stock keeping unit (SKU), pronounced "skew.

3. Effective control of all goods leaving the facility. This job is accomplished with bar codes on items being shipped, magnetic strips on merchandise, or via direct observation. Direct observation can be personnel stationed at exits and in potentially high-loss areas or can take the form of one-way mirrors and video surveillance.

Successful retail operations require very good store-level control with accurate inventory in its proper location. One recent study found that consumers and clerks could not find 16% of the items at one of the U.S.'s largest retailers-not because the items were out of stock, but because they were misplaced (in a backroom, a storage area, or on the wrong aisle). By the researcher's estimates, major retailers lose 10% to 25% of overall profits due to poor or inaccurate inventory records.

3.3 Inventory Models

We now examine a variety of inventory models and the costs associated with them.

3.3.1 Independent versus Dependent Demand

Inventory control models assume that demand for an item is either independent of or dependent on the demand for other items. For example, the demand for refrigerators is independent of the demand for toaster ovens. However, the demand for toaster oven components is dependent on the requirements of toaster ovens.

3.3.2 Holding, Ordering, and Setup Costs

Holding costs are the costs associated with holding or "carrying" inventory over time. Therefore, holding costs also include obsolescence and costs related to storage, such as insurance, extra staffing, and interest payments. Table below shows the kinds of costs that need to be evaluated to determine holding costs. Many firms fail to include all the inventory holding costs. Consequently, inventory holding costs are often understated.

Ordering cost includes costs of supplies, forms, order processing, clerical support, and so forth. When orders are being manufactured, ordering costs also exist, but they are a part of what is called setup costs. Setup cost is the cost to prepare a machine or process for manufacturing an order. This includes time and labor to clean and change tools or holders. Operations managers can lower ordering costs by reducing setup costs and by using such efficient procedures as electronic ordering and payment.

In many environments, setup cost is highly correlated with setup time. Setups usually require a substantial amount of work before a setup is actually performed at the work center. With proper planning much of the preparation required by a setup can be done prior to shutting down the machine or process. Setup times can thus be reduced substantially. Machines and processes that traditionally have taken hours to set up are now being set up in less than a minute by the more imaginative world-class manufacturers. As we shall see later in this unit, reducing setup times is an excellent way to reduce inventory investment and to improve productivity.

Table 1: Determining Inventory Holding Costs

CATEGORY	**Cost and Range as a Percent of Inventory Value**
Housing costs (building rent or depreciation, operating cost,	6% (3-10%)
taxes, insurance) Material handling costs (equipment lease or	3% (1-3.5%)
depreciation, power, operating cost) Labor cost.	3% (3-5%)
Investment costs (borrowing costs, taxes, and insurance on	11% (6-24%)
inventory) Pilferage, scrap, and obsolescence.	3% (2-5%)

Overall carrying cost	26%

3.4 Inventory Models for Independent Demand

In this unit, we introduce three inventory models that address two important questions: when to order and how much to order. These independent demand models are:

In this unit, we introduce three inventory models that address two important questions: when to order and how much to order. These independent demand models are:

1. Basic economic order quantity (EOQ) model.
2. Production order quantity model.
3. Quantity discount model

3.4.1 The Basic Economic Order Quantity (EOQ) Model

The economic order quantity (EOQ) model is one of the oldest and most commonly known inventory-control techniques. This technique is relatively easy to use but is based on several assumptions.

1. Demand is known, constant, and independent
2. Lead time-that is, the time between placement and receipt of the order is known and constant.
3. Receipt of inventory is instantaneous and complete. In other words, the inventory from an order arrives in one batch at one time.
4. Quantity discounts are not possible.
5. The only variable costs are the cost of setting up or placing an order (setup cost) and the cost of holding or storing inventory over time (holding or carrying cost). These costs were discussed in the previous section.
6. Stockouts (shortages) can be completely avoided if orders are placed at the right time

With these assumptions, the graph of inventory usage over time has a sawtooth shape, as in Figure 2. In Figure 2, Q represents the amount that is ordered. If this amount is 500 dresses, all 500 dresses arrive at one time (when an order is received). Thus, the inventory level jumps from 0 to 500 dresses. In general, an inventory level increases from 0 to Q units when an order arrives.

Because demand is constant over time, inventory drops at a uniform rate over time. When the inventory level reaches 0 each time, the new order is placed and received, and the inventory level again jumps to Q units (represented by the vertical lines). This process continues indefinitely over time.

3.4.2 Minimizing Costs

The objective of most inventory models is to minimize total costs. With the assumptions just given, significant costs are setup (or ordering) cost and holding (or carrying) cost. All other costs, such as the cost of the inventory itself, are constant. Thus, if we minimize the sum of setup and holding costs, we will also be minimizing total costs. To help you visualize this, in Figure 3 we graph total costs as a function of the order quantity, Q. The optimal order size, Q*, will be the quantity that minimizes the total costs. As the quantity ordered increases, the total number of orders placed per year will decrease. Thus, as the quantity ordered increases, the annual setup ordering cost will decrease. But as the order quantity increases, the holding cost will increase due to the larger average inventories that are maintained.

As we can see in Figure 3, a reduction in either holding or setup cost will reduce the total cost curve. A reduction in setup cost curve also reduces the optimal order quantity (lot size). In addition, smaller lot sizes have a positive impact on quality and production flexibility. At Toshiba, the N40 billion Japanese conglomerate, workers can make as few as 10 laptop computers before changing models. This lot-size flexibility has allowed Toshiba to move towards a "build-to-order" mass customization system, an important ability in an industry that has product life cycles measured in months, not years.

Figure 2

You should note that in Figure 3, the optimal order quantity occurs at the point where the ordering-cost curve and the carrying-cost curve intersect. This was not by chance. With the EOQ model, the optimal order quantity will occur at a point where the total setup cost is equal to the total holding cost.4 We use this fact to develop equations that solve directly for Q*. The necessary steps are:

Figure 3

Develop an expression for setup or ordering cost.
Develop an expression for holding cost.
Set setup cost equal to holding cost.
Solve the equation for the optimal order quantity.

Using the following variables, we can determine setup and holding costs and solve for Q*:

Q = Number of pieces per order.
Q* = Optimum number of pieces per order (EOQ).
D = Annual demand in units for the inventory item.
S = Setup or ordering cost for each order.
H = Holding or carrying cost per unit per year.

1. Annual setup cost = (Number of orders placed per year) x (Setup or order cost per order).

$$\frac{\text{Annual demand}}{\text{Number of units in each order}} \quad \text{(Setup or order cost per order)}$$

2. Annual holding cost = (Average inventory level) x (Holding cost per unit per year)

$$= \frac{\text{Order quantity}}{2} \quad \text{(Holding cost per unit per year)}$$

$$= \quad (Q) \frac{Q}{2) (H) \quad 2 H}$$

3. Optimal order quantity is found when annual setup cost equals annual holding cost, namely.

$$\frac{D}{Q}S = \frac{Q}{2}H$$

4. To solve for Q*, simply cross multiply terms and isolate Q on the left of the equal sign:

$$2DS = Q^2H$$
$$Q^2 = \frac{2DS}{H}$$
$$Q^* = \sqrt{\frac{2DS}{H}}$$

Now that we have derived equations for the optimal order quantity, Q*, it is possible to solve inventory problems directly, as in Example 3.

Sharp, Inc., a company that markets painless hypodermic needles to hospitals, would like to reduce its inventory cost by determining the optimal number of hypodermic needles to obtain per order. The annual demand is 1,000 units; the setup or ordering cost is N10 per order; and the holding cost per unit per year is N.50. Using these figures, we can calculate the optimal number of units per order.

$$Q^* = \sqrt{\frac{2DS}{H}}$$

$$Q^* = \sqrt{\frac{2(1{,}000)(10)}{0.50}} = \sqrt{40{,}000} = 200 \text{ units}$$

We can also determine the expected number of orders placed during the year (N) and the expected time between orders (D as follows:

$$\text{Expected number of orders} = N = \frac{\text{Demand}}{\text{Order quantity}} = \frac{D}{Q^*}$$

$$\text{Expected time between orders} = T = \frac{\text{Number of working days per year}}{N}$$

Example 4 illustrates this concept.

Using the data from Sharp, Inc., in Example 3, and assuming a 250-day working year, we find the number of orders (N) and the expected time between orders (T) as

$$N = \frac{\text{Demand}}{\text{Order quantity}}$$

$$= \frac{1{,}000}{200} = 5 \text{ orders per year}$$

$$T = \frac{\text{Number of working days per year}}{\text{Expected number of orders}}$$

$$\frac{250 \text{ working days per year}}{5 \text{ orders}} = 50 \text{ days between orders}$$

As mentioned earlier in this section, the total annual variable inventory cost is the sum of setup and holding costs.

Total annual cost = Setup cost + Holding cost.

In terms of the variables in the model, we can express the total cost TC as

$$TC = \frac{D}{Q}S + \frac{Q}{2}H$$

Example 5 shows how to use this formula

The total inventory cost expression may also be written to include the actual cost of the material purchased. If we assume that the annual demand and the price per hypodermic needle are known values (for example, 1,000 hypodermics per year at P = N10) and total annual cost should include purchase cost, then Equation (12-5) becomes.

$$TC = \frac{D}{Q}S + \frac{Q}{2}H + PD$$

Because material cost does not depend on the particular order policy, we still incur an annual material cost of D x P = (1,000) (N10) = N10,000. (Later in this unit we will discuss the case in which this may not be true-namely, when a quantity discount is available.)

Robust Model

A benefit of the EOQ model is that it is robust. By robust we mean that it gives satisfactory answers even with substantial variation in its parameters. As we have observed, determining accurate ordering costs and holding costs for inventory is often difficult. Consequently, a robust model is advantageous. Total cost of the EOQ changes little in the neighborhood of the minimum. The curve is very shallow. This means that variations in setup costs, holding costs, demand, or even EOQ make relatively modest differences in total cost. Example 6 shows the robustness of EOQ.

The formula for the Economic Order Quantity (Q*) can also be determined by finding where the total cost curve is at a minimum (i.e., where the slope of the total cost curve is zero). Using calculus, we set the derivative of the total cost with respect to Q* equal to O

The calculations for finding the minimum of $TC = \frac{D}{Q}S + \frac{Q}{2}H + PD$

are $\frac{d(TC)}{dq} = \left(\frac{-DS}{Q2}\right) + \frac{H}{2} + 0 = 0$

thus $Qx = \sqrt{\frac{2DS}{H}}$

We may conclude that the EOQ is indeed robust and that significant errors do not cost us very much. This attribute of the EOQ model is most convenient because our ability to accurately forecast demand, holding cost, and ordering cost is limited.

3.4.3 Reorder Points

Now that we have decided how much to order, we will look at the second inventory question, when to order. Simple inventory models assume that receipt of an order is instantaneous. In other words, they assume (1) that a firm will place an order when the inventory level for that particular item reaches zero and (2) that it will receive the ordered items immediately. However, the time between placement and receipt of an order, called lead time, or delivery time, can be as short as a few hours or as long as months. Thus, the when-to-order decision is usually expressed in terms of a reorder point (ROP)-the inventory level at which an order should be placed (see-Figure 4).

Figure 4

The reorder point (ROP) is given as

ROP = (Demand per day)(Lead time for a new order in days)
= d x L

This equation for ROP assumes that demand during lead time and lead time itself is constant. When this is not the case, extra stock, often called safety stock, should be added.

The demand per day, d, is found by dividing the annual demand, D, by the number of working days in a year.

$$d = \frac{D}{\text{Number of working days in a year}}$$

Safety stock is especially important in firms whose raw material deliveries may be uniquely unreliable. For example, San Miguel Corp. in the Philippines uses cheese curd imported from Europe. Because the normal mode of delivery is lengthy and variable, safety stock may be substantial.

3.4.4 Production Order Quantity Model

In the previous inventory model, we assumed that the entire inventory order was received at one time. There are times, however, when the firm may receive its inventory over a period of time. Such cases require a different model, one that does not require the instantaneous-receipt assumption. This model is applicable under two situations: (1) when inventory continuously flows or builds up over a period of time after an order has been placed or (2) when units are produced and sold simultaneously. Under these circumstances, we take into account daily production (or inventory-flow) rate and daily demand rate. Figure 5 shows inventory levels as a function of time.

Figure 5

Because this model is especially suitable for the production environment, it is commonly called the production order quantity model.
It is useful when inventory continuously builds up overtime, and traditional economic order quantity assumptions are valid. We derive this model by setting ordering or setup costs equal to holding costs and solving for optimal order size, Q*. Using the following symbols, we can determine the expression for annual inventory holding cost for the production order quantity model.

Q = Number of pieces per order
H = Holding cost per unit per year.
p = Daily production rate.
d = Daily demand rate, or usage rate.
t = Length of the production run in days

1. (Annual inventory holding cost) = (Average inventory level)x (Holding cost per unit per year)

2. (Average inventory level) = (Maximum inventory level)/2

3. (Maximum inventory level) = (Total produced during the production run) – (Total used during the production run)
= pt - dt

However, Q = total produced = pt, and thus t = Q/p. Therefore.

Maximum inventory level = $p\left(\frac{Q}{P}\right) - d\left(\frac{Q}{P}\right) = Q - \frac{d}{P}Q$

$= Q\left(1 - \frac{d}{p}\right)$

4. Annual inventory holding cost (or simply holding cost) =

$\frac{\text{Maximum inventory level}}{2}(H) = \frac{Q}{2}\left[1 - \left(\frac{d}{p}\right)\right]H$

Using this expression for holding cost and the expression for setup cost developed in the basic EOQ model, we solve for the optimal number of pieces per order by equating setup cost and holding cost:

Setup cost = (D/Q)S
Holding cost = 1/2 HQ[1 - (dip)]

Set ordering cost equal to holding cost to obtain Q*p:

$$\frac{D}{Q} S = \frac{1}{2} HQp1 - (d/p)]$$

In Example 8, we use the above equation, Q*p, to solve for the optimum order or production quantity when inventory is consumed as it is produced.

Nathan Manufacturing, Inc., makes and sells specialty hubcaps for the retail automobile aftermarket. Nathan's forecast for its wire-wheel hubcap is 1,000 units next year, with an average daily demand of 4 units. However, the production process is most efficient at 8 units per day. So the company produces 8 per day but uses only 4 per day. Given the following values, solve for the optimum number of units per order. *(Note: This plant schedules production of this hubcap only as needed,* during the 250 days per year the shop operates.)

Annual demand = D = 1,000 units
Setup costs = S = N10
Holding cost = H = N0.50 per unit per year
Daily production rate = p = 8 units daily
Daily demand rate = d = 4 units daily

$$Q^*p = \sqrt{\frac{2DS}{H[1 - (d/p)]}}$$

$$Q^*p = \sqrt{\frac{2(1,000)10}{0.50[1 - 4/8)]}} = \sqrt{\frac{20,000}{0.50(1/2)}} = \sqrt{80,000}$$

= 282.8 hubcaps, or 283 hubcaps.

You may want to compare this solution with the answer in Example 3. Eliminating the instantaneous-receipt assumption, where p = 8 and d = 4, resulted in an increase in Q* from 200 in Example 3 to 283. This increase in Q* occurred because holding cost dropped from N.50 to (N. 50 x t), making a larger order quantity optimal. Also note that

d = 4 = D 1,000
Number of days the plant is in operation = 250

We can also calculate Q*p when annual data are available. When annual data are used, we can express Q; as.

2DS
Q*p = H[1 – annual demand rate]
annual production rate

3.4.5 Quantity Discount Models

To increase sales, many companies offer quantity discounts to their customers. A quantity discount is simply a reduced price (P) for an item when it is purchased in larger quantities. Discount schedules with several discounts for large orders are common. A typical quantity discount schedule appears in Table 12.2. As can be seen in the table, the normal price of the item is N5. When 1,000 to 1,999 units are ordered at one time, the price per unit drops to N4.80; when the quantity ordered at one time is 2,000 units or more, the price is N4.75 per unit. As always, management must decide when and how much to order. However, with an opportunity to save money on quantity discounts. how does the operations manager make these decisions?.

As with other inventory models discussed so far, the overall objective is to minimize total cost. Because the unit cost for the third discount in Table 12.2 is the lowest, you may be tempted to order 2,000 units or more merely to take advantage of the lower product cost. Placing an order for that quantity, however, even with the greatest discount price, may not minimize total inventory cost. Granted, as discount quantity goes up, the product cost goes down. However, holding cost increases because orders are larger. Thus the major trade-off when considering quantity discounts is between reduced product cost and increased *holding cost. When we include the cost of the product, the equation for* the total annual inventory cost can be calculated as follows:

Total cost = Setup cost + Holding cost + Product cost

D
QH TC = QS + 2 + PD

Where Q = Quantity ordered
D = Annual demand in units
S = Ordering or setup cost per order or per setup
P = Price per unit
H = Holding cost per unit per year

Table 2: A Quantity Discount Schedule

DISCOUNT NUMBER	DISCOUNT QUANTITY	DISCOUNT %	DISCOUNT PRICE (P)
1	0 to 999	No discount	N5.00
2	1,000 to 1,999	4	N4.80
3	2,000 to over	5	N4.75

Now, we have to determine the quantity that will minimize the total annual inventory cost. Because there are several discounts, this process involves four steps:

Step 1: For each discount, calculate a value for optimal order size *Q*, using the following equation:*

$$Q^* = \sqrt{\frac{2DS}{IP}}$$

Note that the holding cost is IP instead of H. Because the price of the item is a factor in annual holding cost, we cannot assume that the holding cost is a constant when the price per unit changes for each quantity discount. Thus, it is common to express the holding cost (I) as a percent of unit price (P) instead of as a constant cost per unit per year, *H*.

