
UNIT 1: AN OVERVIEW OF OPERATIONS AND PRODUCTION MANAGEMENT

1.1 INTRODUCTION

Efficient and effective management of production resources (human resource, raw materials, etc) is a critical success factor in this global economy. It is a source of strategic growth and competitiveness in the market. One of the responsible functions to this end is Operation and production management which involves the design and control of a system responsible for the productive use of resources in the development of products or services.

Operations management is the managing of these productive resources .It entails the design and control of systems responsible for the productive use of human resource, raw materials, equipment and facilities in the development of a product or service. The way how we manage productive resources is critical to strategic growth and competitiveness.

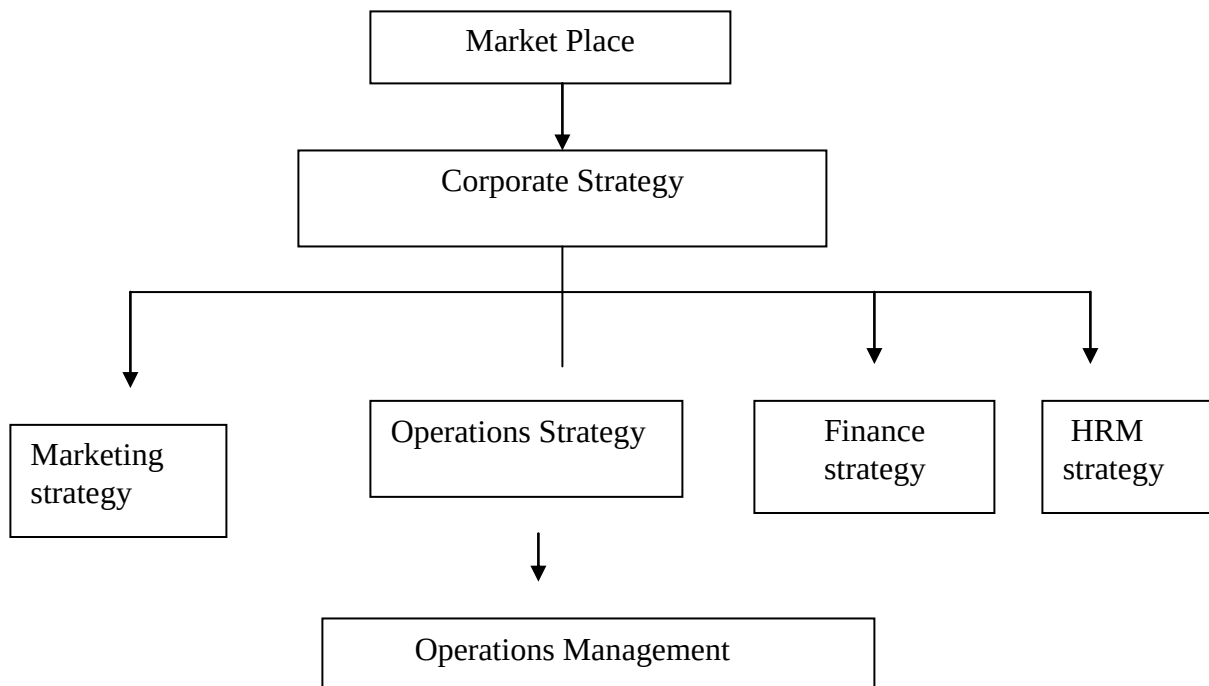
For too many people, the term production creates an image of factories, machines and assembly lines because the field of production management in the past focused almost exclusively on manufacturing sector. Heavy emphasis was placed on methods and techniques that dealt with operating a factory .In recent years, the scope of production management has broadened considerably . Currently production concepts and techniques are being applied to a wide range of activities and situations outside of manufacturing, that is in services as well as in manufacturing. In other words, production management is applicable in all types of organization be it public or private, manufactory or services. Among the service organizations that apply production management are health care, food service recreation, banking, hotel management, retail sales, education, transportation and government. Because of this broadened scope, the field has taken on the name production /operations management (POM) or more simply Operations Management (OM), a term that more closely reflects the diverse nature of activities to which its concepts and techniques are applied.

In this unit, you will learn the meaning of operations management, operations system, the environment of OM, operations decision making and productivity measurement.

1.2. DEFINITIONS

There is no one single definition given to the term operations and production management. The following are few of the definitions given by different writers.

- ❖ Operation management deals with the production of goods and services that people buy and use every day. It is a function that enables organization to achieve their goals through efficient acquisitions and utilization of resources.
- ❖ OM refers to the interaction and control of the process that transform input into finished goods and services.
- ❖ OM may be defined as the design, operation and improvement of the production systems that create the firm's primary products or services.
- ❖ OM may be defined as the management of the direct resources required to produce the goods and services provided by an organization. It is the derivative of the organization strategy and mission .**The following model summarize the field of OM in a broad business context.**



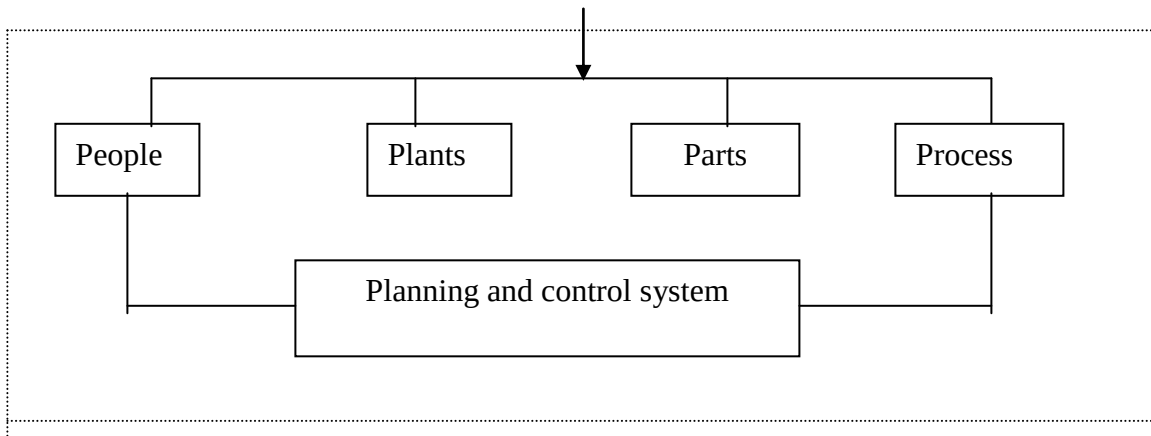


Fig.1.1 production system

Market place includes the firm's customers for its products or services which drives the corporate strategy of the firm. This strategy is based on the corporate mission and in essence reflects how the firm plans to use all its resources and functions to gain competitive advantage.

As it is shown in figure 1.1, production management is involved with the selection, organization, and control of resources to produce the desired product or services. Its most fundamental characteristics are the processes that convert resources such as raw materials, labor, buildings, managerial skills, knowledge and machines into outputs that can be exchanged for money through the marketing process.

The process used in operation system to transform inputs is to some desired outputs consists the **five P's** of operation management, that is,

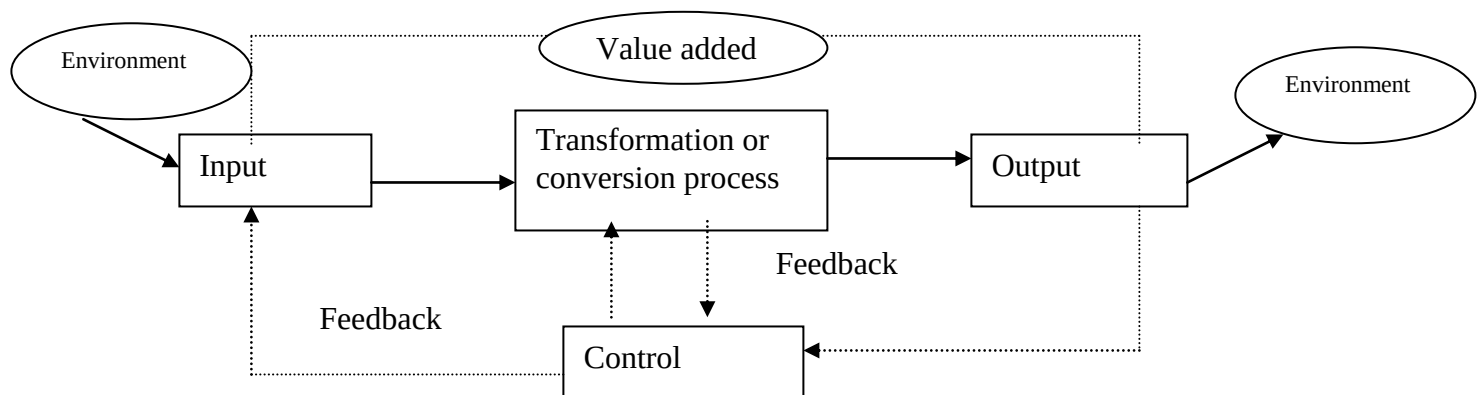
- ❖ People (the direct and indirect workforces)
- ❖ Plants (factories or service branches)
- ❖ Parts (materials or incase of services, the supplies)
- ❖ Processes (equipment and steps by which production is accomplished)
- ❖ Planning and control (procedures and information management uses to operate the system).

In a net shell, operations management is concerned with the activities, concepts and techniques employed in producing goods and services. When emphasis was on the production of goods alone, the term production management was used to describe these managerial responsibilities. The term “Operations Management” is more applicable today because of the equal emphasis on producing both goods and services.

1.3. OPERATIONS SYSTEM

Operation management is the core of most business organization. It is responsible for the creation of an organizations goods or services. Inputs are used to obtain finished goods or services using one or more transformation process. To ensure that the desired outputs are obtained , measurements /assessment/evaluation/are taken at various points in the transformation process (feedback) and then compared to previously established standards to determine if corrective action is needed (control). Figure 1.2 given on page 4, shows the input-output relationship clearly.

Fig. 1.2 The conversion process



The essence of the operations function is to add value during the transformation process. Value added is the term used to describe the difference between the costs of inputs and the value or price of out puts. Typical examples are given in the table 1 below.

Table 1. Input transformation output relationship for typical systems

System	Primary input	Resources	Primary transformation	Desired output
Hospital	Patient	MDS, nurses, medical supplies, equipment, food, bed etc	Healthcare (physiological)	Healthy individuals
Restaurant	Hungry customer	Food, chief waiters	Well prepared well served food	Satisfied customers
Automobile factory	Sheet steel engine parts	Tools, equipment, workers	Fabrication and assembly of car	High quality cars
College University	High school graduate	Teachers, books, class rooms	Imparting knowledge and skills, information	Educated individuals
Department Store	Shoppers	Displays, stocks of goods, sales, clerks	Attract shoppers promote products	Sales to satisfied customers

1.4. OPERATION FUNCTION AND ITS ENVIRONMENT

In every business organization there are three basic functions, that is, finance, marketing production/operation and others such as information system. However, production and operations function is the foundation of any business. Today's competitive and economic realities demand companies upgrade their skill in production. Because, no matter how other functions are effective, if it is difficult to think of success without having a product that can fit the requirements of customers. Doing so requires knowledge and application of operations management techniques.

In most organizations, operations is an internal function that is buffered from the external environment by other organizational functions such as marketing, finance, human resource management, purchasing, R and D departments etc. The following figure depicts this relationship

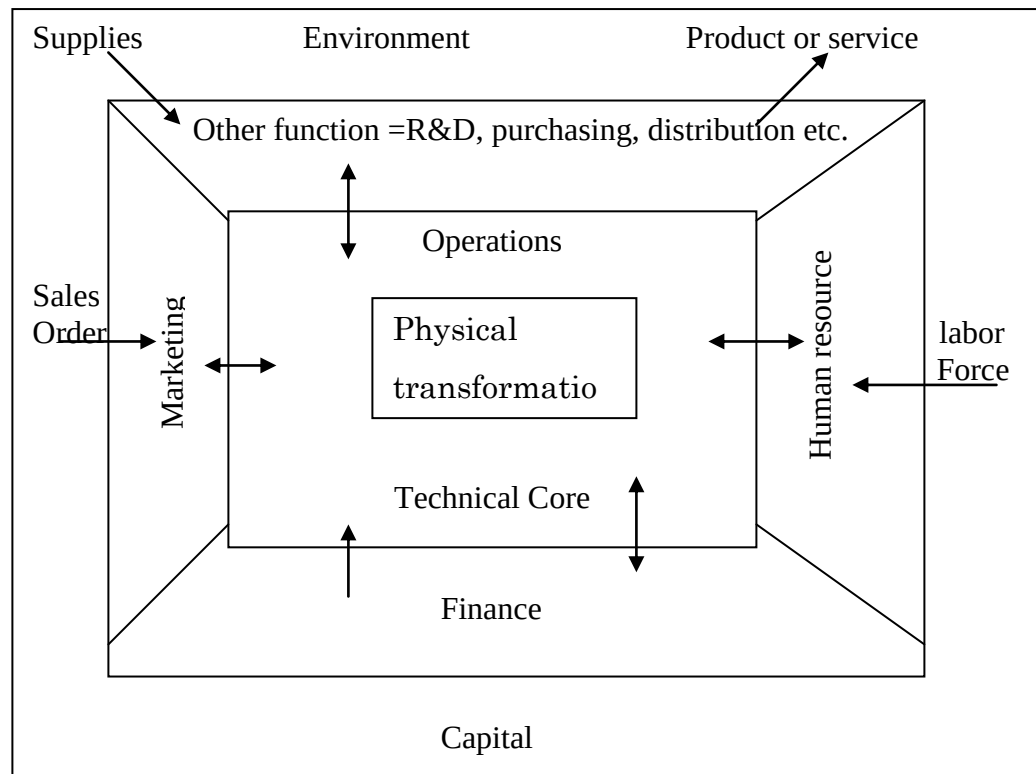


Fig. 1.3 The environment of operation management

As it is shown in figure 1.3 operations function interact/interface and exchange information from the environment indirectly through other functions of the business.

These interfaces with other functions buffer the production function (or technical core) from the direct environmental influence. This situation has been traditionally seen as desirable for the following reasons:

1. Interaction with the environment could have a distributing manner on the operation or production process.
2. In certain situations maximum efficiency can be achieved by making production continuous.
3. The management skill that could be required to carry out successful operation of the production processes are often different from those required for successful operation of the boundary system of marketing , personnel and other functions.

1.5. OPERATIONS DECISION MAKING

Hundreds of decisions are made every day in the operation activity. Even minor decisions determine the company's success or failure. It ranges from simple judgmental to complex analysis which can also involve judgment (past experience & common sense). They involve a way of blending objective and subjective data to arrive at a choice. The use of quantitative methods of analysis adds to the objectivity of such decisions.

The major areas in which operations managers make decisions are:

1. Strategic decision

- Product and service plan
- Competitive priorities (TQM, statistical process,
- Location, capacity and layout decision

2. Design decisions

- Deals with actual production system
- Process design technology
- Job design

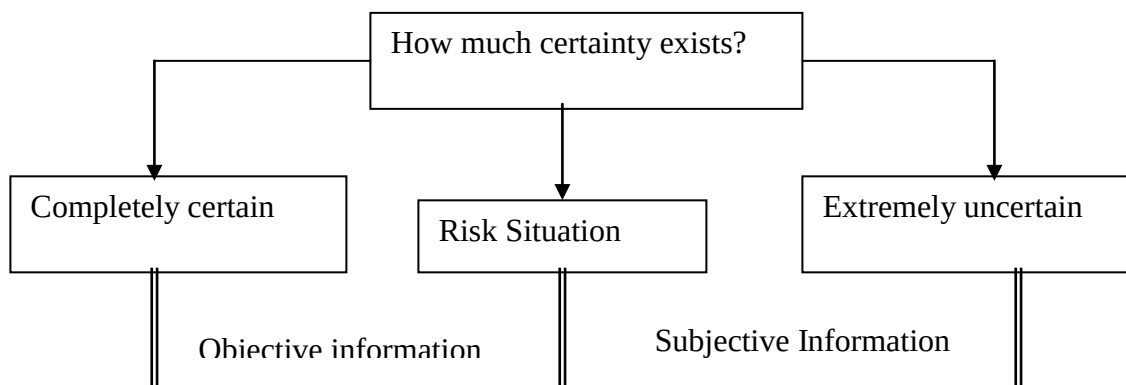
3. Operating Decision—deals with operating the factory system once it is in place. It includes forecasting, materials management, and inventory management, aggregate planning, scheduling.

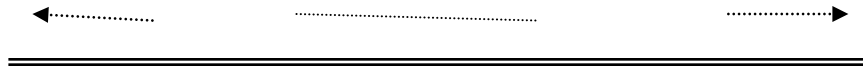
1.5.1. Quantitative Approaches

Quantitative approaches to problem solving often embody an attempt to obtain mathematically optimum solutions to managerial problems. The functions are commonly used quantitative approaches like, linear programming, Queuing techniques, Inventory models, Forecasting techniques, Statistical models.

Operation decision become more complex when: it involves many variables, the variables are highly interdependent or related, and the data describing the variables are incomplete or uncertain. The necessity of working with incomplete and uncertain data has always been a problem for decision maker. The following figures depict the information environment decisions.

Fig. 1.4 Quantitative methods available to operations managers





(All information)

(Some information)

(No information)

The following are quantitative tools used under the three situations.

Certainty Risk

uncertainty

Algebra, Breakeven analysis,
Cost benefit analysis,
Calculus, mathematical
Programming, linear and
Non linear, integer, dynamic
Programming etc.

Statistical analysis
Queuing theory
Simulation
Net Work analysis;
PERT/CPM
Decision tree, Utility theory etc

- Game theory
- Decision theory

Framework for Decisions (process)

An analytical and scientific framework for decisions implies several systematic steps for decision makers. They are:

Step 1. Define the problem and its parameters

Step 2. Establish the decision criteria and set the objective

Step 3. Formulating a relationship (model) between the parameters and the criteria

Step4. Generate alternatives by varying the values of the parameters

Step 5. Choose the course of action, which most closely satisfies the organization.

Step 6. Implement the decision and monitor the result

In the following section of this unit you will learn how to apply the quantitative tools in solving operations related problems. Since it is difficult to illustrate the entire models only one model, which can be used under the three situations of decision-making are discussed.

