NATIONAL OPEN UNIVERSITY OF NIGERIA

BUS 801

Operations Management

Module 2

BUS 801 Operations Management Module 2

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Module 2

Unit 1 Management of Technology

1.0 Introduction

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

2.0 Objectives

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

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

3.0 Main Content

3.1 The Meaning and Role of Technology

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

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

You need to understand that technologies don't occur in a vacuum, rather, they are embedded in support networks. A support network comprises the physical, informational, and organisational relationships that make a technology complete and allow it to function as intended. Using our air travel technology example, its support network will include the infrastructure of airports, baggage handling facilities, travel agencies, air traffic control operations, and the communication systems connecting them.

3.1.1 The Three Primary Aspects of Technology

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

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

3.1.1.1 Product Technology

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

3.1.1.2 Process Technology

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

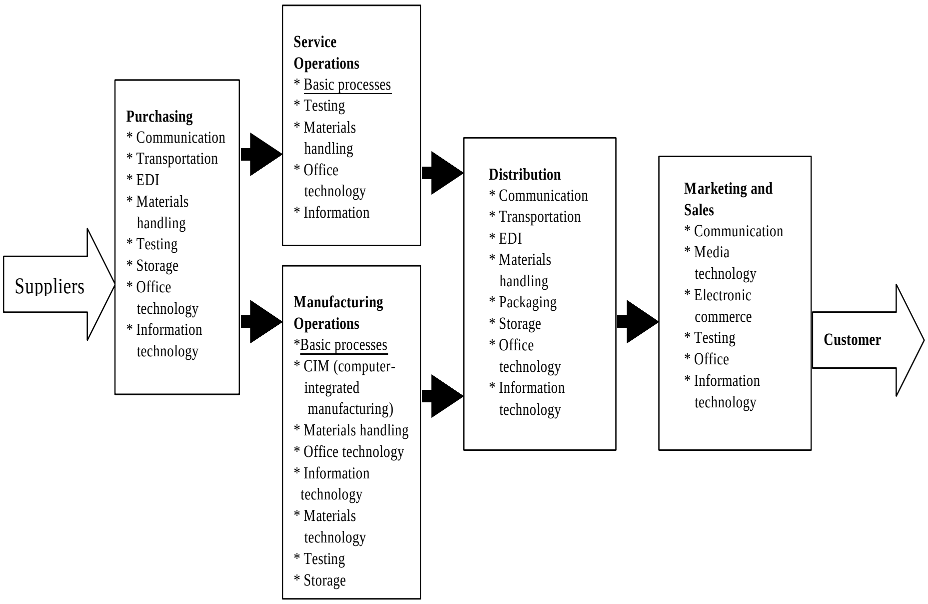

Figure 6.1: Process Technologies

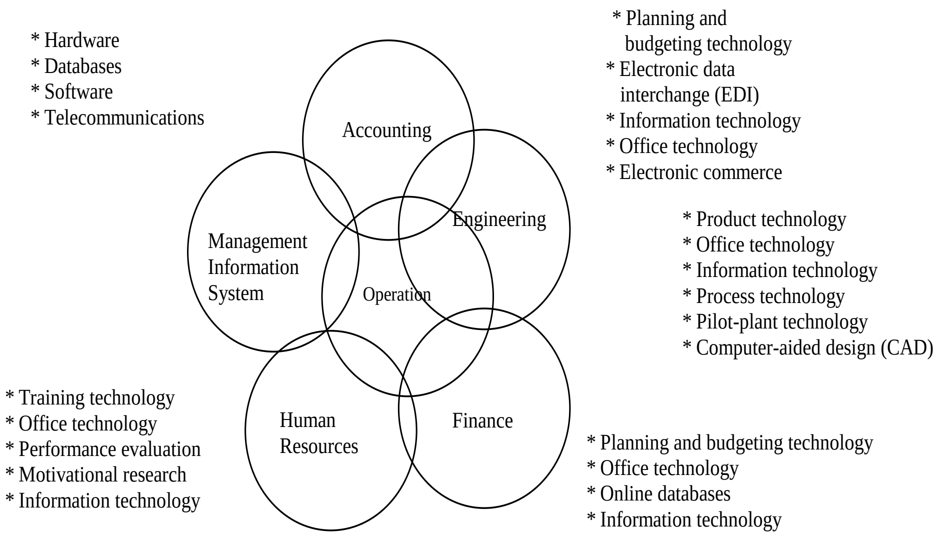

Figure 6.2: Process Technologies - Technologies for other functional areas

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

3.1.1.3 Information Technology

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

3.1.2 Management of Technology

Management of Technology, links R & D, engineering, and management to plan, develop and implement new technological capabilities that can accomplish corporate and operations strategies. This in essence, means identifying technological possibilities that should be pursued through R & D, choosing from both internal and external sources the technologies to implement, and then following through their successful implementation as products, processes, and services.

There is quite a large array of technologies, and yet managers need to be knowledgeable about the technologies used in their operations. What in fact, does a manager need to know about technology? There are two sides to this question. One is that the manager just needs to understand what a technology can do, including its costs and performance possibilities. The second is that such understanding is not enough. Rather, the effective manager must also understand how the technology works and what goes on in the technology “black box”. The better answer is that managers must invest the time to learn more about these technologies, and at the same time develop good sources of technical advice within the organisation.

3.1.3 The Role of Technology in Business Performance

In this modern time, technology is about the most important force during the increase in global competition. It also plays a pivotal role in creating new products and improving processes. It has been shown by many empirical studies that firms that invest in, and apply new technologies often tend to have stronger financial positions than those that think otherwise.

A study by Steele (1988) on large U.S. firms showed that, as the investment in R & D for technology increases, so does profitability and new product introductions. Another study by Roth (1996) of over 1,300 manufacturers in Europe, Japan, and North America focused more on process technologies, and reported a strong relationship between financial performance and technological innovation. The benefits of the application of technology to business are not limited to large firms. For example, small firms that have more technical know-how and use computer based information and manufacturing technologies more intensively enjoy stronger competitive positions (Lefebvre, Harrey, and Lefenbvre, 1992).

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

3.2 Information Technology

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

3.2.1 Components of Information Technology

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

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

3.2.1.1 Hardware

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

3.2.1.2 Software

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

3.2.1.3 Databases

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

3.2.1.4 Telecommunications

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

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

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

3.3 Creating and Applying Technology

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

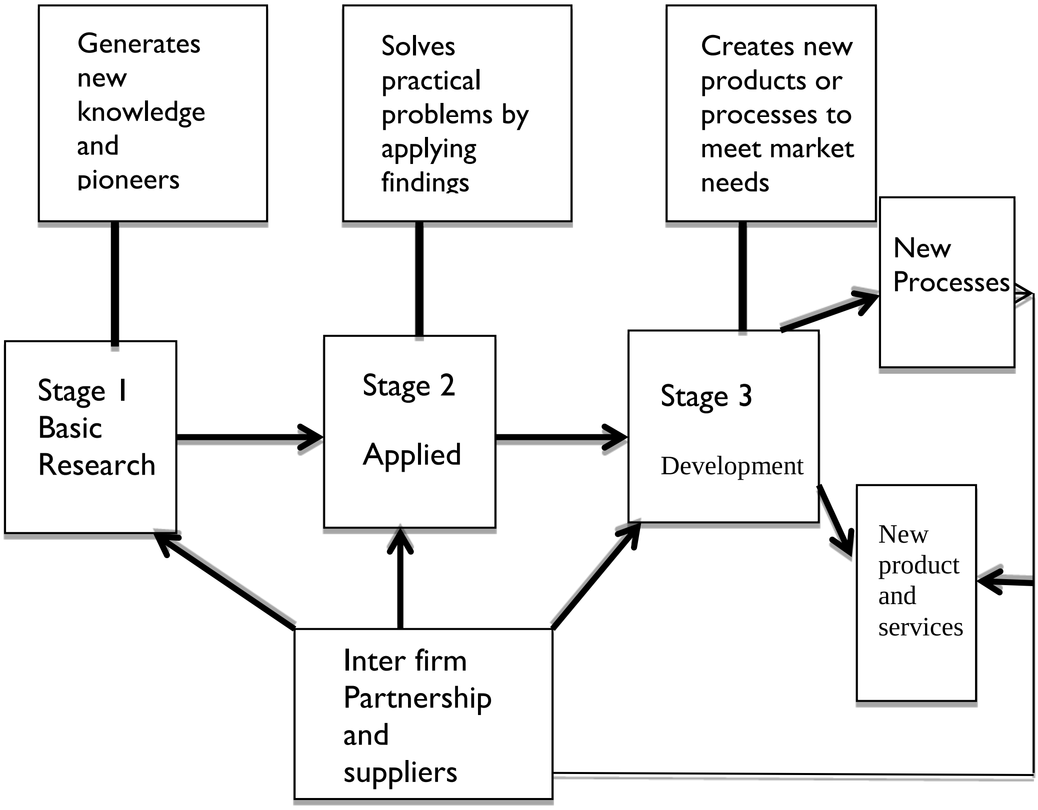

Figure 6.2: Research and Development Stages

3.3.1 Research and Development (R & D) Stages

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

3.3.1.1 Basic Research

A study that explores the potential of narrowly defined technological possibilities, and attempting to generate new knowledge and pioneer technological advances is called *basic research*. It seeks fundamental truths, such as the knowledge that ultimately made space ships possible. It is generally non-directive research that is not targeted for a particular product or process. Basic research is usually science based, as with computer and biotechnology. This is however, not always the case. Successes may come from an inventive mind or a flash of genius. Since basic research is often capital-intensive, it is performed in laboratories owned by government agencies, or some large firms, and universities.

3.3.1.2 Applied Research

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

3.3.1.3 Development

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

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

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

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

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

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

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

3.4 Choosing Technologies

Operations managers need to make intelligent, informed decisions about new product and process technologies now, more than ever before. This is because of the rapid rate at which technology is changing, coupled with the numerous technologies available all over the place, whether choices that are eventually made are bound to have effects on both human, as well as technical aspects of operations.

Consequently, we shall attempt to examine how technologies should be chosen and how these choices link with strategy to create a competitive advantage. It is necessary to stress at this point that, an appropriate technology is one that fits corporate and operations strategies and gives the firm a sustainable advantage. In addition, several tests of a potential technological change should be made. For instance, if the change being considered fails these tests, it should never be pursued even if it represents an impressive technological accomplishment.

3.4.1 Assessing the Technologies

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

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

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

(i) Increase in sales and/or customer satisfaction.

(ii) Improvement in quality.

(iii) Quicker delivery times through reductions in processing times.

(iv) Improvement in inventory control.

(v) Reduction in costs.

(vi) Improvement on the environment.

(vii) Improvement in product design.

(viii) Increase in production.

(ix) Increase in product variety.

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

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

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

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

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

Another strategic consideration deals with when to launch a new technology. Very often, being the first to market with a new technology offers a firm many advantages that may actually outweigh the financial investment needed. In the first place, technological leaders define the competitive rules that others will follow with regard to a new product or process. Secondly, a "first-mover" may be able to gain a large market share early, and this can create an entry barrier for other firms. Even if competitors are able to match the new technology, the first mover's initial advantage in the market can endure. Thirdly, being the first can give a firm the reputation that emulators will find difficult to overcome. Fourthly, a first-mover strategy may lead to a least temporary advantage with suppliers of outside materials and services over those of its late-comer competitors. Finally, technological leadership might also allow the firm to get patents that discourage imitation.

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

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

(i) sources of competitive advantages;

(ii) fit with competitive priorities;

(iii) existence of core competencies; and

(iv) first-mover strategy.

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

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

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

3.5 Implementation Guidelines for New Technologies

Apart from making the right choice, managing technology also means supporting the particular technology selected throughout its implementation. In actual fact, job satisfaction and positive employee attitudes can be sustained only if technological change is managed well. To this end, some useful implementation guidelines have been developed, and these relate to technology acquisition, technology integration, the human side, and leadership. It is necessary to examine each of these areas in the guidelines.

3.5.1 Technology Acquisition

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

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

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

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

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

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

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

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

3.5.2 Technology Integration

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

3.5.3 Technology and Human Resources

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

3.5.4 Leadership

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

It must also be mentioned that when new technologies are being developed or implemented, the operations manager should raise a team, made up of representatives of all relevant departments. This team should then be made to lead and coordinate the work. The head of the team (a project champion) should be someone who promotes the project at every opportunity and who naturally has contagious enthusiasm.

4.0 Conclusion

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

Self-Assessment Exercise

1. How do you understand the term technology?

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

3. IT comprises computing and telecommunications technologies. Explain its basic partitions.

5.0 Summary

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

6.0 Self-Assessment Exercise

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

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Unit 2 Site Selection

1.0 Introduction

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

2.0 Objectives

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

- understand the meaning of site selection
- understand the factors that need to be considered before site-selection decisions are made
- know the interrelationships among relevant factors of site selection
- use quantitative methods to decide on site-selection.

3.0 Main Content

3.1 Definition of Site Selection

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

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

Domestic Example

1. Lever Brothers, based in Lagos, Nigeria selects to have another branch in Gbongan, a town in Ayedaade Local Government Area of Osun State, Nigeria.
2. Eleganza (Nig) Plc, based in Lagos selects to have a distribution centre in Osu, Atakumosa L.G.A., Osun State, Nigeria.

International Examples

Lever Brothers, based in Lagos Nigeria decides to have a distribution centre in Detroit, Michigan, USA

Eleganza (Nig) Plc, based in Lagos, Nigeria selects to have a new plant in Watford, north of London, Great Britain.