Step 2: For any discount, if the order quantity is too low to qualify for the discount, adjust the order quantity upward to the *lowest quantity that will qualify for the discount. For* example, if Q* for discount 2 in Table 12.2 were 500 units, you would adjust this value up to 1,000 units. Look at the second discount in Table 12.2. Order quantities between 1,000 and 1,999 will qualify for the 4% discount. Thus, if Q* is below 1,000 units, we will adjust the order quantity up to 1,000 units.

The reasoning for step 2 may not be obvious. If the order quantity, Q*, is below the range that will qualify for a discount, a quantity within this range may still result in the lowest total cost.

As shown in Figure 6, the total cost curve is broken into three different total cost curves. There is a total cost curve for the first (0 :5 Q:5 999), second (1,000:5 Q:5 1,999), and third (Q ~ 2,000) discount. Look at the total cost (TC) curve for discount 2. Q* for discount 2 is less than the allowable discount range, which is from 1,000 to 1,999 units. As the figure shows, the lowest allowable quantity in this range, which is 1,000 units, is the quantity that minimizes total cost. Thus, the second step is needed to ensure that we do not discard an order quantity that may indeed produce the minimum cost. Note that an order quantity computed in step I that is greater than the range that would qualify it for a discount may be discarded.

Step 3: Using the preceding total cost equation compute a total cost for every Q* determined in steps I and 2. If you had to adjust Q* upward because it was below the allowable quantity range, be sure to use the adjusted value for Q*.

Step 4: Select the Q* that has the lowest total cost, as computed in step 3. It will be the quantity that will minimize the total inventory cost.

Figure 6

Let us see how this procedure can be applied with an example.

Wohl's Discount Store stocks toy race cars. Recently, the store has been given a quantity discount schedule for these cars. This quantity schedule was shown in Table 12.2. Thus, the normal cost for the toy race cars is N5.00. For orders between 1,000 and 1,999 units, the unit cost drops to N4.80; for orders of 2,000 or more units, the unit cost is only N4.75. Furthermore, ordering cost is N49.00 per order, annual demand is 5,000 race cars, and inventory carrying charge, as a percent of cost, 1, is 20%, or .2. What order quantity will minimize the total inventory cost?

The first step is to compute Q* for every discount in Table 12.1 This is done as follows:

$$Q^*1 = \frac{2(5{,}000)(49)}{(.2)(5.00)} = 700 \text{ cars order}$$

$$Q^*2 = \frac{2(5{,}000)(49)}{(.2)(4.80)} = 714 \text{ cars order}$$

$$Q^*3 = \frac{2(5{,}000)(49)}{(.2)(4.75)} = 718 \text{ cars order}$$

The second step is to adjust upward those values of Q* that are below the allowable range. Since Q*1 is between 0 and 999, it need not be adjusted. Because Q2; is below the allowable range of 1,000 to 1,999, it must be adjusted to 1,000 units. The same is true for Q3: It must be adjusted to 2,000 units. After this step, the following order quantities must be tested in the total cost equation:

Q*1 = 700
Q*2 = 1,000 - adjusted
Q*3 = 2,000 – adjusted

The third step is to use the total cost equation and compute a total cost for each order quantity. This step is taken with the aid of Table 3, which presents the computations for each level of discount introduced in Table 2.

Table 3: Total Cost Computations for Wohl's Discount Store

Discount Number	Unit Price	Order Quantity	Annual Product Cost	Annual Orderin g Cost	Annual Holding Cost	Total
1	N5.00	700	N25,000	N350	N350	N25,700
2	N4.80	1,000	N24,000	N245	N480	N24,725
3	N4.74	2,000	N23,750	N122.50	N950	N24,822.50

The fourth step is to select that order quantity with the lowest total cost. Looking at Table 3, you can see that an order quantity of 1,000 toy race cars will minimize the total cost. You should see, however, that the total cost for ordering 2,000 cars is only slightly greater than the total cost for ordering 1,000 cars. Thus, if the third discount cost is lowered to N4.65, for example, then this quantity might be the one that minimizes total inventory cost.

3.5 Probabilistic Models and Safety Stock

All the inventory models we have discussed so far make the assumption that demand for a product is constant and certain. We now relax this assumption. The following inventory models apply when product demand is not known but can be specified by means of a probability distribution. These types of models are called probabilistic models.

An important concern of management is maintaining an adequate service level in the face of uncertain demand. The service level is the complement of the probability of a stockout. For instance, if the probability of a stockout is 0.05, then the service level is .95. Uncertain demand raises the possibility of a stockout. One method of reducing stockouts is to hold extra units in inventory. As we noted, such inventory is usually referred to as safety stock. It involves adding a number of units as a buffer to the reorder point. As you recall from our previous discussion.

Where

Reorder point = ROP = d x L

d = Daily demand

L = Order lead time, or number of working days it takes to deliver an order

The inclusion of safety stock (ss) changes the expression to

ROP = dx L + ss

The amount of safety stock maintained depends on the cost of incurring a stockout and the cost of holding the extra inventory. Annual stockout cost is computed as follows:

Annual stockout costs = The sum of the units short x The probability x The stockout cost/unit x The number of orders per year

Example 10 illustrates this concept.

David Rivera Optical has determined that its reorder point for eyeglass frames is 50 (d x L) units. Its carrying cost per frame per year is N5, and stockout (or lost sale) cost is N40 per frame. The store has experienced the following probability distribution for inventory demand during the reorder period. The optimum number of orders per year is six.

	NUMBER OF UNIT	PROBABILITY
	30	.2
	40	.2
ROP	50	.3
	60	.2
	70	.1
		1.0

How much safety stock should David Rivera keep on hand?

Solution

The objective is to find the amount of safety stock that minimizes the sum of the additional inventory holding costs and stockout costs. The annual holding cost is simply the holding cost per unit multiplied by the units added to the ROP. For example, a safety stock of 20 frames, which implies that the new ROP, with safety stock, is 70 (= 50 + 20), raises the annual carrying cost by N5(20) = N100.

However, computing annual stockout cost is more interesting. For any level of safety stock, stockout cost is the expected cost of stocking out. We can compute it, as in Equation (12-12), by multiplying the number of frames short by the probability of demand at that level, by the stockout cost, by the number of times per year the stockout can occur (which in our case is the number of orders per year). Then we add stockout costs for each possible stockout level for a given ROP. For zero safety stock, for example, a shortage of 10 frames will occur if demand is 60, and a shortage of 20 frames will occur if the demand is 70. Thus the stockout costs for zero safety stock are

10 frames short) (.2) (N40 per stockout) (6 possible stockouts per year)
+ (20 frames short) (. I) (N40) (6) = N960)

The following table summarizes the total costs for each alternative:

SAFETY STOCK	ADDITIONAL HOLDING COST	STOCKOUT COST	TOTAL COST
20	(20) (N5) = N100		N100
10	(10) (N5) = N 50	(10)(.1)(N40)(6) =N240	N290
0		(10)(.2)(N40)(6)+(20)(.1)(N40)(6) =N960	N960

The safety stock with the lowest total cost is 20 frames. Therefore, this safety stock changes the reorder point to 50 + 20 = 70 frames.

Figure 7

When it is difficult or impossible to determine the cost of being out of stock, a manager may decide to follow a policy of keeping enough safety stock on hand to meet a prescribed customer service level. For instance, Figure 7 shows the use of safety stock when demand (for hospital resuscita. tion kits) is probabilistic. We see that the safety stock in Figure 7 is 16.5 units, and the reorder point is also increased by 16.5.

The manager may want to define the service level as meeting 95% of the demand (or, conversely, having stockouts only 5% of the time). Assuming that demand during lead time (the reorder period) follows a normal curve, only the mean and standard deviation are needed to define the inventory requirements for any given service level. Sales data are usually adequate for computing the mean and standard deviation. In the following example we use a normal curve with a known mean (J.I) and standard deviation (cr) to determine the reorder point and safety stock necessary for a 95% service level. We use the following formula:

ROP = Expected demand during lead time + ZcrdLT

Where Z = Number of standard deviations
a dLT = Standard deviation of demand during lead time.

Memphis Regional Hospital stocks a "code blue" resuscitation kit that has a normally distributed demand during the reorder period. The mean (average) demand during the reorder period is 350 kits, and the standard deviation is 10 kits. The hospital administrator wants to follow a policy that results in stockouts only 5% of the time.

Example 11: (a) What is the appropriate value of 2? (b) How much safety stock should the hospital maintain? (c) What reorder point should be used? The figure on page 495 may help you visualize the example:

u = Mean demand = 350 kits
dLT = Standard deviation of demand during lead time = 10 kits
Z = Number of standard normal deviates

Solution

a. We use the properties of a standardized normal curve to get a Z-value for an area under the normal curve of .95 (or I - .05). Using a normal table (see Appendix I), we find a Z-value of 1.65 standard deviations from the mean.

b. Safety stock = x – u

Because $Z = \frac{x-u}{QdLT}$

Then Safety stock = Za dLT

Solving for safety stock, as in Equation (12-14), gives

Safety stock = 1I.65(10) = 16.5 kits

This is the situation illustrated in Figure 7

c. The reorder point is

ROP = Expected demand during lead time + Safety stock

= 350 kits + 16.5 kits of safety stock = 366.5, or 367 kits

3.5.1 Other Probabilistic Models

Equations (12-13) and (12-14) assume that both an estimate of expected demand during lead times and its standard deviation are available. When data on lead time demand are not at hand, these formulas cannot be applied. However, three other models are available. We need to determine which model to use for three situations:

1. Demand is variable and lead time is constant.
2. Lead time is variable, and demand is constant.
3. Both demand and lead time are variable

All three models assume that demand and lead time are independent variables. Note that our examples use days, but weeks can also be used.

Let us examine these three situations separately, because a different formula for the ROP is needed for each.

Demand Is Variable and Lead Time Is Constant. When only the demand is variable, then

ROP = (Average daily demand x Lead time in days) + ZadLT

where

a dLT = Standard deviation of demand during lead time = ad Lead time

and ad = Standard deviation of demand per day

Example 12: The average daily demand for Apple iPods at a Circuit Town store is 15, with a standard deviation of 5 units. The lead time is constant at 2 days. Find the reorder point if management wants a 90% service level (Le., risk stockouts only 10% of the time). How much of this is safety stock?

Solution

Average daily demand (normally distributed) = 15
Lead time in days (constant) = 2
Standard deviation of daily
demand = ad = 5 Service level = 90%

From the normal table (Appendix I), we derive a Z-value for 90% of 1.28. Then, from Equation (12-15),

ROP = (15 units x 2 days) + ZOd. Lead time
= 30 + 1.28(5)(.J2)
= 30 + 1.28(5)(1.41) = 30 + 9.02 = 39.02 = 39

Thus, safety stock is about 9 iPods

Lead Time Is Variable and Demand is Constant. When the demand is constant and only the lead time is variable, then

ROP = (Daily demand x Average lead time in days) + Z (Daily demand) x 0LT (12 - 16)

where aLT = Standard deviation of lead time in days

Example 13: The Circuit Town store in Example 12 sells about 10 digital cameras a day (almost a constant quantity). Lead time for camera delivery is normally distributed with a mean time of 6 days and a standard deviation of 3 days. A 98% service level is set. Find the ROP

Solution

Daily demand = 10
Average lead time = 6 days
Standard deviation of lead time = a LT = 3 days
Service level = 98%, so Z (from Appendix I) = 2.055
From Equation (12-16),

ROP = (10 units x 6 days) + 2.055 (10 units)(3)
= 60 + 61.65 = 121.65

The reorder point is about 122 cameras. Note how the very high service level of 98% drives the ROP up. If a 90% service level is applied, as in Example 12, the ROP drops to

ROP = 60 + (1.28)(10)(3) = 60 + 38.4 = 98.4, since the Z-value is only 1.28

Both Demand and Lead Time Are Variable. When both the demand and lead time are variable, the formula for reorder point becomes more complex.

ROP = (Average daily demand x Average lead time) + ZadLT

where ad = Standard deviation of demand per day
a LT = Standard deviation of lead time in days
and a dLT = (A verage lead time x a2d) + (Average daily demand)2 aLT

Note that Equation (12-17) can also be expressed as:

ROP = Average daily demand x Average lead time + Average lead time x a2d + d-2a2LT

Example 14: The Circuit Town store's most popular item is six-packs of 9-volt batteries. About 150 packs are sold per day, following a normal distribution with a standard deviation of 16 packs. Batteries are ordered from an out-of-state distributor; lead time is normally distributed with an average of 5 days and a standard deviation of I day. To maintain a 95% service level, what Rap is appropriate?

Solution

Average daily demand = 150 packs
Standard deviation of demand = ad = 16 packs
Average lead time = 5 days
Standard deviation of lead time = a LT = I day
Service level = 95%, so Z = 1.65 (from Appendix I)
From Equation (12-17),
ROP = (150 packs x 5 days) +1.65 0dLT

where 0dLT= (5 days x 162) + (1502 x 12)
.J(5 x 256) + (22,500
.JI,280 + 22,500 = ..)23,780 = 154

So, ROP = (150 x 5) + 1.65(154) e 750 + 254 = 1,004 packs

3.6 Fixed-Period (P) Systems

The inventory models that we have considered so far are fixed-quantity, or Q systems. That is, the same fixed amount is added to inventory every time an order for an item is placed. We saw that orders are event-triggered. When inventory decreases to the reorder point (ROP), a new order for Q units is placed.

To use the fixed-quantity model, inventory must be continuously monitored. This is called a perpetual inventory system. Every time an item is added to or withdrawn from inventory, records must be updated to make sure the ROP has not been reached.

In a fixed-period, or P system, on the other hand, inventory is ordered at the end of a given period. Then, and only then, is on-hand inventory counted. Only the amount necessary to bring total inventory up to a prespecified target level is ordered. Figure 8 illustrates this concept.

Fixed-period systems have several of the same assumptions as the basic EOQ fixed-quantity system.

•The only relevant costs are the ordering and holding costs
•Lead times are known and constant.
•Items are independent of one another.

The downward-sloped line in Figure 8 again represents on-hand inventory. But now, when the time between orders (P) passes, we place an order to raise inventory up to the target value (T). The amount ordered during the first period may be QI' the second period Q2' and so on. The Q; value is the difference between current on-hand inventory and the target inventory level. Example 15 illustrates how much to reorder in a simple P system.

Inventory Level in a Fixed Period (P) System

Figure 8

The advantage of the fixed-period system is that there is no physical count of inventory items after an item is withdrawn-this occurs only when the time for the next review comes up. This procedure is also convenient administratively, especially if inventory control is only one of several duties of an employee.

A fixed-period system is appropriate when vendors make routine (that is, at fixed-time interval) visits to customers to take fresh orders or when purchasers want to combine orders to save ordering and transportation costs (therefore, they will have the same review period for similar inventory items).

The disadvantage of the P system is that because there is no tally of inventory during the review period, there is the possibility of a stockout during this time. This scenario is possible if a large order draws the inventory level down to zero right after an order is placed. Therefore, a higher level of safety stock (as compared to a fixed-quantity system) needs to be maintained to provide protection against stockout during both the time between reviews and the lead time.

4.0 CONCLUSION

Inventory represents a major investment for many firms. This investment is often larger than it should be because firms find it easier to have "just-in-case" inventory rather than "just-in-time" inventory. Inventories are of four types:

1. Raw material and purchased components.
2. Work-in-process
3. Maintenance, repair, and operating (MRO).
4. Finished goods

5.0 SUMMARY

In this unit, we discussed independent inventory, ABC analysis, record accuracy, cycle counting and inventory models used to control independent demands. The EOQ model, production order quantity model, and quantity discount model can all be solved using Excel, Excel OM, or POM for Windows software. A summary of the inventory models presented in this unit is shown in below.

Models for Independent Demand Summarized

Q = Number of pieces per order
EOQ = Optimum order quantity (Q)*
D = Annual demand in units
S = Setup or ordering cost for each order
H = Holding or carrying cost per unit per

P = Price
I = Annual inventory carrying cost as a percent of price
Il = Mean demand
σdLT = Standard deviation of demand

year in dollars
p = Daily production rate
d = Daily demand rate

during lead-time
a LT = Standard deviation of lead time
Z = Standardized value under the normal curve.

EOQ: $Q^* = \frac{2DS}{H}$

Example 15: EOQ production order quantity model:

$$Q^*p = \frac{2DS}{H[1-(d/p)]}$$

Total cost for the EOQ and quantity discount EOQ models:

TC = Total cost
= Setup cost + Holding cost + Product cost

Quantity discount EOQ model:

$$Q^* \quad \frac{2DS}{IP}$$

Probability model with expected lead time demand known:

ROP = Expected demand during lead time + ZadLT
Safety stock = Zcr dLT

Probability model with variable demand and constant lead time
ROP = (Average daily demand x Lead time) + ZadLT

Probability model with constant demand and variable lead time:

ROP = (Daily demand x Average lead time) + Z(Daily demand} aLT

Probability model with both demand and lead time variable:

ROP = (Average daily demand x Average lead time) + ZadLT

SELF ASSESSMENT EXERCISE

1. Describe the four types of inventory.
2. With the advent of low cost computing, do you see alternatives to the popular ABC Classifications?
3. What is the purpose of the ABC Classification System?