A. Decision Making under Certainty

As it is shown in the figure 1.4 above different approaches to decision making are available to decision makers. The most widely used decision rule under the certainty situation is break-

even analysis (cost-profit-volume analysis), cost-benefit analysis and mathematical programming. In the next section break-even analysis is illustrated.

1. Breakeven Analysis (BEA)

BEA is a widely used decision making tool. It helps to make a decision whether to produce or not a certain level of output. Breakeven point is a level of output at which, profit is zero or no loss or no gain. Production or operation level below this point results in a loss, whereas level of output above this point helps the company to enjoy some level of profit. Therefore, knowing this point helps the company to take appropriate action.

Example 1. The cost and revenue information of ABC Company are as follows:

Fixed Cost = Br 120,000

Unit Price = Br. 50

Variable Cost/unit (Vc/unit) = Br. 30

Find the break-even point in terms of unit and sales in Birr.

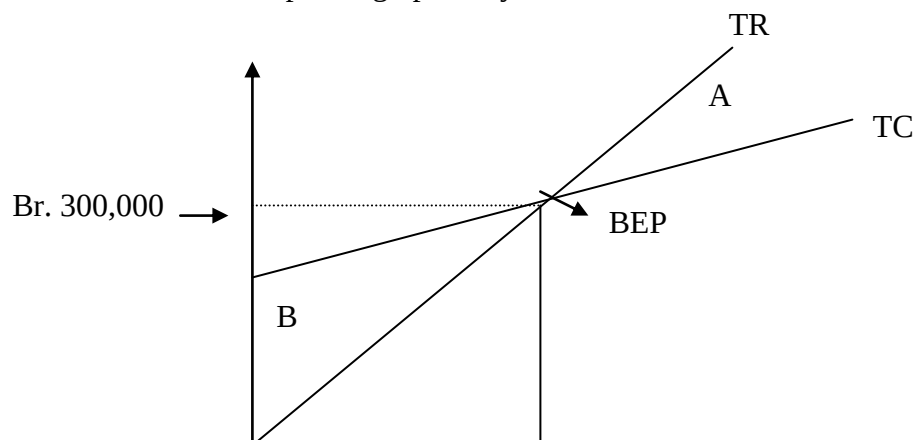
Solution:

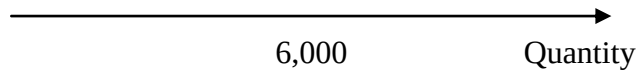
$$\text{Break Even Point-BEP (quantity)} = \frac{\text{Fixed Cost}}{\text{Price/unit} - \text{VC/unit}}$$

$$\begin{aligned} \text{BEP} &= \frac{120,000}{50 - 30} = \frac{120,000}{20} \\ &= \underline{6,000} \text{ units} \end{aligned}$$

$$\text{BEP (In Birr)} = 6,000 \times \text{Br. } 50 = \underline{\text{Br. } 300,000}.$$

This can be depicted graphically as follows:





Where: TR= total revenue A= represents the profit region
 TC= total cost B= represents the loss region
 BEP= breakeven point Vc/unit = Variable cost per unit

Interpretation

The company, if it wants to be profitable, should produce and sale more than 6, 000 units of output. For example, If the external and internal environment force it to produce only 3,000 units of the product the company will incur a loss. So it has to take some short-term as well as long term measures to correct the situation.

B. Decision making under Risk

Decision Tree

Decision tree is a schematic diagram used to determine expected value. It shows the alternative outcomes and independence of choice. It is used in risk situation where there is only probabilistic information stated in probabilistic value.

Example. ABC manufacturing firms wants to meet the excess demand to its products. The firm's management is concerning three alternative courses of action.

- A. Arrange for subcontracting
- B. Begin overtime production
- C. Construct new facilities

The correct choice depends largely on future demand, which may be low, medium or high. Management ranks the respective probabilities as 10%, 50% and 40% to low, medium and

high product demand in the future respectively. A cost analysis reveals the effect on profit of each alternative under a given state. This is given in the payoff table below.

Pay off table

Alternatives	Profit if Demand is (Birr)		
	Low (0.1)	Medium (0.5)	High (0.4)
Arrange for sub contract (A ₁)	10,000	50,000	50,000
Over time (A ₂)	-20,000	60,000	100,000
New facilities (A ₃)	-150,000	20,000	20,000

Required: Which alternative is the viable choice?

We can use expected monetary value approach and decision tree to answer this question.

- 1. Expected monetary value (EMV)** – Determine the expected payoff of each alternative and choose the alternative that has the best expected payoff.

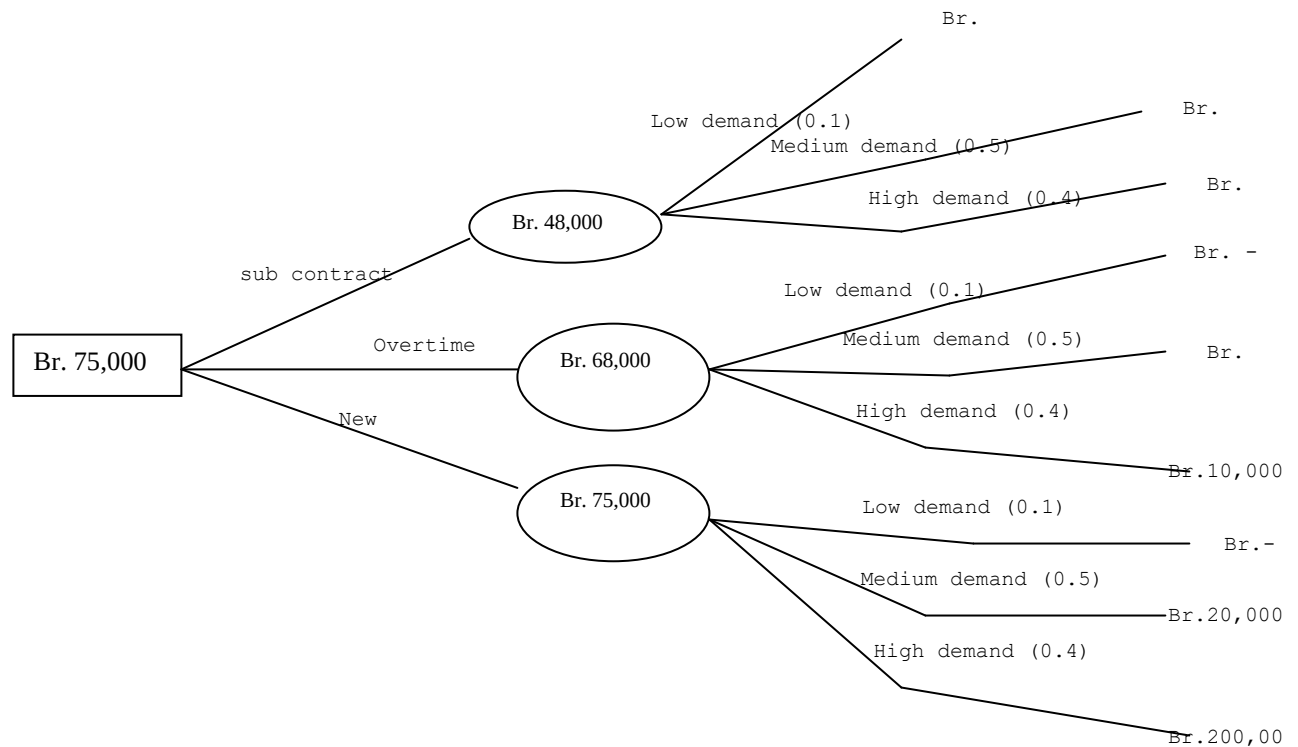
$$\begin{aligned}
 \text{EMV (A}_1\text{)} &= 10,000 \times 0.1 + 0.5 \times 50,000 + 0.4 \times 50,000 \\
 &= 1000 + 25,000 + 20,000 \\
 &= \underline{46,000}
 \end{aligned}$$

$$\begin{aligned}
 \text{EMV (A}_2\text{)} &= -20,000 \times 0.1 + 60,000 \times 0.5 + 100,000 \times 0.4 \\
 &= -2,000 + 30,000 + 40,000 \\
 &= \underline{\text{Br. 68,000}}
 \end{aligned}$$

$$\begin{aligned}
 \text{EMV (A}_3\text{)} &= 150,000 \times 0.1 + 20,000 \times 0.5 + 200,000 \times 0.4 \\
 &= -15,000 + 10,000 + 80,000 \\
 &= \underline{\text{Br.75, 000 (highest expected value)}}
 \end{aligned}$$

Decision: The best alternative is to construct new facilities because it has the highest expected value.

You can also use decision tree two depict this information to make a decision as shown below.



Decision: Construct new facility because it have a better return than other two alternatives

C. Decision making under uncertainty

At the opposite extreme is complete uncertainty, no information is available on how likely the various states of nature are under these condition, four possible decision criteria are :

- A. **Minimax regret** – determine the worst regret for each alternative , and choose the alternative with “ best worst”
- B. **Maximax** – determine the best possible payoff and choose the alternative with that payoff.
- C. **Laplace** – determine the average payoff, and choose the alternative with the best average.
- D. **Maximin**- determine the worst possible pay off for each alternative, and then choose the alternative that has the “ best worst”

Example: Based on the above pay off table and assuming that there is not probability value of occurrence of each outcome, determine which alternative would be chosen under each of these strategies.

- a. Maximin
- b. Maximax
- c. Laplace

Solution:

a) Maximin criteria

The worst pay off for the alternatives are Br. 10,000 for subcontracting, Br. -20,000 for overtime and Br. -150,000 for new facilities and 10,000 is the best out of the worst, hence, the decision is to choose subcontracting as an alternative using the maximin criteria.

b) Maximax criteria

The best pay off for each alternative, that is, for Sub contractiing is 50,000, over time Br. 100,000, and New facilities is Br. 200,000. The decision is to construct new facility which is an alternative with the best payoff value i.e., Br. 200,000

C) Laplace criteria

The average payoff of each alternative is;

$$A_1 = 10,000 + 50,000 + 50,000 / 3 = 36,667$$

$$A_2 = -20,000 + 60,000 + 100,000 / 3 = 46,667$$

$$A_3 = -150,000 + 20,000 + 200,000 / 3 = 23,333$$

Decision: use overtime to absorb the excess demand.

Operations management may be defined as the design, operations and improvement of the production systems that creates the firm's primary products or services. The essential difference between the two is that service is an intangible process, while a goods is the physical output of a process. To put it another way a service is something that "If you drop it on your food it won't hurt you" Other differences are that in service, location of the service facility and direct customer involvement in creating the out put are often essential factors; in goods production, they usually are not.

Manufacturing and service are often similar in terms of what is done but differ in terms of how it is done. For example, both involve design and operating decision. Most of the difference between manufacturing and service operations is that manufacturing is product-oriented and service is act oriented. The difference involve following.

1. Customer Contact

By its very nature, service involves a much higher degree of customer contact than manufacturing does. The performance of service typically occurs at the point of consumption; that is the two often occur simultaneously. For example surgery requires the presence of the surgeon and the patient. Repairing a leaky roof must take place where the roof is on the other hand manufacturing, allows a separation between production and consumption so that manufacturing often occurs in an insulated environment away from the customer.

2. Uniformity of inputs

Service operations are subject to more variability of inputs than manufacturing operations are. Each patient, each TV repair presents a specific problem that often must be diagnosed before it can be remedied. Low variability of inputs requirements for manufacturing are generally more uniform than for service.

3. Labor content of Jobs. Service by its nature is labor intensive whereas manufacturing is capital intensive

4. Uniformity of out put. Service is variable but manufacturing is low variable or highly (uniform).

5. **Measurement of productivity.** Productivity measurement in manufacturing is straightforward and easy but Service productivity measurement is more difficult because, there are certain intangible variables in service that are difficult to measure objectively.

Table2. Difference between manufacturing and service operations (Summary)

Characteristic	Manufacturing	Service
Out put	Tangible	Intangible
Contact with customer	Low	High
Uniformity of input	High	Low
Labor content	Low	High
Uniformity of output	High	Low
Measurement of productivity	Easy	Difficult
Storage	Output can be inventoried	Not
Delivery time	Long lead times	Short lead time
Quality	Objectively determined	Subjectively determined

In reality most firms are not selling purely services or goods rather manufacturers provide many services as part of their product and many services often manufacture the physical product that they deliver to their customers or consumer goods is creating the services. In essence goods are considered as vehicles for services. To put in an another way:

- ❖ In services outputs cannot be inventoried while for goods products can be invigorated
- ❖ There is extensive customer contact for service white for goods production customer contact is little
- ❖ The lead-time is short for services (delivered immediately on spot e.g. doctor) while for goods it is long.
- ❖ Service quality determined with difficulty (customer service and customer satisfaction are difficult to measure.) while product quality can easily be determined.

1.7. THE ROLE OF OPERATION MANAGEMENT EXECUTIVES

The issues facing OM executives are many and interrelated. From operations strategies view, the roles can be summarized as cost (Economy), quantity, speed of delivery, and flexibility.

The production phase of the overall management system begins at the point at which capital is to be converted into physical or operational resources and ends at the point at which those resources have been converted into goods or services.

In this process the major concern of operation personnel includes:

1. To produce a good or service in quantities and at times which will satisfy the demand item **(Quantity)**, concerned personnel will have to engage in production planning and control. This requires forecasting the future demand for a product, translate the future demand for various operation resources, procure the required operation resources, and utilize those resources to produce the product.

The above step include techniques of sales forecasting, learning curve, MRP, inventory, control, purchasing, facility lay out, material handling, work Scheduling, plant location, operation control and the like.

2. To produce a good or service at the lowest possible cost **(economy)**, concerned personnel will have to carry out:

- ❖ Ascertain the most economical work methods
- ❖ Established work standards
- ❖ Motivate employees to adhere to efficient work methods and to satisfy to existing work standard.

The techniques to be employed include method analysis, process charts, safety, maintenance, time study, work sampling, standard date, job enrichment, non financial and wage incentives, (such as profit sharing).

3. To produce a good or service of satisfactory quality (**Quality**) concerned personnel have to work the following:

- ❖ Develop appropriate product specification
- ❖ Maintain conditions, which are conducive to satisfactory quality.
- ❖ Introduce inspection procedures, which will reveal the quality of past out, put.
- ❖ Apply methods which are designed to control the quality of future output

Techniques involved here include:

- ❖ Product design
- ❖ Inspection methods, types of inspections
- ❖ Acceptance sampling
- ❖ Sampling by attributes and by variables
- ❖ Control charts for attributes and variables.

4. **Speed of delivery.** The ability of a firm and provide dependable and fast delivery. This allows the firm to charge a premium price for its product.
5. **Flexibility.** The ability of a company to offer a wide variety of products to its customers. It's a measure of how fast a company can convert its processes from making an old line of products to producing a new product line.
6. **Speed up the time** it takes to get new products is to production or integration of all activities to avoid the common 'silo effect'.
7. **Making global production networks.** Global production network decisions involve:
- Assuring that components produced abroad meet design and quality requirements. (This entails carefully selection of suppliers and anticipating local labor and government actions)
 - managing the logistics of shipping and receiving parts
 - Developing the information system to track and monitor the first two.
8. *Developing and integrating new process technologies into existing production systems.*

9. *Achieving high quality quickly and keeping it up in the face of restructuring.*
Companies do not have the luxury of the long development periods to achieve quality parity with the competition.

10. *Managing a diverse workforce, with different multiple cultures and multiple languages*

11. *Confirming to environmental constraints ethical standards and government regulation.*

- issues of social responsibility affect all parts of the organization, but
- operations is often the focal point because it is the prime user of physical resources that may lead to pollution and other safety hazards.

1.8. PRODUCTIVITY MEASUREMENT

Productivity is a common measure of how well a country, industry or business unit is using its resources (or factors of production). In its broadest sense, productivity is defined as:

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

To increase productivity, we want to make this ratio of output to inputs as large as practical. Productivity is what we call a relative measure. In other words, to be meaningful, it needs to be compared with something else. Comparison can be made with similar operations within its industry, or it can measure productivity over time within the same operation.

Productivity may be expressed as **partial measures**, **multifactor measures**, or **total measures**. If we are concerned with the ratio of output to a single input; we have a partial productivity measure. If we want to look at the ratio of output to a group of inputs (but not all inputs), we have a manufacture productivity measure. If we want to express the ratio of all outputs to all inputs, we have a total factory measure of productivity that might be used to describe the productivity of an entire organization or even a nation.

$$\text{Partial Measure} = \frac{\text{Output}}{\text{Labor}} \quad \text{or} \quad \frac{\text{Output}}{\text{Capital}} \quad \text{or} \quad \frac{\text{Output}}{\text{Material}} \quad \text{or} \quad \frac{\text{Output}}{\text{energy}}$$

$$\text{Multifactor Measure} = \frac{\text{Output}}{L + K + E} \quad \text{or} \quad \frac{\text{Output}}{L + K + Rm}$$

$$\text{Total Measure} = \frac{\text{Output}}{\text{Inputs}} \quad \text{or} \quad \frac{\text{Goods and service produced}}{\text{All resource used}}$$

Where: L = Labor

K = Capital

E = Energy

Rm = Raw materials

Example 1 ABC Co. produces apple pies sold to supermarkets has been able to work with his current equipment, to produce 24 pies per bushel of apples. He currently purchases 100 bushel per day and each gallon requires 3 labor –hours to process. He believes that he can hire a professional food broker, who can buy better – quality apple at the same cost. If this is the case he can increase his production to 26 pies per bushel. This labor hour will have the impact on productivity (pies labor hours) if the food broker is hired. The professional food broker works 8 hours per day. Calculate:

1. The current labor productivity
2. Labor productivity with food broker

Solution:

$$\begin{aligned} \text{Current Labor productivity} &= \frac{24 \text{ pies} \times 100 \text{ bushel}}{100 \text{ bushel} \times 3 \text{ hour}} \\ &= \underline{8 \text{ pies /labor hour}} \end{aligned}$$

$$\begin{aligned} \text{Labor productivity with food broker} &= \frac{26 \text{ pies} \times 100 \text{ bushel}}{(100 \text{ bushel} \times 3 \text{ hrs}) + 8 \text{ hours}} \\ &= \frac{2600}{308} \end{aligned}$$

$$= \underline{\underline{8.44 \text{ pies /labor hours}}}$$

Using last year (i.e. 8 as a base, the increase is $5.5\% = 8.44/8 = 1.055$ or 5.5% increase over last year.