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

3.2 Factors in Site Selection

3.2.1 Staffing

This includes the availability of all the types of personnel needed to run a facility, direct and indirect operating personnel and management. Labour cost is an essential criterion that should be considered under staffing. It helps to explain why many companies based elsewhere have built facilities away from their own countries. The reason might not be unconnected with the fact that labour costs enter directly into the cost of manufactured products or the cost of rendering a service. The cost includes basic salary, wages as well as all social and other charges paid to the employee or paid to government by employer in the form of taxes.

Social laws with the accompanied social charges affect labour flexibility and cover areas such as basic work week, overtime permitted, weekend working living and termination laws. This is very important in deciding where a company should be located.

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

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

Productivity of labour should also accompany the availability of labour. Productivity (absolute) is measured as the output divided by the input of resources. For example, companies tend to locate in South Korea and Hong Kong because of their high labour productivity.

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

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

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

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

3.2.2 Inherent Local Condition

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

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

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

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

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

3.2.3 Infrastructure

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

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

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

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

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

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

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

3.2.4 Construction

Construction costs can reduce the profitability of the facility.

Land cost is often high where land is scarce and this could be of limiting factor in sitting a company Europe, for example is considered high relative to many other regions.

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

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

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

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

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

3.2.5 Factors Affecting Cash Flows

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

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

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

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

3.2.6 Financial Aid

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

3.2.7 Proximity of Resources

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

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

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

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

3.2.8 Quantitative Approaches to Site Selection

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

Weighting the Selection Criteria

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

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

c. Assign a weighting factor F to all the site criteria according to their importance in the selection. The total weighting will be equal to unity.

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

e. Multiply the weighting factor by the numerical score, F x S for each site and for each criterion.

f. Sum the total F x S

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

Example

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

Table 7.1: Weighting factors and scores for each site

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

Total 10.00

Production facility

1. Based on the data provided, determine the preferred location for the construction of this new production facility?

2. What can you say about the sensitivity of using this approach for site selection?

Solution

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

Table 7.2:

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

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

Break-even analysis

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

a. Determine the fixed and variable costs for each site

b. If a site has a variable cost higher than another site but a lower fixed cost then there will be a break-even point. There will be no break-even point if both the fixed costs and variable costs are higher than the corresponding costs at another location.

c. determine the production level expected from each site

d. the preferred site will be that which has the lowest total cost.

Example

Table 7.3:

Fixed costs, □/year	Akure	Ibadan	Osogbo
Salaries/management/staff	3,400,000	2.700,000	3,200,000
Depreciation	750,000	600,000	400,000
Insurance	250,000	225,000	210,000
Energy costs	310,000	275,000	290,000
Taxes	100,000	90,000	80,000
Total	**4,810,000**	**3,890,000**	**4,180,000**
Variable cost, □/unit			
Raw materials	21.50	25.96	24.75
Labour	12.50	11.30	11.10
Packing	1.30	2.05	1.50
Transportation	0.30	1.10	0.95
Total	**35.60**	**40.35**	**38.30**

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

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

Solution

Break-even point is

Total costs = fixed costs + variable cost x production level

The first step is to determine if there will be break-even points comparing their fixed and variable costs with one another shows that there will be:

Total cost for Akure

$TC_A = FC_A + Q_A \times VC_d$

And for Ibadan

$TC_I = FC_I + Q_I \times VC_I$

The break-even point is when the total costs are equal for the two sites at some production level Q or

$FC_A + Q_A \times VC_A = FC_I + Q_I \times VC_I$

making Q, the subject of the formula .

Similar relationships hold between Akure and Osogbo and between Ibadan and Osogbo.

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

Table7.4:

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

The equal break-even units are in bold prints.

Uncertainty and risk

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

Probabilities

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

Examples

Nestle Nig. (Plc), based in Nigeria, manufactures and distributes Nescafe. As a result of an expected increase in demand for its product, the company is considering four possibilities or capacity expansion.

Table7.5 gives estimates of the profits from each facility in the four possible locations: Kano, Kaduna, Sokoto, Lagos; for over five years estimation period.

Table 7.5: Estimates of the profits from each facility in Naira

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

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

a. If management is pessimistic in its approach

b. Using the concept of minimax regret

Solution

Table7.6:

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

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

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

1. Using the concept of minimax regret

Minimax regret matrix is shown in Table7.7 which is determined for each column. Each cell value is obtained by finding the difference between the maximum outcome in that column and the possible outcome of the cell.

Table 7.7:

Kano	4,040,00	0	575,000	11,150,000	11,150,000
Kaduna	0	3,750,000	1,429,000	18,825,000	18,825,000
Sokoto	20,016,500	14,000,000	1,740,000	12,820,000	20,016,500
Lagos	18,890	13,750,000	0	0	18,890,000

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

Centre of Gravity

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

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

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

$$Xc = \frac{\square XQi}{\square Qi} \quad \text{and} \quad Yc = \frac{\square YiQi}{\square Qi}$$

Where,

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

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

4.0 Conclusion

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

5.0 Summary

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

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

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

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

6.0 Self-Assessment Exercise

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

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

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

7.0 References/Further Reading

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Unit 3 Supply Chain Management

1.0 Introduction

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

2.0 Objectives

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

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

3.0 Main Content

3.1 An Overview of Supply – Chain Management

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

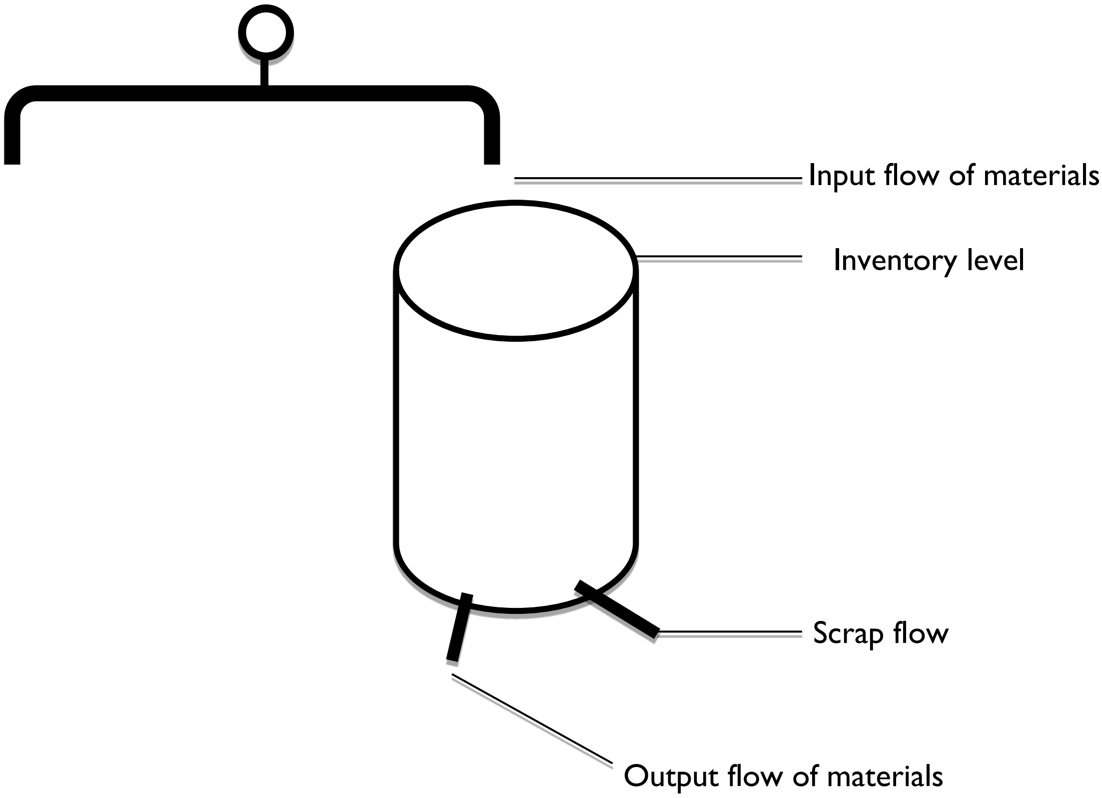


Figure 8.1: Creation of Inventory

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

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

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

Organisation (such as governments, churches, manufacturers, wholesalers, retails and universities) in almost all segments of an economy are becoming more conscious of the need to manage the flow of materials. Manufacturers make products from materials and services they purchased from outside suppliers. Service provides too, use materials in the form of physically items purchased from suppliers. The values of these materials that are purchased from outside sources often represent substantial portions of the total income eared by business organisations. Hence, firms can reap large profits with a small percentage reduction in the cost of materials. This is perhaps one of the reasons why supply-chain management is becoming a key competitive weapon.

3.1.1 Materials Management

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

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

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

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

Granted that the organisational structure and management hierarchy can help integrate decisions and activities in materials management, a lot of cross – functional coordination is still required. Let us use an example to buttress this important point: the marketing department typically makes forecasts and processes incoming customer orders. The production control department uses this information to organise work-force schedule and set work priorities. Simultaneously the marketing department needs to know the current schedule and production capability when processing incoming orders for the purposes of making realistic delivery promises. Immediately purchased materials have been received or furnished goods shipped, the accounting department must necessarily follow through with payments or billing. In order to achieve better cross functional coordination, organisations may have to push responsibilities lower in the organisation; group traditional functions around each major product or service; or create inter-functional coordination units. It has also been suggested that information systems and the reward system maybe used to facilitates coordination across the functional boundaries.

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

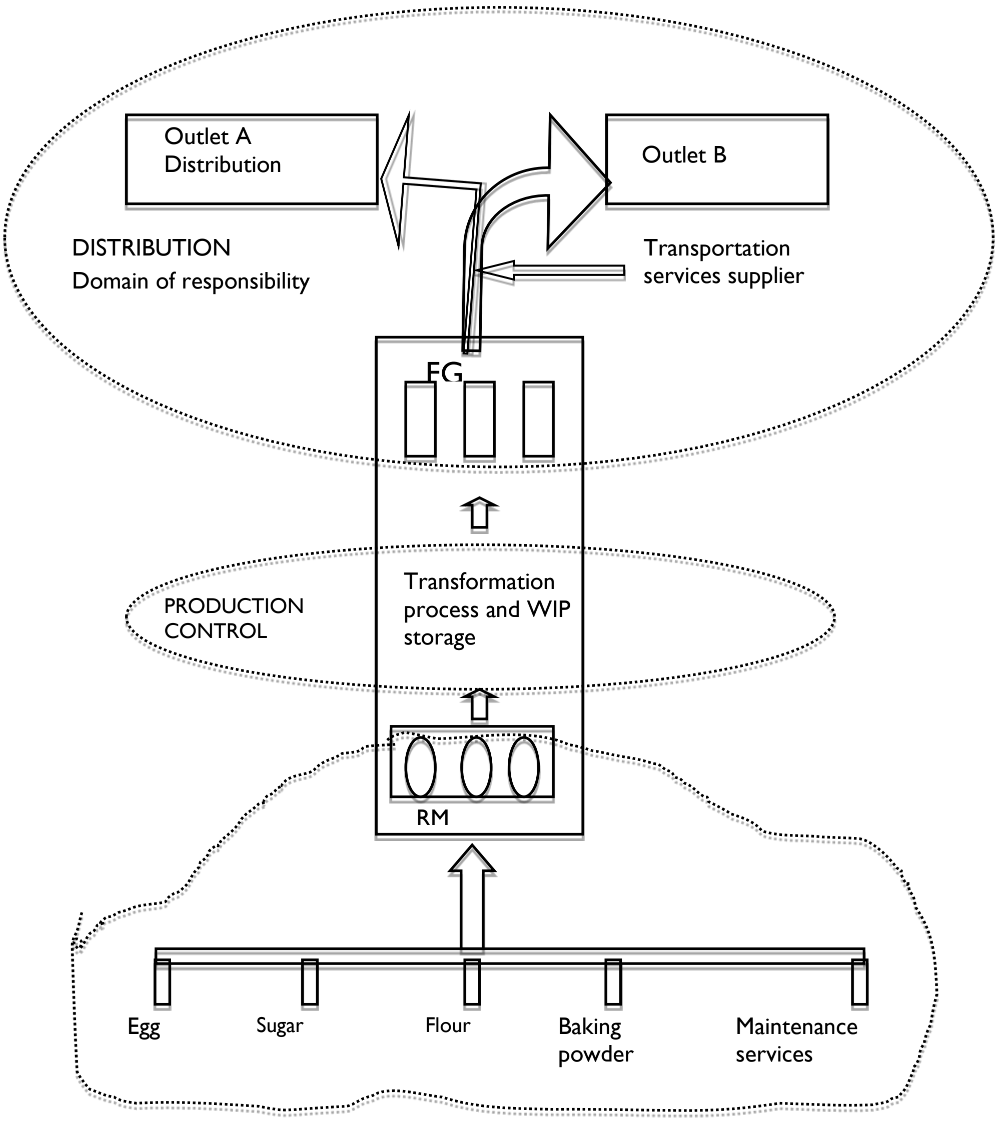


Figure 8.2: Materials management for a Bakery and the Domains of Responsibility for its Three Primary areas of operation