6.0 TUTOR-MARKED ASSIGNMENT

1. The Warren W. Fisher Computer Corporation purchases 8,000 transistors each year as components in minicomputers. The unit cost of each transistor is N10, and the cost of carrying one transistor in inventory for a year is N3. Ordering cost is N30 per order.

   What are (a) the optimal order quantity, (b) the expected number of orders placed each year, and (c) the expected time between orders? Assume that Fisher operates a 200-day working year.

2. Annual demand notebook binders at Salinas' Stationery Shop is 10,000 units. Teresita Salinas operates her business 300 days per year and finds that deliveries from her supplier generally take 5 working days. Calculate the reorder point for the notebook binders.

3. Leonard Presby, Inc., has an annual demand rate of 1,000 units but can produce at an average production rate of 2,000 units. Setup cost is N10: carrying cost is N1, what is the optimal number of units to be produced each time?

7.0 REFERENCES/FURTHER READINGS

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UNIT 4 AGGREGATE PLANNING

CONTENTS

1.0 INTRODUCTION

Manufacturers like Anheuser-Busch, GE, and Yamaha face tough decisions when trying to schedule products like beer, air conditioners, and jet skis, the demand for which is heavily dependent on seasonal variation. If the firms increase output and a summer is warmer than usual, they stand to increase sales and market share. However, if the summer is cool, they may be stuck with expensive unsold product. Developing plans that minimize costs connected with such forecasts is one of the main functions of an operations manager.

Aggregate planning (also known as aggregate scheduling) is concerned with determining the quantity and timing of production for the intermediate future, often from 3 to 18 months ahead. Operations managers try to determine the best way to meet forecasted demand by adjusting production rates, labor levels, inventory levels, overtime work, subcontracting rates, and other controllable variables. Usually, the objective of aggregate planning is to minimize cost over the planning period. However, other strategic issues may be more important than low cost. These strategies may be to smooth employment levels, to drive down inventory levels, or to meet a high level of service.

For manufacturers, the aggregate schedule ties the firm's strategic goals to production plans, but for service organizations, the aggregate schedule ties strategic goals to workforce schedules.

Four things are needed for aggregate planning:

- A logical overall unit for measuring sales and output, such as air-conditioning units.
- A forecast of demand for a reasonable intermediate planning period in these aggregate terms.
- A method for determining the costs that we discuss in this unit
- A model that combines forecasts and costs so that scheduling decisions can be made for the planning period.

In this unit we describe the aggregate planning decision, show how the aggregate plan fits into the overall planning process, and describe several techniques that managers use when developing an aggregate plan. We stress both manufacturing and service-sector firms.

2.0 OBJECTIVES

At the end of this unit, you will be able to

Identify and Define:

- Aggregate Planning
- Tactical Scheduling
- Graphic Technique for Aggregate Planning
- Mathematical Techniques for Planning

Describe or Explain

- how to do Aggregate Planning
- how service firms develop aggregate plans.

3.0 MAIN CONTENT

3.1 The Planning Process

In unit 4, we saw that demand forecasting can address short-, medium, and long-range problems. Long-range forecasts help managers deal with capacity and strategic issues and are the responsibility of top management. Top management formulates policy-related questions, such as facility location and expansion, new product development, research funding, and investment over a period of several years.
Medium-range planning begins once long-term capacity decisions are made. This is the job of the operations manager. Scheduling decisions address the problem of matching productivity to fluctuating demands. These plans need to be consistent with top management's long-range

strategy and work within the resources allocated by earlier strategic decisions. Medium- (or "intermediate") range planning is accomplished by building an aggregate production plan.

Short-range planning may extend up to a year but is usually less than 3 months. This plan is also the responsibility of operations personnel, who work with supervisors and foremen to "disaggregate" the intermediate plan into weekly, daily, and hourly schedules.

3.2 The Nature of Aggregate Planning

As the term aggregate implies, an aggregate plan means combining appropriate resources into general, or overall, terms. Given demand forecast, facility capacity, inventory levels, workforce size, and related inputs, the planner has to select the rate of output for a facility over the next 3 to 18 months. The plan can be for manufacturing firms, hospitals, colleges, and so on.

Take, for a manufacturing example, IBM or Hewlett-Packard, each of which produces different models of microcomputers. They make (I) laptops, (2) desktops, (3) notebook computers, and (4) advanced technology machines with high-speed chips. For each month in the upcoming three quarters, the aggregate plan for IBM or Hewlett-Packard might have the following output (in units of production) for this "family" of microcomputers:

QUARTER 1			QUARTER 2			QUARTER 3		
Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
150,000	120,000	110,000	100,000	130,000	150,000	180,000	150,000	140,000

Note that the plan looks at production in the aggregate, not on a product-by-product breakdown. Likewise, an aggregate plan for GM tells the auto manufacturer how many cars to make, but not how many should be two-door versus four-door or red versus green.

In the service sector, consider Computrain, a company that provides microcomputer training for managers. The firm offers courses on spreadsheets, graphics, databases, word processing, and writing Web pages, and employs several instructors to meet the demand for its services from business and government. Demand for training tends to be very low near holiday seasons and during summer, when many people take their vacations. To meet the fluctuating needs for courses, the company can hire and layoff instructors, advertise to increase demand in slow seasons, or subcontract its work to other training agencies during peak periods. Again, aggregate planning makes decisions about intermediate-range capacity, not specific courses or instructors.

Aggregate planning is part of a larger production planning system. Therefore, understanding the interfaces between the plan and several internal and external factors is useful. In a manufacturing environment, the process of breaking the aggregate plan down into greater detail is called disaggregation. Disaggregation results in a master production schedule, which provides input to material requirements planning (MRP) systems. The master production schedule addresses the purchasing or production of parts or components needed to make final products.

3.3 Aggregate Planning Strategies

When generating an aggregate plan, the operations manager must answer several questions:

1. Should inventories be used to absorb changes in demand during the planning period?
2. Should changes be accommodated by varying the size of the workforce?
3. Should part-timers be used, or should overtime and idle time absorb fluctuations?
4. Should subcontractors be used on fluctuating orders so that a stable workforce can be maintained?
5. Should prices or other factors be changed to influence demand?

All of these are legitimate planning strategies. They involve the manipulation of inventory, production rates, labor levels, capacity, and other controllable variables. We will now examine eight options in more detail. The first five are called capacity options because they do not try to change demand but attempt to absorb the fluctuations in it. The last three are demand options through which firms try to smooth out changes in the demand pattern over the planning period.

3.3.1 Capacity Options

A firm can choose from the following basic capacity (production) options:

1. Changing inventory levels. Managers can increase inventory during periods of low demand to meet high demand in future periods. If this strategy is selected, costs associated with storage, insurance, handling, obsolescence, pilferage, and capital invested will increase. (These costs typically range from 15% to 40% of the value of an item annually.) On the other hand, when the firm enters a period of increasing demand, shortages can result in lost sales due to potentially longer lead times and poorer customer service.

2. Varying workforce size by hiring or layoffs. One way to meet demand is to hire or layoff production workers to match production rates. However, often new employees need to be trained, and the average productivity drops temporarily as they are absorbed into the firm. Layoffs or firings, of course, lower the morale of all workers and can lead to lower productivity.

3. Varying production rates through overtime or idle time. It is sometimes possible to keep a constant workforce while varying working hours, cutting back the number of hours worked when demand is low and increasing them when it rises. Yet when demand is on a large upswing, there is a limit on how much overtime is realistic. Overtime pay requires more money, and too much overtime can wear workers down to the point that overall productivity drops off. Overtime also implies the increased overhead needed to keep a facility open. On the other hand, when there is a period of decreased demand, the company must somehow absorb workers' idle time- usually a difficult process.

4. Subcontracting. A firm can acquire temporary capacity by subcontracting work during peak demand periods. Subcontracting, however, has several pitfalls. First, it may be costly; second, it risks opening the client's door to a competitor. Third, it is often hard to find the perfect subcontract supplier, one who always delivers the quality product on time.

5. Using part-time workers. Especially in the service sector, part-time workers can fill unskilled labor needs. This practice is common in restaurants, retail stores, and supermarkets.

3.3.2 Demand Options

The basic demand options are the following:

1. Influencing demand. When demand is low, a company can try to increase demand through advertising, promotion, personal selling, and price cuts. Airlines and hotels have long offered weekend discounts and off-season rates; telephone companies charge less at night; and air conditioners are least expensive in rainy season. However, even special advertising, promotions, selling, and pricing are not always able to balance demand with production capacity.

2. Back ordering during high-demand periods. Back orders are orders for goods or services that a firm accepts but is unable (either on purpose or by chance) to fill at the moment. If customers are willing

to wait without loss of their goodwill or order, back ordering is a possible strategy. Many firms back order, but the approach often results in lost sales.

3. Counterseasonal product and service mixing. A widely used active smoothing technique among manufacturers is to develop a product mix of counterseasonal items. However, companies that follow this approach may find themselves involved in products or services beyond their area of expertise or beyond their target market.

3.3.3 Mixing Options to Develop a Plan

Although each of the five capacity options and three demand options may produce an effective aggregate schedule, some combination of capacity options and demand options may be better.

Many manufacturers assume that the use of the demand options has been fully explored by the marketing department and those reasonable options incorporated into the demand forecast. The operations manager then builds the aggregate plan based on that forecast. However, using the five capacity options at his command, the operations manager still has a multitude of possible plans. These plans can embody, at one extreme, a chase strategy and, at the other, a level-scheduling strategy. They may, of course, fall somewhere in between.

Chase Strategy: A chase strategy attempts to achieve output rates for each period that match the demand forecast for that period. This strategy can be accomplished in a variety of ways. For example, the operations manager can vary workforce levels by hiring or laying off or can vary production by means of overtime, idle time, part-time employees, or subcontracting. Many service organizations favor the chase strategy because the inventory option is difficult or impossible to adopt. Industries that have moved toward a chase strategy include education, hospitality, and construction.

Level Strategy: A level strategy (or level scheduling) is an aggregate plan in which daily production is uniform from period to period. Firms like Toyota and Nissan keep production at uniform levels and may (1) let the finished-goods inventory go up or down to buffer the difference between demand and production or (2) find alternative work for employees. Their philosophy is that a stable workforce leads to a better-quality product, less turnover and absenteeism, and more employee commitment to corporate goals. Other hidden savings include employees who are more experienced, easier scheduling and supervision, and fewer dramatic startups and shutdowns. Level scheduling works well when demand is reasonably stable.

3.4 Methods for Aggregate Planning

For most firms, neither a chase strategy nor a level strategy is likely to prove ideal, so a combination of the eight options (called a mixed strategy) must be investigated to achieve minimum cost. However, because there are a huge number of possible mixed strategies, managers find that aggregate planning can be a challenging task. Finding the one "optimal" plan is not always possible. Indeed, some companies have no formal aggregate planning process: They use the same plan from year to year, making adjustments up or down just enough to fit the new annual demand. This method certainly does not provide much flexibility, and if the original plan was suboptimal, the entire production process will be locked into suboptimal performance.

In this section, we introduce several techniques that operations managers use to develop more useful and appropriate aggregate plans. They range from the widely used charting (or graphical) method to a series of more formal mathematical approaches, including the transportation method of linear programming.

3.4.1 Graphical and Charting Methods

Graphical and charting techniques are popular because they are easy to understand and use. Basically, these plans work with a few variables at a time to allow planners to compare projected demand with existing capacity. They are trial-and-error approaches that do not guarantee an optimal production plan, but they require only limited computations and can be performed by clerical staff. The following are the five steps in the graphical method:

1. Determine the demand in each period
2. Determine capacity for regular time, overtime, and subcontracting each period.
3. Find labour costs, hiring and layoff costs, and inventory holding costs
4. Consider company policy that may apply to the workers or to stock levels.
5. Develop alternative plans and examine their total costs

3.4.2 Mathematical Approaches to Planning

This section briefly describes some of the mathematical approaches to aggregate planning that have been developed over the past 50 years.

The Transportation Method of Linear Programming: When an aggregate planning problem is' viewed as one of allocating operating capacity to meet forecasted demand, it can be formulated in a linear programming format. The transportation method of linear programming is not a trial-and-error approach like charting but rather produces an optimal plan for minimizing costs. It is also flexible in that it can specify regular and overtime production in each time period, the number of units to be subcontracted, extra shifts, and the inventory carryover from period to period.

The transportation method of linear programming described in the above example was originally formulated by E. H. Bowman in 1956. Although it works well in analyzing the effects of holding inventories, using overtime, and subcontracting, it does not work when nonlinear or negative factors are introduced. Thus, when other factors such as hiring and layoffs are introduced, the more general method of linear programming must be used.

Management Coefficients Model: Bowman's management coefficients model I builds a formal decision model around a manager's experience and performance. The assumption is that the manager's past performance is pretty good, so it can be used as a basis for future decisions. The technique uses a regression analysis of past production decisions made by managers. The regression line provides the relationship between variables (such as demand and labor) for future decisions. According to Bowman, managers' deficiencies are mostly inconsistencies in decision making.

Other Models: Two additional aggregate planning models are the linear decision rule and simulation. The linear decision rule (LDR) attempts to specify an optimum production rate and workforce level over a specific period. It minimizes the total costs of payroll, hiring, layoffs, overtime, and inventory through a series of quadratic cost curves.

A computer model called scheduling by simulation uses a search procedure to look for the minimum-cost combination of values for workforce size and production rate

3.4.3 Comparison of Aggregate Planning Methods

Although these mathematical models have been found by researchers to work well under certain conditions, and linear programming has found some acceptance in industry, the fact is that most sophisticated planning models are not widely used. Why? Perhaps it reflects the average manager's attitude about what he or she views as overly complex models. Like all of us, planners like to understand how and why the models on which they are basing important decisions work. Additionally, operations managers need to make decisions quickly based on the changing dynamics of the workplace-and building good models is time-consuming. This may explain why the simpler charting and graphical approach is more generally accepted.

Table 1 highlights some of the main features of charting, transportation, and management coefficients planning models.

Table 1: Summary of Three Major Aggregate Planning Methods

TECHNIQUE	SOLUTION APPROACHES	IMPORTANT ASPECTS
Graphical/charting methods	Trial and error	Simple to understand and easy to use. Many solutions; one chosen may not be optimal
Transportation method of linear programming	Optimization	LP software available; permits sensitivity analysis and new constraints; linear functions may not be realistic
Management coefficients model	Heuristic	Simple, easy to implement; tries to mimic manager's decision process; uses regression.

3.5 Aggregate Planning in Services

Some service organizations conduct aggregate planning with demand management taking a more active role. Because most services pursue combinations of the eight capacity and demand options discussed earlier, they usually formulate mixed aggregate planning strategies. In actuality, in such industries as banking, trucking, and fast foods, aggregate planning may be easier than in manufacturing.

Controlling the cost of labor in service firms is critical. It involves the following:

1. Close scheduling of labor-hours to assure quick response to customer demand.
2. Some form of on-call labor resource that can be added or deleted to meet unexpected demand.
3. Flexibility of individual worker skills that permits reallocation of available labor.
4. Individual worker flexibility in rate of output or hours of work to meet expanded demand.

These options may seem demanding, but they are not unusual in service industries, in which labour is the primary aggregate planning vehicle.

For instance:

- Excess capacity is used to provide study and planning time by real estate and auto salespersons.
- Police and fire departments have provisions for calling in off-duty personnel for major emergencies. Where the emergency is extended, police or fire personnel may work longer hours and extra shifts.
- When business is unexpectedly light, restaurants and retail stores send personnel home early.
- Supermarket stock clerks work cash registers when checkout lines become too lengthy.
- Experienced waitresses increase their pace and efficiency of service as crowds of customers arrive.

Approaches to aggregate planning differ by the type of service provided. Here we discuss five service scenarios.

3.5.1 Restaurants

In a business with a highly variable demand, such as a restaurant, aggregate scheduling is directed towards (1) smoothing the production rate and (2) finding the size of the workforce to be employed. The general approach usually requires building very modest levels of inventory during slack periods and depleting inventory during peak periods, but using labour to accommodate most of the changes in demand. Because this situation is very similar to those found in manufacturing, traditional aggregate planning methods may be applied to services as well. One difference that should be noted is that even modest amounts of inventory may be perishable. In addition, the relevant units of time may be much smaller than in manufacturing. For example, in fast-food restaurants, peak and slack periods may be measured in hours and the "product" may be inventoried for as little as 10 minutes.

3.5.2 Hospitals

Hospitals face aggregate planning problems in allocating money, staff, and supplies to meet the demands of patients. The necessary labour focus of its aggregate plan has led to the creation of a new floating staff pool serving each nursing pod.

3.5.3 National Chains of Small Service Firms

With the advent of national chains of small service businesses such as funeral homes, quick-lube outlets, photocopy/printing centers, and computer centers, the question of aggregate planning versus independent planning at each business establishment becomes an issue. Both output and purchasing may be centrally planned when demand can be influenced through special promotions. This approach to aggregate scheduling is advantageous because it reduces purchasing and advertising costs and helps manage cash flow at independent sites.

3.5.4 Miscellaneous Services

Most "miscellaneous" services-financial, transportation, and many communication and recreation services-provide intangible output. Aggregate planning for these services deals mainly with planning for human resource requirements and managing demand. The twofold goal is to level demand peaks and to design methods for fully utilizing labour resources during low-demand periods.