Example 2 A) Determine the productivity of four workers who installed 640 square yards of carpeting in 8 hours per day.

B) Calculate the productivity of a machine that produces 60 units in two hours

Solution:

$$\text{Productivity} = \frac{\text{Yards of carpet installed}}{\text{Labor hours worked}}$$

$$= \frac{640 \text{ yards}}{4 \text{ workers} \times 8 \text{ hours}}$$

$$= \frac{640}{32}$$

$$= \underline{20 \text{ yards/hour}}$$

$$\text{Productivity} = \frac{\text{Outputs (in units)}}{\text{Production time}}$$

$$= \frac{60 \text{ units}}{2 \text{ hours}}$$

$$= \underline{30 \text{ pieces /hour}}$$

Example 3 A company that produces fruits and vegetable is able to produce 400 cases of canned peaches in one half hour with two workers. What is labor productivity?

Solution

$$\text{Labor productivity} = \frac{\text{Quantity produced}}$$

Labor hours

$$= \underline{400 \text{ cases}}$$

$$2 \text{ workers} \times 1/2 \text{ hour /workers}$$

$$= \underline{400 \text{ cases per hour}}$$

Examples 4 A wrapping paper Company produced 2000 rolls of paper one day at a standard price of Br. 1 per roll. Labor cost was Br. 160, material cost was Br. 50, and overhead was Br. 320. Determine the (multifactor and total) productivity.

Solution

$$\text{Multifactor productivity} = \frac{\text{quantity produced @standard price}}{\text{Labor cost + material cost + overheads}}$$

$$= \frac{2,000 \text{ rolls X Br. 1 /roll}}{\text{Br. 160 + Br 50 + 320}}$$

$$= \frac{2000}{530}$$

$$= \underline{3.77}$$

Improving Productivity

Factors Affecting Productivity and Improving

- Numerous factors affect productivity. Among them are methods, capital, quality, technology, and management.

There are a number of key steps that a company or a department can take toward improving productivity:

1. Develop productivity measures for all operations
2. Look at the system as a whole in deciding which operations to concentrate on; it is overall productivity that is important.
3. Develop methods for achieving productivity improvements

4. Establish reasonable goals for improvement.
5. Make it clear that management supports and encourage productivity improvement.
6. Measure improvements, and publicize them

1.9 COMPETITIVENESS AND OPERATIONS STRATEGY

Companies must be competitive to sell their goods and services in the market place. Competitiveness is an important factor in determining whether a company prospers, barely gets by, or fails. Business organizations compete with one another in variety of ways i.e. by identifying operating priorities. Scholars have identifying operating priorities. A few basic operations priorities include:

1. **Cost:-** within every industry, there is usually a segment of the market that buys strictly on the basis of low cost. To successfully compete in this niche, a firm must be the low-cost producer, but even doing this not always guarantee profitability and success.
2. **Product quality and process reliability.**
 - Product quality, Process quality
3. **Delivery speed (time)**
4. **Flexibility: - ability** to respond to changes. The better a company as able to respond to changes, the greater the competitive education over another company that is not able to respond.
5. **New product introduction speed** etc.

Over the years, the top three priorities have included conformance quality (ability to build a product to designed specifications), product reliability, and delivery dependability, low price, and speedy new product introduction.

Operations Strategy

Operations strategy is concerned with setting broad policies and plans for using the resources of the firm to best support the firm's long-term competitive strategy. It has a long-term impact on the nature and characteristics of the organization. In large measure, strategies affect the ability of an organization to compete.

Strategies: - are plans for achieving goals. The organization strategy provides the overall direction for the organization. It is broad in scope, covering the entire organization. Operations strategy is narrower in scope, dealing primarily with the operations aspect of the organization.

Operations Strategy relates to products, processes, methods, operating resources quality, costs, lead times, and scheduling.

New Strategies:

Traditional strategies of business organizations have tended to emphasize cost minimization or product differentiation. While not abandoning these strategies, many organizations are adopting new strategies that are based on **quality and/or time**.

1. Time Based Strategies

This strategy focus on reducing the time required to accomplish various activities (such as the time taken to develop new products or services and to market them, the time needed to respond to a change in customer demand, or the time needed to deliver a product or perform a service). By doing so, organizations seek to improve service to the customer, and to gain a competitive advantage over rivals who take more time to accomplish the same tasks.

The rationale is that by reducing time; costs are generally less, productivity is higher, quality tends to be higher, product innovations appear on the market earlier, and customer services improved.

Some of the areas in which organizations have achieved time reduction are:

- Planning time
- Product/service design time
- Processing time
- Change over time
- Delivery time
- Response time for complaints.

2. Quality-based Strategies (will be discussed in later chapters)

This strategy focuses on satisfying the customer by integrating quality in to all phases of the organization. This includes not only the final product or service that is provided to the customer, but also the processes related to the design, production, or service after the sale.

UNIT 2: PRODUCT DESIGN AND PROCESS SELECTION

2.1 INTRODUCTION

The essence of any organization is the products or services it offers. There is an obvious link between the design of those products or services and the success of the organization that have well-designed products or services. Firms that have well-designed products or services are more likely to realize their goals than those with poorly designed products or services. Hence, organizations have a vital stake in a good product and service design. This unit presents the major aspects of product and services design and how the process to produce them is designed and selected.

Product and service design plays a strategic role in the degree to which an organization is able to achieve its goals. It is a major factor in customer satisfaction, product and service quality, and production costs (price). Because product design is concerned with the functional (use) and aesthetic requirements necessary to meet the demands of the market place and at the sometime achieve an acceptable rate of return. Decisions related to product designs have far reaching effect on the future of an organization. Therefore, great care must be taken while designing a product/service.

The objectives of product and service design may vary from situation to situation. Generally, however, the objectives/reasons are:

1. To introduce new or revised products or service to the market as quickly as possible;
2. To design product or service that have customer appeal;
3. To increase the level of customer satisfaction;

4. To reduce costs and;
5. To increase quality

In a competitive environment getting new or improved products or services to the market a head of competitors gives an organization a competitive advantage that can lead to increased profits as well increased market share and can create an image of the organization as a leader.

2.2. FACTORS AFFECTING PRODUCT DESIGN

Decision pertaining to the final product design will influence or determine; the firm's image profitability, opportunities and the problems it may face in the future.

The product chosen for the firm's market will also determine:

- The need for capital
- The size and composition of the organizational structure
- The type of quantity of processing equipments
- The type quantity and quality of material and supply used
- The size and skill requirements of its work force.

Product design can require the input of different functional managers. The following discussion will help you to understand the decisions and roles of the different managers pertaining to product design.

1. Product design – a production manager's viewpoint

The production manager makes decision concerning process employed, quality, quantity, and type of materials that will go into it and the required supervision.

2. Product design – a marketing viewpoint

Marketing's optimal product design would be an innovative product that leads to high volume of sales, complements the firm's general product line, enhance the firms image in the market place, and available in any desired quantities at an attractive cost.

3. Product design – A Financial manager’s view point

The concern of financial manager is to have a product that help to achieve the maximum return on investment, maintain the firm’s financial liquidity and assures its survival. The strategic choice of a design becomes an important decision, which will materially affect the firm’s profitability, growth and survival.

4. Product design – a top management view point.

The product decision represents one of the major decision top managers must make. However top managers must make a careful analysis and evaluation of the firm’s strengths, weaknesses, interests, financial strength, managerial abilities and environment and numerous other factors prior to making the final product design decision

5. Product design- Quality Control View Point

Quality control, and indirect cost, will often be greatly affected by the product design choice. Designs will increase both production and quality control cost, if they are difficult to manufacture and require close process monitoring and numerous quality control checks to determine whether the product is in conformance with product specifications. These higher costs may come from a combination of higher reject and rework levels and high quality control costs, primarily from inspection.

2.3. THE STRUCTURE/ PROCESS OF PRODUCT DESIGN

The three major functions involved in product and service design are marketing, product development and manufacturing. **Marketing** has the responsibility for suggesting ideas for new product and for providing product specification for existing product lines. **Product development** has the responsibility for moving the technical concept for the product to its final design and **manufacturing/operation** function has the responsibility for selecting and/or configuring the process by which the product is to be manufactured.

The product development activity provides the link between the customer needs and expectations and the activity required to manufacturing the product. This will take you to the discussion of new product design processes.

The design process begins with motivation for design. For a new business or a new product, the motivation may be obvious to achieve the goals of the organization and realize new opportunities. However, making them happen /utilized them is a demanding challenge. New product development entails a complex set of activities that cut across most functions in business.

There are also specific external factors to consider, such as government regulations, competitive pressures, customer needs, the appearance of new technologies etc. Ultimately, the customer is the challenging force for product and service design.

Product or service design follows seven consecutive steps. They are briefly explained as follows.

Step 1. Idea/concept stage

For product design and development the starting point is product idea. It comes from a variety of sources. The most obvious source is the customer. Marketing can tap this source of ideas in a number of ways such as the use of focus groups, surveys, and the analyses of buying pattern. Other sources of idea include:

- concept or creation of an inventor
- a product already conceived and available from outside the firm.
- the results of individual designers or design teams employed by the firms for that specific purpose(employees)
- research and development department (R&D)
- distribution channel members
- Government agencies such as patent and copyright office
- Competitors or
- Any combination of the above sources

Product design research is the major source of product idea for most firms. It can be applied or basic. Product design research basically is search for ideas, information or relationships. If its purpose is the advancement of knowledge irrespective of short- term results, it is generally referred to as pure or basic research. The term “**applied research**” has Commercial overtones. Because it seeks to answer real or anticipated problems, applied research has short range objectives compared to those of basic research. Applied research projects includes the study of one’s own product line for functional or aesthetic improvement, the analysis of competitor’s product to determine how it was manufactured, the analysis of one’s own manufacturing processes to improve output or reduce cost, and the analysis of the firm’s organizational structure to increase efficiency. All of these research projects would be undertaken with the expectation of increasing profitability.

Innovation is an omnipresent in product development, the continual search for improvement takes place at each step or phase, from idea to finalize design. Design improvements may include a new product shape, color or texture while processing improvement may include that make a product or service economically attractive by increasing process efficiency, eliminating the number of conversion steps required or change packaging needs.

Step 2. Preliminary product design evaluation /Initial feasibility analysis/

In this stage of the product design process responsible personnel are involved in screening and evaluation of the product idea and they should:

- ensure that there is market potential or suffices demand
- ensure that the product can be produced with the existing resources and/or check what additional resources are required
- check financial feasibility implications by estimating the approximate cost and return or investment
- Finally, it may be necessary to consider the product is appropriate as to the company’s policy and fulfills legal and environmental requirements.

Step 3: Product development and prototype stage

The process of converting a set of ideas and invention, or a new product concept into the final form for manufacturing is called product development. The specification for material, processing tolerance, functional performance, maintainability, structural shape, reliability and appearance will be embodied in a set of blue prints, drawings, lists, diagrams to supplement the prototype and parallel its development through preproduction and production phases. The first physical embodiment is the prototype. Prototype is a physical model of a proposed product or service and it should serve many purposes:-

- It demonstrates the functional requirements or its manufacturing feasibility.
- It illustrates or demonstrates some aesthetic or style requirements.
- It allows a firm to determine the need for specific processes or equipment to produce the products;
- Determine the functional reliability, ship ability, reparability, and packaging requirement of the proposed product,
- The probable sequence of manufacturing steps
- The feasibility of using standard parts,
- The identification of assembly problems and
- The need for and feasibility of refinement of design features.

Step 4 Economic Evaluation of the design

Designers should develop criteria for evaluation of alternative designs. The following are the four commonly used criteria

- Product performance /how well the product meets customer needs and requirements
- Development speed /how long it takes to get the product to market.
- Product cost/ the total cost to the customer/including manufacturing cost and
- Development program expense /one time development costs for the development project

Step 5 Preparation of product design specification.

The fundamental structure of the production process to be employed in producing a product is determined largely by the design specifications that are defined in blue prints, drawings,

diagrams and material lists. These describe in detail the required dimensions, tolerances, finishes and materials of the parts or product.

Step 6. The pilot production Run

Small-scale production run or pilot production run is important for the following reasons. Some of these are:

1. If the product requires new technology or processes not commonly used by the firm, the output rate a process lay out envisioned may be less than that anticipated.
2. To reveal problems not anticipated or planned
3. To know yield, the percentage of acceptable product from a specific process step, may be less than what is required to match the output from another process step.
4. To provide a quantity of product for further studying market acceptance, developing better production, cost figures, evaluate labor and maintenance requirements, and determining reject levels more accurately.
5. To provide an opportunity to observe the manufacturing process more or less as they will occur if the decision for full-scale production is approved.
6. To reveal unidentified process problems, coordination requirements, needed quality control techniques difficulties in material handling and storage, and physical environmental factors such as noise or heat and other possible safety hazards.

A pilot run often employees scaled-down or modified equipment or use presently owned equipment or lease others. Some new product development programs do not include a pilot run if the product is similar to those already made or if the processes are very similar.

Step 7 Final product design selection decision

Few ideas will reach the final product selection stage. The process of searching ideas and evaluating their profit potential in light of the limits on the technological ability of the firm, the required financial investment, and the competitive and market conditions will eliminate all but a few when the design staff reaches this point, the final decision rests with top management.

Management based on their judgments, experience and additional information that point to better investment opportunities will accept or reject the design.

2.4. OTHER DESIGN CONSIDERATIONS

1. Consumer Quality level. The design process should be aware of the market segment which the product is designed to serve and determine tolerance level with its cost implication.

Four specific characteristics are related to quality in product design:

- i. **Functionality.** It is the degree to which a product performs its intended functions /use/.
- ii. **Maintainability.** Maintainability refers to the ease of performing maintenance on the product such as (lubricating, repairing hoses).
- iii. **Reliability.** It is the ability of a product to perform as expected under normal conditions without excessive frequency of failure.
- iv. **Reproducibility.** Refers to the ability of the production system to consistently produce products of the desired quality.

2. Standardization

Standardization is a means of achieve lower production. and assembly costs through reducing variety. The choice of standardized parts is aimed at reducing unnecessary or economically unjustifiable variety in a group of products or parts.

Through standardization the hidden costs of unnecessary product controls; additional paper work, near duplicate designs; and the inefficient use of space, equipment, and tools can be reduced.

3. Value analysis and value engineering

Value analysis is a systematic organizational effort to reduce the costs of materials and purchased parts for producing a product, without sacrificing aesthetic or functional requirements, which is the (responsibility purchasing). Value engineering, closely related to value analysis, directs efforts at ensuring the functional ability of a product at minimum cost. It is the responsibility of engineering department.

4. Product Diversification and Simplification

Product diversification is the proliferation of product designs or an increase in the types, qualities, sizes, and colors of a particular product. There are economic reasons for caution in expanding product lines. These are:

- Smaller manufacturing runs
- Less efficient use of processes
- Higher labor, material, and set up costs.
- Higher level of inventory for the producer, distributor, and retailer.

Product Simplification on the other hand, is the elimination of the complex features of a product so that the intended function is performed but with reduced costs, higher quality and more custom satisfaction.

6. Modular Design /use of modules/ standardized block/

It is used to identify basic functional or aesthetic requirements for one or a number of products and designs a standard part, component, or subassembly that will meet the specification requirement of all the products in which it will be used.

7. CAD and Robotics

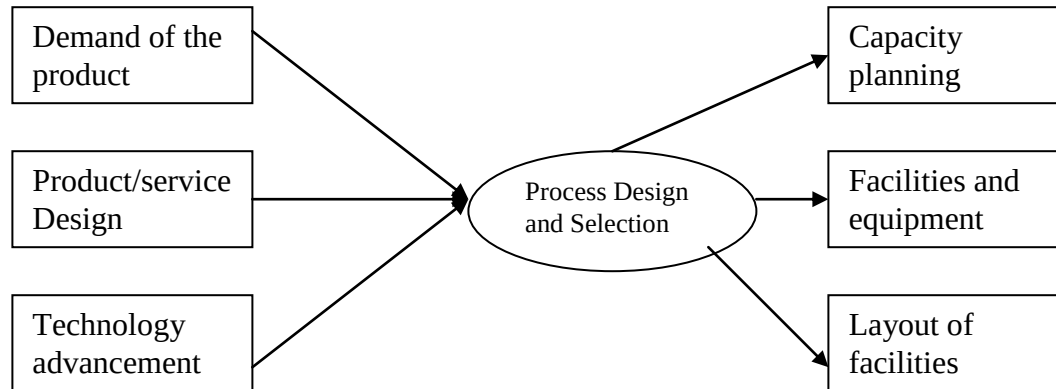
Design and redesign capabilities of such technology computerized design /CAD/ allow specifications to be tested singly or as part of a system for aesthetic or functional analysis.

- Use of robots
- Repetitive assembly
- Loading and unloading machines
- Painting and welding operations

2.5. PROCESS PLANNING AND PROCESS DESIGN

Process planning and design is the complete delineation and description of the specific steps in production. The design and redesign of products and the design or redesign of processes are interrelated. Process planning and selection also involves choice of technology and related

issues and it has major implications for capacity planning, layout of facilities, equipment, and design of work systems. This relationship can be best understood by having a look at on the following figure.



Process selection occurs as a matter of course when new products or services are being planned. However, it also occurs periodically due to technological changes in equipment as well as changes in existing product or services.

2.5.1 Types of Processes

At the basic level, the types of process can be categorized into three main categories:

1. *Conversion Processes*

Under this process the reaction under specific controlled conditions yields products that may hardly resemble their parents. For example, changing iron ore into steel sheets or making all the ingredients listed on the box of toothpaste into tooth paste are conversion processes.

2. *Fabricating Processes*

This process involves changing raw materials into some specific form. For example making sheet metal into car fender and making chair out of wood are fabricating processes.

3. *Assembly processes*

Assembly processes brings together necessary raw materials or components that makeup a product. For examples, assembly automobiles, building construction, house appliances etc.

2. Types of Process Design /process flow structure

Production system exists to produce product/ services of a kind that customers want and like a *process flow structure* refers to how a factory organizes material flow using one or more of the process technologies.

Major factors affecting choice of process designs decisions include:

1. *Nature of product demand pattern of demand and price-volume relationship.* Production processes must have adequate capacity to produce the volume of the product that consumers want. Seasonality, growth trends, and other patterns of demand affect the amount of production capacity needed. /to meet quantities during peak demand seasons/. Therefore, provisions must be made for expanding or contracting capacity to keep pace with the growth trends of sales.