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

3.1.2 Supply Chains

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

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

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

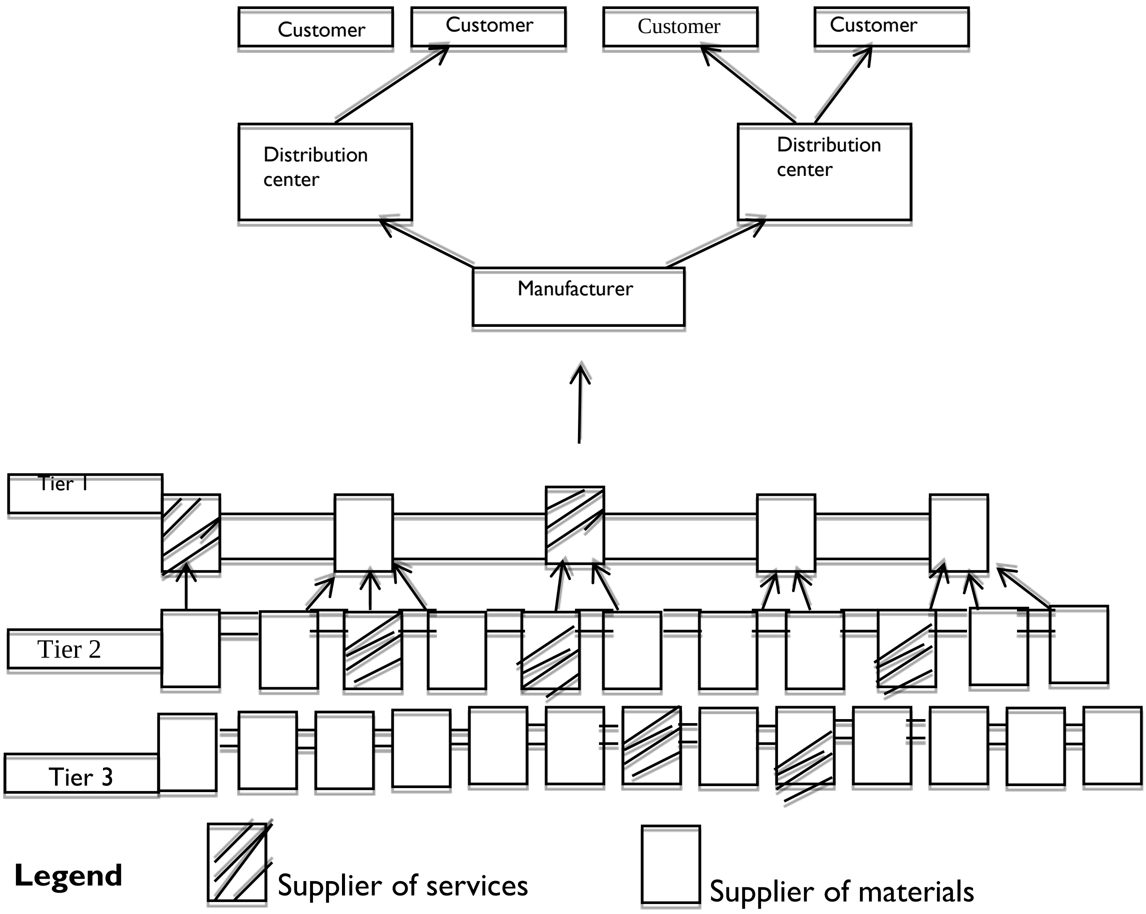


Figure 8.3: Supply Chain for a manufacturing firm

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

3.1.3 Developing integrated Supply chain

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

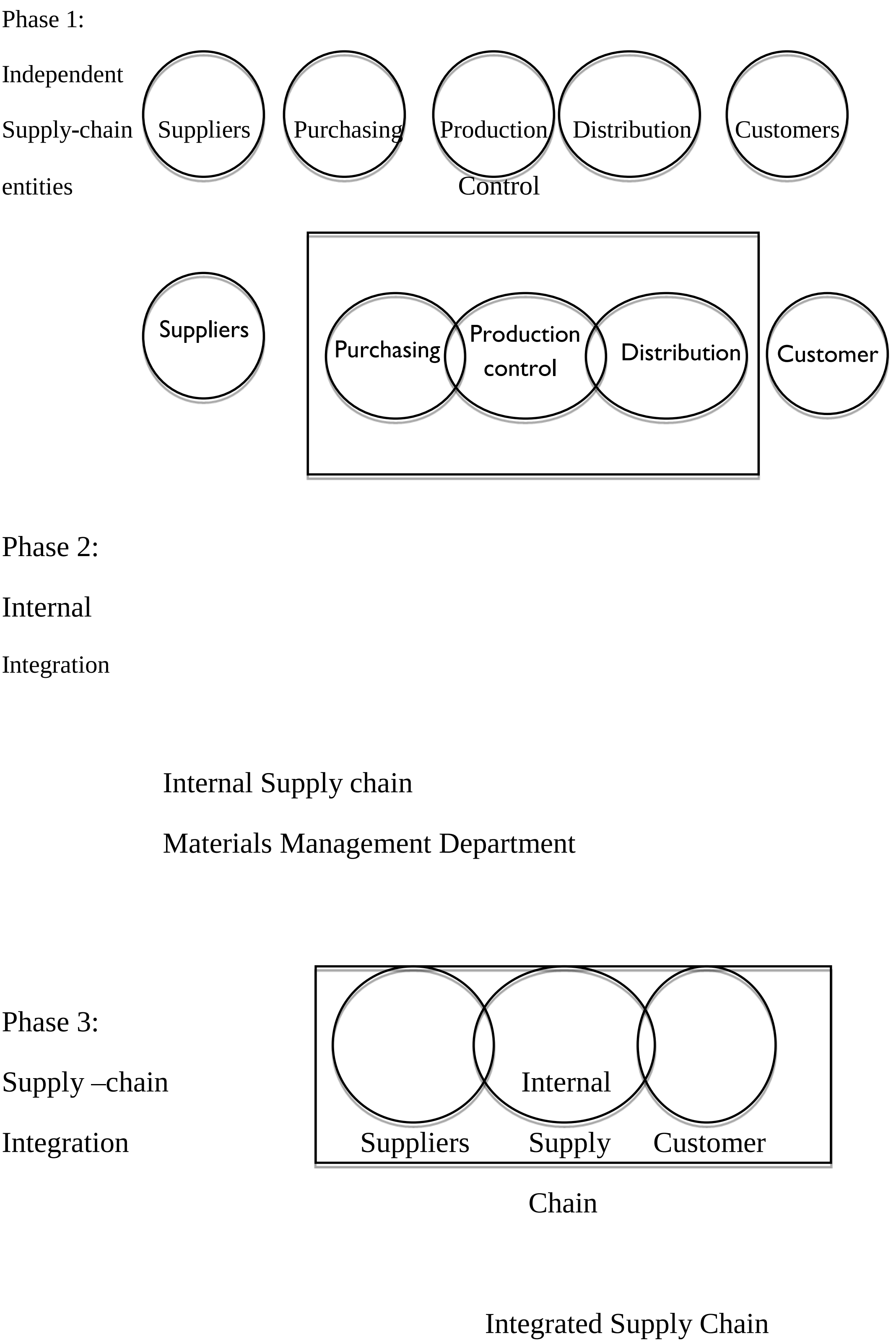


Figure 8.4: Phases in the Development of an Integrated Supply Chain

Source: Adapted from: Krajweski, L.J. and L.P. Ritzman 1999.

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

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

3.2 Purchasing

Purchasing is the management of the acquisition process, and it involves deciding, decoding which suppliers to use, negotiating contracts, as well as deciding whether to buy locally. It is basically the duty of purchasing to satisfy the firm's long-term supply needs. Furthermore, it should support the firm's capabilities to produce goods and services. We need to understand that the performance of both the internal and external supply chains depends on how well this critical task is performed.

3.2.1 The Acquisition Process

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

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

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

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

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

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

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

3.2.2 Criteria for the Selection and Certification of Suppliers

From our discussion so far, it should be clear that the purchasing department is the eyes and eyes of the organisation in the suppliers' market place. It therefore continuously seeks better buys and new materials from suppliers for this reason, the purchasing department is in a good position to select suppliers for the supply chain and to conduct certification programmes.

With respect to supplier selection decision and the review of the performance of current suppliers, it is necessary for the organisation to review the market segments it wants to serve and relate their needs to the supply chain. Usually, the starting point in developing a list of performance criteria to be used is competitive priorities being adopted by the organisation. For example, food-service firms use on-time delivery and quality as the top two criteria for selecting suppliers.

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

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

3.2.3 Types and Effects of Supplier Relations

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

3.2.3.1 Competitive Relationship

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

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

3.2.3.2 Cooperative Relationship

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

Another interesting feature of the cooperative relationship is that he buyer shares more information with the supplier on its future buying intention. This then allows suppliers to make better, more reliable forecasts of future demand. The buyer at times, visits supplier's plants for familiarization purposes, and may actually suggest ways to improve the supplier's operations. This relationship may grow so well that the buyer wouldn't see the need to inspect incoming materials. Moreover, the supplier may be given more freedom in specifications involving the supplier more in designing parts, implementing cost-reduction ideas, and sharing in savings. One major advantage of the cooperative relationship is the potential to reduce the number of suppliers in the supply chain, thereby reducing the complexity of managing them.

3.3 Distribution

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

(i) Where to stock finished goods;

(ii) What transportation mode to use; and

(iii) How to schedule, route, and select carriers.

3.3.1 Placement of Finished Goods Inventory

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

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

3.3.2 Selection of Transportation Mode

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

For instance, if flexibility is a key competitive priority, highway transportation can be used to ship goods to almost any location within a geographical region. One of the advantages inherent in the highway mode is that, no re-handling is needed as so is often the case with other modes that rely on trucks for initial pick up and final delivery. In addition, transit times are good, and rates are usually less than rail rates for small quantities and short hauls.

If cost is the competitive priority, rail or water transportation may be appropriate. Rail transportation, in particular can ship large quantities of goods very cheaply. However, its transit times are long and variable. This mode is usually recommended for shipping raw materials, rather than finished goods. Rail shipments often require pickup and delivery rehandling. Water transportation provides high capacity at low unit cost, but its transit times are low. It also has limited geographical flexibility.

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

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

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

3.3.3 Scheduling, Routing and Carrier Selection

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

3.4 Measures of Supply-Chain Performance

It is now clear to you, that supply chain management involves managing the flow of materials that create inventories in the supply chain. Hence, managers need to closely monitor inventories in order to keep them at acceptable levels. For instance, the flow of materials affects various financial measures of concern to the firm. It is therefore necessary to examine the typical inventory measures that are usually used to monitor supply-chain performance.

3.4.1 Inventory Measures

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

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

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

$$\text{Average Aggregate inventory value} = \begin{pmatrix}\text{Number of Units of} \\ \text{Item A typically on hand}\end{pmatrix}\begin{pmatrix}\text{Value of each} \\ \text{unit of Item A}\end{pmatrix} + \begin{pmatrix}\text{Number of Units of} \\ \text{Item B typically on hand}\end{pmatrix}\begin{pmatrix}\text{Value of each unit} \\ \text{of Item B}\end{pmatrix}$$

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

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

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

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

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

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

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

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

Example

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

Solution

(a)

$$\text{Weeks of Supply} = \frac{\text{N2m}}{\text{(N10m) / (52 weeks)}}$$
$$= 10.4 \text{ weeks}$$

(b)

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

4.0 Conclusion

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

5.0 Summary

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

6.0 Self-Assessment Exercise

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

(a) What is the average aggregate inventory value?

(b) What weeks of supply does the firm maintain?

(c) What was the inventory turnover last year?

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

7.0 References/Further Reading

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

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

Unit 4 Inventory Management

1.0 Introduction

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

2.0 Objectives

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

- define the term inventory and list the major reasons for holding inventories
- contrast independent and dependent demand
- list the main requirement for effective inventory management
- discuss period and perpetual review system
- describe the A. B. C approach and explain how it is useful
- discuss the objectives of inventory management
- describe the basic EOQ model and its assumptions and solve typical problems
- describe the economic run size model and solve typical problems
- describe the quantity discount model and solve typical problems
- describe reorder point models and solve typical problems
- describe situation in which the single period model would be appropriate
- solve typical problems that involve shortage costs and excess costs.

3.0 Main Content

3.1 Purpose of Inventories

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

1. To meet anticipated demand or planned demand.

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

3. To decouple components of the production distribution system – manufacturing firms have used inventories as buffers between successive operations to maintain continuity of production that would otherwise be disrupted by events such as breakdown of equipment and accidents that cause a portion of the operation to shut down temporarily. The buffers will permit other operations to continue temporarily while the problem is resolved. Similarly, firms can use buffers of raw materials to insulate production from disruptions in deliveries from suppliers, and finished goods inventory to buffer sales operations from manufacturing disruptions.

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

5. To allow economic production and purchase or to take advantage of order cycles. To minimize purchasing and inventory costs, a firm can buy in quantities that exceed immediate requirements. This necessitates storing some or all of the purchased amount for later use. Similarly, it is usually economical to produce in large rather than small quantities. Again, the excess output must be stored for later use. Thus inventory storage enables a firm to buy and produce in economic lot sizes without having to try to match purchases or production with demand requirements in the short run. This results in periodic orders, or order cycles. The resulting stock is known as cycle stock. You have to know that economic lot sizes are not the only cause of order cycles. In some instances, it is practical or economical to group orders and/or to order at fixed intervals.

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

7. To permit operations. The fact that production operations take a certain amount of time (i.e. they are not instantaneous) means that there will generally be some work-in-progress inventory. In addition, intermediate stocking of goods – including raw materials,

semi-finished items and finished goods at production sites, as well as goods stored in ware houses, - leads to pipeline inventories throughout a production – distribution system. As a follow up to question asked in section 1: What functions do those inventories identified perform?

3.2 Inventory Cost Structures

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

3.2.1 Item Cost

This is the cost of buying or producing the individual inventory items. The item cost is usually expressed as a cost per unit multiplied by the quantity procured or produced. Sometimes item cost is discounted if enough units are purchased at one time.