3.5.5 Airline Industry

Airlines and auto-rental firm also have unique aggregate scheduling problems.' Consider an airline that has its headquarters in Abuja, two hub sites in cities such as Lagos and Kano, and 150 offices in airports throughout the country. This planning is considerably more complex than aggregate planning for a single site or even for a number of independent sites.

Aggregate planning consists of tables or schedules for (I) number of flights in and out of each hub; (2) number of flights on all routes; (3) number of passengers to be serviced on all flights; (4) number of air personnel and ground personnel required at each hub and airport; and (5) determining the seats to be allocated to various fare classes. Techniques for determining seat allocation are called yield, or revenue, management, our next topic.

3.6 Yield Management

Yield (or revenue) management is the aggregate planning process of allocating resources to customers at prices that will maximize yield or revenue. Its use dates to the 1980s when American Airlines' reservation system (called SABRE) allowed the airline to alter ticket prices, in real time and on any route, based on demand information. If it looked like demand for expensive seats was low, more discounted seats were offered. If demand for full-fare seats was high, the number of discounted seats was reduced.

American Airlines' success in yield management spawned many other companies and industries to adopt the concept.

Organizations that have perishable inventory, such as airlines, hotels, car rental agencies, cruise lines, and even electrical utilities, have the following shared characteristics that make yield management of interest:

1. Service or product can be sold in advance of consumption.
2. Demand fluctuates.
3. Capacity is relatively fixed.
4. Demand can be segmented.
5. Variable costs are low and fixed costs are high.

4.0 CONCLUSION

Aggregate planning provides companies with a necessary weapon to help capture market shares in the global economy. The aggregate plan provides both manufacturing and service firms the ability to respond to changing customer demands while still producing at low-cost and high-quality levels.

5.0 SUMMARY

The aggregate schedule sets levels of inventory, production, subcontracting, and employment over an intermediate time range, usually 3 to 18 months. This c1JPm describes several aggregate planning techniques, ranging from the popular charting approach to a variety of mathematical models such as linear programming.

The aggregate plan is an important responsibility of an operations manager and a key to efficient production. Output from the aggregate schedule leads to a more detailed master production schedule, which is the basis for disaggregation, job scheduling, and MRP systems.

Aggregate plans for manufacturing firms and service systems are similar. Restaurants, airlines, and hotels are all service systems that employ aggregate plans, and have an opportunity to implement yield management. But regardless of the industry or planning method, the most important issue is the implementation of the plan. In this respect, managers appear to be more comfortable with faster, less complex, and less mathematical approaches to planning.

6.0 TUTOR-MARKED ASSIGNMENT

1. List the strategic objectives of aggregate planning. Which one of these is most often addressed by the quantitative techniques of aggregate planning? Which one of these is generally the most important?

2. Define chase strategy.

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UNIT 5 MATERIAL REQUIREMENTS PLANNING (MRP) AND ENTERPRISES RESOURCE PLANNING (ERP)

CONTENTS

1.0 INTRODUCTION

Dependency exists for all component parts, sub-assemblies, and supplies once a master schedule is known. Dependent models are better not only for manufacturers and distributors but also for a wide variety of firms from restaurants to hospitals. The dependent technique used in a production environment is called material requirements planning (MRP).

Because MRP provides such a clean structure for dependent demand, it has evolved as the basis for Enterprise Resource Planning (ERP). ERP is an information system for identifying and planning the enterprise-wide resources needed to take, make, ship, and account for customer orders. We will discuss ERP in the latter part of this unit.

2.0 OBJECTIVES

At the end of this unit, you will be able to

Identify and Define:

• Planning bill and kits
• Phantom bills
• Low-level coding
• Low sizing.

Describe or Explain:

• Material Requirement Planning
• Distribution requirement planning
• Enterprise resource planning
• How ERP works
• Advantages and Disadvantages of ERP systems.

3.0 MAIN CONTENT

3.1 Dependent Inventory Model Requirements

Effective use of dependent inventory models requires that the operations manager know the following:

1. Master production schedule (what is to be made and when).
2. Specifications or bill of material (materials and parts required to make the product).
3. Inventory availability (what is in stock.)
4. Purchase orders outstanding (what is on order).
5. Lead times (how long it takes to get various components).

We now discuss each of these requirements in the context of material requirements planning (MRP).

3.1.1 Master Production Schedule

A master production schedule (MPS) specifies what is to be made (i.e., the number of finished products or items) and when. The schedule must be in accordance with a production plan. The production plan sets the overall level of output in broad terms (for example, product families, standard hours, or dollar volume). The plan also includes a variety of inputs, including financial plans, customer demand, engineering capabilities, labor availability, inventory fluctuations, supplier performance, and other considerations. Each of these inputs contributes in its own way to the production plan.

As the planning process moves from the production plan to executing each of the lower-level plans must be feasible. When one is not, feedback to the next higher level is used to make the necessary adjustment. One of the major strengths of MRP is its ability to determine precisely the feasibility of a schedule within aggregate capacity constraints. This planning process can yield excellent results. The production plan sets the upper and lower bounds on the master production schedule. The result of this production planning process is the master production schedule.

The master production schedule tells us what is required to satisfy demand and meet the production plan. This schedule establishes what items to make and when: It disaggregates the aggregate production plan. While the aggregate production plan is established in gross terms such as families of products or tons of steel, the master production schedule is established in terms of specific products.

Managers must adhere to the schedule for a reasonable length of time (usually a major portion of the production cycle-the time it takes to produce a product). Many organizations establish a master production schedule and establish a policy of not changing ("fixing") the near term portion of the plan. This near-term portion of the plan is then referred to as the "fixed," "firm," or "frozen" schedule.

Note that the master production schedule is a statement of what is to be produced, not a forecast of demand. The master schedule can be expressed in any of the following terms:

1. A customer order in a job shop (make-to-order) company
2. Module in a repetitive (assemble-to-order or forecast) company
3. An end item in a continuous (stock-to-forecast) company.

3.1.2 Bills of Material

Defining what goes into a product may seem simple, but it can be difficult in practice. A bill of material (ROM) is a list of quantities of components, ingredients, and materials required to make a product. Individual drawings describe not only physical dimensions but also any special processing as well as the raw material from which each part is made.
Because there is often a rush to get a new product to market, however, drawings and bills of material may be incomplete or even nonexistent. Moreover, complete drawings and BOM (as well as other forms of specifications) often contain errors in dimensions, quantities, or countless other areas. When errors are identified, engineering change notices (ECNs) are created, further complicating the process. An engineering change notice is a change or correction to an engineering drawing or bill of material.

Bills of material not only specify requirements but also are useful for costing, and they can serve as a list of items to be issued to production or assembly personnel. When bills of material are used in this way, they are usually called pick lists.

Modular Bills: Bills of material may be organized around product modules. Modules are not final products to be sold but are components that can be produced and assembled into units. They are often major components of the final product or product options. Bills of material for modules are called modular bills. Bills of material are sometimes organized as modules (rather than as part of a final product) because production scheduling and production are often facilitated by organizing around relatively few modules rather than a multitude of final assemblies. For instance, a firm may make 138,000 different final products but may have only 40 modules that are mixed and matched to produce those 138,000 final products. The firm builds an aggregate production plan and prepares its master production schedule for the 40 modules, not the 138,000 configurations of the final product. This approach allows the MPS to be prepared for a reasonable number of items and to postpone assembly. The 40 modules can then be configured for specific orders at final assembly.

Planning Bills and Phantom Bills: Two other special kinds of bills of material are planning bills and phantom bills. Planning bills are created in order to assign an artificial parent to the bill of material. Such bills are used (I) when we want to group sub-assemblies so the number of items to be scheduled is reduced and (2) when we want to issue "kits" to the production department. For instance, it may not be efficient to issue inexpensive items such as washers and cotter pins with each of numerous subassemblies, so we call this a kit and generate a planning bill. The planning bill specifies the kit to be issued. Consequently, a planning bill may also be known as kitted material or kit. Phantom bills of material are bHls of material for components, usually subassemblies that exist only temporarily. These components go directly into another assembly and are never inventoried. Therefore, components of phantom bills' of material are coded to receive special treatment; lead times are zero, and they are handled as an integral part of their parent item. An example is a transmission shaft with gears and bearings assembly that is placed directly into a transmission.

Low-level Coding: Low-level coding of an item in a BOM is necessary when identical items exist at various levels in the BOM. Low-level coding means that the item is coded at the lowest level at which it occurs.

3.1.3 Accurate Inventory Records

As we have seen, knowledge of what is in stock is the result of good inventory management.

Good inventory management is an absolute necessity for an MRP system to work. If the firm has not yet achieved at least 99% record accuracy, then material requirements planning will not work

3.1.4 Purchase Orders Outstanding

Knowledge of outstanding orders should exist as a by-product of well-managed purchasing and inventory-control departments. When purchase orders are executed, records of those orders and their scheduled delivery dates must be available to production personnel. Only with good purchasing data can managers prepare good production plans ails effectively execute an MRP system.

3.1.5 Lead Times for Each Component

Once managers determine when products are needed, they determine when to acquire them. The time required to acquire (that is, purchase, produce, or assemble) an item is known as lead time. Lead time for a manufactured item consists of move, setup, and assembly or run times for each component. For a purchased item, the lead time includes the time between recognition of need for an order and when it is available for production.

3.2 MRP Structure

Although most MRP systems are computerized, the MRP procedure is straightforward and can be done by hand. A master production schedule" a bill of material, inventory and purchase records, and lead times for each item are the ingredients of a material requirements planning system.

Once these ingredients are available and accurate, the next step is to construct a gross material requirements plan. The gross material requirements plan is a schedule, it combines a master production schedule and the time-phased schedule. It shows when an item must be ordered from suppliers if there is no inventory on hand or when the production of an item must be started to satisfy demand for the finished product by a particular date.

3.3 MRP Management

The material requirements plan is not static. And since MRP systems increasingly are integrated with just-in-time (JIT) techniques, we now discuss these two issues.

3.3.1 MRP Dynamics

Bills of material and material requirements plans are altered as changes in design, schedules, and production processes occur. Additionally, changes occur in material requirements whenever the master production schedule is modified. Regardless of the cause of any changes, the MRP model can be manipulated to reflect them. In this manner, an up-to-date requirements schedule is possible.

Due to the changes that occur in MRP data, it is not uncommon to recompute MRP requirements about once a week. Conveniently, a central strength of MRP is its timely and accurate replanning capability. However, many firms find they do not want to respond to minor scheduling or quantity changes even if they are aware of them. These frequent changes generate what is called system nervousness and can create havoc in purchasing and production departments if implemented. Consequently, OM personnel reduce such nervousness by evaluating the need and impact of changes prior to disseminating requests to other departments. Two tools are particularly helpful when trying to reduce MRP system nervousness.

The first is time fences. Time fences allow a segment of the master schedule to be designated as "not to be rescheduled." This segment of the master schedule is thus not changed during the periodic regeneration of schedules. The second tool is pegging. Pegging means tracing upward in the BOM from the component to the parent item. By pegging upward, the production planner can determine the cause for the requirement and make a judgment about the necessity for a change in the schedule.

With MRP, the operations manager can react to the dynamics of the real world. How frequently the manager wishes to impose those changes on the firm requires professional judgment. Moreover, if the nervousness is caused by legitimate changes, then the proper response may be to investigate the production environment-not adjust via MRP.

3.3.2 MRP and JIT

MRP does not do detail scheduling it plans. MRP will tell you that a job needs to be completed on a certain week or day but does not tell you that Job X needs to run on Machine A at 10:30 A.M. and be completed by II :30 A.M. so that it can then run on machine B. MRP is also a planning technique with fixed lead times. Fixed lead times can be a limitation. For instance, the lead time to produce 50 units may vary substantially from the lead time to produce 5 units. These limitations complicate the marriage of MRP and just-in-time (JIT). What is needed is a way to make MRP more responsive to moving material rapidly in small batches. An MRP system combined with JIT can provide the best of both worlds. MRP provides the plan and an accurate picture of requirements; then JIT rapidly moves material in small batches, reducing work-in-process inventory. Let's look at four approaches for integrating MRP and JIT: finite capacity scheduling, small buckets, balanced flow, and supermarkets.

Finite Capacity Scheduling (FCS): Most MRP software loads work into infinite size "buckets." The buckets are time units, usually one week. Traditionally, when work is to be done in a given week, MRP puts the work there without regard to capacity. Consequently, MRP is considered an infinite scheduling technique. Frequently, as you might suspect, this is not realistic. Finite capacity scheduling (FCS), considers department and machine capacity, which is finite, hence the name. FCS provides the precise scheduling needed for rapid material movement. We are now witnessing a convergence of FCS and MRP. Sophisticated FCS systems modify the output from MRP systems to provide a finite schedule.

Small Bucket Approach MRP is an excellent tool for resource and scheduling management in process-focused facilities, that is, in job shops: Such facilities include machine shops, hospitals, and restaurants, where lead times are relatively stable and poor balance between work centers is expected. Schedules are often driven by work orders, and lot sizes are the exploded bill-of-material size. In these enterprises, MRP can be integrated with JIT through the following steps.

Step 1: Reduce MRP "buckets" from weekly to daily to perhaps hourly. Buckets are time units in an MRP system. Although the examples in this unit have used weekly time buckets, many firms now use daily or even fraction-of-a-day time buckets. Some systems use a bucketless system in which all time-phased data have dates attached rather than defined time periods or buckets

Step 2: The planned receipts that are part of a firm's planned orders in an MRP system are communicated to the work areas for production purposes and used to sequence production.

Step 3: Inventory is moved through the plant on a JIT basis.

Step 4: As products are completed, they are moved into inventory (typically finished-goods inventory) in the normal way. Receipt of these products into inventory reduces the quantities required for subsequent planned orders in the MRP system.

Step 5: A system known as back flush is used to reduce inventory balances. Back flushing uses the bill of material to deduct component quantities from inventory as each unit is completed.

The focus in these facilities becomes one of maintaining schedules. Nissan achieves success with this approach by computer communication links to suppliers. These schedules are confirmed, updated, or changed every 15 to 20 minutes. Suppliers provide deliveries 4 to 16 times per day. Master schedule performance is 99% on time, as measured every hour. On-time delivery from suppliers is 99.9% and for manufactured piece parts, 99.5%.

Balanced Flow Approach: MRP supports the planning and scheduling necessary for repetitive operations, such as the assembly lines at Harley-Davidson, Whirlpool, and a thousand other places. In these environments, the planning portion of MRP is combined with JIT execution. The JIT portion uses kanbans, visual signals, and reliable suppliers to pull the material through the facility. In these systems, execution is achieved by maintaining a carefully balanced flow of material to assembly areas with small lot sizes.

Supermarket: Another technique that joins MRP and JIT is the use of a "supermarket." In many firms, subassemblies, their components, and many hardware items are common to a variety of products. In such cases, releasing orders for these common items with traditional lead-time offset, as is done in an MRP system, is not necessary. The subassemblies, components, and hardware items can be maintained in a common area, sometimes called a supermarket, adjacent to the production areas where they are used. Items in the supermarket are replenished by a JIT/kanban system.

3.4 Lot-Sizing Techniques

An MRP system is an excellent way to determine production schedules and net requirements. However, whenever we have a net requirement, a decision must be made about how much to order. This decision is called a lot-sizing decision. There are a variety of ways to determine lot sizes in an MRP system; commercial MRP software usually includes the choice of several lot-sizing techniques. We now review a few of them.

Lot-for-Lot: We used a lot-sizing technique known as lot-for-lot, which produced exactly what was required. This decision is consistent with the objective of an MRP system, which is to meet the requirements of dependent demand. Thus, an MRP system should produce units only as needed, with no safety stock and no anticipation of further orders. When frequent orders are economical and just-in-time inventory techniques implemented, lot-for-lot can be very efficient. However, when setup costs are significant or management has been unable to implement JIT, lot-for-lot can be expensive.

Economic Order Quantity: EOQ can be used as a lot-sizing technique. But as we indicated there, EOQ is preferable when relatively constant independent demand exists, not when we know the demand. EOQ is a statistical technique using averages (such as average demand for a year), whereas the MRP procedure assumes known (dependent) demand reflected in a master production schedule. Operations managers should take advantage of demand information when it is known, rather than assuming a constant demand.

Part Period Balancing: Part period balancing (PPB) is a more dynamic approach to balance setup and holding cost. PPB uses additional information by changing the lot size to reflect requirements of the next lot size in the future. PPB attempts to balance setup and holding cost for known demands. Part period balancing develops an economic part period (EPP), which is the ratio of setup cost to holding cost.

Wagner-Whitin Algorithm: The Wagner-Whitin procedure is a dynamic programming model that adds some complexity to the lot-size computation. It assumes a finite time horizon beyond which there are no additional net requirements. It does, however. provide good results.

3.5 Extensions of MRP

Recent years have seen the development of a number of extensions of MRP. In this section, we review three of them.

3.5.1 Closed-Loop MRP

Closed-loop material requirements planning implies an MRP system that provides feedback to scheduling from the inventory control system. Specifically, a closed-loop MRP system provides information to the capacity plan, master production schedule, and ultimately to the production plan. Virtually all commercial MRP systems are closed-loop.