Different types of production processes provide a different mix of competitive advantage therefore the choice of price and the choice of the design of production processes must be synchronized.

2. *Degree of Vertical Integration.* Vertical integration is the amount of the production and distribution chain, from suppliers of components to the delivery of products to customers, that is brought under the ownership of accompany. There two types of vertical integration, that is forward and backward integration. **Forward integration** is expanding ownership of the

production and distribution chain toward the market whereas, **backward integration** means expanding ownership of the production and distribution chain backward towards the source of supply. The degree to which a company decides to be vertically integrated determines how many production processes need to be planned and designed.

3. *Production flexibility*. It refers to the ability to respond fast to customer's needs. Flexibility is of two types. The first is **Product flexibility**, which refers to the ability of the production system to quickly change from producing one product to producing another. For such cases, production process must be designed to include general-purpose equipment and cross-trained employees. The second type of flexibility is **volume flexibility**. It is the ability to quickly increase or reduce the volume of products produced. Volume flexibility is needed when demand is subject to peaks and valleys and when it is impractical to inventory products in anticipation of customer demands. In this case production process must be designed with production capacities that can be quickly and inexpensively expanded and contracted. The fundamental nature of service creates the need for flexibility.

4. *Degree of Automation*. Automation is the substitution of machinery for human labor. The machinery includes sensing, the control devices that enable it to operate automatically. A key question in process planning is whether to automate or not; and how much to automate, (fully or partially).

Advantages of Automation

Automation offers a number of advantages over human labor. Some of these are:

1. It has low variability, it is difficult for a human to perform as fast in exactly the same way, and in the same amount of time on a repetitive basis.
2. Machines do not get bored or distracted nor do they go out on strike, ask for higher wages, or file labor grievances.
3. It is taken as a necessary strategy for competitiveness.

Disadvantages/limitations

1. Automation can be costly because the acquisition of new technology can be expensive

2. Usually, it requires high volumes of output to offset high costs of initial investment.
3. Automation is much less flexible than human beings are.
4. Once process has been automated, there is substantial reason for not changing it
5. It often becomes an emotional issue with workers because of the fear of job loss.

Therefore, the degree of automation must be carefully examined so that its limitation can be minimized and its benefits can be exploited.

5. Level of Product quality

The choice of design of production processes is certainly affected by the desired level of product quality.

6. Degree of customer contact

For most services and for some manufacturers, customers are an active part of the process of producing and delivering products. The extent to which customers become involved in the production systems has important implications for the design of production processes. In this case every element of the equipment, employee training, and building must be designed with the customer in mind. Also courteous attention, comfortable surrounding must be provided to receive, hold, process and release customers.

At the other extreme of customer involvement, the design is little affected by interaction with customers.

2.5.2 Types of Process Flow Structure

There are basically, four (4) types of processing systems: continuous, assembly line, intermittent and project processing. These major operation processes are described briefly as follows:

1. Continues process (product-focused)

A form of production processing organization in which production departments are organized according to the type of product being produced. All of the production operation required to

produce a product are ordinarily grouped in to one production department. It is also called line flow production or continuous production because; the product follows a pre-determined sequence of steps. In line flow production, products tend to follow along direct linear paths without backtracking or side tracking.

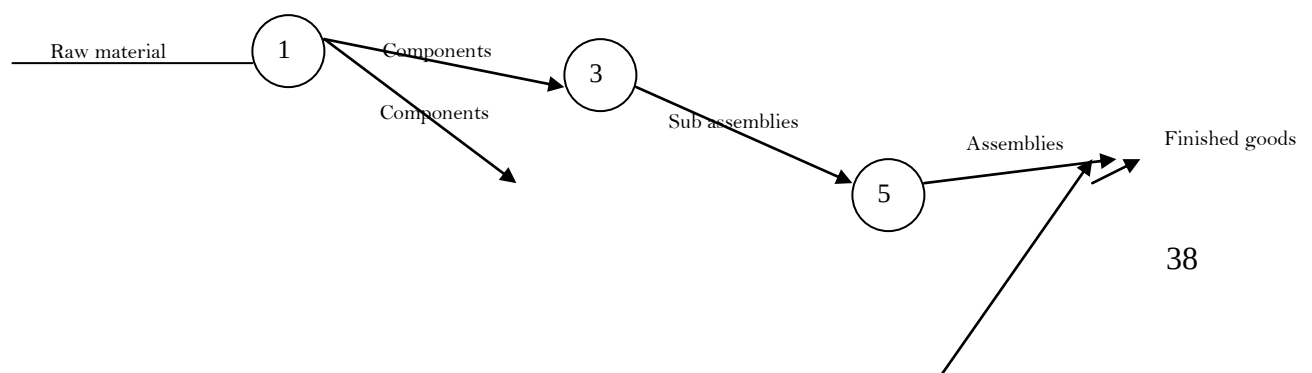
Continuous processing systems produce high volume of standardized output. The ultimate continues processing systems produce a single product such as flour, sugar, chemicals, liquid, powder, detergents, gasoline, oil, and the like. Generally, these products are measured on continues basis rather than counted as discrete units.

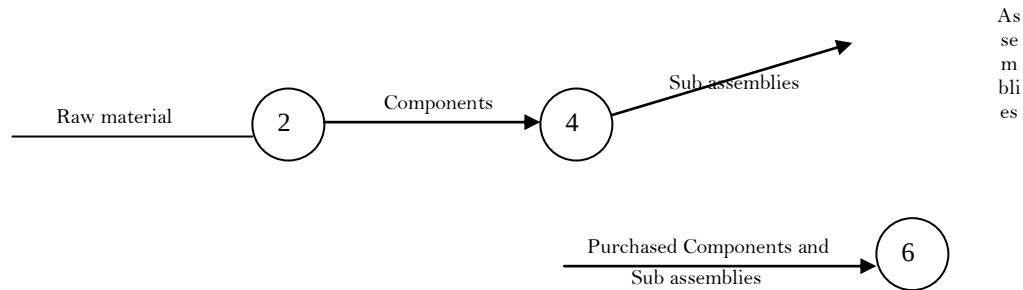
Characteristics of continues or product-focused process

- The system produce highly uniform or standardized output
- uses highly standardized machine/equipments and methods, and operated for 24 hours to avoid expensive shutdowns and startups.
- the skills requirements of workers are usually fairly low because of division of labour
- equipment tends to be highly specialized which tends to make it expensive relative to more general purpose equipment, but the high volume of output result in a low cost per unit
- product of such process are generally made for stock/inventory rather than customer order
- the process is inflexible, it handles only one product
- Product focused systems usually require high initial investment because it uses expensive, fixed-position material -handling equipment e.g. Overhead conveyors.

In continuous production products tend to proceed through production without stopping.

This figure shows the flow of raw material from one end of production process to the other end following a straight line.





2. Assembly line process (Repetitive process)

Assembly line process refers to production of discrete parts moving from workstation to workstation at a controlled rate, following the sequence steps needed to build the product. This part of continuous process produces output that allows for some variety; products are highly similar but not identical. Examples include assembly of automobiles, televisions, computers calculators, cameras, appliances etc. Typically, these products are produced in discrete units. This form of processing is often referred to as repetitive manufacturing.

The application of this process in service area is less common because services tend to be more customized on a per-unit basis. But still it can be applied in car washes, mechanical caressers, mail service, fast-food operations etc.

3. Intermittent Processing (Process-focused)

Intermittent processing is used when systems handle a variety of processing requirements on a start-and stop basis. This system is characterized by:

- A low volume of output than continuous process
- Use general-purpose equipment that can satisfy a variety of processing requirements.
- Require semiskilled or skilled workers who operate the general equipment
- The system is relatively flexible.
- Span of supervision is narrow than the low in the case of continuous process system.

Intermittent Processing takes two forms:

1. **Batch Processing**- Produces the same item again and again, usually in a specified lot sizes. Such system is generally employed when a business has a relatively stable line of products, each of which is produced in periodic batches, either to customers order or for inventory.
2. **Job shop process**- Used to handle/produce small batches/lots of a large number of different products most of which require a different set or sequence of processing steps.

Examples

- Commercial printing firms, publication
- airplane manufacturers
- Machine tool shops, Educational system

In job shops products do not follow continuous routes through production. On the contrary, the system is:

- highly irregular stop and go
- zigzag type routs with side tracking and backtracking
- Jobs spend the majority of this time waiting to be processed in production departments. Process focused production systems include hospitals, automobile repair shop machine shop and manufacturing plants.

The advantages of job shop

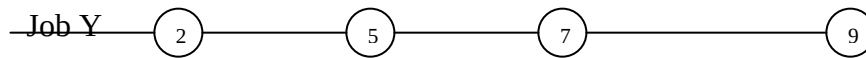
- Product flexibility /able to produce small batches of a wide variety of products
- Less initial investment/they use general purpose equipment.

Problems

- greater employee skill
- more employee training
- more supervision

The following flow structure illustrates the process-focused production system.





What makes this system different from batch process is that the job requirements often vary considerably from job to job, so that the sequence of processing steps and the job content of the steps, vary considerably, for example, Auto repair shops.

2. Projects

Projects are set up to handle complex jobs consisting of unique sets of activities that must be completed in a limited time span. Examples of application include large or unusual construction projects, new product development or promotion and so on. This process is characterized by:

- high variable cost
- fixed costs are negligible or non existent
- High skilled manpower-the process requires manpower who can work independently without much supervision and guidance.
- Involves the manufacture of a single, one-of-a kind product.

2.5.3 Processing Alternative decision

In deciding on a particular type of production processing organizations, several factors must be considered. Some these factors are:

1. *Batch size and product variety.* This factor includes the amount of product variety and the volume to be demanded of each product model

If the demand for a single product is high, product -focused is appropriate because cost/unit is very low but not flexible. Whereas, if products are many and one-of -kind job shop/ process focused is appropriate. Because this process flow structure allows companies to take the advantage of product flexibility.

2. *Capital requirements for process Designs*

The second factor that affects the choice of production process is capital requirements for the process design. The amount of capital required for the production system tends to differ for each type of production processing organization. If a firm has only a little capital available for a particular product, process focused may be the only type of process design that can be planned.

3. *Economic analysis*

Commonly used to compare alternative processing plans for the production of products, four (4) important considerations include:

- a. *Cost function of processing alternatives.* Each type of process design tends to require a different amount of capital. The greater that initial cost of equipment, buildings, and other fixed assets, the greater one the fixed costs. The cost function of a job shop usually exhibits very low fixed cost and very high variable costs.

If capital availability is not a factor and annual production costs are the predominate consideration, the process design that is preferred depends on the production volume of the product.

- b. *Concept of operating leverage.* Operating leverage is a measure of the relationship between a firm's annual cost and its annual sales. If a high percentage of a firms total costs are fixed then the firm is said to have a high degree of operating leverage.

Other things being equal /held constant/, a high degree of operating leverage implies that a relatively small percentage change in sales will result in a large percentage change in operating income (the difference between annual sales and annual production costs).

The concept of operating leverage has the following important implications for the choice of process design.

1. creator long range profits can be realized from production processes with greater operating leverage once the production volume reaches a certain level.

2. Greater long-range losses can result from operation processes with greater operating leverage if the production volume is less than the breakeven point.
3. The high the operating leverage of a production process, the greater is uncertainty of future volume.
4. The great the uncertainty of sales forecasts, the great is the risk of losses using production processes with high operating leverage.

If there is a substantial amount of uncertainty concerning the forecast of number of products to be produced, process design with lower levels of operating leverage tend to be performed.

Break Even Analysis (BEA) is commonly used to choose between processing alternatives. It does have some weaknesses, however, when compared to other methods:

1. A primary weakness is the techniques inability to deal in a direct way with uncertainty. All of the costs, volumes and other information used in the technique must be assumed to be known with certainty.
2. The costs are assumed to hold over the entire range of possible volumes.
3. It does not take into account the time value of money.

Example: Three production processes, automated (A), Cellular(C) and job shop (J) have the following cost structure.

Process	Fixed cost per year	Variable cost per unit
A	110,000	2
C	80,000	4
T	75,000	5

- a) What is the most economical process for a volume of 10,000 units per year?
- b) At what volume would each of processes be preferred?

Solution

P = Price/unit

V = Variable cost/unit

Fc = Fixed cost/period

Q = quantity produced and sold/period

P = Profit/period

TR = total revenue/period

TVC = Total Variable cost/period

C = Contribution /period

TC = Total cost/period

C = Contribution/unit

a) $TC = FC + V(Q)$

$$TCA = FCA + VA(10,000)$$

$$= 110,000 + 2(10,000) = 130,000$$

$$TCc = FCc + Vc(10,000)$$

$$= 80,000 + 4(10,000) = 120,000$$

$$TCT = FCT + VT(10,000)$$

$$= 75,000 + 5(10,000) = 125,000$$

The cellular manufacturing production process has the lowest cost when $Q = 10,000$

b) $TCJ = TCc$

$$FCJ + VJ(Q) = FCc + Vc(Q)$$

$$75,000 + 5(Q) = 80,000 + 4(Q)$$

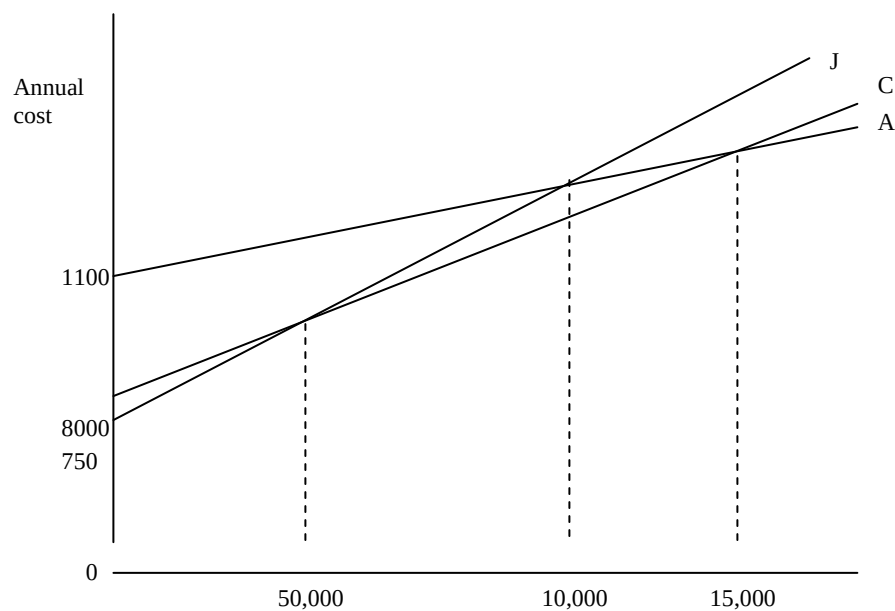
$$Q = \underline{5,000 \text{ units}}$$

$$TCc = TCA$$

$$FCc + Vc(Q) = FCA + VA(Q)$$

$$80,000 + 4(Q) = 110,000 + 2(Q)$$

$$Q = 15,000 \text{ units}$$



The job shop process would be preferred in the annual volume rate of 0 – 5000 units, cellular manufacturing in the 5000 – 15000 range and automated at 15000 or above

D Financial Analysis

The great amount of money to be invested in production processing alternative and the length of time these assets are expected to last make the time value of money an important concept. The payback period, R_{Pu}, IRT and profitability under are used to analyze POM problems involving long periods of time.

2.6 SERVICE DESIGN

Because of the difference between services and products, the design of services must take in to account different elements than the design of products. Consider these differences:

1. Products are generally tangible; service is generally intangible. Consequently service design often focuses more on intangible factors such as peace of mind, ambiance than does product design.
2. Services are often produced and received at the same time. (e.g. Haircut, a car wash, repair etc), Because of this there is less latitude in finding and correcting errors before the customer has a chance to discover them. Consequently, training, process design; the customer relations are particularly important.
3. Service cannot be inventoried. This poses restriction on flexibility, and makes capacity design very important.
4. Services are highly visible to customers, and must be designed with that in mind; this adds an extra dimension to process design usually not present in product design
5. Some services have low barriers to entry and exit. This poses another burden on service design to continually be aware of what competitors are offering.

6. Location is often important in service design with convenience as a major factor. Hence, design of services and choice of location are often closely linked.

Matching the Process and the Product

A key concept in process selection is the need to match market requirements with process capabilities. The distance between success and failure in production can sometimes be traced to choice of process. Products range from highly customized to highly standardized. Generally, volume requirements tend to increase as standardization increases; customized products tend to be low volume, and standardized products then to be high volume. These factors should be considered in determining the process to be used. This can be understood using a product-process matrix given below.

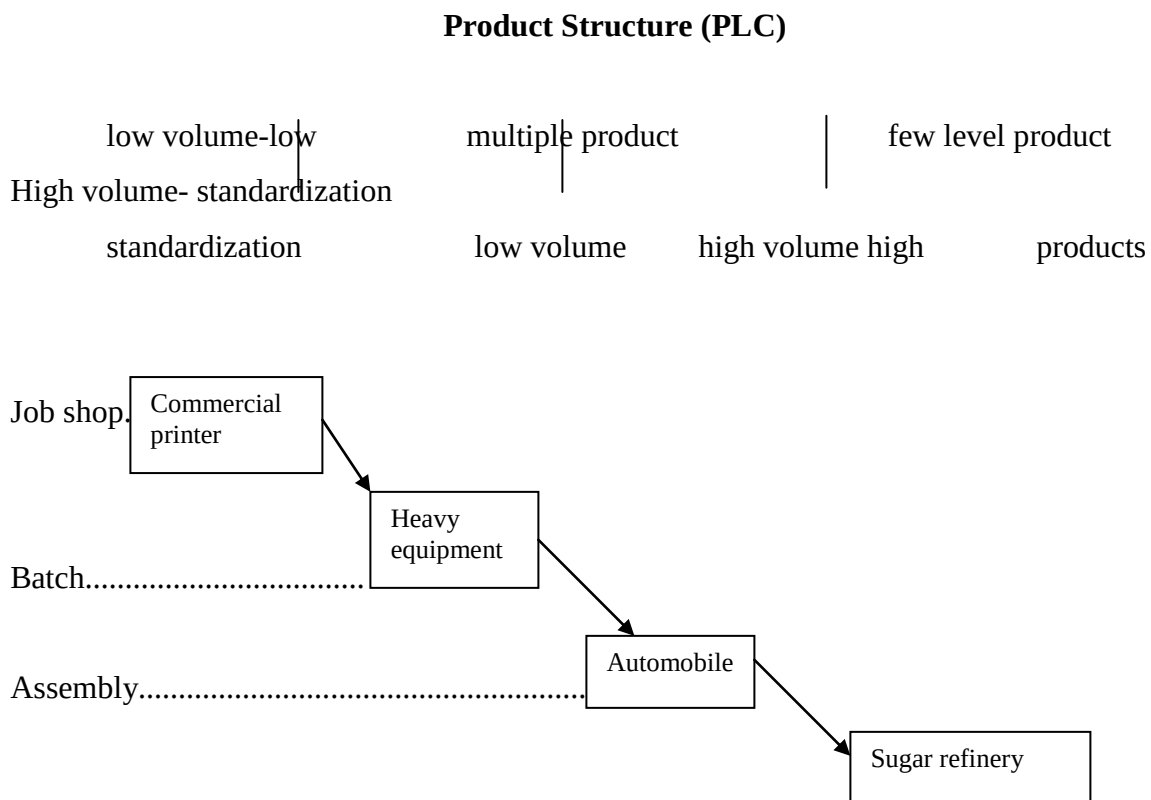


Table 2.1. Summarizes the difference and similarities of the basic processes.