3.2.2 Ordering (or set up) Costs

These are costs of ordering and receiving inventory. They include typing purchase order, expediting the order, transportation costs, receiving costs, and so on. Ordering costs are generally expressed in fixed Naira per ordering regardless of order size. When a firm produces its own inventory instead of ordering it from a supplier, the costs of machine setup (e.g., preparing equipment for the job by adjusting the machine, changing cutting tools) are analogous to ordering costs; they are expressed as a fixed charge per run regardless of the size of the run.

3.2.3 Carrying (or holding) Cost

This is associated with physically having items in storage for a period of time. Holding costs are stated in either of two ways: as a percentage of unit price, for example, a 15 percent annual holding cost means that it will cost 15 kobo to hold N1 of inventory for a year or in Naira per unit.

The carrying cost usually consists of three components:

3.2.3.1 Cost of Capital

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

3.2.3.2 Cost of Storage

This includes variable space cost, insurance, and taxes. In some cases, a part of the storage cost is fixed, for example, when a ware house is owned and cannot be used for other purpose. Such fixed costs should not be included in the cost of inventory storage. Similarly, taxes and insurance should be included only if they vary with inventory levels.

3.2.3.3 Costs of Obsolescence, Deterioration, and Loss

Obsolescence costs should be assigned to items which have a high risk of becoming obsolete; the higher the risk, the higher the costs. Perishable products such as fresh seafood, meat and poultry and blood should be charged with deterioration costs when the item deteriorates over time. The costs of loss include pilferage and breakage costs associated with holding items in inventory. For example, items that are easily concealed (e.g. pocket cameras, transistor radios, calculators) or fairly expensive (e.g. cars TVs) are prone to theft.

Stock out or shortage costs result when demand exceeds the supply of inventory on hand. These costs can include the sale lost because material is not on hand, loss of customer goodwill due to delay in delivery of order, late charges and similar costs. Also, if the shortage occurs in an item carried for internal use (e.g. to supply and assembly line), the cost of lost production or downtime is considered a shortage cost. Shortage costs are usually difficult to measure, and they are often subjectively estimated. Estimates can be based on the concept of foregone profits.

3.3 Independent versus Dependent Demand

A crucial distinction in inventory management is whether demand is independent or dependent. Dependent demand items are typically subassemblies or component parts that will be used in the production of a final or finished product. Demand (i.e. usage) of subassemblies and component parts is derived from the number of finished units that will be produced. A classic example of this is demand for wheels for new cars. If each car is to have five wheels, then the total number of wheels required for a production run is simply a function of the number of cars that are to be produced in that run. For example, 200 cars would require 200 x 5 = 1,000 wheels.

Independent demand items are the finished goods or end items. Generally these items are sold or at least shipped out rather than being used in making another product. This demand includes an element of randomness.

The nature of demand leads to two different philosophies of inventory management. A replenishment philosophy, that is, as the stock is used, an order is triggered for more material and inventory is replenished.

A requirements philosophy, that is, as one stock begins to run out. More materials or ordered only as required by the need for other higher-level or end items.

The sections that follow focus on independent demand items.

3.4 Requirements for Effective Inventory Management

Management has two basic functions concerning inventory. One is to establish a system of keeping track of items in inventory and other is to make decision about how much and when to order. To be effective management must have the following:

1. A system to keep track of the inventory on hand and on order.

2. A reliable forecast of demand that includes an indication of possible forecast error.

3. Knowledge of lead times and head time and lead time variability.

4. Reasonable estimates of inventory holding costs, ordering costs and shortage costs.

5. A classification system for inventory items.

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

3.4.1 Inventory Counting Systems

Inventory counting system can be periodic or perpetual. Under a periodic system, a physical count of items in inventory is made at periodic intervals (e.g., weekly, monthly) in order to know how much to order of each item. An advantage of this type of system is that orders for many items occur at the same time, which can result in economies in processing and shipping orders. There are also several disadvantages of periodic reviews. One is a lack of control between reviews. Another is the need to protect against shortages between review periods by carrying extra stock. A third disadvantages is the need to make a decision on order quantities at each review.

A perpetual inventory system (also known as a continual system) keeps tracks of removal from inventory on a continuous basis, so when the system can provide information on the current level of inventory for each item, when the amount on hand reaches a pre determined minimum a fixed quantity, Q, is ordered. The advantages of this system include;

(i) Continuous monitoring of inventory withdrawals.

(ii) Fixed order quantity that makes it possible for management to identify an economic order size (discuss in detail later in the unit). The disadvantages include added cost of record keeping and also a physical count shall be performed.

Bank transactions such as customer deposit and withdrawals are examples of continuous recording of inventory changes. An example of perpetual system is in two- bin system that uses two containers of inventory; reorder is done when the first is empty. It does not demand record of withdrawal.

Perpetual system can be batch or on line. In batch system inventory records are collected periodically and entered into the system. In on-line system the transactions are recorded instantaneously. The advantage of latter over the former is that they are always up to date.

3.4.2 Demand Forecasts and Lead Time Information

Since inventories are used to satisfy demand requirement it is essential to;

(i) have reliable estimates of the amount and timing of demand

(ii) know how to long it will take for orders to be delivered

(iii) know the extent to which demand and lead time (the time between submitting an order and receiving it) might vary.

3.4.3 Classification System

Since items held in inventory are not of equal importance in terms of naira invested, profit potential, sales, or usage volume or stock out penalties. They must be classified in order of their importance to the business. One way you can do this is to employ A- B- C approach which classifies inventory items according to some measures of importance, usually annual naira usage (i.e. naira value per unit multiplied by annual usage rate) and then allocates control efforts accordingly. Here, A is used for very important items, B for moderately important and C for least important. A items generally account for about 15 percent to 20 percent of the items in inventory but 60 percent to 70 percent of the naira usage. While C items might account for about 60 percent of the number of items only abort 10 percent of the items of the naira usage of an inventory. In most instances A items account for large share of the value or cost associated with an inventory; and they should receive a relatively greater share of control efforts. The C items should receive only loose control and B items should have controls that lie between the two extremes.

The A. B. C concept is used by managers in many different settings to improve operations. For example in customer service, a manager can focus attention on the most important aspects of customer service as very important, or of only minor importance. This is to ensure that he does not overemphasize minor aspect of customer service at the expense of major aspects.

A-B- C. concept can also be used as a guide to cycle counting, which is a physical count of items in inventory. The purpose of cycle counting is to reduce discrepancies between the amounts indicated by inventory records and the actual quantities of inventory on hand. Using A- B- C. concept let us attempt to classify the inventory items contained in the following table as A, B, or C based on annual naira value.

Item	Annual **Demand** X	Unit **Cost** =	Annual Naira Value
1	1,000	N4,300	N4,300,000
2	5,000	720	N3,600,000
3	1,900	500	950,000
4	1,000	710	710,000
5	2,500	250	625,000
6	2,500	192	480,000
7	400	200	80,000
8	500	100	50,000
9	200	210	42,000

10	1,000	35	35,000
11	3,000	10	30,000
12	900	3	27,000

When you look at the information contained in the table carefully, we can say that the first two items have a relatively high annual naira value so it seems reasonable to classify them as A items. The next four items appear to have moderate annual naira values and should be classified as B items. The remainders are C items, based on their low naira value. The key questions concerning cycle counting for management are:

1. How much accuracy is needed
2. When should cycle counting be performed
3. Who should do it?

The American Production and Inventory Control Society (APICS) recommends the following guideline for inventory record accuracy ± 0.2 percent for A items, 1 percent for B items and± 5 percent for C items.

On when cycle counted be performed, you can decide to do it on periodic (scheduled) basis or certain events may trigger you do it on a periodic (scheduled) basis. An-out-of-stock report written on an item indicated by inventory records to be in stock, an inventory report that indicate a low or zero balance of an item and a specified level of activity (e.g. every 2000 units sold.)

On who should do it, you may use regular stock room personnel especially during period of slow activity or give the contract to outside firms to do it on a periodic basis. The latter provides an independent check on inventory and may reduce the risk of problem created by dishonest employees.

3.5 Economic Order Quantity Model

The question of how much to order is frequently determined by using economic order quantity (EOQ) models. EOQ models identify the optimal order quantity in terms of minimising order costs. These models can take the following forms:

1. The economic order quantity model
2. The quantity discount model
3. The economic order quantity model with no instantaneous delivery.

3.5.1 Basic Economic Order Quantity Model

This basic model assumes the followings:

1. Only one product is involved.
2. Annual demand requirements are known
3. Lead time do not vary
4. Each order is received in a single delivery
5. There are no quantity discount
6. Demand is spread evenly throughout the year so that the demand rate is reasonably constant.

The exact amount to order will depend on the relative magnitudes of carrying and ordering cost. Annual carrying cost is computed by multiplying the average amount of inventory on hand by the cost to carry one unit for one year, even though any given unit would not be held for a year. The average inventory is simply half of the order quantity. Using the symbol H to represent the average annual carrying cost per unit, the total annual carrying cost is

Annual carrying cost = $\frac{Q}{2}H$……………………… (1)

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

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

Where

S = ordering cost

D = annual demand

Q = order size

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

The total cost associated with carrying and ordering inventory when Q units are ordered each time is therefore:

TC = Annual carrying cost + Annual ordering cost = $\frac{QH}{2} + \frac{DS}{Q}$

Where

D = Demand, usually in units per year

Q = Order quantity, in units

S = Ordering cost in Naira

H = Carrying cost, usually in Naira per unit per year.

If TC is differentiated with respect to Q and equated to zero, and solving for Q, we will obtain the expression which we use to determine optimum order quantity, Q_0

$$Q_0 = \sqrt{\frac{2DS}{H}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

The minimum total cost is then found by substituting Q_0 in total cost formula. The length of an order cycle is obtained by dividing optimum quantity (Q_0) by annual demand (D).

To illustrate the use of expression (3), suppose a local distributor for Michelin tyre expect to sell approximately 9,600 steel-belted radial tires of a certain size and tread designs next year. Annual carrying costs are **N**16 per time, and ordering cost are **N** 75. The distributor operates 288 days a year

a) What is the EOQ?

b) How many times per year does the store reorder?

c) What is the length of an order cycle?

To answer these question demands that you know the value of D, H and S. These are as follows D= 9,600 tires per year

H = **N** 16 per unit per year   S = **N** 75

Having determined these values, answers to those questions are thus:

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

(b) Number of order per year

D/Q_0 = <u>9.600 tires</u> =32

300 tires

(c) (length of order cycle:

$$Q_0/D = \frac{300 \text{ tires}}{9{,}600 \text{ tires}} =$$

1/32 of a year, which is 1/32 x 288 or nine workdays.

Now, if your carrying costs are stated as a percentage of the purchase price of an item rather then as a naira amount per unit, is (3) still appropriate to determine Q_0, optimum order size? The answer is yes as long as you can convert the percentage in naira equivalent.

Let us illustrate this with an example: suppose Tijani and Osot. Ltd assembled television sets. It purchases 3,600 black and white picture tubes a year at **N** 65 each. Ordering costs are **N** 31, and annual carrying costs are 20 percentage of the purchase price. Compute the optimal quantity and the total annual cost of ordering and carrying the inventory

Solution

D= 3,600 picture tubes per year

S= **N** 31

H= 20 (**N**65) = **N**13 (since this can be done, Q_0 expression is therefore appropriate)

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

TC = carrying costs + ordering costs

$= (Q_0/2)\ H + (D/Q_0)\ S$

= (131/2) 13 + (3.600/13)31

= **N**852 + **N**852 = **N**1, 704

3.5.2 EOQ with Non Instantaneous Replenishment

Recall the assumptions of the basic EOQ model discussed in the last section, it as assumed that each order is delivered at a single point in time. In some in time instances, however, such as when a firm is both a producer and user or when deliveries are spread over time, inventories tend to build up gradually instead of instantaneously.

When a company makes the product itself there are no ordering costs as such. Nonetheless, with every run there are setup costs. Setup costs are similar to ordering cost hence they are treated in (3) in exactly the same way. In this case, the number of runs is D/Q_o and the annual setup cost is equal to the number of runs per year times the setup cost per run:

$(D/Q_o)S$

Total cost is

TC_{mh} = carrying cost + setup cost

$$= \frac{I_{max}}{2} H + (D/Q_0)S \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where

I_{max} = maximum inventory

The economic run quantity is

$$Q_0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where

P = production or delivery rate

U= usage rate

The maximum and average inventories are

$$I_{max} = \frac{Q_0}{P}(P-U) \text{ and } I_{average} = \frac{I_{max}}{2}$$

The cycle time (the time between orders or between the beginning of runs) for the economic run size is dependent on the run size and use (demand) rate:

$$\text{Cycle time} = \frac{Q_0}{U}$$

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

$$\text{Run time} = \frac{Q_0}{P}$$

Now let us illustrate our discussion in this section with an example:

A toy manufacturer uses 48,000 rubber wheels per year for its popular dump truck series. The firm makes its own wheels which it can produce at a rate of 800 per day. The toy trucks are assembled uniformly over the entire year. Carrying cost for a production run of wheel is 45. The firm operates 240 days per year. Determine each of the following:

a) optimal run size

b) minimum total annual cost for carrying and setup

c) cycle time for the optimal run size

d) run time

Solution

D= 48,000 wheels per year

S= **N**45

H= **N** 1 per wheel per year

P= 800 wheels per day

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

$$Q_0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}} = \sqrt{\frac{2(48000)45}{1}}\sqrt{\frac{800}{800-200}} = 2400 \text{ wheels}$$

(b) Tc_{min} = carrying cost + set up cost =

$$\frac{(I_{max})}{2} H + (D/Q_0)S$$

Thus you must first compute I_{max}

$$I_{max} = \frac{Q_0}{P}(P-U) = \frac{2{,}400}{800}(800-200) = 1{,}800 \text{ wheels}$$

$$TC = \mathbf{N}\frac{1{,}800}{2} \times \mathbf{N}1 + \frac{48{,}000}{2{,}400} \times \mathbf{N}45 = \mathbf{N}900 + \mathbf{N}900 = \mathbf{N}1{,}800$$

(c) $$\text{Cycle time} = \frac{Q_0}{U} = \frac{2{,}400 \text{ wheels}}{200 \text{ wheels per day}} = 12 \text{ days.}$$

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

(d) $$\text{Run time} = \frac{Q_0}{P} = \frac{2{,}400 \text{ wheel}}{800 \text{ wheels per day}} = 13\text{days}$$

Thus, each run will require 3 days to complete.