3.5.2 Capacity Planning

In keeping with the definition of closed-loop MRP, feedback about workload is obtained from each work center. Load reports show the resource requirements in a work center for all work currently assigned to the work center, all work planned, and expected orders. Closed-loop MRP systems allow production planners to move the work between time periods to smooth the load or at least bring it within capacity. The closed loop MRP system can then reschedule all items in the net requirements plan.

Tactics for smoothing the load and minimizing the impact of changed lead time include the following:

1. Overlapping, which reduces the lead time, sends pieces to the second operation before the entire lot is completed on the first operation.
2. Operations splitting sends the lot to two different machines for the same operation. This involves an additional setup, but results in shorter throughput times, because only part of the lot is processed on each machine.
3. Lot splitting involves breaking up the order and running part of it ahead of schedule.

When the workload consistently exceeds work-center capacity, the tactics just discussed are not adequate. This may mean adding capacity. Options include adding capacity via personnel, machinery, overtime, or subcontracting.

3.5.3 Material Requirements Planning II (MRP II)

Material requirements planning II is an extremely powerful technique. Once a firm has MRP in place, inventory data can be augmented by labor-hours, by material cost (rather than material quantity), by capital cost, or by virtually any other resource. When MRP is used this way, it is usually referred to as MRP II, and resource is usually substituted for *requirements. MRP then stands for material resource planning.*

For instance, so far in our discussion of MRP, we have scheduled units (quantity). However, each of these units requires resources in addition to its components. Those additional resources include labor-hours, machine-hours, and accounts payable (cash). Each of these resources can be used in an MRP format just as we used quantities. These requirements are then compared with the respective capacity (that is, labor-hours, machine-hours, cash, etc.), so operations managers can make schedules that will work.

To aid the functioning of MRP II, most MRP II computer programs are tied into other computer files that provide data to the MRP system or receive data from the MRP system. Purchasing, production scheduling, capacity planning, and warehouse management are a few examples of this data integration.

3.5.3 MRP in Services

The demand for many services or service items is classified as dependent demand when it is directly related to or derived from the demand for other services. Such services often require product-structure trees, bills-of-material and labour, and scheduling. MRP can make a major contribution to operational performance in such services.

3.6 Distribution Resource Planning (DRP)

When dependent techniques are used in the supply chain, they are called distribution resource planning (DRP). Distribution resource planning (DRP) is a time-phased stock-replenishment plan for all levels of the supply chain. DRP procedures and logic are analogous to MRP. DRP requires the following:

1. Gross requirements, which are the same as expected demand or sales forecasts.
2. Minimum levels of inventory to meet customer-service levels.
3. Accurate lead time.
4. Definition of the distribution structure.

With DRP, expected demand becomes gross requirements. Net requirements are determined by allocating available inventory to gross requirements. The DRP procedure starts with the forecast at the retail level (or the most distant point of the distribution network being supplied). All other levels are computed. As is the case with MRP, inventory is then reviewed with an aim to satisfying demand. So that stock will arrive when it is needed, net requirements are offset by the necessary lead time. A planned order release quantity becomes the gross requirement at the next level down the distribution chain.

DRP pulls inventory through the system. Pulls are initiated when the top or retail level orders more stock. Allocations are made to the top level from available inventory and production after being adjusted to obtain shipping economies. The goal of the DRP system is small and frequent replenishment within the bounds of economical ordering and shipping.

3.7 Enterprise Resource Planning

Advances in MRP II systems that tie customers and suppliers to MRP II have led to the development of Enterprise Resource Planning (ERP) systems. Enterprise Resource Planning (ERP) is software that allows companies to (I) automate and integrate many of their business processes, (2) share a common database and business practices throughout the enterprise, and (3) produce information in real time.

The objective of an ERP system is to coordinate a firm's whole business, from supplier evaluation to customer invoicing. This objective is seldom achieved, but ERP systems are evolving as umbrella systems that tie together a variety of specialized systems. This is accomplished by using a centralized database to assist the flow of information among business functions. Exactly what is tied together, and how, varies on a case-by-case basis. In addition to the traditional components of MRP, ERP systems usually provide financial and human resource (HR) management information. ERP systems also include.

Supply-Chain Management (SCM) software to support sophisticated vendor communication, e-commerce, and those activities necessary for efficient warehousing and logistics. The idea is to tie operations (MRP) to procurement, to materials management, and to suppliers, providing the tools necessary for evaluation of all four.

Customer Relationship Management (CRM) software for the incoming side of the business. CRM is designed to aid analysis of sales, target the most profitable customers, and manage the sales force.

3.7.1 Advantages and Disadvantages of ERP Systems

We have alluded to some of the pluses and minuses of ERP. Here is a more complete list of both.

Advantages

1. Provides integration of the supply-chain, production, and administrative process
2. Creates commonality of databases.
3. Can incorporate improved, reengineered, "best processes.
4. Increases communication and collaboration among business units and sites.
5. Has a software database that is off-the-shelf coding.
6. May provide a strategic advantage over competitors

Disadvantages

1. Is very expensive to purchase, and even more costly to customize.
2. Implementation may require major changes in the company and its processes.
3. Is so complex that many companies cannot adjust to it.
4. Involves an ongoing process for implementation, which may never be completed.
5. Expertise in ERP is limited, with staffing an ongoing problem.

SELF ASSESSMENT EXERCISE

1. What is the difference between a gross requirements plan and a net requirements plan?
2. Once a material requirement plan MRP has been established, what other managerial application might be found for the technique.

4.0 CONCLUSION

Material requirements planning (MRP) is the preferred way to schedule production and inventory when demand is dependent. For MRP to work, management must have a master schedule, precise requirements for all components, accurate inventory and purchasing records, and accurate lead times. Distribution resource planning (DRP) is a time-phased stock-replacement technique for supply chains based on MRP procedures and logic

5.0 SUMMARY

Production should often be lot-for-lot in an MRP system, and replenishment orders in a DRP system should be small and frequent, given the constraints of ordering and transportation costs.

Both MRP and DRP, when properly implemented, can contribute in a major way to reduction in inventory while improving customer-service levels. These techniques allow the operations manager to schedule and replenish stock on a "need-to-order" basis rather than simply a “time-to-order” basis.

The continuing development of MRP systems has led to the integration of production data with a variety of other activities, including the supply chain and sales. As a result, we now have integrated database-oriented Enterprise Resource Management (ERP) systems. These expensive and difficult-to install ERP systems, when successful, support strategies of differentiation, response, and cost leadership.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the disadvantages of ERP?
2. Use the Web or other sources to:

a. Find stories that highlight the advantages of an ERP system
b. Find stories that highlight the difficulties of purchasing installing, or failure of an ERP system.

7.0 REFERENCES/FURTHER READINGS

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UNIT 6 SHORT TERM SCHEDULING

1.0 INTRODUCTION

The strategic importance of scheduling is clear:

•Effective scheduling means faster movement of goods and services through a facility. This means greater use of assets and hence greater capacity per dollar invested, which, in turn, lowers cost.
•Added capacity, faster throughput, and the related flexibility mean better customer service through faster delivery
•Good scheduling also contributes to realistic commitments and hence dependable delivery

2.0 OBJECTIVES

At the end of this unit, you will be able to

Identify and Define:

• Gantt Charts
• Assignment Method
• Sequencing Rules
• Johnson's Rule
• Bottlenecks

Describe or Explain

- Scheduling
- Sequencing
- Shop Loading
- Theory of Constraints.

3.0 MAIN CONTENT

3.1 Scheduling

Scheduling deals with the timing of operations. Schedule decisions begin with capacity planning, which involves total facility and equipment resources available. Capacity plans are usually annual or quarterly as new equipment and facilities are purchased or discarded. Aggregate planning makes decisions regarding the use of facilities, inventory, people, and outside contractors. Aggregate plans are typically monthly, and resources are allocated in terms of an aggregate measure such as total units, tons, or shop hours. However, the master schedule breaks down the aggre gate plan and develops a schedule for specific products or product lines for each week. Short-term schedules then translate capacity decisions, aggregate (intermediate) planning, and master schedules into job sequences and specific assignments of personnel, material and machinery. In this unit, we describe the narrow issue of scheduling goods and services in the short run (that is, matching daily or hourly requirements to specific personnel and equipment).

The scheduling task is one of allocating and prioritizing demand (generated by either forecasts or customer orders) to available facilities. Two significant factors in achieving this allocation and prioritizing are (1) the type of scheduling, forward or backward, and (2) the criteria for priorities.

3.1.1 Forward and Backward Scheduling

Scheduling involves assigning due dates to specific jobs, but many jobs compete simultaneously for the same resources. To help address the difficulties inherent in scheduling, we can categorize scheduling techniques as (I) forward scheduling and (2) backward scheduling.

Forward scheduling starts the schedule as soon as the job requirements are known. Forward scheduling is used in a variety of organizations such as hospitals, clinics, fine-dining restaurants, and machine tool manufacturers. In these facilities, jobs are performed to customer order, and delivery is often requested as soon as possible. Forward scheduling is usually designed to produce a schedule that can be accomplished even if it means not meeting the due date. In many instances, forward scheduling causes a buildup of work-in-process inventory.

Backward scheduling begins with the due date, scheduling the final operation first. Steps in the job are then scheduled, one at a time, in reverse order. By subtracting the lead time for each item, the start time is obtained. However, the resources necessary to accomplish the schedule may not exist. Backward scheduling is used in many manufacturing environments, as well as service environments such as catering a banquet or scheduling surgery. In practice, a combination of forward and backward scheduling is often used to find a reasonable trade-off between what can be achieved and customer due dates.

Machine breakdowns, absenteeism, quality problems, shortages, and other factors further complicate scheduling. Consequently, assignment of a date does not ensure that the work will be performed according to the schedule. Many specialized techniques have been developed to aid in preparing reliable schedules.

3.1.2 Scheduling Criteria

The correct scheduling technique depends on the volume of orders, the nature of operations, and the overall complexity of jobs, as well as the importance placed on each of four criteria. These four criteria are

1. Minimize completion time. This criterion is evaluated by determining the average completion time per job.
2. Maximize utilization. This is evaluated by determining the percent of the time the facility is utilized.
3. Minimize work-in-process (WIP) inventory. This is evaluated by determining the average number of jobs in the system. The relationship between the number of jobs in the system and WIP inventory will be high. Therefore, the fewer the number of jobs that are in the system the lower the inventory.
4. Minimize customer waiting time. This is evaluated by determining the average number of late days.

These four criteria are used in this chapter, as they are in industry, to evaluate scheduling performance. Additionally, good scheduling approaches should be simple, clear, easily understood, easy to carry out, flexible, and realistic. Given these considerations, the objective of scheduling is to optimize the use of resources so that production objectives are met.

3.2. Scheduling Process-Focused Facilities

Process-focused facilities (also known as intermittent or job-shop facilities). These are production systems in which products are made to order. Items made under this system usually differ considerably in terms of materials used, order of processing, processing requirements, time of processing, and setup requirements. Because of these differences, scheduling can .be complex. To run a facility in a balanced and efficient manner, the manager needs a production planning and control system. This system should:

1. Schedule incoming orders without violating capacity constraints of individual work centers.
2. Check the availability of tools and materials before releasing an order to a department.
3. Establish due dates for each job and check progress against need dates and order lead times.
4. Check work in progress as jobs move through the shop.
5. Provide feedback on plant and production activities
6. Provide work efficiency statistics and monitor operator times for payroll and labor distribution analysis.

Whether the scheduling system is manual or automated, it must be accurate and relevant. This means it requires a production database with both planning and control files. Three types of planning files are.

1. An item master file, which contains information about each component the firm produces or purchases.
2. A routing file, which indicates each component's flow through the shop
3. A work-center master file, which contains information about the work center such as capacity and efficiency.

Control files track the actual progress made against the plan for each work order.

3.3 Loading Job

Loading means the assignment of jobs to work or processing centers. Operations managers assign jobs to work centers so that costs, idle time, or completion times are kept to a minimum. Loading work centers takes two forms. One is oriented to capacity; the second is related to assigning specific jobs to work centers.

First, we examine loading from the perspective of capacity via a technique known as input output control. Then, we present two approaches used for loading: Gantt charts and the assignment method of linear programming.

3.3.1 Input-Output Control

Many firms have difficulty scheduling (that is, achieving effective throughput) because they overload the production processes. This often occurs because they do not know actual performance in the work centers. Effective scheduling depends on matching the schedule to performance. Lack of knowledge about capacity and performance causes reduced throughput.

Input-output control is a technique that allows operations personnel to manage facility work flows. If the work is arriving faster than it is being processed, the facility is overloaded, and a backlog develops. Overloading causes crowding in the facility leading to inefficiencies and quality problems. If the work is arriving at a slower rate than jobs are being performed, the facility is underloaded, and the work center may run out of work. Underloading the facility results in idle capacity and wasted resources.

Input-output control can be maintained by a system of ConWIP cards, which control the amount of work in a work center. ConWIP is an acronym for constant work-in-process. The ConWIP card travels with a job (or batch) through the work center. When the job is finished, the card is released and returned to the initial workstation, authorizing the entry of a new batch into the work center. The Con WIP card effectively limits the amount of work in the work center, controls lead time, and monitors the backlog.

The options available to operations personnel to manage facility work flow include the following:

1. Correcting performances.
2. Increasing' capacity.
3. Increasing or reducing input to the work center by (a) routing work to or from other work centers, (b) increasing or decreasing subcontracting, (c) producing less (or producing more).

Producing less is not a popular solution, but the advantages can be substantial. First, customer service level may improve because units may be produced on time. Second, efficiency may actually improve because there is less work in process cluttering the work center and adding to overhead costs. Third, quality may improve because less work in process hides fewer problems.

3.3.2 Gantt Charts

Gantt charts are visual aids that are useful in loading and scheduling. The name is derived from Henry Gantt, who developed them in the late 1800s. The charts show the use of resources, such as work centers and labor.

When used in loading, Gantt charts show the loading and idle times of several departments, machines, or facilities. They display the relative workloads in the system so that the manager knows what adjustments are appropriate. For example, when one work center becomes overloaded, employees from a low-load center can be transferred temporarily to increase the workforce. Or if waiting jobs can be processed at different work centers, some jobs at high-load centers can be transferred to low-load centers. Versatile equipment may also be transferred among centers.

The Gantt load chart has a major limitation: It does not account for production variability such as unexpected breakdowns or human errors that require reworking a job. Consequently, the chart must also be updated regularly to account for new jobs and revised time estimates.

A Gantt schedule chart is used to monitor jobs in progress.4 It indicates which jobs are on schedule and which are ahead of or behind schedule. In practice, many versions of the chart are found.

3.3.3 Assignment Method

The assignment method involves assigning tasks or jobs to resources. Examples include assigning jobs to machines, contracts to bidders, people to projects, and salespeople to territories. The objective is most often to minimize total costs or time required to perform the tasks at hand. One important characteristic of assignment problems is that only one job (or worker) is assigned to one machine (or project).

Each assignment problem uses a table. The numbers in the table will be the costs or times associated with each particular assignment. For example, if First Printing and Copy Center has three available typesetters (A, B, and C) and three new jobs to be completed, its table might appear as follows. The dollar entries represent the firm's estimate of what it will cost for each job to be completed by each typesetter.

The assignment method involves adding and subtracting appropriate numbers in the table to find the lowest opportunity cost for each assignment. There are four steps to follow:

1. Subtract the smallest number in each row from every number in that row and then, from the resulting matrix, subtract the smallest number in each column from every number in that column. This step has the effect of reducing the numbers in the table until a series of zeros, meaning zero opportunity costs, appear. Even though the numbers change, this reduced problem is equivalent to the original one, and the same solution will be optimal.

2. Draw the minimum number of vertical and horizontal straight lines necessary to cover all zeros in the table. If the number of lines equals either the number of rows or the number of columns in the table, then we can make an optimal assignment (see step 4). If the number of lines is less than the number of rows or columns, we proceed to step 3.

3. Subtract the smallest number not covered by a line from every other uncovered number. Add the same number to any number(s) lying at the intersection of any two lines. Do not change the value of the numbers that are covered by only one line. Return to step 2 and continue until an optimal assignment is possible.

4. Optimal assignments will always be at zero locations in the table. One systematic way of making a valid assignment is first to select a row or column that contains only one zero square. We can make an assignment to that square and then draw lines through its row and column. From the uncovered rows and columns, we choose another row or column in which there is only one zero square. We make that assignment and continue the procedure until we have assigned each person or machine to one task.

Some assignment problem entail maximizing profit, effectiveness, or payoff of an assignment of people to tasks or of jobs to machines. It is easy to obtain an equivalent minimization problem by converting every number in the table to an opportunity loss. To convert maximizing problem to an equivalent minimization problem, we subtract every number in the original payoff table from the largest single number in that table. We then proceed to step I of the four-step assignment method. It turns out that minimizing the opportunity loss produces the same assignment solution as the original maximization problem.

3.4 Sequencing Jobs

Scheduling provides a basis for assigning jobs to work centers. Loading is a capacity-control technique that highlights overloads and underloads. Sequencing (also referred to as dispatching) specifies the order in which jobs should be done at each center. For example, suppose that 10 patients are assigned to a medical clinic for treatment. In what order should they be treated? Should the first patient to be served, be the one who arrived first or the one who needs emergency treatment? Sequencing methods provide such detailed information. These methods are referred to as priority rules for sequencing or dispatching jobs to work centers.