Types of Production Processes	Product Volume	Product Variety	Automation & Specialized equipment	Frequency of machine set up & changes	Labor Skill	Unit Cost
1. Continuous	High	low	High	low	low	low
2. Assembly	Medium	medium	high	low	low	low
3. Batch	Medium	medium	medium	medium	medium	medium
4. Job Shop	low	high	high	high	high	high
5. Project	low	low	low	low	high	high

Process flow Design

Process flow design focuses on the specific processes that raw materials, parts, and subassemblies follow as they move through the plant. The most common production management tools used in planning the process flow are:

1. Assembly drawings
2. Assembly Charts
3. Route Sheets
4. flow process Chart

Each of these charts is useful diagnostic tool and can be used to improve operations during the steady state of the productive system. Indeed, the standard first step in analyzing any production system is to map the flows and operations using one or more of these techniques. These are the “organizations charts” of the manufacturing system.

Assembly Drawing- is an exploded view of the product showing its component parts. The relative location of components is drawn in relation to each other to show how to assemble the unit.

Assembly Chart: - Uses the information presented in the assembly drawing and defines how parts go together their order of assembly, and often the overall managerial flow pattern. It lists all major materials, operations, inspection etc.

Operation and route sheet:- As its name implies, it specifies operations and processes routing for a particular part. It conveys such information as the type of equipment, tooling, and operations required to complete the part.

UNIT 3 CAPACITY PLANNING, PLANT LAYOUT AND LOCATION ANALYSIS

3.1 Introduction

How much should a plant be able to produce, where should it be located? Are important strategic question that must be addressed when a firm is starting out, when it expands and when it contracts because these decisions have long-term consequences for the organization. In this unit, you will examine capacity planning, location analysis and layout of facilities.

3.2. CAPACITY PLANNING

How many units of equipment do we need to achieve our production forecast? This is the concept of capacity planning. Capacity can be defined as ability to produce certain out put within a specified time period or the rate of output that can be achieved from a process. Capacity is related to the equipment and process selection decision in that a selection of specific equipment and processes represents a selection of both technological flexibility and capacity. Capacity is also a product design specification. Decisions related to capacity have to answer:

- a. How much capacity do we have and how much future capacity should we provide (process)
- b. What form should capacity take?
- c. How should people or processes be physically related to one another within the facility?
- d. What is the optimal location for the facilities

3.2.1. Important Concepts of Capacity Decisions

A. Design Capacity

The design capacity represents the maximum output that can be achieved in a specific time period under ideal condition. Design capacity values are stated by the manufacturer of the equipment. It may and commonly does include recognition of the need for routine maintenance but does not include recognition of delays caused by factors like scheduling, conflicts, defective products, low quality material, or change in product mix. In other words, manufacturers cannot anticipate the actual conditions of use. Therefore, this level of capacity cannot to be achieved under the real situation.

B. Effective Capacity

Effective capacity represents the maximum output per unit time given a particular product mix, labour skills, supervision, product quality level, material quality, available maintenance, and time between setups. Effective capacity is rarely equivalent to design capacity and is frequently much lower.

C. Actual or Operating Capacity

Operating capacity is defined as the average output per unit of time over a preceding time period adjusted to reflect actual reject levels and scheduling and maintenance losses.

D. Capacity Measures

Though, there is no single measure of capacity, the two measures frequently cited to justify investments in equipment and processes are:

- 1) Efficiency and
- 2) Utilization

Efficiency is a measure of the use of effective capacity in producing a particular result. It is given by the formula:

$$\text{Efficiency} = \frac{\text{actual output per time period}}{\text{Effective capacity per time period}}$$

Utilization is a measure relating design capacity to output. It is calculated as follows:

$$\text{Utilization} = \frac{\text{actual output per time period}}{\text{Design capacity per time period}}$$

These measures will be modified for service industries. It tells you the degree to which the resources, that is, machine, labor, etc are utilized.

3.2.2 Factors Influencing Effective Capacity

Effective capacity determines upper limit for actual capacity, which in turn determines actual output. Narrowing the difference between design capacity and effective capacity is a managerial opportunity because it may result in lower total investment.

Low effective capacity may indicate poor management practice, inadequate supervision, poor equipment choice, obsolete equipment etc. The major factors affecting effective capacity are the following.

a) Product Design

Product design affects capacity by determining the total work content or processing requirements for producing a product changes in design or a greater variety of products will generally affect capacity adversely by requiring more frequent changes in setups, rework, and solution.

- simplify product design
- changes infrequent
- Long production run

b) Layout of facilities

It affects on the flow of materials in the process production and the effectiveness of labour.

c) *Job design* – by establishing a lower time limit for operator controlled jobs.

d) *Output standards*: Differences in expected performance speeds and allowances for such necessities as personal time and fatigue alter effective capacity. This is four both operator-controlled and mechanic controlled jobs.

e) The **quality of and variation** in the materials used by altering the number of process adjustment required, scrap and rework and material quality as well as by the number of setups required.

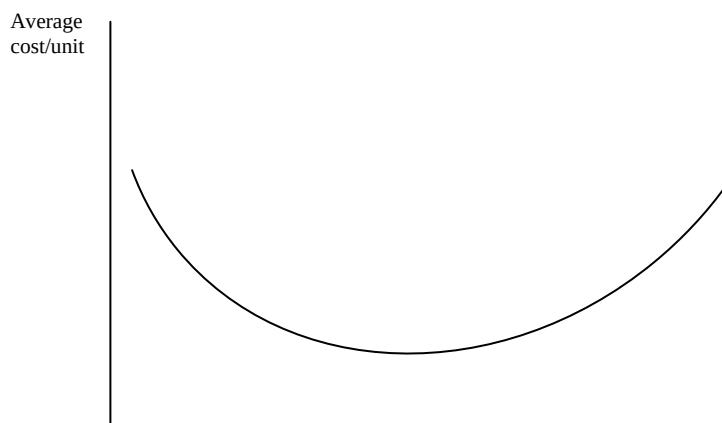
f) **Employee attitude and motivation** through labor turnover, absenteeism, and employees being busy but not productive.

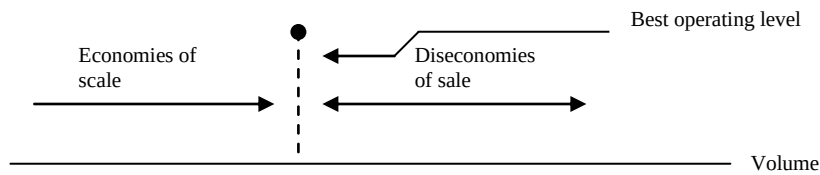
g) **Operational factors**. Inventory stocking decisions, late deliveries, acceptability of purchased materials, quality of inspection and control procedures also can have an impact on effective capacity.

h) **External factors**. Product standards, especially minimum quality and performance standards, and government regulation can restrict management's option for increasing and using capacity. Thus, pollution standards on products and equipment often reduce effective capacity, as does paper work required by engaging employees in non-productive activities. A similar effect occurs when a union contract limits the member of hours and type of work an employee may do.

3.2.3 Capacity and Level of Operation

The best operating level is the level of capacity for which the average unit cost is at a minimum. This level of operation is shown in the figure below:





As we move down the curve, we achieve economies of scale until we reach the best operating level and we encounter diseconomies of scale as we exceed this point. The upward swing of unit cost as volume increases results from:

- using less efficient machines
- working overtimes
- increasing the cost of maintenance or
- using inexperience or less skilled employees

3.2.4 Capacity planning decisions

Capacity planning normally involves the following steps.

1. Assessing existing capacity
2. Forecasting capacity needs
3. Identifying alternative ways to modify capacity
4. Evaluating financial, economical and technological capacity alternatives.
5. Selecting a capacity alternative most suited to achieving strategic mission.

Following these steps, organization should design the right capacity, that is, the capacity best matches with the demands of the product. However, there are several reasons why the production capacity to be provided does not necessarily equal the amount of products and services expected to be demanded. First enough capital and other resources may not be economically available to satisfy all of the demand. Secondly, because of the uncertainty of forecasts and the need to link production capacity to operations strategy interns of competitive priorities, a capacity cushion may be provided. A capacity cushion is an additional amount of production capacity added onto the expected demand to allow;

1. Extra capacity incase more demand than expected occurs
2. The ability to satisfy demand during peak demand seasons.
3. Lower production costs; production facilities operated to close to capacity experience higher costs.
4. Product and volume flexibility responding to customers' needs for different products and high volumes is possible because of the extra capacity.
5. Improved quality of products and services; production facilities operated close to capacity experience deteriorating quality.

3.2.5 Ways of changing long range capacity

A. Expansion. Expansion would take either or a combination of the ways;

- Sub-contract with other companies to become suppliers of the expanding firm's components or entire products.
- Acquire other companies, facilities or resources
- Develop sites, build buildings, by equipment
- Expand, update, or modify existing facilities or
- Reactivate facilities on standby status.

B. Reduction. This strategy requires managers to take the following actions when expansion is not appropriate due low demand or any other internal and external factors.

- Sell of existing facilities, sell inventories, and lay off or transfer employees.
- Mothball facilities and standby status, sell inventories, and layoff or transfer employees.
- Develop and produce new products as other products decline.

3.2.6 Evaluating Capacity Alternatives

An organization needs to examine alternatives for future capacity from a number of different perspectives. Most obvious are economic considerations. Such as; will an alternative be economically feasible? How much will it cost? How soon can we have it? What will the

operating and maintenance costs be? What will its useful life be? Will it be compatible with present personnel and present operations?

A number of techniques are useful for evaluating capacity alternatives from an economic standpoint. Some of the more common are cost-volume analysis (Break-even analysis), financial analysis, decision theory, and waiting line analysis. Only cost volume analysis and decision tree are described in this unit.

1. Break-Even Analysis

Though different tactics can be used to adjust demand to existing facilities, the strategic issue is, of course, how to have facility of the correct size. Break-even analysis may help with that decision.

Breakeven can aid capacity decisions by identifying the processes with the lowest total cost for the volume expected. The objective of break-even analysis is to find the point, in dollars and units, at which costs equal revenues-which is the break-even point. Break-even analysis requires an estimation of *fixed costs*, *variable cost*, and *revenue*.

Fixed costs are costs that continue even if no units are produced such as depreciation, taxes, debt and mortgage payments where as variable costs are those that vary with the volume of units produced. The major components of variable costs are labour and materials and other costs such as the portion of the utilities that varies with volume.

Another element in break-even analysis is the revenue function that begins at the origin and proceeds upward to the right increasing by the selling price of each unit. Where the revenue function crosses the total cost line is the break-even point, with a profit corridor to the right and a loss corridor to the left. Break-even analysis assumes that costs and revenue increase in direct proportion to the volume of units being produced. However, neither fixed costs nor variable costs (nor, for that matter, the revenue function) need be a straight line.

Example:

XYZ Company is now contemplating to adding new line of product, which require leasing new machine for a monthly payment of Br. 6000. Variable costs would be Br.2.00 per unit, and the product would be sold for Br.7.00 each.

Required:

1. What should be the monthly production capacity of a machine for achieving a breakeven point?
2. What should be a production capacity so that a firm can achieve a profit target of Br. 4000?

Solution:

1. Given:

Fixed cost (FC) = Br.6000

Variable cost per unit (V) = Br. 2.00

Price per unit (P) = Br.7.00

Breakeven point (Q) =?

At a breakeven point, a firm earns zero normal profit. That is total revenue equals total cost and hence profit becomes zero. Thus,

Total profit = total revenue (TR) – Total cost (TC)

Total profit = TR – TC

$$TR = P \times Q$$

TC = Total variable cost (which is $V \times Q$) + FC, hence

Total profit = $(P \times Q) - (V \times Q + FC)$

At break-even point total profit is zero. Thus,

$$0 = PQ - VQ - FC$$

$$0 = Q(P - V) - FC$$

$$FC = Q(P - V)$$

$$Q = FC \div (P - V)$$

$Q = FC \div (p - v) = \text{Br. } 6000 \div (7.00 - 2.00) = 1,200$ units of pies per month. In order to achieve the break even goal a firm must lease a machine that has a monthly production capacity of 1,200 units.

2. Given:

Total profit = Br.4000

P = Br.7.00

V = Br.2.00

FC = Br. 6000

The quantity level required to achieve any profit level is obtained as follows:

$$\text{Total profit (TP)} = \text{TR} - \text{TC}$$

$$\text{TP} = \text{PQ} - \text{VQ} - \text{FC}$$

$$\text{TP} + \text{FC} = \text{PQ} - \text{VQ}$$

$$\text{TP} + \text{FC} = \text{Q}(\text{P} - \text{V})$$

$$\text{Q} = (\text{TP} + \text{FC}) \div (\text{P} - \text{V})$$

$$\text{Q} = (\text{Br.4000} + \text{Br.6000}) \div (\text{Br.7.00} - \text{Br. 2.00}) = 2,000 \text{ units.}$$

To achieve this profit level per month, a firm must lease a machine with the monthly production capacity of 2,00 units.

The following graph depicts the example just presented above.

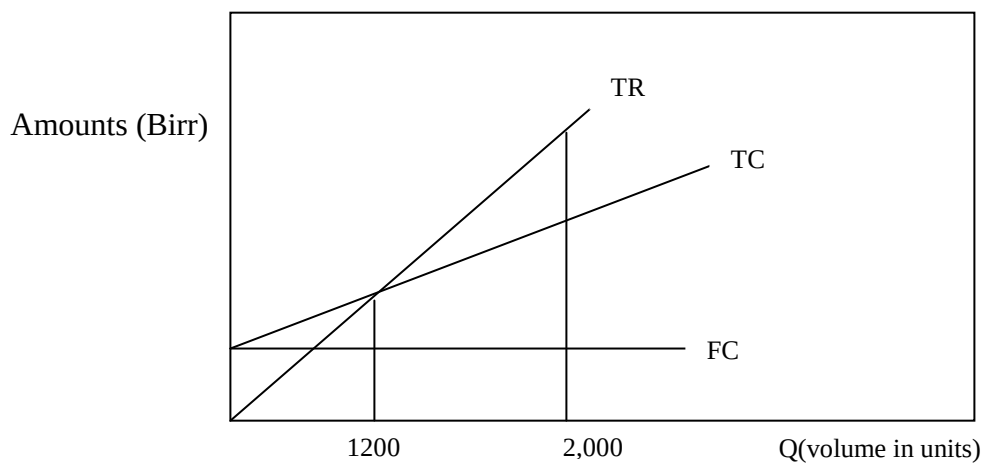


Figure 3.2 Breakeven analyses

As a figure illustrates, total revenue and total curve crosses each other at the quantity level 1,200 units and that is a breakeven point. Once the quantity produced exceeds that level, a company starts to earn point and the size of profit increases with the quantity of output (production). As stated above, for this particular example a machine under consideration must have monthly production capacity of 2,000 units for a company to achieve the stated level of profit (Br.4,000). To utilize the concept of breakeven analysis for capacity planning decision, we first define out goal such as a profit level, and then work back to determine the size of facility to be owned so that its production capacity can effectively lead to the production level required (i.e., quantity) to achieve a goal.

2. Decision Tree

Decision tree is a tree like diagram that depicts alternatives and their possible outcomes. This tool can be used to evaluate alternative capacities and enable managers make appropriate decisions.

Example. A firm that plans to expand its product line must decide whether to build a small or a large facility to produce the new products. If it builds a small facility and demand is low, the net present value (NPV) after deducting for building costs will be Br. 400,000. If demand is high, the firm can either maintain the small facility or expand it. Expansion would have a net present value of Br. 450,000 and maintaining the small facility would have a net present value of Br. 50,000.

If a large facility is build and demand is high, the estimated NPV is Br. 800,000. If demand turns out to be low, the NPV will be Br. 10,000.