3.5.3 Quantity Discounts

This section discusses the third variant of EOQ model. This requires that the assumption of no quantity discounts is relaxed. A convenient point to start our discussion in this section is to understand what quantity discounts mean. We would define quantity discounts as a price reduction for large orders offered to customers to induce them to buy in large quantities.

The buyer's goal with discount is to select the order quantity that will minimize total cost, which is the sum of carrying cost, ordering cost, + purchasing cost:

TC = Carrying cost + ordering cost of purchasing

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

Where

P = unit price

Recall that in the basic EOQ model, determination of order size does not involve the purchasing cost. The rationale for not including unit price is that under the assumption of no quantity discounts, price per unit is the same for all order sizes.

There are two general cases of the model. In one, carrying costs are constant (e.g. **N**20 per unit) in the other, carrying costs are stated as a percentage of purchase price (e.g. 20 percent of unit price).

The procedure for determining the overall EOQ differs slightly, depending on which of these two cases is relevant. For carrying cost that is constant, the procedure is as follows:

(1) Compute the common EOQ

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

(a) if the feasible EOQ is on the lowest price range, that is the optimum order quantity.

(b) If the feasible EOQ is in any other range, compute the total cost for the EOQ and for the price break of all lower unit cost. Compare the total costs: the quantity (EOQ or the price break) that yield the lowest total is the optimum order quantity.

This is illustrated with the following example:

The maintenance departments of a large hospital used about 816 cases of liquid cleaner annually. Ordering costs are **N**12, carrying costs are **N**4 per case a year and the new price schedule indicate that orders of less that 50 cases will cost **N**20 per case, 50 to 79 cases will cost **N**18 per case 80, to **N**99 will cost **N**17 per case, and the large order will cost **N**16 per case. Determine the optimal order quantity and the total cost.

Solution

D= 816 cases per year S= **N** 120 H = **N**40 per case per year.

Range	Price
1 to 49 --	₦20
50 to 79 --------------------------------------	18
80 to 99 ---------------------------------------	17
100 or more ----------------------------------	16

1. compute the common EOQ =

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

2. The 70 cases can be bought at 18 per case since 70 falls in the range of 50 to 79 cases. The total cost to purchase 816 cases a year, 70 cases a year, at the rate of 70 cases per order will be

TC_{70},= carrying cost + order cost + purchase cost

= (Q/2)H + (D/Q)S + PD

= (70/2) 4 + (816/70)12 + 18 (816) = **N**14,968.

Since lower cost ranges exist, each must be checked against the minimum cost generated by 70 cases at 18 each. In order to buy at 17 per case, at least 80 cases must be purchased. The total cost at 80 cases will be:

TC_{80} = (80/2) 4 + (816/100) 12 + 17 (816) = **N**14, 154.

To obtain a cost of 16 per case, at least 100 cases per order are required and the total cost will be

TC_{100} = (100/2)4 + (816/100) 12+16 (816 = 13,354.

Therefore, since 100 cases per order yields the lowest total cost, 100 cases is the overall optimal order quantity. Next let us consider a situation, when carrying costs are expressed as a percentage of price; in this case you can determine the best purchase quantity with the following procedure

(1) Beginning with the lowest price compute the EOQ_s for each price range until an EOQ is found (i.e., until an EOQ is found that falls in the quantity range for its price).

(2) If the EOQ for the lowest price is feasible, it is the optimal order quantity. If the EOQ is not the lowest price range, compare the total cost at the price break for all lower prices with the total cost of the highest feasible EOQ. The quantity that yields the lowest total cost is the optimum.

To illustrate this, suppose Tijani electric uses 4,000 toggle switches a year priced as follows: 1 to 499, 90 kobo each; 500 to 999, 85 kobo each: and 1,000 or more, 82 kobo each. It costs a approximately **N**18 to prepare an order and receive it and carrying costs are 18 percent of purchase price per unit on an annual basis. Determine the optimal order quantity and the total annual cost.

Solution

D = 4, 000 switches per year S = **N**18 H = 0.18P

Range	Unit Price	H
1 to 499	0.90	0.18 (0.90) = 0.1620
500 to 999	0.85	0.18 (0.85) = 0.1530
1000 0r more	0.82	0.18 (0.82) = 0.1476

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

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

Since 988 stitches will cost **N**0.85 each, 988 is not a feasible EOQ. Next try 0.85 per unit

$$EOQ_{\ 0.85} = \sqrt{\frac{2\ (4000)18}{0.153}} = 970 \text{ switches}$$

This is feasible; 970 switches falls in the **N**0.85 range of 500 to 999.

(b) Compute TC for 970, and compare it to the total cost at the minimum quantity necessary to obtain a price of **N**0.82 per switch.

TC = carrying cost + ordering cost + purchase cost

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

TC_{970}= (970/2) (0.153) + (4,000/970) 18 + 0.85 (4,000) = **N**3, 548.

Tc_{100}= (1000/2 (0.1476) + (4,000/1,000) 18 + 0.82 (4,000) = **N**3, 426

Thus, the minimum cost order size is 1,000 switches.

3.5.4 When to Reorder with EOQ Ordering

EOQ models answer the question of how much to order but not the question of when to order. The latter is the function of models that identity the reorder point (ROP) in terms of a quantity: the reorder point occur when the quantity on hand drop to a predetermine amount. The amount generally includes expected demand during lead time and perhaps an extra cushion of stock, which serves to reduce the probability of experiencing a stock out during lead time. There are four determinants of the reorder point quantity.

(1) The rate of demand (usually based on a forecast).

(2) The length of lead time.

(3) The extent of demand and/or lead time variability.

(4) The degree of stock-out risk acceptable to management.

If demand and lead time are both constant, the reorder point is simply: ROP = D x LT

Where

D = demand per day or week

LT = lead time in days or weeks

Note: Demand and lead time must be in the same units.

The following example illustrates this concept: Osot takes Two – a Day vitamins, which are delivered to his home by salesman seven days after an order is called in. At what point should Osot telephone his order in?

Usage = 2 vitamins per day

Lead time = 2 days

ROP = Usage x lead time

= 2 vitamins per day x 7 days

= 14 vitamins

Thus, Osot should reorder when 14 vitamin tablets are left. Now let us look at a scenario where demand or lead time is not constant as earlier assumed. If this is the case, there is the possibility that actual demand will exceed expected demand. It therefore becomes necessary to carry additional inventory called safety stock, to reduce the risk of running out of inventory (a stock-out) during lead time. The reorder point then increased by the amount of the safety stock.

ROP = Expected demand + safety stock during lead time.

For example, if expected demand during lead time is 100 units and the desire amount of safety stock is 10 units the ROP would be 110 units.

Service Level: Because it cost money to hold safety stock, a manager must carefully weigh the cost of carrying safety stock against the reduction in stock – out risk it provides, since the service level increases as the risk of stock-out decreases. Order cycle service level can be defined as the probability that demand will not exceed supply during lead time (i.e., that amount of stock on hand will be sufficient to meet demand) Hence a service level of 95 percent implies a probability of 95 percent that demand will not exceed supply during lead time.

An equivalent statement that demand will be satisfied in 95 percent of such instance does not mean that as percent of demand will be satisfied. The risk of a stock out is the compliment of service level; a customer service level of 95 percent implies a stock-out risk of 5 percent. That is service level = 100 percent – stock-out risk. Later you will see how the order cycle service level relates to annual service level.

The amount of safety stock that is appropriate for a given situation depends on the following factors:

(1) The average demand rate & average lead time.

(2) Demand and lead time variability.

(3) The desire service level.

For a given order cycle, service level the greater the variability in either demand rate or lead time, the greater the amount of safety stock that will be needed to achieve that service level. Similarly, for a given amount of variation in demand rate or head time, achieving an increase in the service level will require increasing the amount of safety stock. Selection of a service level may reflect stock out costs (e.g. lost sales, customer dissatisfaction) or it might simply be a policy variable (e.g. manager wanting to achieve a specified service level for a certain item). Several models will be described that can be used in cases when variability is present. The first model can be used if an estimate of expected demand during lead time and its standard deviation are available. The formula:

ROP = expected demand + $Z\delta dLT$ during lead time.

Where

Z = Number of standard deviations

δdLT = The standard deviation of lead time demand.

The models generally assume that any variability in demand rate or lead time can be adequately described by a normal distribution. However, this is not a strict requirement;

the models provide approximately reorder points even where actual distribution departs from normal.

The value of Z, used in a particular instance depends on the stock-out risk that the manager is willing to accept. Generally, the smaller the risk the manager is willing to accept, the greater the value of Z. Let us illustrate this with an example:

Suppose that the manager of a construction supply house determined from historical records that the lead time demand for sand averaged 50 tons. In addition, suppose the manager determined the demand during lead time could be described by a normal distribution that has a mean of 50 tons and a standard deviation of 5 tons. Answer the following questions assuming that the manager is willing to accept a stock out risk of no more than 3 percent.

(a) What value of Z is appropriate?

(b) How much safety stock should be held?

(c) What reorder point should be used?

Expected lead time demand = 50 tons

δdLT = 5 tons

Risk = 3 percent

(a) From normal deviate table, using a service level of 1 – 0.3 =.9700 you obtain a value of Z = +1.82.

(b) Safety stock = ZδdLT

= 1.88 (5)

= 9.40 tons

(c) ROP = expected lead time demand + safety stock

= 50 + 9.40

= 59.40 tons

If data are available, a manager can determine whether demand and/or lead time is variable, and if variability exist in one or both, the related standard deviation. For those situations, one of the following formulae can be used.

If only demand is variable, then $\delta_{d\,LT}$ =

$\sqrt{}$ $\text{ILT}\delta_d$ and the reorder point is

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

Where

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

δ_d = standard deviation of demand per day or week

LT = lead time in days or weeks if only lead time is variable, than $\delta_d LT = d\delta_{dLT}$ and the reorder point is $ROP = d \times LT + Z\, d_{LT}$ ---------- 2)

Where

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

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

δdLT = Standard deviation of lead-time in days or weeks.

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

$\delta LT = \sqrt{\overline{LT}\,\delta^2_d + \bar{d}^{\,2}\,\delta_{LT}^2}$

and the reorder point is

$ROP = d_l \times L_l T_l + Z \sqrt{LT\,\delta_d^2 + d^2\,\delta LT^2}$ …………………. (3)

Note: each of these models assumes that demand and time are independent. Let us illustrate the use of these formulas with the following.

Example

Suppose a restaurant uses an average of 50 jars of a special sauce each week. Weekly usage of sauce has a standard deviation of 3 jars. The manager is willing to accept no more than a 10 percent risk of a stock-out during lead time, which is two weeks. Assume the distribution of usage is normal.

(a) Which of the above formulas is appropriate for this situation? Why?

(b) Determine the value of Z

(c) Determine the ROP

Solution

d = 50 jars per week

LT = 2 weeks

δ_d = 3 jars per week

Acceptable risk = 10 percent, so service level is .90

(a) Because only demand is variable (i.e., has a standard deviation) formula (I) is appropriate

(b) From the normal distribution table, using a service level of. 9000, you obtain Z = + 1.28.

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

$= 50 \times 2 + 1.28\sqrt{2}\,(3)$

= 100 + 5.43

= 105.43.

3.6 How Much to Order: Fixed-Order-Interval Model

When inventory replenishment is based on EOQ /ROP model, fixed quantities of items are ordered at varying time interval. Just the opposite occurs under the fixed-order-interval (FOI) model orders for varying quantities are placed at fixed time intervals (e.g. weeks, every 20 days).

3.6.1 Reasons for Using the Fixed-Order-Interval Model

In some cases, a supplier policy might encourage orders at fixed interval. Grouping orders for items from the same supplier can produce saving in shipping costs. Furthermore some situations to not readily lend themselves to continuous monitoring of inventory levels. Many retail operator (e.g. drug stores) falls into this category. The alternative for them is to use fixed-interval-ordering, which requires only periodic checks on inventory levels.

3.6.2 Determining the Amount to Order

If both the demand rate and lead time are constant, the fixed interval model and the fixed quantity model function identically. The difference in the two models becomes apparent only when examined under condition of variability. Like the ROP model, the two models can have variation in demand only, in lead time only, or in both demand and lead time. However, for the sake of simplicity ad because it is perhaps the most frequently encountered situation, the discussion here will focus on variable demand and constant lead time.

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

Amount = Expected demand during protection interval + safe stock – Amount on hand at reorder time= $\bar{d}\,(\text{OI} + \text{LT}) + Z\delta_d\sqrt{O_I + \text{LT}} - A$

Where

0_I = order interval (length of time between order)

A = Amount on hand at reorder time

As in previous models, it is assumed that demand during the protection interval is normally distributed.