3.4.1 Priority Rules for Dispatching Jobs

Priority rules provide guidelines for the sequence in which jobs should be worked. The rules are especially applicable for process-focused facilities such as clinics, print shops, and manufacturing job shops. We will examine a few of the most popular priority rules. Priority rules try to minimize completion time, number of jobs in the system, and job lateness while maximizing facility utilization.

The most popular priority rules are

- FCFS: first come, first served. The first job to arrive at a work center is processed first.
- SPT: shortest processing time. The shortest jobs are handled first and completed.
- EDD: earliest due date. The job with the earliest due date is selected first.
- LPT: longest processing time. The longer, bigger jobs are often very important and are selected first.

SPT is superior in three measures and EDD in the fourth (average lateness). This is typically true in the real world also. We find that no one sequencing rule always excels on all criteria. Experience indicates the following:

1. Shortest processing time is generally the best technique for minimizing job flow and minimizing the average number of jobs in the system. Its chief disadvantage is that long-duration jobs may be continuously pushed back in priority in favor of short-duration jobs. Customers may view this dimly, and a periodic adjustment for longer jobs must be made.

2. First come, first served does not -score well on most criteria (but neither does it score particularly poorly). It has the advantage, however, of appearing fair to customers, which is important in service systems.

3. Earliest due date minimizes maximum tardiness, which may be necessary for jobs that have a very heavy penalty after a certain date. In general, EDD works well when lateness is an issue

3.4.2 Critical Ratio

Another type of sequencing rule is the critical ratio. The critical ratio (CR) is an index number computed by dividing the time remaining until due date by the work time remaining. As opposed to the priority rules, critical ratio is dynamic and easily updated. It tends to perform better than FCFS, PT, EDD, or LPT on the average job-lateness criterion.

The critical ratio gives priority to jobs that must be done to keep shipping on schedule. A job with a low critical ratio (less than 1.0) is one that is falling behind schedule. If CR is exactly .0, the job is on schedule. A CR greater than 1.0 means the job is ahead of schedule and has some slack.

The formula for critical ratio is

$$\frac{\text{Time remaining}}{\text{Workdays remaining}} = \frac{\text{Due date - Today's date}}{\text{Work (lead) time remaining}}$$

In most production scheduling systems, the critical-ratio rule can help do the following:

1. Determine the status of a specific job.
2. Establish relative priority among jobs on a common basis.
3. Relate both stock and make-to-order jobs on a common basis.
4. Adjust priorities (and revise schedules) automatically for changes in both demand and job progress.
5. Dynamically track job progress.

3.4.3 Sequencing N Jobs on Two Machines: Johnson's Rule

The next step in complexity is the case in which N jobs (where N is 2 or more) must go through two different machines or work centers in the same order. This is called the N/2 problem Johnson's rule can be used to minimize the processing time for sequencing a group of jobs through two work centers. It also minimizes total idle time on the machines. Johnson's rule involves four steps:

1. All jobs are to be listed, and the time that each requires on a machine is to be shown.
2. Select the job with the shortest activity time. If the shortest time lies with the first machine the job is scheduled first. If the shortest time lies with the second machine, schedule the job last. Ties in activity times can be broken arbitrarily.
3. Once a job is scheduled, eliminate it.
4. Apply steps 2 and 3 to the remaining jobs, working toward the center of the sequence.

3.4.4 Limitations of Rule-Based Dispatching System

The scheduling techniques just discussed are rule-based techniques, but rule-based systems have a number of limitations. Among these are the following:

1. Scheduling is dynamic; therefore, rules need to be revised to adjust to changes in orders, process, equipment, product mix, and so forth.
2. Rules do not look upstream or downstream; idle resources and bottleneck resources in other department may not be recognized.
3. Rules do not look beyond due dates. For instance, two orders may have the same due date. One order involves restocking a distributor and the other is a custom order that will shut down the customer's factory if not completed. Both may have the same due date, but clearly the custom order is more important.

Despite these limitations. schedulers often use sequencing rules such as SPT. EDD. or critical ratio. They apply these methods at each work center and then modify the sequence to deal with a multitude of real-world variables. They may do this manually or with finite capacity scheduling software.

3.5 Finite Capacity Scheduling

Short-term scheduling is increasingly called finite capacity scheduling? Finite capacity scheduling (FCS) overcomes the disadvantages of systems based exclusively on rules by providing the scheduler with interactive computing and graphic output. In dynamic scheduling environments such as job shops (with a high variety. low volume. and shared resources) we expect changes: but changes disrupt schedules. Therefore operations managers are moving toward FCS systems that allow virtually instantaneous change by the operator. Finite capacity schedules allow the scheduler to make schedule changes based on up-to-the-minute information. These schedules are often displayed in Gantt chart form. In addition to including priority rule options many of the current FCS systems also combine an "expert system" or simulation techniques and allow the scheduler to assign costs to various options. The scheduler has the flexibility to handle any situation, including order, Labor, or machine changes.

The initial data for finite scheduling systems is often the output from an MRP system. The output from MRP systems is traditionally in weekly "buckets" that have no capacity constraint. These systems just tell the planner when the material is needed, ignoring the capacity issue. Because infinite-size buckets are unrealistic and inadequate for detail scheduling, MRP data require refinement. MRP output is combined with routing files due dates, capacity of work centers. Tooling, and other resource availability to provide the data needed for an effective FCS. These are the same data needed in any manual system, but FCS software formalizes them, speeds analysis, and makes changes easier.

Finite capacity scheduling allows delivery needs to be balanced against efficiency, not according to some predefined rule, and based on today's conditions and today's orders. The scheduler determines what constitutes a "good" schedule.

3.6 Theory of Constraints

Throughput, an important concept in operations, is the number of units processed through the facility and sold. Throughput is a critical difference between the successful and the unsuccessful enterprise. This has led to a focus on constraints, which has been popularized by the book The Goal: A Process of Ongoing Improvement by Eliyahu Goldratt and Jeff Cox. The theory of constraints (TOC) is a body of knowledge that deals with anything that limits an organization's ability to achieve its goals. Constraints can be physical (such as process or personnel availability, raw materials, or supplies) or nonphysical (such as procedures, morale, and training). Recognizing and managing these limitations through a five-step process is the basis of the theory of constraints:

Step 1: Identify the constraints
Step 2: Develop a plan for overcoming the identified constraints.
Step 3: Focus resources on accomplishing step 2
Step 4: Reduce the effects of the constraints by off-loading work or by expanding capability. Make sure that the constraints are recognized by all those who can have impact on them
Step 5: Once one set of constraints is overcome, go back to step I and identify new constraints

3.6.1 Bottlenecks

Bottleneck work centers are constraints that limit the output of production. Bottlenecks have less capacity than the preceding or following work centers. They constrain throughput. Bottlenecks are a common occurrence because even well-designed systems are seldom balanced for very long. Changing products, product mixes, and volumes often create multiple and shifting bottlenecks. Consequently, bottleneck work centers occur in nearly all process-focused facilities, from hospitals and restaurants to factories. Successful operations managers deal with bottlenecks by ensuring that the bottleneck stays busy, increasing the bottleneck's capacity, rerouting work, changing lot size, changing work sequence, or accepting idleness at other workstations.

Several techniques for dealing with the bottleneck are:

- Increasing capacity of the constraint. This may require a capital investment or more people and may take a while to implement.
- Ensuring that well-trained and cross-trained employees are available to ensure full operation and maintenance of the work center causing the constraint.
- Developing alternative routings, processing procedures, or subcontractors.
- Moving inspections and tests to a position just before the bottleneck. This approach has the advantage of rejecting any potential defects before they enter the bottleneck.
- Scheduling throughput to match the capacity of the bottleneck. This may mean scheduling less work at the work centers supplying the bottleneck.

3.6.2 Drum, Buffer, Rope

Drum, buffer, rope is another idea from the theory of constraints. In this context, the drum is the beat of the system. It provides the schedule-the pace of production. The buffer is the resource, usually inventory, necessary to keep the constraint(s) operating at capacity. And the rope provides the synchronization necessary to pull the units through the system. The rope can be thought of as kanban signals.

3.7 Scheduling Repetitive Facilities

The scheduling goals defined at the beginning of this chapter are also appropriate for repetitive production. You may recall from Chapter 7 that repetitive producers make standard products from modules. Repetitive producers want to satisfy customer demands, lower inventory investment, reduce the batch (or lot) size, and utilize equipment and processes. The way to move toward these goals is to move to a level-material-use schedule. Level material use means frequent, high-quality, small lot sizes that contribute to just-in-time production. This is exactly what world-class producers such as Harley-Davidson and John Deere do. The advantages of level material use are:

1. Lower inventory levels, which releases capital for other uses.
2. Faster product throughput (that is, shorter lead times).
3. Improved component quality and hence improved product quality.
4. Reduced floor-space requirements.
5. Improved communication among employees because they are closer together (which can result in improved teamwork and esprit de corps).
6. Smoother production process because large lots have not "hidden" the problems.

Suppose a repetitive producer runs large monthly batches: With a level-material-use schedule, management would move toward shortening this monthly cycle to a weekly, daily, or even hourly cycle.

One way to develop a level-material-use schedule is to first determine the minimum lot size that will keep the production process moving. This is illustrated in the next chapter, "Just-in-Time and Lean Production Systems.

3.8 Scheduling Services

Scheduling service systems differs from scheduling manufacturing systems in several ways:

In manufacturing, the scheduling emphasis is on machines and materials; in services, it is on staffing levels.

Inventories can help smooth demand for manufacturers, but many service systems do not maintain inventories.

Services are labour-intensive and the demand for this labour can be highly variable.

Legal considerations, such as wage and hour laws and union contracts that limit hours worked per shift, week, or month, constrain scheduling decisions.

Because services usually schedule people rather than material, behavioral, social, seniority and status issues are more important and can complicate scheduling.

3.8.1 Scheduling Service Employees with Cyclical Scheduling

A number of techniques and algorithms exist for scheduling service-sector employees such as police officers, nurses, restaurant staff, tellers, and retail sales clerks. Managers, trying to set a timely and efficient schedule that keeps personnel happy, can spend substantial time each month developing employee schedules. Such schedules often consider a fairly long planning period (say, 6 weeks). One approach that is both workable yet simple is cyclical scheduling.

Cyclical Scheduling: Cyclical scheduling with inconsistent staffing needs is often the case in services such as restaurants and police work. Here the objective focuses on developing a schedule with the minimum number of workers. In these cases, each employee is assigned to a shift and has time off.

SELF ASSESSMENT EXERCISE

1. What is the overall objective of scheduling?
2. List the four criteria for determining the effectiveness of a scheduling decision. How do these criteria relate to the four criteria for sequencing decisions?

4.0 CONCLUSION

Scheduling involves the timing of operations to achieve the efficient movement of units through a system. This chapter addressed the issues of short-term scheduling in process-focused, repetitive, and service environments. We saw that process-focused facilities are production systems in which products are made to order and that scheduling tasks in them can become complex. Several aspects and approaches to scheduling, assignment methods of scheduling to a series of priority rules, the critical-ratio loading, and sequencing of jobs were introduced. These ranged from Gantt charts and the rule, Johnson's rule for sequencing, and finite capacity scheduling. We also examined the theory of constraints and the concept of bottlenecks.

5.0 SUMMARY

Service systems generally differ from manufacturing systems. This leads to the use of appointment systems; first-come, first-served systems; and reservation systems, as well as to heuristics and linear programming approaches for matching capacity to demand in service environments

6.0 TUTOR-MARKED ASSIGNMENT

1. Name five priority sequencing rules. Explain how each works to assign jobs.
2. What are the advantages and disadvantages of the shortest processing time (SPT) rule?

7.0 REFERENCES/FURTHER READINGS

Goetsch, David L. and Davies, Stanley B. (2006). Quality Management, New Jersey: Pearson Education Inc.

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Adeola A. Kupoluyi, Question and Answer on Operation and Quality *Management.*

UNIT 7 JUST-IN-TIME AND LEAN PRODUCTION SYSTEM

CONTENTS

1.0 INTRODUCTION

Just-in-time is a philosophy of continuous and forced problem solving that supports lean production. Lean production supplies the customer with exactly what the customer wants when the customer wants it, without waste, through continuous improvement. Lean production is driven by the "pull" of the customer's order. JIT is a key ingredient of lean production. When implemented as a comprehensive manufacturing strategy, JIT and lean production sustain competitive advantage and result in greater overall returns.

With JIT, supplies and components are "pulled" through a system to arrive where they are needed when they are needed. When good units do not arrive just as needed, a "problem" has been identified. This makes JIT an excellent tool to help operations managers add value by driving out waste and unwanted variability. Because there is no excess inventory or excess time in a JIT system, costs associated with unneeded inventory are eliminated and throughput improved. Consequently, the benefits of JIT are particularly helpful in supporting strategies of rapid response and low cost.

2.0 OBJECTIVES

At the end of this unit, you will be able to

Identify and Define:

- Variability
- Kanban
- 5S System
- Seven Wastes

Describe or Explain

- Just-in-time philosophy
- Pull Systems

• Push Systems
• The goals of JIT Partnerships
• Lean Production
• Principles of Toyota Production System.

3.0 MAIN CONTENT

3.1 Just-in-Time and Lean Production System

Suppliers

Incoming material is often delayed at the shipper, in transit, at receiving departments, and at incoming inspection. Similarly, finished goods are often stored or held at warehouses prior to shipment to distributors or customers. Because holding inventory is wasteful, JIT partnerships are directed toward reducing such waste.

JIT partnerships exist when supplier and purchaser work together with a mutual goal of removing waste and driving down costs. Such relationships are critical of successful JIT. Every moment material is held, some process that adds value should be occurring. To ensure this is the case, Xerox, like other leading organizations, views the supplier as an extension of its own organization. Because of this view, the Xerox staff expects suppliers to be as fully committed to improvement as Xerox. This relationship requires a high degree of openness by both supplier and purchaser.

3.1.1 Goals of JIT Partnerships

The four goals of JIT partnerships are:

1. Elimination of unnecessary activities. With good suppliers, for instance, receiving activity and incoming-inspection activity are unnecessary under JIT.

2. Elimination of in-plant inventory. JIT delivers materials where and when needed. Raw material inventory is necessary only if there is reason to believe that suppliers are unde pendable. Likewise, parts or components should be delivered in small lots directly to the using department as needed.

3. Elimination of in-transit inventory. General Motors once estimated that at any given time, over half its inventory is in-transit. Modern

purchasing departments are now addressing in-transit inventory reduction by encouraging suppliers and prospective suppliers to locate near manufacturing plants and provide frequent small shipments. The shorter the flow of material in the resource pipeline, the less inventory. Inventory can also be reduced by a technique known as consignment. Consignment inventory a variation of vendor-managed inventory means the supplier maintains the title to the inventory until it is used. For instance, an assembly plant may find a hardware supplier that is willing to locate its warehouse where the user currently has its stockroom. Thus, when hardware is needed, it is no farther than the stockroom, and the supplier can ship to other, perhaps smaller, purchasers from the "stockroom."

4. Elimination of poor suppliers. When a firm reduces the number of suppliers, it increases long-term commitments. To obtain improved quality and reliability, vendors and purchasers have mutual understanding and trust. Achieving deliveries only when needed and in the exact quantities needed also requires perfect quality-or as it is also known, zero defects. Of course, both the supplier and the delivery system must be excellent.

3.1.2 Concerns of Suppliers

To establish JIT partnerships, several supplier concerns must be addressed. The supplier concerns include.

Desire for diversification: Many suppliers do not want to tie themselves to long-term contracts with one customer. The suppliers' perception is that they reduce their risk if they have a variety of customers.

Poor customer scheduling: Many suppliers have little faith in the purchaser's ability to reduce orders to a smooth, coordinated schedule.

Engineering changes: Frequent engineering changes, with inadequate lead time for suppliers to carry out tooling and process changes, play havoc with JIT.

Quality assurance: Production with zero defects is not considered realistic by many suppliers. Small lot sizes. Suppliers often have processes designed for large lot sizes and see frequent delivery to the customer in small lots as a way to transfer holding costs to suppliers.

Proximity: Depending on the customer's location, frequent supplier delivery of small lots may be seen as economically prohibitive.

For those who remain skeptical of JIT partnerships, we would point out that virtually every restaurant in the world practices JIT, and with little staff support. Many restaurants order food for the next day in the middle of the night for delivery the next morning. They are ordering just what is needed for delivery when it is needed, from reliable suppliers.

3.2 JIT Layout

JIT layouts reduce another kind of waste-movement. The movement of material on a factory floor (or paper in an office) does not add value. Consequently, we want flexible layouts that reduce the movement of both people and material. JIT layouts move material directly to the location where needed. For instance, an assembly line should be designed with delivery points next to the line so material need not be delivered first to a receiving department elsewhere in the plant, then moved again.

3.3 Inventory

Inventories in production and distribution systems often exist "just in case" something goes wrong. That is, they are used just in case some variation from the production plan occurs. The "extra" inventory is then used to cover variations or problems. Effective inventory tactics require "just in time," not "just in case." Just-in-time inventory is the minimum inventory necessary to keep a perfect system running. With just-in-time inventory, the exact amount of goods arrives at the moment it is needed, not a minute before or a minute after.

3.3.1 Reduce Variability

The idea behind JIT is to eliminate inventory that hides variability in the production system.

3.3.2 Reduce Inventory

Operations managers move toward JIT by first removing inventory. With reduced inventory, management chips away at the exposed problems until the lake is clear. After the lake is clear, managers make additional cuts in inventory and continue to chip away at the next level of exposed problems. Ultimately, there will be virtually no inventory and no problems (variability).