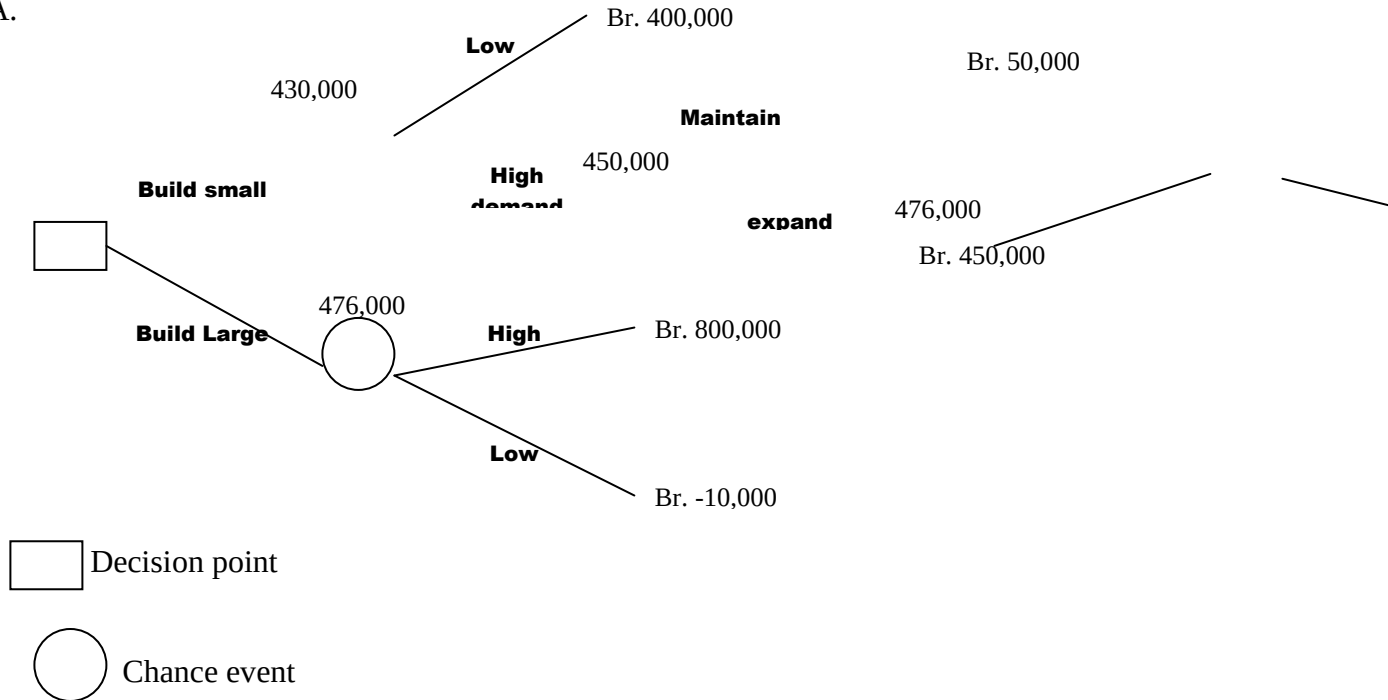
The problem that demand will be high is estimated to be 0.60, and the problem of low demand is estimated to be 0.4.

Required:

- A. Draw the tree diagram.
- B. Which alternative capacity should be build? What is the expected NPV of the alternative chosen?

Solution:

A.



B. The expected NPV

i. Build small facility:

$$\begin{aligned} \text{High demand} &= 0.6 \times 450,000 \\ &= \underline{270,000} \end{aligned}$$

$$\begin{aligned} \text{Low demand} &= 0.4 \times 400,000 \\ &= \underline{160,000} \end{aligned}$$

$$\begin{aligned} \text{Expected value} &= 270,000 + 160,000 \\ &= \underline{430,000 \text{ Br}} \end{aligned}$$

ii. Build large facility

$$\begin{aligned} \text{High demand} &= 0.6 \times 800,000 \\ &= \underline{480,000} \end{aligned}$$

$$\begin{aligned} \text{Low demand} &= 0.4 \times -10,000 \\ &= \underline{-4,000} \end{aligned}$$

$$\text{Expected value} = \underline{476,000 \text{ Br}}$$

Decision: The firm should build the large facility with the highest expected profit
i.e., Br. 476,000.

3.3 FACILITY LAYOUT

The general objective of facility layout is to locate people, machines, and processes in an optimal time-saving and money saving relationship that meets the anticipated production level and the products functional and aesthetic requirements as embodied in the design specification. Layout refers to the configuration of departments, work centers and equipment with a particular emphasis on movement of work through the system.

3.3.1 Objectives of Facility layout

The overall objective in designing a layout is to provide a smooth work flow and control; reducing cost of material through the factory or uncomplicated pattern for both consumers and workers in a service organization. Specific objectives of layout decision in service and manufacturing operations are outlined in the following section.

1. For manufacturing firm.

- Provide enough production capacity
- Minimize material handling cost and effort
- Minimize labour requirements
- Provide a smooth flow of materials and product
- Maximize the use of available space
- Provide for volume and product flexibility and avoid bottleneck operations and contested areas
- Minimize health hazards
- Maximize the uses of machine tools.
- Provide communication opportunities for employees by positioning equipment and processes appropriately
- Maximize output
- Minimize supervisory and control requirements
- Ease of maintenance
- Provide space for personal – care needs and others

2. For service operations layout serves the following purposes.

- provide for customer comfort and convenience

- allow attractive display
- reduce travel of personnel and customers
- provide for private in work areas
- promote communication
- provide for stock rotation for shelf life.

3.3.2 Basic Types of Layouts

There are four basic types of plant or facility layouts. The basic difference among these layouts is in their handling of the flow of materials and product. They are discussed as follows.

1. Process layout /for job-shops/

It is concerned with the grouping of machines, processes or services according to their function i.e. similar equipments or functions are grouped together. For example, Drilling, milling, routing, typing, shipping etc are activities that require such types of arrangements. The primary efficiency criterion for evaluating process layout designs is material and product handling cost.

Advantages

- a. Process layouts are less vulnerable to breakdowns or absenteeism than other types of layouts since work can be shifted to other operating machines, and substitute for absent employees are more readily available because employees have multiple skills.
- b. Lower capital costs use. Because this layout uses a general – purpose machines, which are less likely to become obsolete than special-purpose machines.
- c. Lower labour costs /training and scheduling employees to operate more than one type of machine.
- d. Lower installation and maintenance costs since excess capacity is often available.

Disadvantages

- b. Work scheduling is complicated by the difficulty of determining process workloads, by the different processing sequence required for different products, and by bottleneck operations and conflicts in completion time requirements.

- c. Low output rates result from material handling inefficiencies and from the number of special setups and fear downs necessitated by changes in the pattern of demand.
- d. If the number of in-process products is large, process confession may result as efforts are made to meet schedule completion dates.
- e. Material – handling requirements are a major problem because they are costly and time consuming. Conveyors are expensive to install and difficult to design since there may be many destinations for materials or products in process.

Materials used in manufacturing are many, some of these are: raw materials, purchased components, materials-in-process, finished goods, packing materials, maintenance and repair supplies, scrap and waste and rejects or reworks.

The layout of these facilities is directly affected by the nature /characteristics/ of materials such as: Large or bulky materials; heavy materials; solids; fluids or flexible and inflexible. Special materials for heat, cold, light, humidity, flame, vibration also will affect the layout of facilities for handling, storing, and processing of this materials.

2. Product or Line Layout

Product layout focuses on the sequence of production or assembly operation required for producing a part or a product of cement, oil refining, auto assembly and the so on. In contrast to process layouts, product layouts are not flexible since they are designed specifically for making one product.

Major Advantages

- 1. If there is adequate output volume, processing and assembly unit costs are low because of the high utilization rates of plant equipment and processes.
- 2. Raw materials and parts inventory control requirements are lower because inputs are required for only one product.
- 3. Production scheduling is simpler
- 4. High volume of output and high labour efficiency result when the sequential tasks performed require approximately the same amount of time.

5. Material – handling costs are low because of the wide use of conveyors and other mechanical or automated transfer equipment.
6. Supervisory and control costs are low because of the repetitive and routine nature of the tasks and the uniformity of the processing result.

Disadvantages

1. High volume is required to justify the large investment in special or modified equipment.
2. Product standardization is required within close limits because of the inflexibility of specialized equipment and transfer mechanisms.
3. High interchangeability of product parts is required because the time and the space available to work on a given unit of production are limited.
4. Good maintenance is crucial since the failure of one piece of equipment requires stopping the entire line while it is being repaired.
5. Quality control inspection must be strategically located and must be capable of detecting undesirable variances. The inspection system must feed the information ‘upstream’ efficiently to signal the need to correct processing or assembly failures and to prevent the production of a large volume of non standard product.
6. Highly skilled behind-the-scenes labour is required for quick and efficient machine maintenance.
7. Scheduling and conditioning of materials, parts and subassemblies with line requirements is crucial because any bottleneck will result in products being incompletely fabricated or assembled or will require that the line be shut down.

3. Cellular Manufacturing (CM) Layouts’

Machines are grouped into cells and the cells function somewhat like a product layout is land within a larger shop or process this layout groups dissimilar machines into work centers (or cells) to work on products that have similar shapes and processing requirements. Since machines are frequently able to perform more than one operation on a particular part or product they take on some of the characteristics of a production line but without its

rigidity and it is similar to process layout in that cells are designed to perform a specific set of processes. The reasons why a CM layout would be attempted are:

- Machine changeovers are simplified.
- Training periods for workers are shortened
- Material handling costs are reduced
- Parts can be made faster and shipped more quickly
- Less-in-process inventory is required
- Production is easier to automate

4. Fixed position Layout

Unlike the three other basic layout options, fixed position layouts require that both people and machine be brought to the product being made, assembled, or tested. The product by virtue of its bulk or weight remaining at one location, For example, Shipbuilding, dam construction, power generating (steam) turbines, bridge etc which are (bulky, large, heavy, and fragile). The fixed position nature of the layout minimizes the amount of product movement required.

3.3.3 Developing and Analyzing Facility Layouts

Important inputs to the layout decision are:

1. Specification of objectives of the system in terms of output and flexibility
2. Estimation of product or service demand on the system
3. Processing requirements in terms of number of operations and amount of flow between departments and work centers.
4. Space availability with in the facility itself.

Facility Layout Techniques

There are four major layout techniques that can be used to make a layout decision. These are operations sequence analysis, block diagram analysis, systematic layout planning and load distance analysis. The following section describes these techniques.

1. Operations Sequence Analysis

This approach develops a good scheme for the arrangement of departments by graphically analyzing the layout problem. It determines the location of operating departments relative to one another when the external shape and dimensions of the building are not limiting factors.

To make a process layout of a plant or department we must have information on the movement of material within the plant and on the in process goods moving from department to department, i.e., the number of moves and the cost of making these moves.

N.B. 1000 units of material being moved from location A to B at one time constitutes one move not 1000.

The following table shows the flow of materials and in process production for a period of months. The data represents all the firms' products whose fabrication or assembly requires some or all of the same process steps in the same sequence or a different sequence.

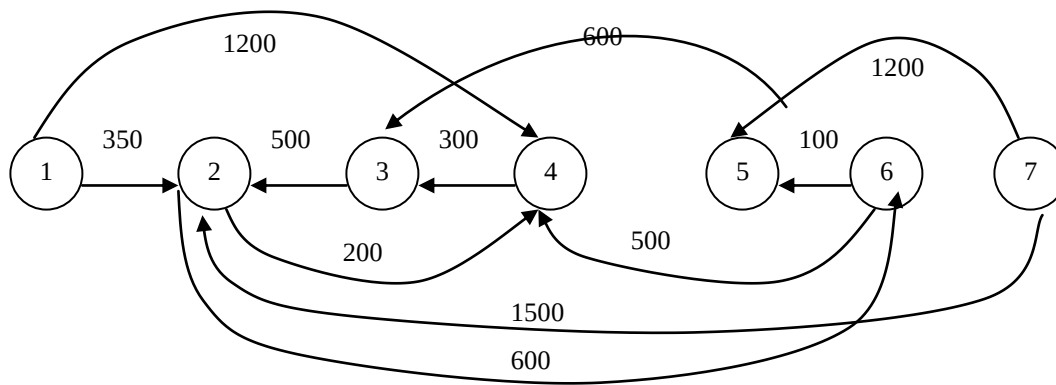
Table 2.1 Interdependent flow of in process production.

From department	To Department							
Name	Number	1	2	3	4	5	6	7
Assembly	1		<u>350</u>	400				
Inspection			1		3			
	2				<u>100</u>	500		
Painting					2			3
Stamping	3		<u>500</u>					
		1						
	4			<u>300</u>				

Casting		1			
Drilling	5	<u>300</u>			
[		2			
Shipping and	6	<u>300250100</u>			
		2	2	1	
Receiving	7			<u>400</u>	
				3	

Step 1. Line up departments like nodes on a string, connect them by arrows that show the direction of movement of the load

Step 2. Then post the cost of each movement (number of loads x cost per load) adjacent to the arrow.



This is the first attempt at pursuing the optimum criteria of no nonadjacent loads. Since we cannot improve on the position of two departments that are adjacent to each other, we can measure improvements on the basis of the cost of non-adjacent loads.

The above 1st layout reveals a number of costly nonadjacent loads. The non adjacent load cost is as follows.

<u>From Department</u>	<u>To Department</u>	<u>Cost</u>
1	4	Br. 1,200
2	7	1,500

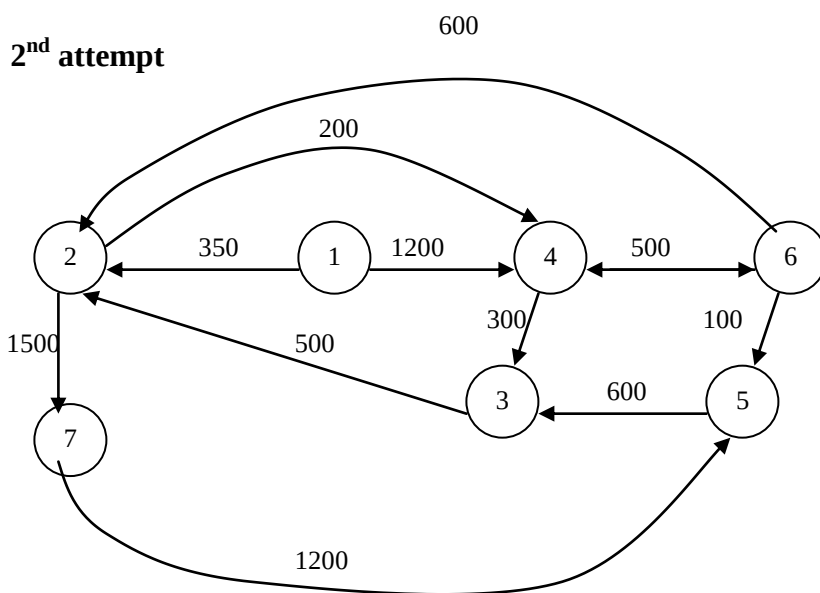
2	4	200
5	3	600
6	2	600
6	4	500
7	5	<u>1,200</u>

Total cost of nonadjacent loads

Br. 5,800

N.B. Further analysis of the above layout reveals some possible improvements.

The cost of moving loads between adjacent departments is a minimal cost where as moving loads between nonadjacent departments always involves a greater cost.



Cost of nonadjacent loads

<u>From Department</u>	<u>To Department</u>	<u>Cost</u>
2	4	Br. 200
6	2	600
7	5	<u>1200</u>

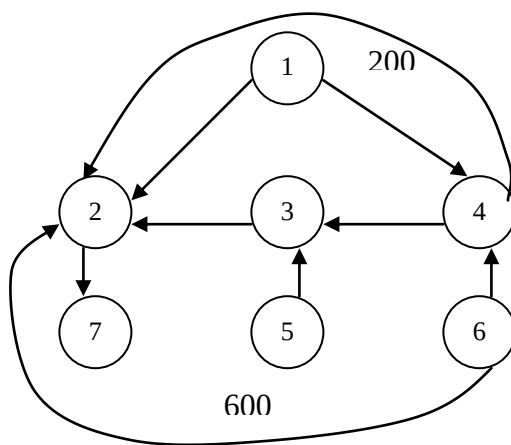
Total cost for nonadjacent loads

Br. 2,000

The comparison between the first and second layout attempts shows that we have potentially reduced the costs of moving the products between departments from Br. 5800 to Br. 2000.

If we move department 5 between department 7 and 3 we can further reduce interdepartmental transportation cost by 1200. If we do this, however, department 5 and 6 will not be adjacent, and we shall incur an additional cost of 100. Since our cost advantage will be $1200 - 100 = 1100$ the move of department 5 between department 3 and 7 will be cost advantageous.

The final effort is the following



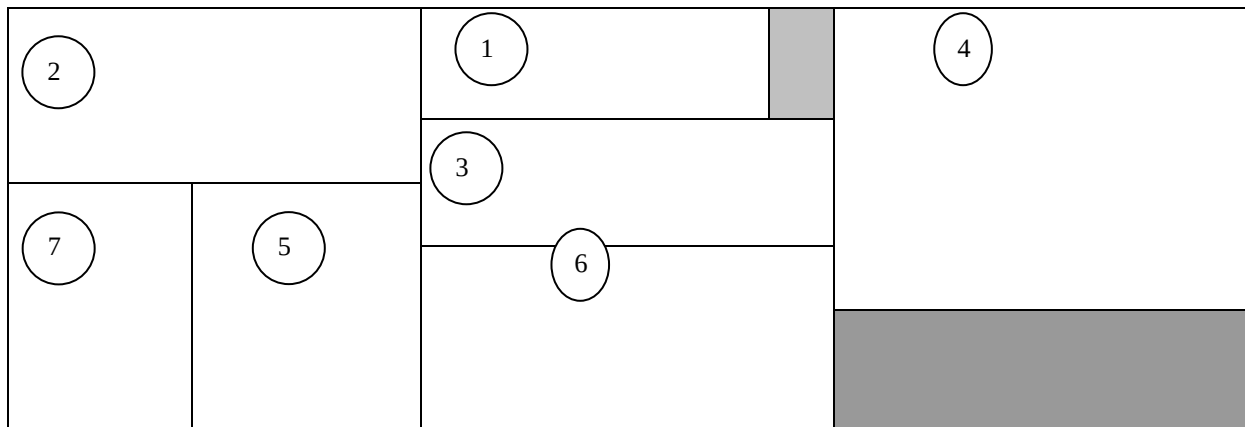
The cost for transporting materials or in process product has been reduced from Br. 8500 to Br. 800

2. Block Diagram Analysis

Block diagram analysis sets the general shape and dimensions of the building and the location of the interior departmental boundary. For the above layout assume the following area for each department.

<u>Department</u>	<u>Minimal area</u>	<u>Minimal Dimension</u>
Assembly	800	20 x 40
Inspection	1800	30 x 60
Painting	1500	30 x 50
Stamping	2400	40 x 60
Casting	1500	30 x 50
Drilling	1500	30 x 50
Shipping ad receiving	1500	30 x 50

Now substitute functional areas for the nodes to indicate departmental processing centers. Consider the floor plan 80 x 150. We have to meet the constraint of space and minimal dimensions for the individual departments. The analysis will be more difficult when it is necessary to layout an existing building with different side dimension.



3. Systematic Layout Planning (SLP)

In some production systems, such as service systems, the amount of material that flows between departments. May not be critical to developing a good facility layout. In these systems systematic layout planning can be used. The application of systematic layout planning (SLP) requires you to follow the following steps.

Step I. Develop a chart to rate the relative importance of each department being close to every other department. The rating range from the extremes of absolutely necessary to undesirable. The ratings are based on various reasons such as:

- types of customers
- ease of supervision
- common personnel
- common equipment etc.