Given the following information determine the amount to order

d = 30 unit per day   Desired service = 99 percent

δ_d = 3 units per day

LT = 2 days   Amount on hand at reorder time = 71 units

0_I = 7 days

Solution

Z = 2.33 for 99 percent service level

$$\text{Amount} = d\,(0_I + LT) + Z\delta_d \sqrt{0_I + LT} - A$$

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

3.6.2 Benefits and Disadvantages

The fixed-interval system result in the tight control need for A items in an A-B-C classification due to the periodic review it requires. In addition, when two or more items come from the same supplier, grouping orders can yield saving in ordering, packing and shipping costs. Moreover, it may be the only practical approach if inventory withdrawal cannot be closely monitored.

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

3.7 The Single-Period Model

The single-period is used to handle ordering of perishable (e.g. fresh fruits, vegetables, seafood, cut flowers) and items that have a limited useful life (e.g. newspaper's magazines, spare parts for specialized employment.) The period for parts is the life of the equipment (assuming that the part cannot be used for other equipment) what sets unsold or unused goods apart is that they are not typically carried over from one period to the next, at least not without penalty. Day-old baked goods, for instance, are often sold at reduced prices, left over seafood may be discarded, and out of-date magazines may be offered to used book stores at bargain rates. At times, there may even be some cost associated with disposing of left over goods.

Analysis of single – period situation generally focuses on two costs: Shortages and excess shortage cost may include a charge for loss of customer goodwill as well as the opportunity cost of lost sales. Generally shortage cost is unrealised profit per unit. That is, C shortage = C = Revenue per unit-cost.

If a shortage or stock – out relates to an items used in production or to a spare parts for a machine, then shortage cost refer to the actual cost of production. Excess cost pertains to items left over at the end of the period. In effects, excess cost is the difference between purchase cost and salvage value. That is

C excess = C_2 = Original cost per unit – salvage value per unit.

If there is cost associated with disposing of excess items, the salvage will be negative and will therefore increase the excess cost per unit. The goal of the single-period model is to identify the order quantity or stocking level that will minimize the long-run excess and shortages costs.

There are two general categories of problem that we will consider; those for which demand can be approximated using a continuous distribution (perhaps a theoretical one such as a uniform or normal distribution) and those for which demand can be approximated using a discrete distribution (say historical frequencies or a theoretical distribution such as the Poisson). The kind of inventory can indicate which types of model might be appropriate. For example demand for petroleum, liquid and gases tend to vary over some continuous scale, thus lending itself to description by a continuous distribution. Demand for tractors cars and computer is expressed in terms of the number of units demanded and lends itself to description by a discrete distribution.

3.7.1 Continuous Stocking Levels

The concept of identifying an optimal stocking level is perhaps easiest to visualize when demand is uniform. Choosing the stocking level is similar to balancing a seesaw, but instead of a person on each end of the see saw, we have excess cost per unit (C_e) on one and of the distribution and shortage cost per unit (C_s) on the other. The optioned stocking level is analogous to the fulcrum of the seesaw; the stocking level equalizes the cost weights, as illustrated in the figure below.

The service level is the probability that demand will not exceed the stocking level, and computation of the service level is the key to determining the optimal stocking level, so

$$\text{Service level} = \frac{C_s}{C_s + C_e}$$

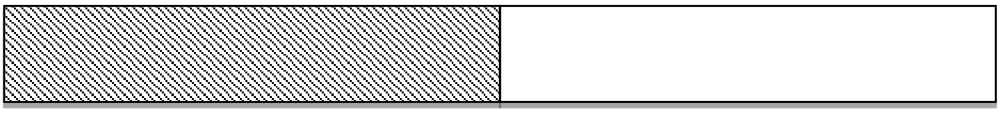
Where

C_s = shortage cost per unit

C_e = Excess cost per unit

↑C_e ↓C_s

Service level



S_0 quantity

Balance point

S_o = optimum stocking quantity

If actual demand exceeds S_0 there is a shortage: hence C_s is on the right end of the distribution. When $C_e = C_s$ the optimal stocking level is half way between the end points of the distribution. If one cost is greater than the other, S_0 will be closer to the larger cost.

A similar approach applies if demand is normally distributed.

Example

Sweet order is delivered whereby to Osot's produce stand. Demand varies uniformly between 300 litres and 500 litres per week. Osot pays 20 kobo per litres for the cider and charges 80 kobo per litre for it. Unsold cider has no salvage value and cannot be carried over into the next week due to spoilage. Find the optimal stocking level and its stock-out risk for that quantity.

C_e = cost per unit – Salvage Value per Unit

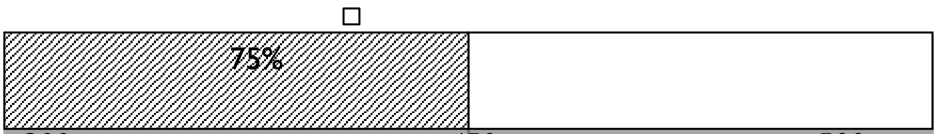
= **N** 0.20 - - **N** 0

= **N** 0.20 per unit

$$SL = \frac{C_s}{C_s + C_e} \qquad \frac{\mathbf{N}\,0.06}{\mathbf{N}\,0.06 + \mathbf{N}\,0.20} = .75$$

Thus, the optimal stocking level must satisfy demand 75 percent of the time. For the uniform distribution this will at a point equal to the minimum demand plus 75 percent of the difference between maximum and minimum demands

$S_0 = 300+0.75\ (500 – 300) = 450$ litres



300 450 500

The stock out risk is 1.00 – 0.75 = 0.25

Suppose Osot's stand also sells blend of cherry juice and apple cider. Demand for the blend is approximately normal with a mean of 200 litres per week and a standard deviation of 10 litres per week. C_s = 60 kobo per litre, and C_e = 20 kobo per litre find the optimal stocking level for the apple cherry blend.

$$S_L = \frac{C_s}{C_s + C_e} = \frac{\text{N } 0.60}{\text{N } 0.60 + \text{N } 0.20} = .75$$

This indicates that 75 percent of the normal curve must be to the left of the stocking level. Normal Table shows that a value of Z between + 0.67 and 0.68 say, + 0.675, will satisfy this.

Thus, S_0 = 200 litres + 0.675 (10 litres)

= 206.75 litres

3.7.2 Discrete Stocking Level

When stocking level are indiscrete rather than continuous, the service level computed using the ratio C_s/ (Cs + Ce) usually does not coincide with a feasible stocking level (e.g. the optimal amount may be between a five and six units). The solution is to stock at the next higher level (e.g. six units).

In other words, choose the stocking level so that the desire service level is equalled or exceeded.

Example

Historical records on the use of spare parts for several large hydraulic presses are to serve as an estimate of usage for spares of a newly installed press. Stock-out costs involve downtime expenses and special ordering cost. There average **N**4, 200 per unit short. Spares cost **N** 800 each, and unused parts have zero salvage. Determine the optimal stocking level.

Nos of spare used	Relative frequency	Cumulative frequency
0	.20	. 20
1	.40	. 60
2	.30	.90
3	.10	1.00
4 or more	.00	1.00
	1.00	

C_s = **N** 4,200 C_e = **N** 800

$$S_L = \frac{Cs}{C_e + C_s} = \frac{\text{N } 4{,}200}{\text{N } 800 + \text{N } 4{,}200} = 0.90$$

The cumulative frequency column indicates the percentage of time that demand did not exceed (has equal to or less than) some amount. For example, demand does not exceed one spare 60 percent of the time or two spares 90 percent of the time. Thus, in order to achieve a service level of at least 90 percent, it will be necessary to stock two spare (i.e. to go to the next highest stocking level).

Let's consider another example:

Suppose the demand for long steamed red roses at a small flower shop can be approximated using a Poisson distribution that has a mean of four dozens per day. Profit on the roses is **N** 3 per dozen. Left over flowers are marked down and sold the next day at a loss of **N** 2 per dozen. Assume that all marked down flowers are sold. What is the optimal level?

C_s = **N** 3 C_e = **N** 2

$$SL = \frac{Cs}{C_s + C_e} = \frac{\mathbf{N}\ 3}{\mathbf{N}\ 3 + \mathbf{N}\ 2} = .60$$

Obtain the cumulative frequency from the Poisson table for a mean of 4.0

Demand (dozen per day)	Cumulative frequency
0	018
I	092
2	238
3 -	434
4	629
5	785
.	.
.	.

Compare the service level to the cumulative frequency. In order to attain a service level of at least .60 it is necessary to stock four dozens.

3.8 Operation Strategy

Inventories are necessary parts of doing business, but having too much inventory is not good. One reason is that inventories tend to hide problems: they make it easier to "live with" problems rather than eliminate them. Another reason is that inventories are costly to maintain. Consequently, a wise operation strategy is to work toward cutting back inventories by (1) reducing lot size (2) reducing safety stocks.

Japanese manufactures use smaller lots sizes than their western counterparts because they have a different perspective on inventory carrying costs. Recall that carrying costs and ordering costs are equal at the EOQ. A higher carrying cost, results in a steeper carrying-cost line, and the resulting intersection with the ordering-cost line at a smaller quantity; hence, a smaller EOQ.

The second factor in the EOQ mode that can contribute to smaller lot seizes is the set up or ordering processing cost. Numerous cases can be cited where these costs have been reduced through research efforts. However while reduction due to carrying costs stems from a reassessment of those costs, a reduction due to ordering or set up cost must come from actually pursuing improvement. Together, these cost reduction can lead to even smaller lot seizes.

Additional reductions in inventory can be achieved by reducing the amount of safety stock carried. Important factor in safety stock are lead time variability, reductions of which will result in lower safety stocks. These reductions can often be realized by working with supplier, choosing suppliers located close to the buyer, and shifting to smaller lot sizes.

To achieve these reductions, an A-B-C approach is very beneficial. This means that all phases of operation should be examined, and those showing the greatest potential for improvement (A items) should be attacked first.

Last, it is important to make sure that inventory records be kept accurate and up to date. Estimated of holding costs, setup costs, and lead time should be reviewed periodically and updated as necessary.

4.0 Conclusion

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

5.0 Summary

Good inventory management is often the mark of a well-run organization. Inventory levels must be planned carefully in order to balance the cost of holding inventory and the cost of providing reasonable levels of customer service. Successful inventory transactions, accurate information about demand and lead times, realistic estimates for certain inventory-related costs, and a priority system for classifying the items in inventory and allocating control efforts.

The models described in this unit are relevant for instances where demand for inventory items is independent. Four classes of models are described; EOQ, ROP, fixed-interval and the single-period models. The first three are appropriate if unused items can be carried over into subsequent periods. The single-period model is appropriate when items cannot be carried over. EOQ models address the question of how much to order. The ROP models address the question of when to order and are particularly helpful in dealing with situations that include variations in either demand rate or lead time. ROP models involve service level and safety stock considerations. When the time between orders is fixed, the F0I model is useful. The single-period model is used for items that have a "shelf life" of one period.

6.0 Self-Assessment Exercise

1a. Does inventory control increase profitability? Explain your answer

b. The Dangobell Corporation produces water heating unit in a number of types and sizes. Most of the parts for these units are made by the company and stored for later use during assembly of the heaters.

Since many different items are made and stored, the company wishes to be certain to manufacture these items in the most economical lot size.

The formular used to make this determination is:

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

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

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

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

7.0 References/Further Reading

Bonini, C.P.; Hansman, W.H. and Bierman, H. Jr. (1997). *Quantitative Analysis for Management.* Chicago: Irwin.

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

Unit 5 Aggregate Planning

1.0 Introduction

This unit introduces the concept of aggregate planning, which is the intermediate range of capacity planning that typically covers a time horizon of 2 to 12 month. In some organisations, this time horizon might be extended to as much as 18 months. It is particularly useful for organisations that experience seasonal or other fluctuations in demand or capacity. The goal of aggregate planning is to achieve a production plan that will effectively utilize the organisations resources to satisfy expected demand.

2.0 Objectives

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

- explain what aggregate planning is and how it is useful
- identify the variables decision makers have to work with in aggregate planning
- identify some of the possible strategies decision makers use
- describe some of the techniques planners use.

3.0 Main Content

3.1 Production – Planning Hierarchy

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

(i) Product and service selection i.e. determining which predicts or services to offer;

(ii) Facilities i.e. plan locations, layout, size send capacities

(iii) Processing plans i.e., new production technology, new production processes, new systems of automation etc; and

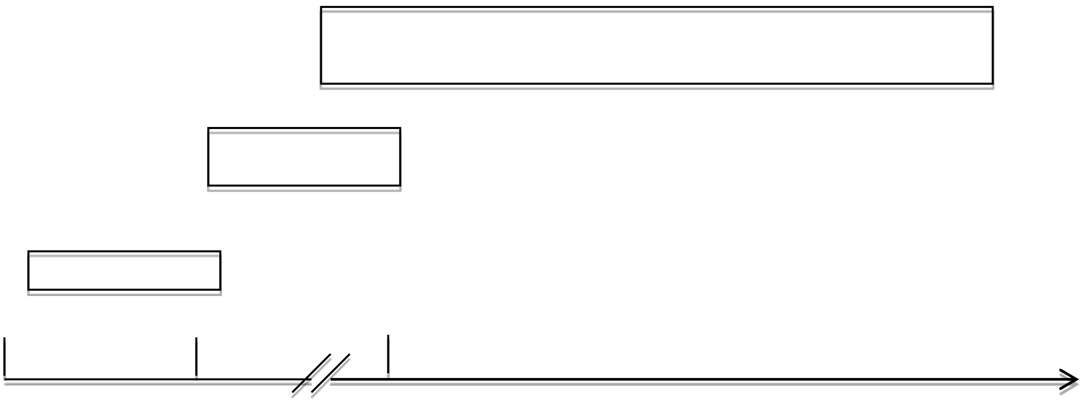
(iv) Major supplier plans and amount of vertical integration.