3.3.3 Reduce Lot Sizes

Just-in-time has also come to mean elimination of waste by reducing investment in inventory. The key to JIT is producing good product in small lot sizes. Reducing the size of batches can be a major help in reducing inventory and inventory costs.

Ideally, in a JIT environment, order size is one and single units are being pulled from one adjacent process to another. More realistically, analysis of the process, transportation time, and containers used for transport are considered when determining lot size. Such analysis typically results in a small lot size but a lot size larger than one. Once a lot size has been determined, the EOQ production order quantity model can be modified to determine the desired setup time.

3.3.4 Reduce Setup Costs

Both inventory and the cost of holding it go down as the inventory-reorder quantity and the maximum inventory level drop. However, because inventory requires incurring an ordering or setup cost that must be applied to the units produced, managers tend to purchase (or produce) large orders. With large orders, each unit purchased or ordered absorbs only a small part of the setup cost. Consequently, the way to drive down lot sizes and reduce average inventory is to reduce setup cost, which in turn lowers the optimum order size.

Moreover, smaller lot sizes hide fewer problems. In many environments, setup cost is highly correlated with setup time. In a manufacturing facility, setups usually require a substantial amount of preparation. Much of the preparation required by a setup can be done prior to shutting down the machine or process. For instance, in Kodak's Guadalajara, Mexico, plant a team reduced the setup time to change a bearing from 12 hours to 6 minutes. This is the kind of progress that is typical of world-class manufacturers.

Just as setup costs can be reduced at a machine in a factory, setup time can also be reduced during the process of getting the order ready. It does little good to drive down factory setup time from hours to minutes if orders are going to take 2 weeks to process or "set up" in the office. This is exactly what happens in organizations that forget that JIT concepts have applications in offices as well as in the factory. Reducing setup time (and cost) is an excellent way to reduce inventory investment and to improve productivity.

Figure 1: Steps for Reducing Setup Times

3.4 Scheduling

Effective schedules, communicated both within the organization and to outside suppliers, support JIT. Better scheduling also improves the ability to meet customer orders, drives down inventory by allowing smaller lot sizes, and reduces work-in-process. For instance, Ford Motor Company now ties some suppliers to its final assembly schedule. Ford communicates its schedules to bumper manufacturer Polycon Industries from the Ford Oakville production control system. The scheduling system describes the style and color of the bumper needed for each vehicle moving down the final assembly line. The scheduling system transmits the information to portable terminals carried by Polycon warehouse personnel who load the bumpers onto conveyors leading to the loading dock. The bumpers are then trucked 50 miles to the Ford plant. Total time is 4 hours.

3.4.1 Level Schedules

Level schedules process frequent small batches rather than a few large batches. Because this technique schedules many small lots that are always changing, it has on occasion been called "jelly bean" scheduling. The operations manager's task is to make and move small lots so the level schedule is economical. This requires success with the'" issues discussed in this chapter that allow small lots. As lots get smaller, the constraints may change and become increasingly challenging. At some point, processing a unit or two may not be feasible. The constraint may be the way units are sold and shipped (four to a carton), or an expensive paint changeover (on an automobile assembly line), or the proper number pf units in a sterilizer (for a food-canning line).

The scheduler may find that freezing the portion of the schedule closest to due dates allows the production system to function and the schedule to be met. Freezing means not allowing changes to be part of the schedule. Operations managers expect the schedule to be achieved with no deviations from the schedule.

3.4.2 Kanban

One way to achieve small lot sizes is to move inventory through the shop only as needed rather than pushing it on to the next workstation whether or not the personnel there are ready for it. As noted earlier, when inventory is moved only as needed, it is referred to as a pull system, and the ideal lot size is one. The Japanese call this system kanban. Kanbans allow arrivals at a work center to match (or nearly match) the processing time.

Kanban is a Japanese word for card. In their effort to reduce inventory, the Japanese use systems that "pull" inventory through work centers. They often use a "card" to signal the need for another container of material-hence the name kanban. The card is the authorization for the next container of material to be produced. Typically, a kanban signal exists for each container of items to be obtained. An order for the container is then initiated by each kanban and “pulled” from the producing department or supplier. A sequence of kanbans "pulls" the material through the plant.

The system has been modified in many facilities so that even though it is called a kanban, the card itself does not exist. In some cases, an empty position on the floor is sufficient indication that the next container is needed. In other cases, some sort of signal, such as a flag or rag alerts that it is time for the next container.
When there is visual contact between producer and user, the process works like this:

1. The user removes a standard-size container of parts from a small storage area.
2. The signal at the storage area is seen by the producing department as authorization to replenish the using department or storage area. Because there is an optimum lot size, the producing department may make several containers at a time.

This system is similar to the resupply that occurs in your neighborhood supermarket: The customer buys; the stock clerk observes the shelf or receives notice from the end-of-day sales list and restocks. When the limited supply, if any, in the store's storage is depleted, a "pull" signal is sent to the warehouse, distributor, or manufacturer for resupply, usually that night. The complicating factor in a manufacturing firm is the need for the actual manufacturing (production) to take place.

Several additional points regarding kanbans may be helpful:

- When the producer and user are not in visual contact, a card can be used; otherwise, a light or flag or empty spot on the floor may be adequate.
- Because a pull station may require several resupply components, several kanban pull techniques can be used for different products at the same pull station
- Usually, each card controls a specific quantity or parts, although multiple card systems are used if the producing work cell produces several components or if the lot size is different from the move size.
- In an MRP system the schedule can be thought of as a "build" authorization and the kanban as a type of "pull" system that initiates the actual production.
- The kanban cards provide a direct control (limit) on the amount of work-in-process between cells.
- If there is an immediate storage area, a two-card system may be used-one card circulates between user and storage area, and the other circulates between the storage area and the producing area .

Determining the Number of Kanban Cards or Containers: The number of kanban cards, or containers, in a JIT system sets the amount of authorized inventory. To determine the number of containers moving back and forth between the using area and the producing areas, management first sets the size of each container. This is done by computing the lot size, using a model such as the production order quantity mode.

Setting the number of containers involves knowing (1) lead time needed to produce a container of parts and (2) the amount of safety stock needed to account for variability or uncertainty in the system. The number of kanban cards is computed as follows:

$$\text{Number of kanbans (containers)} = \frac{\text{Demand during lead time + Safety stock}}{\text{Size of container}}$$

Example 2 illustrates how to calculate the number of kanbans needed

Hobbs Bakery produces short runs of cakes that are shipped to grocery stores. The owner, Ken Hobbs, wants to try to reduce inventory by changing to a kanban system. He has developed the following data and asked you to finish the project by telling him the number of kanbans (containers) needed.

Daily demand = 500 cakes
Production lead time = Wait time + Material handling time + Processing time
= 2 days
Safety stock = ½ day
Container size (determined on a production order size EOQ basis) = 250 cakes

Solution

Demand during lead time (= Lead time x Daily demand = 2 days x 500 cakes =) 1,000

Safety stock = 250

Number of kanbans. (containers) needed =

$$\frac{\text{Demand during lead time + Safety stock}}{\text{Container size}} = \frac{1{,}000 + 250}{250} = 5$$

Advantages of Kanban Containers are typically very small, usually a matter of a few hours' worth of production. Such a system requires tight schedules. Small quantities must be produced several times a day. The process must run smoothly with little variability in quality of lead time because any shortage has an almost immediate impact on the entire system. Kanban places added emphasis on meeting schedules, reducing the time and cost required by setups, and economical material handling.

Whether it is called kanban or something else, the advantages of small inventory and pulling material through the plant only when needed are significant. For instance, small batches allow only a very limited amount of faulty or delayed material. Problems are immediately evident. Numerous aspects of inventory are bad; only one aspect-availability-is good. Among the bad aspects are poor quality, obsolescence, damage, occupied space, committed assets, increased insurance, increased material handling, and increased accidents. Kanban systems put downward pressure on all these negative aspects of inventory.

In-plant kanban systems often use standardized, re-usable containers that protect the specific quantities to be moved. Such containers are also desirable in the supply chain. Standardized containers reduce weight and disposal costs, generate less wasted space in trailers, and require less labor to pack, unpack, and prepare items.

3.5 Quality

The relationship between JIT and quality is a strong one. They are related in three ways. First, JIT cuts the cost of obtaining good quality.
This saving occurs because scrap, rework, inventory investment, and

damage costs are buried in inventory. JIT forces down inventory; therefore, fewer bad units are produced and fewer units must be reworked. In short, whereas inventory hides bad quality, JIT immediately exposes it.

Second, JIT improves quality. As JIT shrinks queues and lead time, it keeps evidence of errors fresh and limits the number of potential sources of error. In effect, JIT creates an early warning system for quality problems so that fewer bad units are produced and feedback is immediate. This advantage can accrue both within the firm and with goods received from outside vendors.

Finally, better quality means fewer buffers are needed and, therefore, a better, easier-to-employ JIT system can exist. Often the purpose of keeping inventory is to protect against unreliable quality.

If consistent quality exists, JIT allows firms to reduce all costs associated with inventory.

3.6 Employee Empowerment

Whereas some JIT techniques require policy and strategy decisions, many are part of the purview of empowered employees. Empowered employees can bring their involvement to bear on most of the daily operations issues that are so much a part of a just-in-time philosophy. This means that those tasks that have traditionally been assigned to staff can move to empowered employees.

Employee empowerment follows the management adage that no one knows the job better than those who do it. Firms need to not only train and cross train but also take full advantage of that investment by enriching jobs. Aided by aggressive cross training and few job classifications, firms can engage the mental as well as physical capacities of employees in the challenging task of improving the workplace.

JIT's philosophy of continuous improvement gives employees the opportunity to enrich their jobs and their lives. When empowerment is managed successfully, companies gain from mutual commitment and respect on the part of both employees and management.

3.7 Lean Production

Lean production can be thought of as the end result of a well-run OM function. The major difference between JIT and lean production is that JIT is a philosophy of continuing improvement with an internal focus, while lean production begins externally with a focus on the customer. Understanding what the customer wants and ensuring customer input and feedback are starting points for lean production. Lean production means identifying customer value by analyzing all of the activities required to produce the product, and then optimizing the entire process from the view of the customer. The manager finds what creates value for the customer and what does not. Lean production is sometimes called the Toyota Production System (TPS), with Toyota Motor Company's Eiji Toyoda and Taiichi Ohno given credit for its approach and innovations. There are four underlying principles to TPS:

- Work shall be completely specified as to content, sequence, timing, and outcome.
- Every customer-supplier connection, both internal and external, must be direct and specify personnel, methods, timing, and quantity of goods or services provided.
- Product and service flows must be simple and direct-goods and services are directed to a specific person or machine.
- Any improvement in the system must be made in accordance with the "scientific method," at the lowest possible level in the organization.

The Toyota Production System require that activities, connections, and flow paths have built-in tests to signal problems automatically. Any gap between what is expected and what occurs becomes immediately evident. It is the education and training of Toyota's employees and the responsiveness of the system to problems that makes the seemingly rigid system so flexible and adaptable to changing circumstances. The result is ongoing improvements in reliability, flexibility, safety, and efficiency: These lead to increases in market share and profitability.
If there is any distinction between JIT, lean production, and TPS it is that JIT emphasizes continuous improvement, lean production emphasizes understanding the customer, and TPS emphasizes employee learning and empowerment in an assembly line environment. In practice, there is little difference, and the terms are often used interchangeably.

3.7.1 Building a Lean Organization

The transition to lean production is difficult. Building an organizational culture where learning and continuous improvement are the norm is a challenge. However, we find that organizations that focus on JIT, quality, and employee empowerment are often lean producers. Such firms drive out activities that do not add value in the eyes of the customer: They include leaders like Toyota, United Parcel Service, and Dell Computer.

These lean producers adopt a philosophy of minimizing waste by striving for perfection through continuous learning, creativity, and teamwork. Success requires the full commitment and involvement of all employees and of the company's suppliers. The rewards reaped by lean producers are spectacular. Lean producers often become benchmark performers. They share the following attributes:

- Use just-in-time techniques to eliminate virtually all inventory
- Build systems that help employees produce a perfect part every time.
- Reduce space requirements by minimizing the distance a part travels.
- Develop close relationships with suppliers, helping them to understand their needs and their customers' needs.
- Educate suppliers to accept responsibility for helping meet customer needs.
- Eliminate all but value-added activities. Material handling, inspection, inventory, and rework jobs are among the likely targets because these do not add value to the product.
- Develop the workforce by constantly improving job design, training, employee participation and commitment, and teamwork.
- Make jobs more challenging, pushing responsibility to the lowest level possible.
- Reduce the number of job classes and build worker flexibility.

3.7.2 5Ss

Since the early days of the 20th century, managers focused on "housekeeping" and all that it entails for a neat, orderly, and efficient workplace. In recent years operations managers have embellished "housekeeping" to include a checklist-now known as the 5Ss. The Japanese developed the initial 5Ss. Not only are the 5Ss a good checklist for lean operations but they also provide an easy vehicle with which to assist the culture change that is often necessary to bring about lean operations. The 5Ss follow:

- Sort/segregate-keep what is needed and remove everything else from the work area; when in doubt, throw it out. Identify nonvalue items and remove them. Getting rid of these items makes space available and usually improves workflow.
- Simplify/straighten-arrange and use methods analysis tools to improve work flow and reduce wasted motion. Consider long-run and short-run ergonomic issues. Label and display for easy use only what is needed in the immediate work area. For examples of visual displays
- Shine/sweep-dean daily; eliminate all forms of dirt, contamination, and clutter from the work area.

- Standardize-remove variations from the process by developing standard operating procedures and checklists; good standards make the abnormal obvious. Standardize equipment and tooling so that cross-training time and cost are reduced. Train and retrain the work team so when deviations occur they are readily apparent to all.
- Sustain/self-discipline-review periodically to recognize efforts and to motivate to sustain progress. Use visuals wherever possible to communicate and sustain progress.

U.S. managers often add two additional Ss that contribute to establishing and maintaining a lean workplace.

- Safety-build good safety practices into the above 5 activities.
- Support/maintenance-reduce variability, unplanned downtime, and costs. Integrate daily shine tasks with preventive maintenance.

The Ss provide a vehicle for continuous improvement with which all employees can identify. Operations managers need think only of the examples set by a well-run hospital emergency room or the spit and polish of a fire department for a benchmark. Offices and retail stores, as well as manufacturers, have also successfully used the 5Ss in their respective efforts to move to lean operations.

3.7.3 Seven Wastes

Traditional producers have limited goals-accepting, for instance, the production of some defective parts and inventory. Lean producers set their sights on perfection: no bad parts, no inventory, only value-added activities, and no waste. Taiichi Ohno, noted for his work on the Toyota Production System, identified seven categories of waste. These categories have become popular in lean organizations and cover many of the ways organizations waste or lose money. The customer defines the value of the product. If production performs an activity that does not add value in the eyes of the customer, then it is a waste. If the customer does not want it or will not pay for it, it is a waste. Ohno's seven wastes are:

Overproduction - producing more than the customer orders or producing early (before it is demanded) is waste. Inventory of any kind is usually a waste.

Queues - idle time, storage, and waiting are wastes (they add no value).

Transportation - moving material between plants, between work centers, and handling more than once is waste.

Inventory - unnecessary raw material, work-in-process (WIP), finished goods, and excess operating supplies add no value.

Motion-movement of equipment or people that adds no value is waste.

Overprocessing - work performed on the product that adds no value is waste.

Defective product-returns, warranty claims, rework, and scrap are a waste.

A broader perspective-one that goes beyond immediate production-suggests that other resources, such as energy, water, and air. are often wasted, but should not be. Efficient, ethical, socially responsible production minimizes inputs and maximizes outputs, wasting nothing.

SELF ASSESSMENT EXERCISE

1. What is JIT?
2. What is a "Lean Producer"?

4.0 CONCLUSION

JIT and lean production are philosophies of continuous improvement. Lean production begins with a focus on customer desires, but both concepts focus on driving all waste out of the production process. Because waste is found in anything that does not add value, JIT and lean organizations are adding value more efficiently than other firms.

5.0 SUMMARY

Waste occurs when defects are produced within the production process or by outside suppliers. JIT and lean production attack wasted space because of a less-than-optimal layout; they attack wasted time because of poor scheduling; they attack waste in idle inventory; they attack waste from poorly maintained machinery and equipment. The expectation is that committed, empowered employees work with committed management and suppliers to build systems that respond to customers with ever lower cost and higher

6.0 TUTOR-MARKED ASSIGNMENT

1. What are three ways in which JIT and quality are related?
2. How does JIT contribute to competitive advantage?

7.0 REFERENCES/FURTHER READINGS

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UNIT 8 MAINTENANCE AND RELIABILITY

CONTENTS

7.0 References /Further Readings

1.0 INTRODUCTION

A good maintenance and reliability strategy protects both a firm's performance and its investment.

The objective of maintenance and reliability is to maintain the capability of the system while controlling costs. Good maintenance drives out system variability. Systems must be designed and maintained to reach expected performance and quality standards. Maintenance includes all activities involved in keeping a system's equipment in working order. Reliability is the probability that a machine part or product will function properly for a specified time under stated conditions.

2.0 OBJECTIVES

At the end of this unit, you will be able to

Identify and Define:

- Maintenance
- Mean time between failures
- Redundancy
- Preventive maintenance
- Breakdown maintenance
- Infant mortality

Describe or Explain

- How to measure system reliability
- How to improve maintenance
- How to evaluate maintenance performance.