Step II

An initial schematic diagram, similar to the one is operation sequence analysis is developed. This initial schematic diagram is modified through trial and error until departments with high closeness ratings are adjacent to one another and department and space limitations are satisfied SLP is quite similar to operation sequence and block diagram analysis is both procedures and end results. The only significant difference between these approaches is that SLP allows many reasons for assigning a closeness rating between departments, whereas operation sequence and block diagram analyses allow a single reason product or material travel per time.

4. Load Distance Analysis

Load distance Analysis is useful in comparing alternative layouts to identify the one with the least product or material travel per time period.

Example: Two layout alternatives are shown below. The facilities products, their travel between departments and the distance between departments. For each layout alternative are also displayed. Which layout alternative minimizes the monthly product travel through the facility?

Layout A

Layout B

7	1	9	6	3
4	10	2	5	8

8	4	10	2	5
3	7	1	9	6

Product	Dept. processing sequence	Number of products processed per month	Department Move ment Combination	Distance between Departments Layout A	Department move ment Combination Layout B
			1-5	30	30
			1-7	10	10
			1-9	10	10
			1-10	10	10
			2-5	10	10
			2-6	20	20
			2-10	10	10
			3-6	40	10
			3-9	30	20
			4-5	30	30
			4-7	10	10
			4-10	10	10
			5-6	10	10
			6-9	10	10
			7-8	20	50
			8-10	20	30

a	1-5-4-10	1000
b	2-6-3-9	2000
c	2-10-1-9	3000
d	1-7-8-10	1000
e	2-5-6-9	2000
f	1-7-4-10	4000

Table: Products and

their processing sequences in the facility

Solution: To answer the questions follow the following steps.

1. Compute the total travel for each product through each layout alternative.

Product	Dept. processing sequence	Distance Per Product	
		Layout A	Layout B
a	1-5-4-10	$30 + 30 + 10 = 70$	$30 + 30 + 10 = 70$
b	2-6-3-9	$20 + 40 + 30 = 90$	$20 + 10 + 20 = 50$
c	2-10-1-9	$10 + 10 + 10 = 30$	$10 + 10 + 10 = 30$
d	1-7-8-10	$10 + 20 + 20 = 50$	$10 + 50 + 30 = 90$
e	2-5-6-9	$10 + 10 + 10 = 30$	$10 + 10 + 10 = 30$
f	1-7-4-10	$10 + 10 + 10 = 30$	$10 + 10 + 10 = 30$

- 2) Compute the total distance traveled per month for each product through each layout alternative.

Product	Number Product Processed per month	Distance Per Product		Distance Per Month	
		Layout A	Layout B	Layout A	Layout B
a	1000	70	70	7000	70000
b	2000	90	50	180000	100000

c	3000	30	30	90,000	90000
d	1000	50	90	50000	90000
e	2000	30	30	60000	60000
f	4000	30	30	120000	120000
				570000	530000

3. Choose the layout alternative that minimizes total travel distance. Based on the above analysis, Layout B results are the least total distance traveled per month through the facility by the products.

3.4. FACILITY LOCATION

Choice of location for business organization is an important issue in the design of the production system. Where should a plant or service facility be located? This is a top question on the strategic agendas of contemporary manufacturing and service firms, particularly in this age of global markets and global production. Globalization allows companies greater flexibility in their location choices. However, in practice, the question of location is very much linked to two competitive imperatives.

1. The need to produce close to the customer due to time based competition, trade agreements, and shipment costs.
2. The need to locate near the appropriate resource pool to take advantage of low costs.

Location decision is an integral part of the strategic planning process of every organization. Although it might appear that location decision are mostly one-time problem pertaining to new organization, the fact is that existing organization often have a bigger stake in these kinds of decisions than new organization. In other words, location problems are common to new and existing businesses.

3.4.1 The Need for location Decisions

Existing organization become involved in location decision for a variety of reasons. The following are some of the reasons for such decisions (other than the need for greater capacity).

1. Opportunity for expanding market share

From such as banks, fast food chains, supermarkets, and retail stores view location as part of marketing strategy, and they look for locations that will help them to expand their markets. Basically, the location decisions in those cases reflect additional new location to existing suppliers.

2. Business growth in demand

A similar situation occurs when an organization experiences a growth in demand for its products or service that can not be satisfied by expansion at an existing location. The addition of a new location to complement an existing system is often a realistic alternative.

3. Depletion of Basic resources

Some firms become presented with location decision because of the depletion of basic inputs. For example fishing and logging operations are forced to relocate due to the temporarily exhaustions of fish or forest at a given location. Mining and petroleum organization face the same sort of situation, although usually over a longer time horizon.

4. Shift in Market /demand

If the demand for the product does not exist in the existing location, it is a good reason to consider and find out a better location.

5. Operating Costs

Cost of doing business in a particular location reach a point where other location begin to look more attractive. In this case, the company may shift to a cost effective location.

6. Merge of companies

Merger of companies changes the ownership titles and may require change in management and operation of the merging firms, and then leading to location decisions.

7. Introduction of new product.

This may require to a new resource, labour or material which may not exist in the existing location. Therefore, firms make a location decision to produce a sell their new product.

3.4.2 Characteristics of location decision

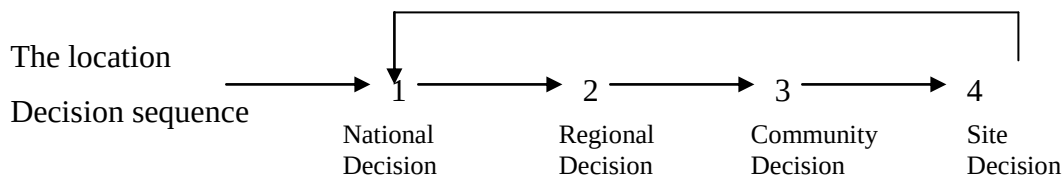
1. Location decisions entail a long-term commitment, which makes mistakes difficult to overcome. In addition, location decision often has an impact on operating costs both fixed and variables and revenues as well as an operation. Example, a poor choice of location might result in excessive transportation cost, shortage of qualified labour, loss of competitive advantage, shortage of raw materials and location of customer (operation problem).
2. Location decision requires the selection of location form a number of acceptable location instead of identifying the “One best” location. If one site is clearly superior to all others in all respects, the location decision is an easy one. However, several site candidates, each with its strengths and weaknesses emerge as good choice and the location decision becomes a trade off decision.
3. Location decision involves four options that mangers can consider in location planning. These are:
 - A. ***Expanding an existing facility*** – These options can be attractive if there is adequate room for expansion, especially if the location has desirable features that are not readily available elsewhere. Expansion costs are often less than those of other alternatives.
 - B. ***Addition new location.*** Another option is to add new location while retaining existing ones, as it is done in many retail operations. The advantage of this option are: it draws /attracts customers who are already looking for an existing business, and used as a defensive strategy designed to maintain a market share or prevent competitors form entering a market.

- C. **Shutting down.** The third option is to shut down at one location and move to another. An organization must weight the cost of a move and the resulting benefits against the costs and benefits and remaining in an existing location. This option is considered when market shifts, exhaustion of raw materials and the cost of operation often cause firms to seriously consider this option.
- D. **Doing nothing.** If is a detailed analysis of potential locations fails to uncover benefits that make one of the previous three alternatives attractive, a firm may decide to maintain a status of at least for the time being

3.4.2 Factors Affecting Location Decisions

Many factors influence location decisions. Managers must identify the relevant factors to make decisions that involve a sequence of decisions. This sequence can include a national, a regional, community and site decisions.

First management must decide whether the facility will be located internationally or domestically. (Where in the world political, military, social and economic instability can make such decision risky.)



Relative importance of location factors in types of outgoing transportation cost

Retailing facilities

Facilities affecting decision	Mining quarrying Heavy manufacturing	Light manufacturing	Warehousing	Retailing	Customer service for profit	Local government service	Health and emergency service
1. Proximity to constituents	C	C	B	A	A	A	A
2. Labour	B	A	B	B	A	B	B

availability and cost							
3. Degree of unionization	A	A	B	B	B	C	B
4. Construction and land costs	A	B	B	B	B	B	B
5. Proximity to transportation facilities	A	B	A	B	C	C	C
6. Incoming transportation cost	A	B	A	B	C	C	C
7. Outgoing transportation cost	B	B	A	C	C	C	C
8. Utilities and availability and cost	A	B	C	C	C	C	C
9. Proximity to raw materials and supplies	A	B	C	C	C	C	C
10. Zoning restriction of governmental impact	A	B	C	C	B	C	C

were: A is very important

B important

C less important

Types of facilities and this dominant location factors. Each type of facility under consideration has a few dominant factors that ultimately determine its location decision.

A. Mining, heavy manufacturing.

They are capital intensive, cover large geographic areas, use great quantities of heavy and bulky raw materials, population processes disead large amount of wastes, total finished outputs weight much less than raw material input, enormous utilities are absorbed and products are shipped to a few customers.

B. Light Manufacturing/Making electronic components, small mechanical parts, assembly etc.

- do not necessary locate near either raw material or market.
- They ship products to a few regional warehouses of wholesalers
- Availability and cost of labour is important

C. Warehouses

Dominant factors are those affecting incoming and outgoing transportation cost retailing facilities

D. Retailing facilities

The studies involve the identification of target customer because it should be located near concentration of customers. Residential concentration, traffic data on nearby streets growth trends and of communities and suburbs, spending level and other demographic information.

E. Facilities for customer service organizations such as dry cleaning, banks, hotels, welding shops, photo processors like retailing shops target this customers

- Can discharge large quantities of waste paper, chemical and spent supplies,

F. Local government service

- Often grouped together so that constituents can economize in their time, effort, and transportation cost
- Are grouped to allow interagency interactions

G. Health and emergency services (Fire station, ambulances, hospitals, etc)

- lowest overall response times between the constituent and the service
- Minimize property and loss of life

- The type of facility
- The number of its products and services
- The nature of its daily activities

The national, regional, community and side related factors are briefly all explained in the next section.

(A) Regional factors

1. Proximity to customers

A location close to the customer is important because of the ever increasing need to be customer responsive. This enables faster delivery of goods to customers. In addition, it ensures that customers' needs are incorporated into the products being developed and built.

2. Business Climate.

A favorable business climate can include the presence of similar sized business, the presence of companies in the same industry, and in the case of international location, the presence of other foreign companies. Government legislation and local Government intervention to facilitate business locating in an area etc are also factors.

3. **Total Costs.** The objective is to select a site with the lowest total cost. This includes regional costs, inbound distribution costs, and an outbound distribution costs comprise the regional costs. In addition, there are hidden costs that are difficult to measure such as loss of customer responsiveness arising from locating away from the main customer base.

4. Infrastructure

Adequate road, rail, air and sea transportation is vital. Energy & telecommunications requirements must also be met. In addition, the local government willingness to invest in upgrading infrastructure to the level required may be an incentive to select a specific location.

5. Quality of Labor

The educational and skill levels of the labor pool must match the company's needs. Primary labor consideration relate to the cost and availability of labor, wage relates in an area, labour productivity, attitude, and towards work.

6. Suppliers

A high quality and competitive supplier base makes a given location suitable.

7. Location of raw materials

Firm's location near or at the source of raw materials for three primary reasons; necessity, perishability, and transportation costs

For example, mining and forestry firms must locate at the source of necessity. Those firms that produce short shelf –life products take perishability as primary criteria when consider location.

B. Community Considerations

From a company standpoint, a number of factors determine the desirability of a community as a place for its workers and managers to live. They include:

- Facilities for education, shopping, recreation transportation , religious workshop, entertainment, the quality of policy, fire and medical services
- attitude towards the company
- The size of the community
- Cost and availability of utilities
- Environmental regulations
- Taxes and
- Existence of development support or incentive.

C. Site related factors.

The primary consideration related to site involves land, transportation, and zoning or other restrictions, utilities etc.

Service location Vs manufacturing facilities

Service facilities are more common than new factories and warehouses because of their low cost of establishing a service facility compared to one for manufacturing e.g. restaurants, hotels entertaining facilities retail shops etc. Typically has multiple sites to maintain close contact with customers. The location decision is closely tied to the market selection decision. Whereas manufacturing location decisions are often made by minimizing costs, but profit maximizing for service location.

3.4.4 Facility Location Methods /Models

Various quantitative models are used to help determine the best location of facilities. Evaluation of alternative regions, sub regions, and community is termed micro analysis. Evaluation of specific sites in the selected community is termed micro analysis.

Techniques used to support macro analysis include:

1. Breakeven analysis (cost – profit - volume analysis)
2. Factor rating method
3. The Center of gravity method and
4. Linear programming (transportation model)

1. Cost Profit Volume Analysis

The economic comparison of location alternatives is facilitated by the use of cost-volume profit analysis. The analysis can be done numerically or graphically.

Graphical assumptions:

1. Fixed costs are constant for the range of probable output.
2. Variable costs are linear for the range of probable output.
3. The required level of output can be closely estimated
4. Only one product is involved.

Graphical procedure

Step 1. Determine the fixed and variable costs associated with each location alternative.

Step 2. Plot the total-cost lines for all location alternatives on the same graph.

$$\text{Total cost} = \text{FC} + \text{VC} \times \text{Q}$$

where

FC = fixed cost

VC = variable cost per unit

Q = quantity or volume of output

Step 3. Determine which location will have the lowest total cost for the expected level of output. Alternatively, determine which location will have the highest profit.

Example. Fixed (land, property taxes, insurance, building etc) and variable costs (labor, raw materials, transportation, overhead) for four potential plant locations are shown below.

Location	Fixed cost per year	Variable cost per year
A	\$150,000	\$62
B	300,000	38
C	500,000	24
C	600,00	30

Required

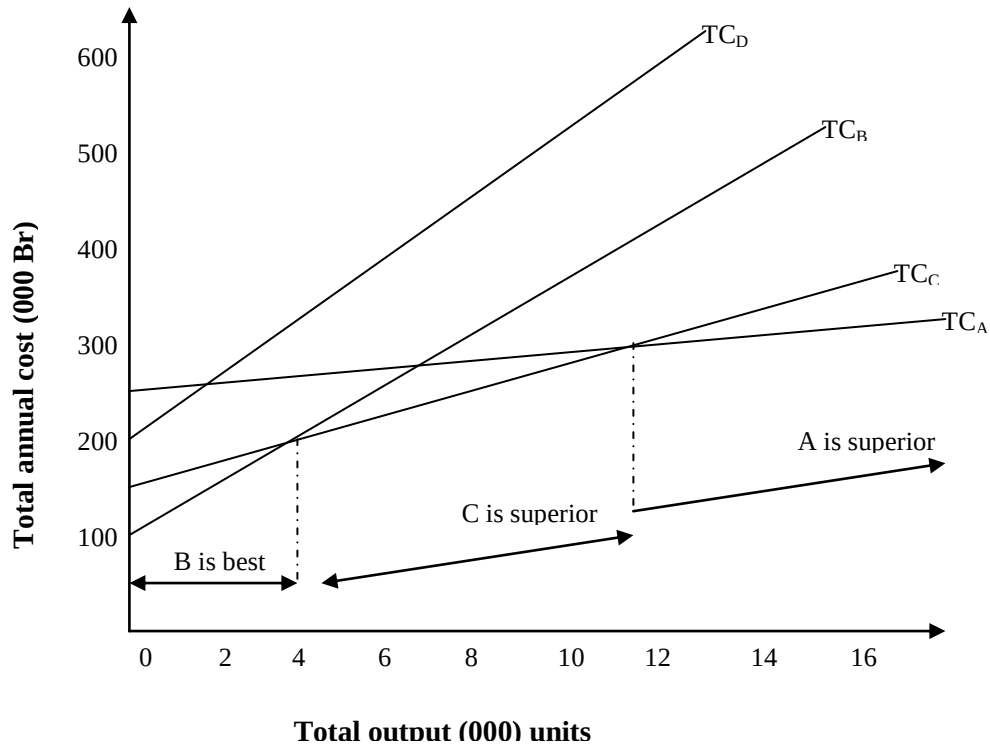
- Plot the total cost lines for these locations on a single graph
- Identify a range of output for which each alternative is superior (i.e., has the lowest total cost)
- If expected output at the selected location is to be 8,000 units per year, which location would provide the lowest total cost?

Solution

- To plot the total cost-lines, select an output that is approximately equal to the expected output level (e.g., 10,000 units per year). Compute the total cost for each location at that level.

Fixed cost	+ Variable cost	= Total cost
A -----\$250,000	\$11(10,000)	\$360,000
B -----100,000	30(30,000)	400,000
C -----150,000	20(10,000)	350,000
D -----200,000	35(10,000)	550,000

Plot each location's fixed cost (at output = 0) and the total cost at 10,000; and connect the two points with a straight line. See the accompanying graph.



b) the approximate ranges for which the various alternatives will yield the lowest costs are shown on the graph. Note that location D is never superior. The exact ranges can be determined by finding the output level at which line B and C and A cross. To do this set their total cost equations equal and solve for Q, the breakeven output level. Thus, for B and C.

$$\begin{array}{ll} \text{(B)} & \text{(C)} \\ \$100,000 + \$30Q & = \$150,000 + \$20Q \end{array}$$

Solving, you find $Q = 5,000$ units per year.

For C and A:

$$\begin{array}{ll} \text{(C)} & \text{(A)} \\ \$150,000 + \$20Q & = \$250,000 + \$11Q \end{array}$$

Solving, $Q = 11,111$ units per year.

C. From the graph, you can see that, 8,000 units per year, location C provides the lowest total cost.

For a profit analysis, compute total profit using the following formula:

$$\text{Total profit} = QR - (FC + VC \times Q) = Q(R - VC) - FC,$$

Where:

R = revenue per unit.

FC = total fixed cost

Q = total units of products (quantity)

VC = variable cost per unit

2. Factor rating method

Factor ratings are frequently used to evaluate location alternatives because

1. their simplicity facilitates communication about why one site is better than another
2. they enable managers to bring diverse location consideration into the evaluation process
3. Then faster consistency and judgment about location alternatives.

Procedures:

1. List the most relevant factors in the location decision
2. Assign a weight to each factors that indicates its relative importance compared with all other factors. The weight sum should be 1.00
3. Decide on a common scale for all factors. Each factors should be rated, say from 1 (very low) to 5 (very high) , according to its relative importance
4. Score rate each location alternative (1-100)or (1-10)
5. Multiply factor weight or rate by the score (location rate for each factor , and sum the results for each location alternatives
6. Choose the location that has the highest composite score. The score indicates alternative locations are most promising.