These long-term decisions essentially define the capacity decisions naturally set the capacity constraints within which intermediate planning must function.

Aggregate planning develops medium-range production plans concerning employment level and changes, inventory levels and changes, utilities, facility modifications, back orders, and subcontracting. These aggregate plans in turn impose constraints on the short range production plans that follow. Short term decisions, therefore, essentially relate to taking decisions on the best way to achieve desired results within the constraints resulting from long-term and intermediate decisions. These involve scheduling jobs, machine loading, job sequencing etc. the three levels of capacity decisions are illustrated in Table 10.1

Table 10.1: Overview of planning levels

Short range plans	**Long-range plans**	**Long-range plans**
Detailed plans:	General levels of;	
Machine loading Job assignments Job sequencing Production lot size Order quantities	Employment Output Finished- goods Inventories	Location Long term capacity Layout



Long- range

Intermediate

Short range

Now 2 month 1 year Planning horizon

It is usual to find many business organisations developing a business plan that comprises both long-term and intermediate-term planning. This business plan sets guidelines for the organisations, taking into account the organisations strategies and policies; forecasts of demand for the organisation's products or services; and economic, competitive, and political conditions. A major objective in business planning is to coordinate the intermediate plans of various organisations functions, such as marketing, operations, and finance. In the case of manufacturing firms elements of engineering and materials management also form part of the coordination.

The business plan guides the planning processes of each functional area. For example, in operations functions, a production plan (or operations plan in the services organisation) is usually developed to guide the more detailed planing that eventually leads to a master schedule. The illustration of the planning sequence is given in Figure 10.2.

3.2 The Concept of Aggregation

Aggregate planning can be looked at as a “big picture” approach to planning. It is the usual practice for planners to try to avoid focussing on individual products or services, unless the organisation deals in only product or service. Rather, they focus on a group of similar products or sometimes an entire product line.

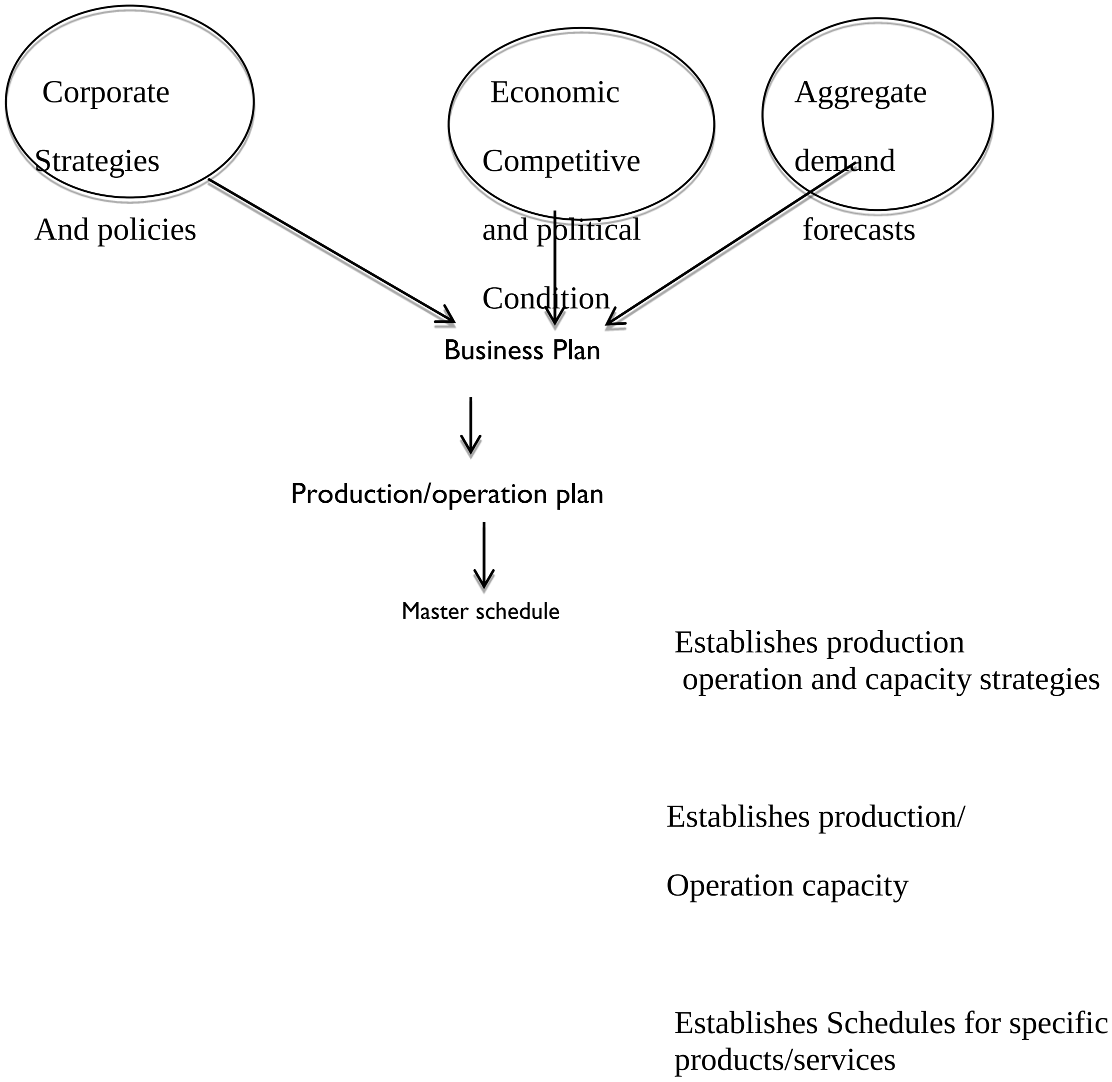


Figure 10.2: Planning Sequence

(a) For purposes of aggregate planning, planners in a television manufacturing firm would not concern themselves with 21 –inch sets versus 18-inch or 14-inch. Instead, they would lump all models together and deal with them as a simple product. Hence, the term aggregate planning.

(b) Again, for the purposes of aggregate planning, a refrigerator manufacturing firm might lump all different sizes and styles of refrigerators it produces into a single category of "frigdes".

(c) In the same vein, when fast-food outfit such as Mr. Biggs, sweet sensation, and Tasty Fried Chicken plan employment and output levels, they would not try to determine how demand will be broken down into the various options they offer. Instead, they focus generally on overall demands and the overall capacity they want to provide.

In each of the examples cited above, it can be seen that an aggregate approach permits planners to make general decisions about intermediate – range capacity without having to deal with highly specific details. Instead, they often concern themselves with overall decision on levels of output, employment and inventories. This is done by lumping demand for all products into one or a few categories, and then planning on that basis.

For purposes of aggregate, it is better to think of capacity in terms of labour hours or machine hours per period, or output rates (e.g. barrels per period, units per period), without necessarily worrying about how much of a particular item will actually be involved .

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

3.1 The Purpose and Scope of aggregate Planning

We shall briefly examine the basic problem addressed by aggregate planning (i.e the balancing of supply and demand) along with the purpose of aggregate planning, the primary decision variable available to planners and associated costs.

3.1.1 Demand and Capacity

Aggregate planners are usually pre-occupied with the quantity and timing of expected demand. For instance, it total expected demand for the planning period is much different from available capacity over the particular planning period, the major approach of planners is either to try to increase demand (in case demand is less than capacity) or increase capacity (if demand exceeds capacity). It could happen that capacity and demand are approximately equal for the planning horizon as a whole. Even here, planners may still be faced with the problem of dealing with uneven demand within the planning interval. For example, in some periods, expect demand may exceed projected capacity; in others, expected demand may be less than projected capacity, and in some periods, the two may be equal, thus, the task of aggregate demand is to achieve rough equality of demand and capacity over the entire planning horizon.

3.1.2 The Purpose of Aggregate Planning.

The major purpose of aggregate planning is to develop a feasible production plan on an aggregate level that achieves a balance of expected demand and supply. Furthermore, planners are usually concerned with minimising the cost of the production plan. However, cost is not the only consideration.

Generally, aggregate planning is necessary in Production and Operations Management because it provides for:

(i) Fully loaded facilities and minimisies over-loading and under-loading, thereby reducing production costs.

(ii) Adequate production capacity to meet expected aggregate demand

(iii) A plan for the orderly and systematic change of production capacity to meet the peaks and valleys of expected customer demand.

(iv) Getting the most output for the amount of resources available, which is important in time of scarce production resources.

3.1.3 Inputs to Aggregate Planning

For an effective aggregate planning to take place, at least three important informational needs must be met. First, the available resources over the planning period must be known. Second, a forecast of expected demand must also be available. Thirdly, planners much take into account any policies regarding changes in employment levels. For example, some organizations view layoffs as extremely undesirable, so they would exclude that option from consideration, or use it only as a last resort). Added to these inputs are the costs of activities, such as inventory carrying costs, general costs of backorders, hiring/firing, overtime, inventory changes and subcontracting.

3.1.4 Demand and Capacity Options

For the purposes of aggregate planning, management has a wide range of decision options at its disposal. Among these are changing prices, promotion, backlogging orders, using overtime, using part-time workers, subcontracting, adding or deleting extra shifts, and stockpiling inventories. Some of these options are for the purposes of altering the pattern of demand. Examples here include pricing and promotion. Others, such as using part-time workers, overtime, and subcontracting represent options that are being used to alter capacity or supply we shall examine these options in the section that follow:

3.3.4.1 Demand Options

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

1. **Pricing:** Differential pricing is often used to shift demand from peak periods to off-peak periods. For example, some air-lines offer lower fares for mid-week travel and change higher fares other times. Similarly, some restaurants offer "early bird specials" in an attempt to shift some of the heavier dinner demand to an earlier time that traditionally has less traffic. Another example is to be found in the telephone service sector, where there are different rates for peak and off-peak periods. If the pricing is effective, demand will be shifted so that it corresponds closely to capacity, except for an opportunity cost that represents the lost profit stemming from capacity insufficient to meet demand during certain period. The major analytical factors to consider is the degree of price elasticity for the product or service: the more the elasticity, the more effective pricing will be in influencing demand patterns.

2. **Promotion:** Promotional tools such as advertising, displays, direct marketing etc., can sometimes be effective in shifting demand so that it conforms more closely to capacity. The timing of these efforts and knowledge of response rates and response patterns will needed to achieve the desired results. However, unlike pricing policy, there is much less control over the timing of demand.

3. **Back orders:** Back orders involves taking orders in one period, and promising deliveries for a later period. This approach can be used by an organisation to shift demand to other periods. The success of back orders however depends on the willingness of customers to want for later delivery. In addition, the hidden costs associated with back orders can be difficult to pin down, since it would include lost sales, annoyed or disappointed customers, and additional paperwork.

4. **New Demand:** In situations where demand is very uneven, organizations often face the problem of having to provide products or services for peak demand, for instance, demand for public transportation tends to be more intense during the moving and late afternoon rush hours; ironically, the demand is much lighter at other times. By creating new demand for buses at these other times, (e.g. excursions by school, clubs etc) there would be an opportunity to make use of the excess capacity during such slack periods. This way, organisations can achieve a more consistent use of labour, equipment and facilities.

3.3.4.2 Capacity Options

There are five basic options available for altering the capacity (or supply) or production. These are discussed below:

1. **Hire and Fire Workers:** The main determinant of the impact changes in the workforce level will have on capacity is the labour – intensiveness of operations. Another factor is the resource requirements of each worker. For instance, if a transport service firm has 15 drivers for its fleet of 22 buses, an additional seven drivers could be hired. Thus, the ability to add workers is constrained at some point by other resources needed to support the workers. On the other hand, there may be a lower limit on the number of workers needed to maintain a viable operation (e..g a skeleton crew).

At times, union contracts may restrict the amount of hiring and firing an organisation can do. Furthermore, since the issue of firing and laying-off can give workers serious problems, some organisations have policies that either disallowed or limit downward adjustments to a workforce. On the other hand, hiring presumes an available supply of workers. There are times when labour may be in short supply, and hence have an impact on the ability of an organisation to pursue this approach.

It is necessary to know that hiring and firing entails certain costs. For instance, hiring costs include recruitment, screening, and training to bring new workers "up to speed". And quality may suffer. However, some savings may occur if previously laid off workers are re-hired. Firing costs include payment of terminal benefits, the cost of realigning the remaining workforce, potential bad feelings toward the firm on the part of fired workers, and some loss of morale for workers who are retained.

2. **Overtime/Slack time:** The use of overtime or slack time is a less severe method for changing capacity than hiring and firing workers. It can generally be used across the board or selectively as needed. In addition, it can also be implemented more quickly than hiring and firing, and allows the firm to maintain a steady base of employers. In particular, overtime can be very attractive in dealing with seasonal demand peaks by reducing the need to hire and train people who will eventually be laid off during the off-season. Overtime also allows the firm to maintain a skilled workforce and employees to increase earnings. However, overtime often results in lower productivity, poorer quality, more accidents, and increased payroll costs, whereas idle time results in less efficient use of machines, and other fixed assets.

3. **Part-time workers:** The use of part-time workers has been found to be a viable option in particular situations. It usually depends on the nature of the work, training and skills needed, and union agreements. Seasonal work that require low-to-moderate job skills lends itself to part-time workers, who generally cost less than regular workers in hourly wages and fringe benefits.

4. **Inventories:** The use of finished – goods inventories allows forms to produce goods in one period and sell them in another period. This normally involves holding or carrying such goods as inventory until they are needed. In essence, inventories can be built up during periods when production capacity exceeds demand and drawn down in periods when demand exceeds production capacity. The use of inventories is not without its costs, such as storage costs, cost of money tied up, costs of insurance, obsolescence, deterioration, spoilage, breakage etc.