3.1 The Strategic Importance of Maintenance and Reliability

The interdependency of operator, machine, and mechanic is a hallmark of successful maintenance and reliability.

In this unit, we examine four important tactics for improving the reliability and maintenance not only of products and equipment but also of the systems that produce them. The four tactics are organized around reliability and maintenance.

The reliability tactics are:

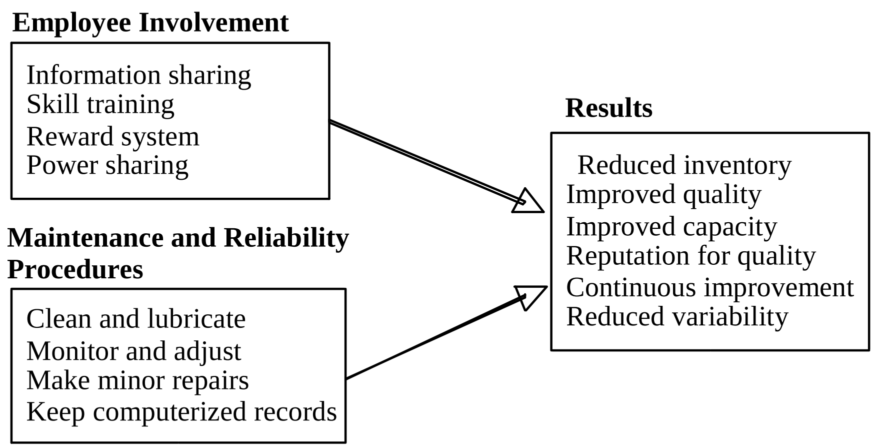
1. Improving individual components.

2. Providing redundancy.

The maintenance tactics are:

1. Implementing or improving preventive maintenance.
2. Increasing repair capabilities or speed.

Figure 1: Good Maintenance and Reliability Strategy Requires Employee Involvement and Good Procedures



Variability corrupts processes and creates waste. The operations manager must drive out variability:

Designing for reliability and managing for maintenance are crucial ingredients for doing so

3.2 Reliability

Systems are composed of a series of individual interrelated components, each performing a specific job. If anyone component fails to perform, for whatever reason, the overall system (for example, an airplane or machine) can fail

3.2.1 Improving Individual Components

Because failures do occur in the real world, understanding their occurrence is an important reliability concept. We now examine the impact of failure in a series. Figure 2 shows that as the number of components in a series increases, the reliability of the whole system declines very quickly. A system of n = 50 interacting parts, each of which has a 99.5% reliability, has an overall reliability of 78%. If the system or machine has 100 interacting parts, each with an individual reliability of 99.5%, the overall reliability will be only about 60%.

To measure reliability in a system in which each individual part or component may have its own unique rate of reliability, we cannot use the reliability curve in Figure 17.2. However, the method of computing system reliability (Rs) is simple. It consists of finding the product of individual reliabilities as follows:

$$R_s = R_1 \times R_2 \times R_3 \times \ldots \times R_n$$

where R_1 = reliability of component 1
R_2 = reliability of component 2
an so on

Equation (17-1) assumes that the reliability of an individual component does not depend on the reliability of other components (that is, each component is independent). Additionally, in this equation as in most reliability discussions, reliabilities are presented as probabilities, Thus, a .90 reliability means that the unit will perform as intended 90% of the time. It also means that it will fail I - .90 = .10 = 10% of the time. We can use this method to evaluate the reliability of a service or a product, such as the one we examine .in Example 1.

Figure 2: Overall System Reliability as a Function of Number of Components and Component Reliability with Components in a Series

Example 1: Reliability in a series

The National Bank of Greeley, Colorado, processes loan applications through three clerks set up in series:

If the clerks have reliabilities of .90, .80, .99, then the reliability of the loan process is

$$R_S = R_1 \times R_2 \times R_3 = (.90)(.80)(.99) = .713, \text{ or } 71.3\%$$

Component reliability is often a design or specification issue for which engineering design personnel may be responsible. However, supply-chain personnel may be able to improve components of systems by staying abreast of suppliers' products and research efforts. Supply-chain personnel can also contribute directly to the evaluation of supplier performance.

The basic unit of measure for reliability is the product failure rate (FR). Firms producing high technology equipment often provide failure-rate data on their products. As shown in Equations (17-2) and (17-3), the failure rate measures the percent of failures among the total number of products tested, FR(%), or a number of failures during a period of time, FR(N):

$$FR(\%) = \frac{\text{Number of failures}}{\text{Number of units tested}} \times 100\%$$

$$FR(N) = \frac{\text{Number of failures}}{\text{Number of unit-hours of operating time}}$$

Perhaps the most common term in reliability analysis is the mean time between failures (MTBF), which is the reciprocal of FR(N):

$$MTBF = \frac{1}{FR(N)}$$

In Example 2, we compute the percentage of failure FR(%), number of failures FR(N), and mean time between failures (MTBF).

Twenty air-conditioning systems designed for use by astronauts in NASA space shuttles were operated for 1,000 hours at NASA's Huntsville, Alabama, test facility. Two of the systems failed during the test – one after 200 hours and the other after 600 hours. To compute the percentage of failures, we use the following equation:

$$FR(\%) = \frac{Number\ of\ failures}{Number\ of\ units\ tested} = \frac{2}{20}(100\%) = 10\%$$

Next we compute the number of failures per operating hour:

$$FR(N) = \frac{Number\ of\ failures}{Operating\ time}$$

Where

Total time = (1,000hrs)(20 units)
= 20,000 unit-hour
Non-operating time = 800hr for 1s t failure + 400hr for 2nd failure
= 1,200 unit-hour
Operating time = Total time – Non-operating time

$$FR(N) = \frac{2}{20{,}000 - 1{,}200} = \frac{2}{18{,}800}$$

= .000106 failure/unit-hour

And because $MTBF = \frac{1}{FR(N)}$

$$MTBF = \frac{1}{.000106} = 9{,}434hr$$

If the typical space shuttle trip lasts 60 days, NASA may be interested in the failure rate per trip:

Failure rate = (failures/unit-hr)(24hr/day)(60 days/trip)
= (.000106)(24)(600)
= .153 failure/trip.

Because the failure rate recorded in Example 2 is probably too high, NASA will have to either increase the reliability of individual components, and thus of the system, or else install several backup air-conditioning units on each space shuttle. Backup units provide redundancy.

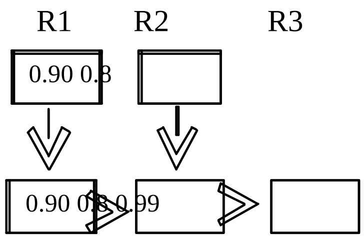
3.2.2 Providing Redundancy

To increase the reliability of systems, redundancy is added. The technique here is to "back up" components with additional components. This is known as putting units in parallel and is a standard operations management tactic. Redundancy is provided to ensure that if one component fails, the system has recourse to another. For instance, say that reliability of a component is .80 and we back it up with another component with reliability of .80. The resulting reliability is the probability of the first component working plus the probability of the backup (or parallel) component working multiplied by the probability of needing the backup component (1 - .8 = .2). Therefore:

Probability of first Probability of second Probability of

Example 3 shows how redundancy can improve the reliability of the loan process presented in Example 1.

The National Bank is disturbed that its loan-application process has a reliability of only .713 (see Example 1). Therefore, the bank decides to provide redundancy for the two least reliable clerks. This procedure results in the following system:



$$= [.9 + .9(1 - .9)] \times [.8 + .8(1 - .8)] \times .99$$
$$= [.9 + (.9)(.1)] \times [.8 + (.8)(.2)] \times .99$$
$$= .99 \times .96 \times .99 = .94$$

3.3 Maintenance

There are two types of maintenance: preventive maintenance and breakdown maintenance. Preventive maintenance involves performing routine inspections and servicing and keeping facilities in good repair. These activities are intended to build a system that will find potential failures and make changes or repairs that will prevent failure. Preventive maintenance is much more than just keeping machinery and equipment running. It also involves designing technical and human systems that will keep the productive process working within tolerance; it allows the system to perform. The emphasis of preventive maintenance is on understanding the process and keeping it working without interruption. Breakdown maintenance occurs when equipment fails and must be repaired on an emergency or priority basis.

3.3.1 Implementing Preventive Maintenance

Preventive maintenance implies that we can determine when a system needs service or will need repair. Therefore, to perform preventive maintenance, we must know when a system requires service or when it is likely to fail. Failures occur at different rates during the life of a product. A high initial failure rate, known as infant mortality, may exist for many products.' This is why many electronic firms "burn in" their products prior to shipment: That is to say, they execute a variety of tests (such as a full wash cycle at Maytag) to detect "start-up" problems prior to shipment. Firms may also provide 90-day warranties. We should note that many infant mortality failures are not product failures per se, but rather failure due to improper use. This fact points up the importance in many industries of operations management's building an after-sales service system that includes installing and training.

Once the product, machine, or process "settles in," a study can be made of the MTBF (mean time between failure) distribution. Such distributions often follow a normal curve. When these distributions exhibit small standard deviations, then we know we have a candidate for preventive maintenance, even if the maintenance is expensive.

Once our firm has a candidate for preventive maintenance, we want to determine when preventive maintenance is economical. Typically, the more expensive the maintenance, the narrower must be the MTBF distribution (that is, have a small standard deviation). Additionally, if the process is no more expensive to repair when it breaks down than the cost of preventive maintenance, perhaps we should let the process break down and then do the repair. However, the consequence of the breakdown must be fully considered. Even some relatively minor breakdowns have catastrophic consequences. At the other extreme, preventive maintenance costs may be so incidental that preventive maintenance is appropriate even if the MTBF distribution is rather flat (that is, it has a large standard deviation). In any event, consistent with job enrichment practices machine operators must be held responsible for preventive maintenance of their own equipment and tools.
With good reporting techniques, firms can maintain records of individual processes, machines, or equipment. Such records can provide a profile of both the kinds of maintenance required and the timing of maintenance needed. Maintaining equipment history is an important part of a preventive maintenance system, as is a record of the time and cost to make the repair. Such records can also contribute to similar information about the family of equipment as well as suppliers.

Record keeping is of such importance that most good maintenance systems are now computerized.

Allocating more resources to preventive maintenance will reduce the number of breakdowns. At some point, however, the decrease in breakdown maintenance costs may be less than the increase in preventive maintenance costs. At this point, the total cost curve begins to rise. Beyond this optimal point, the firm will be better off waiting for breakdowns to occur and repairing them when they do.

Unfortunately, cost curves seldom consider the full costs of a breakdown. Many costs are ignored because they are not directly related to the immediate breakdown. For instance, the cost of inventory maintained to compensate for downtime is not typically considered. Moreover, downtime can have a devastating effect on morale: Employees may begin to believe that performance to standards and maintaining equipment are not important. Finally, downtime adversely affects delivery schedules, destroying customer relations and future sales.

Assuming that all potential costs associated with downtime have been identified, the operations staff can compute the optimal level of maintenance activity on a theoretical basis. Such analysis, of course, also requires accurate historical data on maintenance costs, breakdown probabilities, and repair times. Example 4 shows how to compare preventive and breakdown maintenance costs to select the least expensive maintenance policy.

Through variations of the technique shown in Example 4, operations managers can examine maintenance policies.

Farlen & Halikman is a CPA firm specializing in payroll preparation. The firm has been successful in automating much of its work, using high-speed printers for check processing and report preparation. The computerized approach, however, has problems. Over the past 20 months, the printers have broken down at the rate indicated in the following table:

Num ber of Breakdowns	**Num ber of Months that Breakdowns Occurred**
0	2
1	8
2	6
3	4
	Total: 20

Each time the printers break down, Farlen & Halikman estimates that it loses an average of ₦300 in time and service expenses. One alternative is to purchase a service contract for preventive maintenance. Even if Farlen & Halikman contracts for preventive maintenance, there will still be breakdowns, averaging one breakdown per month. The price for this service is 150 per month. To decide whether the CPA firm should contract for preventive maintenance, we follow a 4-step approach:

Step 1: Computer the expected number of breakdowns (based on past history) if the firm continues as is, without the service contract.

Step 2: Compute the expected breakdown cost per month with no preventive maintenance contract.

Step 3: Compute the cost of preventive maintenance

Step 4: Compare the two options and select the one that will cost less.

1.

Number of Breakdowns	Frequency	Number of Breakdowns	Frequency
0	2/20 = .1	2	6/20 = 0.3
1	8/20 = .4	3	4/20 = 0.2

$$\textit{Expected number of breakdowns} = \sum \left[\textit{Number of breakdowns} \times \textit{Corresponding frequency} \right]$$

$= (0)(.1) + (1)(4) + (2)(.3) + (3)(.2)$

$= 0 + .4 + .6 + .6$

$= 1.6$ breakdowns/month

2. Expected breakdown cost = $\begin{pmatrix}\text{Expected number}\\\text{of breakdowns}\end{pmatrix} \times \begin{pmatrix}\text{Cost per}\\\text{breakdown}\end{pmatrix}$

= (1.6)(₦300)

= ₦480/month

3. $\begin{pmatrix}\text{Preventive}\\\text{maintenance cost}\end{pmatrix} = \begin{pmatrix}\text{Cost of expected}\\\text{breakdowns if service}\\\text{contract signed}\end{pmatrix} + \begin{pmatrix}\text{Cost of}\\\text{service contract}\end{pmatrix}$

= (1 breakdown/month)($300) + N150/month

= N450/month

4. Because it is less expensive overall to hire a maintenance service firm (₦450) than to not do so (480), Farlen & Halikman should hire the service firm.

3.3.2 Increasing Repair Capabilities

Because reliability and preventive maintenance are seldom perfect, most firms opt for some level of repair capability. Enlarging or improving repair facilities can get the system back in operation faster. A good maintenance facility should have these six features:

1. Well-trained personnel
2. Adequate resources
3. Ability to establish a repair plan and priorities
4. Ability and authority to do material planning
5. Ability to identify the cause of breakdowns
6. Ability to design ways to extend MTBF

However, not all repairs can be done in the firm's facility. Managers must, therefore, decide where repairs are to be performed. Consistent with the advantages of employee empowerment, a strong case can be made for employees' maintaining their own equipment. This approach, however, may also be the weakest link in the repair chain because not every employee can be trained in all aspects of equipment repair.

However, preventive maintenance policies and techniques must include an emphasis on employees accepting responsibility for the maintenance they are capable of doing. Employee maintenance may be only of the "clean, check, and observe" variety, but if each operator performs those activities within his or her capability, the manager has made a step toward both employee empowerment

3.4 Total Productive Maintenance

Many firms have moved to bring total quality management concepts to the practice of preventive maintenance with an approach known as total productive maintenance (TPM). It involves the concept of reducing variability through employee involvement and excellent maintenance records. In addition, total productive maintenance includes:

•Designing machines that are reliable, easy to operate, and easy to maintain.
•Emphasizing total cost of ownership when purchasing machines, so that service and maintenance are included in the cost.
•Developing preventive maintenance plans that utilize the best practices of operators, maintenance departments, and depot service.
•Training workers to operate and maintain their own machines.
•High utilization of facilities, tight scheduling, low inventory, and consistent quality demand reliability. Total productive maintenance is the key to reducing variability and improving reliability.

3.5 Techniques for Establishing Maintenance Policies

Two other OM techniques have proven beneficial to effective maintenance: simulation and expert systems.

Simulation Because of the complexity of some maintenance decisions, computer simulation is a good tool for evaluating the impact of various policies. For instance, operations personnel can decide whether to add more staff by determining the trade-offs between machine downtime costs and the costs of additional labor. Management can also simulate the replacement of parts that have not yet failed as a way of preventing future breakdowns. Simulation via physical models can also be useful. For example, a physical model can vibrate an airplane to simulate thousands of hours of flight time to evaluate maintenance needs.

Expert Systems OM managers use expert systems (that is, computer programs that mimic human logic) to assist staff in isolating and repairing various faults in machinery and equipment.

SELF ASSESSMENT EXERCISE

1. What is the objective of maintenance and reliability?
2. How does one identify a candidate for preventive maintenance?

4.0 CONCLUSION

Operations managers focus on design improvements and backup components to improve reliability. Reliability improvements also can be obtained through the use of preventive maintenance and excellent repair facilities

Some firms use automated sensors and other controls to warn when production machinery is about to fail or is becoming damaged by heat, vibration, or fluid leaks. The goal of such procedures is not only to avoid failures but also to perform preventive maintenance before machines are damaged.

5.0 SUMMARY

Finally, many firms give employees a sense of "ownership" of their equipment. When workers repair or do preventive maintenance on their own machines, breakdowns are less common. Well-trained and empowered employees ensure reliable systems through preventive maintenance. In turn, reliable, well-maintained equipment not only provides higher utilization but also improves quality and performance to schedule. Top firms build and maintain systems so that customers can count on products and services that are produced to specifications and on time

6.0 TUTOR-MARKED ASSIGNMENT

1. The semiconductor used in the Sullivan Wrist Calculator has five parts, each of which has its own reliability rate. Component I has a reliability of .90; component 2, .95; component 3, .98; component 4, .90; and component 5, .99. What is the reliability of one semiconductor?

2. Explain the notion of “infant mortality” in the context of product reliability.

7.0 REFERENCES/FURTHER READINGS

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