5. **Subcontracting:** Subcontracting allows organizations to acquire temporary capacity. However, organisations often have less control over the output; hence this approach may lead to higher costs and quality problems. The decision of whether to make or buy (i.e., in manufacturing) or to perform a service or hire someone else to do the work generally depends on such factors as available capacity, relative expertise, quality considerations, costs and the amount and stability of demand.

It is possible for a firm to choose to perform part of the work itself, and let others handle the remaining so as to maintain flexibility and as a hedge against loss of a subcontractor. In addition, this approach gives the firm a bargaining power in negotiations with contractor and a head start, if it decides at a later date to take over the production entirely.

3.2 Basic strategies for Meeting Uneven Demand

From our discussions in section 3.3.34 and its subsections, it should be clear to you that manages have a wide range of decision options they can consider for achieving a balance of demand and capacity in aggregate planning. The options that are most suited to influencing demand fall more in the area of marketing than in Operations (with the exception of backlogging). Hence we will be concentrating on the capacity options here, within the ambit of operations (With the inclusion of back orders).

There are a number of strategies open to aggregate planners. Some of the notable ones include:

1. Maintaining a level workforce

2. Maintaining a steady output rate
3. Matching demand period by period
4. Using a combination of decision variables.

The first three strategies can be regarded as "pure" strategies since each of them has a single focal point. The fourth strategy is however "mixed" because it lacks the single focus. With respect to the level capacity strategy, variations in demand are met by using some combination of inventories, overtime, part-time workers, subcontracting and back orders. The purpose here is to maintain a steady rate of regular-time output, although total output could vary. Maintaining a steady rate of output means absorbing demand variations with inventories, subcontracting, or backlogging. In the case of Chain demand strategy, capacity is match to demand, whereby the planned output for a period is set at the expected demand for that period.

Maintaining a level workforce has been found to have strong appeals in some organisations. And as earlier mentioned, workforce changes through hiring and firing often have a major impact on the lives and morale of employees hence can be disruptive for managers. Consequently, organisations usually prefer to handle uneven demand in other ways. Again, as already mentioned, changes in workforce size can be very costly and there is always the risk that a sufficient pool of workers with the appropriate skills may not be forthcoming when needed. Furthermore, such changes can involve a significant amount of administrative work.

In order to maintain a constant level of output and still meet demand requirements, an organisation necessarily needs to resort to some combination of subcontracting, backlogging, and use of inventories to absorb fluctuations: subcontracting requires an investment in evaluating sources of supply as well as possible increased costs, less control over output, and quality considerations. Backlogs may lead to lost dales, increased record keeping and lower levels of customer services. With regard to the issue of allowing inventories to absorb fluctuations, it has been realized that such an alternative also has substantial costs. These including having money tied up in inventories, having to maintain relatively large storage facilities, and incurring other costs related to inventories. Actually, inventories are not usually an alternative for service – oriented organisations, however, there are certain advantages inherent in the strategy: minimum costs of recruitment and training, minimum overtime and idle-time costs, fewer morale problems and stable use of equipment and facilities.

It is assumed in the chase demand strategy, that there is a great deal of ability and willingness on the part of managers to be flexible in adjusting to demand. One important advantage of this approach is that inventories can be kept relatively low, and this can yield substantial savings for an organisation. A major limitation is the lack of stability in operations i.e the organisation has to dance to demand's tune.

In addition, where there are gaps between forecasts and reality, morale may suffer since it quickly dawns on workers and managers that lot of efforts have been wasted.

Another alternative approach for organisations is to opt for a strategy that involves some combination of the pure strategy. This often permits managers greater flexibility in dealing with uneven demand, as well as in experimenting with a wide choice of alternatives. The major problem inherent in this mixed strategy is the absence of a clear focus, which may lead to an erratic approach and confusion on the part of employees.

3.2.1 How to choose a strategy

All the four strategies discussed above have their merits as well as limitations. Organisations are free to choose anyone. Whatever strategy an organisation is considering however depends on two important factors: company policy and costs. Company policy may set constraints on the available options or the extent to which they can be used. For instance, company policy may discourage firing and layoffs, except under unavoidable conditions. Similarly, sub-contracting may not be a viable option due to the desire to maintain secrecy about some aspects of the manufacturing of the product.

3.5 Analytical Techniques for Aggregate Planning

There are many techniques which can assist planners with the task of aggregate planning. These are broadly placed into one of two categories; informal trial-an-error techniques and mathematical techniques. The informal techniques are more widely used.

1. Determine demand for each product
2. Determine capacities (regular time, overtime, subcontracting) for each period
3. Identify company or departmental policies that are pertinent. (e.g. maintain a safety stock of 5 percent of demand, maintain a reasonably stable workforce).
4. Determine unit costs for regular time, overtime, subcontracting, holding inventories, back orders, and other relevant costs.
5. Develop alternative plans and compute the costs for each
6. If satisfactory plans emerge, select the one that best satisfies objectives. Otherwise, return to step 5.

It may be helpful to use a worksheet that summarises demand, capacity, and cost for each plan. This is shown in Figure – 3. Graphs can also be used to guide the development of alternatives.

Period	1	2	3	4	5	TOTAL
Forecast						
Output Regular time Overtime Subcontract						

Output-Forecast Inventory Beginning Ending Average Backlog						
Costs Output Regular Overtime Subcontract Hire/Fire Inventory Back orders						
TOTAL						

Figure 3: Example of a Worksheet

3.5.1 Informal Techniques

These usually consist of developing simple tables or graphs that allow planners to virtually compare projected demand requirements with existing capacity. The various alternatives are then evaluated on the basis of their overall costs. The major limitation of these techniques is that they do not necessarily result in the optional aggregate plan.

Let us make use of an examples provided by Stevenson (1996). It is based on the following assumptions:

1. The regular output capacity is the same in all periods. No allowance is made for holidays, different numbers of workdays in different months. Etc. this has been done for simplicity and ease of computation.

2. Cost (back order, inventory, subcontracting etc) is a linear function composed of unit cost and number of units, this often has a reasonable approximation to reality, although there maybe only narrow ranges over which this is true. Cost is sometimes more of a step function.

3. Plans are feasible: i.e. sufficient inventory capacity exists to accommodate a plan, sub-contractors with appropriate quality and capacity are standing by and changes in output can be made as needed.

4. All costs associated with a decision option can be represented by a lump sum or by unit costs that are independent of the quantity involved. Again, a step function may be more realistic; but for purposes of illustration and simplicity, this assumption is appropriate.

5. Cost of figures can be reasonably estimated and are constant for the planning horizon.

6. Inventories are built up and drawn down at a uniform rate and output occurs at a uniform rate throughout each period. However, backlogs are treated as if they exist for an entire period, even though in periods where they initially appear, they would tend to build up toward the end of the period. Hence, this assumption is a bit unrealistic for some periods, but it simplifies computations.

In addition to the assumptions above, the following relationships are used in the determination of the number of workers, the amount of inventory, and the cost of a particular plan.

(a) the number of workers available in any period is:

$$\begin{bmatrix} \text{Number of} \\ \text{Workers ina} \\ \text{Period} \end{bmatrix} = \begin{bmatrix} \text{Numbers of} \\ \text{workers atend of} \\ \text{the previous period} \end{bmatrix} + \begin{bmatrix} \text{Number ofnew} \\ \text{workers atstart} \\ \text{of the period} \end{bmatrix} - \begin{bmatrix} \text{Number oflaid - off} \\ \text{workers atstart of} \\ \text{the period} \end{bmatrix}$$

(b) The amount of inventory at the end of a given period is:

Inventory at the end of a period

$$= \begin{bmatrix} \text{Inventory at end} \\ \text{of the previous} \\ \text{period} \end{bmatrix} + \begin{bmatrix} \text{Production in} \\ \text{the current} \\ \text{period} \end{bmatrix} - \begin{bmatrix} \text{Amount used to satisfy} \\ \text{demand in the current} \\ \text{period} \end{bmatrix}$$

(c) The average inventory for a period is equal to:

Beginning Inventory + Ending Inventory

(d) The cost of a particular plan for a given period can be determined by summing the appropriate costs:

Cost for a period

$$= \begin{bmatrix} \text{Output cost} \\ \text{(Regular + Overtime + Subcontract} \end{bmatrix} + \begin{bmatrix} \text{Hire / Fire} \\ \text{Cos} \end{bmatrix} + \begin{bmatrix} \text{Inventory} \\ \text{cost} \end{bmatrix} + \begin{bmatrix} \text{Back - order} \\ \text{Cost} \end{bmatrix}$$

The appropriate costs are calculated as follows:

Type of Cost	How to Calculate
Output	
Regular	Regular cost/unit x quantity of regular output
Overtime	Overtime cost/unit x overtime quantity
Subcontract	Subcontract cost/unit x subcontract quantity
Hire/Fire	Cost/hire x Number hired
Hire	Cost/Fire x Number fired
Fire	Carrying cost/unit x Average inventory
Inventory	Back order cost/unit x Number of back-order units
Back order	

Let us make use of an example to illustrate the process of developing and evaluating an aggregate plan; with the trial and error techniques. Note that the intention here is not to find the lowest cost plan. With trial and error, one can never be completely sure that the lowest cost alliterative has been found, unless all possible alternatives are evaluated.

Example

Planners for a company are about to prepare the aggregate plan that will cover six periods. They have assembled the following information:

Period	1	2	3	4	5	6	Total
Forecast	200	200	300	400	500	200	1,800
Costs							
Output							
Regular time	= N2/unit						
Overtime	= N3/unit						
Subcontract	= N6/unit						
Inventory	= N1/unit/period on average inventory						
Back orders	= N/unit/period						

They now want to evaluate a plan that calls for a steady rate of regular time output, mainly using inventory to absorb the uneven demand, but allowing some backlog. They intend to start with zero inventories on hand in the first period. Prepare an aggregate plan and determine its cost using the preceding information. Assume a level output rate of 300 units per period with regular time (i.e. 1,800/6 = 300). Note that the planned ending inventory is zero. There are 15 workers.

Period	1	2	3	4	5	6	Total
Forecast	200	200	300	400	500	200	1,800
Output							
Regular	300	300	300	300	300	300	1,800
Overtime	-	-	-	-	-	-	
Subcontract							
Output – Forecast	100	100	0	100	200	100	0
Inventory							
Beginning	0	100	200	200	100	0	
Ending	100	200	200	100	-	0	
Average	50	150	200	150	50	0	600
Backlog	0	0	0	0	100	0	100
Costs							
Output							
Regular	N600	600	600	600	600	600	3600
Overtime	-	-	-	-	-	-	
Subcontract	-	-	-	-	-	-	
Hire/Fire	-	-	-	-	-	-	
Inventory	50	150	200	150	50	0	600
Back orders	0	0	0	0	500	0	500
Total	**650**	**750**	**800**	**750**	**1,150**	**600**	**4,700**

Solution

Note that the total regular-time output of 1,800 units equals the total expected demand. Ending inventory equals beginning inventory plus or minus the quantity output-forecast.

3.5.2 Mathematical Techniques

Some mathematical techniques are available to handle aggregate planning. The notable one include linear programming techniques, linear decision rule and simulation models. We shall briefly describe these techniques.

3.5.2.1 Linear Programming

These are methods for obtaining optimal solutions involving the allocation of scarce resources in terms of cost minimisation or profit maximisation. With aggregate planning, the goal is usually to minimise the sum of costs related to regular labour time, overtime, subcontracting, inventory, holding costs, and costs associated with changing the size of the workforce. The capacities of the workforce, inventories, and subcontracting constitute the constraints.

3.5.2.2 Linear Decision Rule

The Linear decision rule is another optimising technique. It was developed in the 1950s, by Charles Holt, Franco Modigliand, John Mush, and Herbert Simon. Its objectives are to minimize the combined costs of regular payroll, hiring and layoffs, overtime, and inventory by using a set of cost-approximation function. Three at these functions are quadratic in order to obtain a single quadratic equation. With the use of calculus, two linear equations can be derived from the quadratic equation. One of the equations can be used to plan the output for each period in the planning horizon, and the other can be used to plan the workforce for each period. The model has been found to suffer from three limitations. In the first place, a specific type of cost function is assumed. Secondly, considerable efforts must usually be expended in obtaining relevant cost data and developing cost functions for each organisation. Finally, the method can produce solutions that are unfeasible or impractical.

3.5.2.3 Simulation Models

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

3.5 Disaggregating the Aggregate Plan

There is the need to disaggregate the aggregate plan so that the production plan might be translated into meaning terms for production. This generally involves breaking down the aggregate plan into specific product requirements in order to determine labour requirements (skill, size of work force), materials and inventory requirements.

It is a fact that working with aggregate units often facilitates intermediate planning. However, for the production plan to be put into operation, those aggregate units must be decomposed into units of actual products or services that are to be produced or offered.

The result of disaggregate the aggregate plan is a master schedule, showing the quantity and timing of specific and items for a schedule horizon (Which often covers about six to eight weeks ahead). The master schedule shows demand for individual products rather than an entire product group, along with the timing of production. The master schedule usually contains important information for marketing as well as for production. It reveals when orders are scheduled for production and when completed orders are to be shipped.

Self-Assessment Exercise

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

4.0 Conclusion

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

5.0 Summary

Aggregate planning establishes general levels of employment, output, and inventories for periods of two to twelve months. In the spectrum of planning, it falls between the broad design decisions of long-range planning and the very specific and detailed short-range planning decisions. It begins with overall forecasts for the planning horizon and ends with preparations for applying the plans to specific products and services.

6.0 Self-Assessment Exercise

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

7.0 References/Further Reading

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