Example 1:

ABC shoe factory intends to open a new branch store. The exhibit below contains information on two potential locations, A and B. Which location is promising?

Factors	Factor rating		Location rating		Product of rating	
	A	B	A	B	A	B
Tax advantage	4	3	8	9	32	27
suitability of labor skills	3	4	2	7	6	28
Proximity to customers	3	4	6	8	18	32
Proximity to suppliers	5	3	2	5	10	15
Adequacy of water	1	2	3	2	3	4
Receptivity of community	5	4	4	8	20	32
Quality of education system	4	1	1	2	4	2
Access to transpiration	3	5	10	3	30	15
Suitability of climate	2	5	7	10	14	50
Availability of power	1	1	6	6	12	6
Total Score					149	211

Note: Factor rating scale = 1-5 and location rating scale =1-10

B is better than A because it has the higher composite score (211) managers some times may set a minimum standard, if it goes below that they can reject all alternatives.

Example 2

Using the following factors ratings, determine which location alternatives should be chosen on the basis of maximum composite score A, B or C.

Factor		Locations (max score 100)	Weighted score
--------	--	---------------------------	----------------

(100 pts. each)	Weight	A	B	C	A	B	C
1. Convenient	0.15	80	70	60	12.0	10.5	9
2. Parking facilities	0.20	72	76	92	14.4	15.2	18.4
3. Display area	0.18	88	90	90	15.84	16.2	16.2
4. Shopper traffic	0.27	94	86	80	25.38	23.22	21.6
5. Operating costs	0.10	98	90	82	9.8	9	8.2
6. Neighborhood	0.10	96	85	75	9.6	8.5	7.5
Sum	1.00				87.02	79.92	73.6

Decision: - Location A is better because it results in a highest score.

3. Center of gravity method:

For locating single facilities that considers the existing facilities, the distance between them, and the volumes of goods that need to be shipped.

It is used to locate intermediate or distribution warehouses.

This method begins by locating the existing locations on a coordinate grid system. The purpose is to establish relative distance between locations. The center of gravity is found by calculating the X and Y coordinates that will result is the minimal transportation cost. This is given by the following weighted formula.

$$C_x = \frac{\sum d_{ix} V_i}{\sum V_i}$$

$$C_y = \frac{\sum d_{iy} V_i}{\sum V_i}$$

where:

C_x = X coordinate of the center of gravity

C_y = Y coordinate of the center of gravity

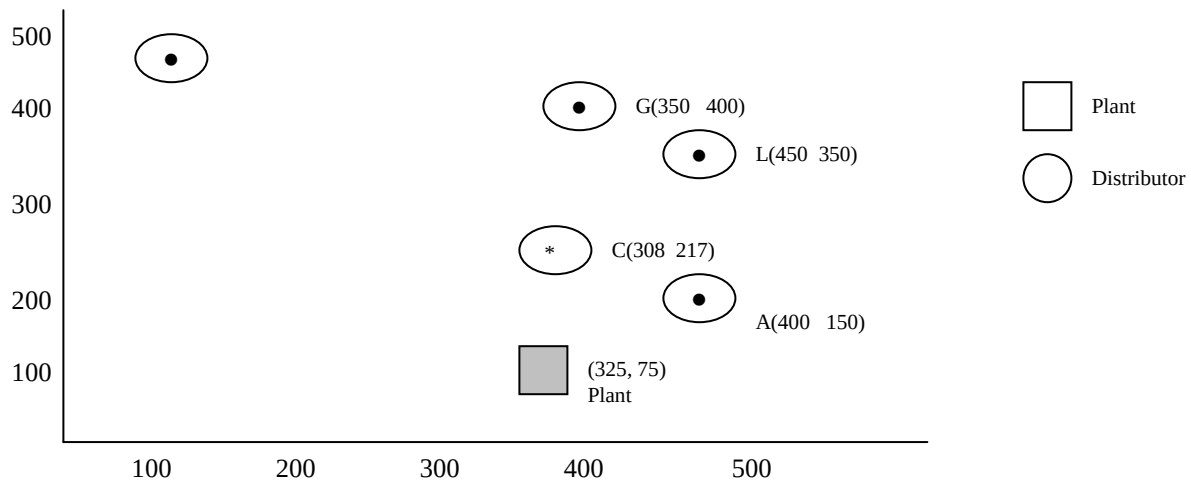
D_{ix} = X coordinate of the i^{th} location

D_{iy} = Y coordinate of the i^{th} location

V_i = Volume of goods moved to or from the i^{th} location

Example 1:

A refining company needs to locate an intermediate holding facility between its refining plant and its major distributors. The coordinate map is the following.



Shipping Volumes and the coordinates of the destinations shown in map is summarized as follows:

<u>Location</u>	<u>X</u>	<u>Y</u>	<u>Gallons of Gasoline/month (000')</u>
Plant	325	75	1500
A	400	150	250
L	450	350	450
G	350	400	350
T	25	450	450

$$d_{ix} = 325$$

$$d_{iy} = 75$$

$$V_i = 1500$$

$$C_x = \frac{(325 \times 1500) + (400 \times 250) + (450 \times 450) + (350 \times 350) + (25 \times 450)}{1500 + 250 + 450 + 350 + 450}$$

$$C_x = \frac{925,750}{3000} = 307.9$$

$$C_y = \frac{(75 \times 1500) + (150 \times 250) + (350 \times 450) + (400 \times 350) + (450 \times 450)}{3000}$$

$$= 216.7$$

X and Y coordinate are approximately 308 and 217 respectively. Therefore, the location of the intermediate holding facility should be at (x, y) = (308, 217). On the map it is represented by point C.

Example 2

A clothing manufacturing produces children's cloth at four locations in northern Ethiopia. Relative locations have been determined, as shown in the table below. The location of a central shipping point for bolts of cloth must now be determined. Weekly quantities to be shipped to each location are shown below. Determine the coordinates of the location that will minimize distribution costs.

<u>Location</u>	<u>(X, Y)</u>	<u>Weekly Quantity</u>
A	5, 9	15
B	6, 9	20
C	3, 9	25
D	9, 4	30

Solution

Coordinate point is given by the formula:

$$(\bar{x}, \bar{y}) = \left(\frac{\sum x_i \sum d_i}{\sum d_i}, \frac{\sum y_i \sum d_i}{\sum d_i} \right)$$

$$\begin{aligned} \bar{X} &= \frac{\sum x_i d_i}{\sum d_i} = \frac{5 \times 15 + 6 \times 20 + 3 \times 25 + 9 \times 30}{15 + 20 + 25 + 30} \\ &= \frac{540}{90} = \underline{6} \end{aligned}$$

$$\begin{aligned} \bar{Y} &= \frac{\sum Y_i d_i}{\sum d_i} = \frac{9 \times 15 + 9 \times 20 + 9 \times 25 + 4 \times 30}{15 + 20 + 25 + 30} \\ &= \frac{660}{90} = \underline{7.33} \end{aligned}$$

$$(\bar{x}, \bar{y}) = (\underline{6}, \underline{7.33})$$

3.4.5 Locating Service outlets**A Heuristic Method****Example**

Suppose that a medical consortium wishes to establish two clinics to provide medical care for people living in four communities. Assume that the sites under study are in each community and that the population of each community is evenly distributed within the community's boundaries. Further, assume that the potential use for the clinic members of the various communities has been determined and weighting factors reflecting the relative importance of serving members of the population of each community have been developed.

Find the two clinics that can serve all communities at the lowest weighted travel distance cost. Distances, population and relative weights are given below.

From	Miles to clinic	Population of	Relative weighting of
------	-----------------	---------------	-----------------------

Community					Community	population
	A	B	C	D		
A	0	11	8	12	10,000	1.1
B	11	0	10	7	8,000	1.4
C	8	10	0	9	20,000	0.7
D	9.5	7	9	0	12,000	1.0

To answer this question, you can follow the following processes/steps.

Steps:

Steps I. Construct a weighted population distance table the above data table (multiplying distance times weighting factors)

From Community	To clinic located in community			
	A	B	C	D
A	0	121	88	132
B	123.2	0	112	78.4
C	112	140	0	126
D	114	84	108	0
Total	349.2	345	308	338

Step II. Add the amounts in each column. Choose the community with the lowest cost and locate the facility there. Based on the weighted score, community C is the first choice.

NB. Costs are expressed is weighted population distance units

Step III. For each raw compare the cost of each column entry to the communities already located if the cost is also do not change them. If the cost is greater reduce the cost to the lowest of the communities already selected.

Step IV. If additional locations are required, choose the community with the lowest cost from those not already selected.

Community	To clinic located is community			
	A	B	C	D
A	0	88	88	88
B	112	0	112	78.4
C	0	0	0	0
D	108	84	108	0
Total	220	172	308	166.4

Step V. Repeat step 3 reducing each raw entry that exceeds the entry in the columns just selected to clinic.

From Communit y	To clinic located is community		
	A	B	D
A	0	88	88
B	78.4	0	78.4
C	0	0	0
D	0	0	0
Total	78.4	88	166.4

Continue repeating step 4 and 5 until the desired number of location is selected.

Final table

From	To clinic	
	A	B
A	0	88

B	78.4	0
C	0	0
D	0	0
Total	78.4	88

The problem has now solved for all four possible location.

1st C

2nd D

3rd A

4th B

UNIT 4 PRODUCTION PLANNING AND CONTROL

4.1 INTRODUCTION

Planning is an integral part of a manager's job. If uncertainties cloud the planning horizon, it can be quite difficult for a manager to plan effectively. Forecasts can help managers by reducing some of the uncertainty, thereby enabling them to develop more meaningful plans than they might otherwise. This unit deals with business forecasting and aggregate planning. It covers basic forecasting techniques, how to monitor a forecast, the necessary steps in preparing a forecast, and elements that are common to forecasts, techniques of forecasting. Moreover, it addresses the concept of aggregate planning, techniques of aggregate planning, master scheduling and controlling.

4.2. FORECASTING

Forecasting is an integral part of planning. Forecasting is estimating the future demand for products and the resources necessary to produce these outputs. Sales forecasts are the starting point for all other forecasts in production and operations activities. It becomes an input of both business strategy and production strategy.

Why forecasting?

1. New facility planning /build new factory or design and important new production process.
2. Production planning /demands vary from month to month production rates must
3. Work force scheduling/ demand vary from week to week

4.2.1. What is Forecasting?

Forecasting is the art and science of predicting future events. It may involve taking historical data and projecting them into the future with some sort of mathematical model. It may be a

subjective or intuitive prediction (subjective) or a combination of mathematical model adjusted by a manager's good adjustment. In a summarized form a forecast:

1. Is a statement of the future
2. Is a basis for planning
3. Is not for forecasting demand only, it can be used in forecasts such as economic, technological and the like.
4. Requires a skillful blending of art and science.
5. Assumes that the underlying system will continue to exist in the future.
6. Is rarely perfect i.e., actual results usually defer from predicted values. Perfect forecast is usually impossible. Too many factors in the business environment cannot be predicted with certainty. - Do not to be accurate but improve the system.
7. Forecast accuracy decreases as the time period covered by the forecast increases.

Production and operations managers use forecasts to made periodic decisions involving:

- process selection
- capacity planning
- facility layout and
- continual decisions about production planning, scheduling and inventory
- budgeting
- sales planning

4.2.2. Elements of a Good Forecast

- The forecast horizon must cover the sufficient time necessary to implement possible changes.
- The degree of accuracy should be stated
- The forecast should be reliable: it should work consistently.
- The forecast should be expressed in meaningful units
- The forecast should in writing
- The forecast should be simple to understand and use, or consistent with historical data intuitively.

4.2.3. Steps in Forecasting Process

There are certain basic steps in the process of forecasting.

1. Determine the purpose of the forecast.
2. Select the item to be forecasted.
3. Establish a time horizon.
4. Select a forecasting technique.
5. Gather and analyze the appropriate data.
6. Prepare a forecast.
7. Monitor a forecast.

4.2.4. Approaches to Forecasting

Which forecasting model a firm should choose depends on:

- Time horizon to forecast
- Data availability
- Accuracy required
- Size of forecasting budget
- Availability of qualified personnel
- Degree of flexibility

There are two general approaches to forecasting. There are Qualitative and Quantitative approaches.

A. **Qualitative approach** - Qualitative methods consist mainly of subjective inputs, which often disregard precise numerical description. It permits inclusion of soft information (human factors, personal opinions, etc) in the forecasting process. Those factors are often omitted or downplayed when quantitative techniques are used because they are difficult or impossible to quantify.

- they are difficult to express precisely by number
- they are based on personal estimates or opinions or judgment

Qualitative techniques include:

1. *Jury of executive opinions*

A small group of upper-level managers may meet and collectively develop a forecast. This approach is often used as a part of long-range planning and new product development. It helps to bring together the considerable knowledge and talents of top management people, simple, inexpensive. However, there is the risk that the view of one person will prevail and it is based on opinion only.

2. *Sales for composite*

The sales staff is often a good source of information because of its direct contact with customers and experience.

3. Delphi method - used to develop consumers of expert opinion

4. Customer analysis /Evaluation/

B. Quantitative approaches

Involves either the extension/projection of historical data or the development of associative models that attempt to utilize causal (explanatory) variables to make a forecast. They include:

1. *Time series forecasts*

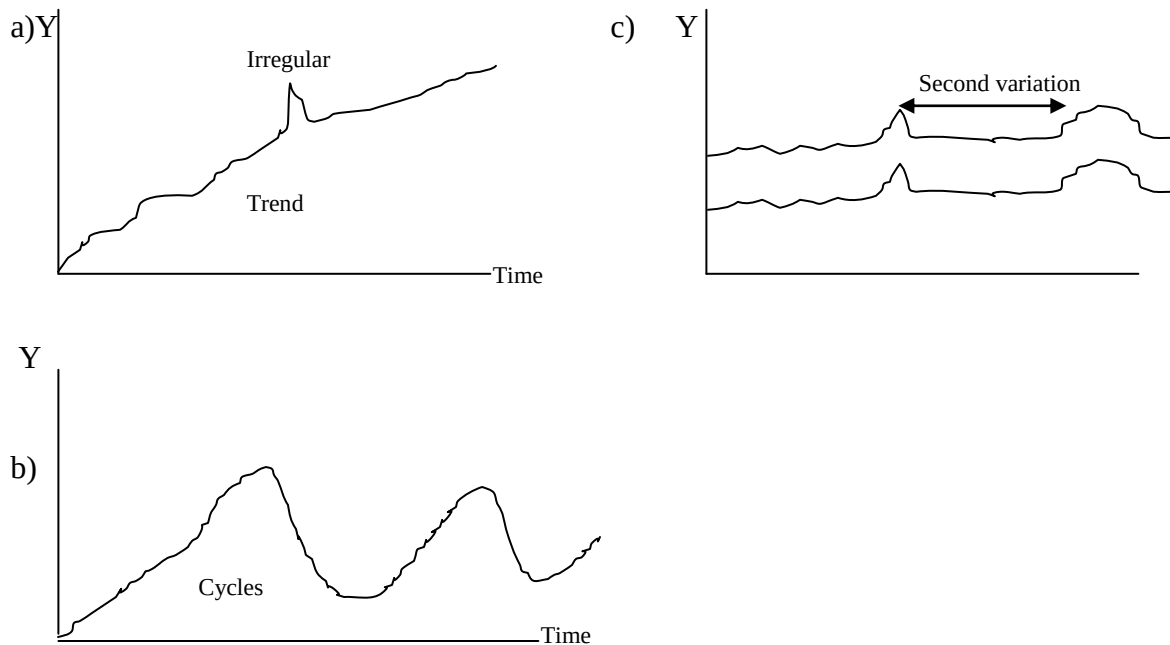
Is a technique that uses a series of past data points to make a forecast. A time series is a time ordered sequence of observations taken at a regular interval over a period of time (e.g. Hourly, weekly, monthly, quarterly or annually). The observation or the data may be the measurements of demand, earnings, profits, productivity etc.

Forecasting techniques based on time series data are made on the assumption that future values of the series can be estimated from the past.

This technique requires analysts to identify the underlying behavior of the series. The time series typically has four components

- | | |
|------------------------|---------------------|
| 1. Trends | 3. Cycles |
| 2. Seasonal variations | 4. Random variation |

Trend - refers to a gradual, long-term upward or downward movement in data



Techniques for Averaging

When historical data typically contain a certain amount of random variation or disturbance that tends to affect the systematic movements in the data. This randomness arises from the combined influence of many relative unimportant factors and cannot be reliably predicted.

- To reduce the impact of such random variations, different averaging techniques are used. These are:
 1. Naïve forecasts
 2. Moving averages - Simple or weighted
 3. Exponential smoothing

1. Naïve forecast

It is Simple forecasting technique that assumes demand in the next period is equal to demand in the most recent period i.e., the forecast for any period equals the previous period's actual value.

Example: If last week demand was 100 units, the naïve forecast for the upcoming week is 100 units.

- The forecast can be represented by the following formula:

$$Y_t = Y_{t-1}$$

where: Y_t = forecast at time t

Y_{t-1} = actual data at time t

Advantage:

1. Less cost
2. quick
3. easy to prepare and
4. easy to understand

Limitations: unable to provide highly accurate forecasts

2. Moving Average - simple or weighted

A moving average uses a number of the most recent actual data values in generating a forecast. One weakness of the naïve method is that the forecast must trace the actual data, with a lag of one period; it does not smooth at all. However, by expanding the amount of historical data a forecast is based, this difficulty can be overcome using a moving average.

The moving average (MA) forecast can be computed using the following equation: (simple moving average)

$$MA_n = \frac{\sum_{i=1}^n Y_i}{n}$$

where: i = refers to the most recent period (i = 1, 2, 3, ..., n)

n = number of periods in the moving average

y_i = actual value with period i

MA_n = moving average of the most recent n actual forecast

For example MA_3 would refer to a 3 period moving average.

Example 1. Compute a three period moving average forecast for period six given demand for shipping a product for the last five periods.

Period	Age	Demand
1	5	42
2	4	40
3	3	43
4	2	40
5	1	41

Solution

$$MA_3 = (41 + 40 + 43)/3 = \underline{41.33}$$

If actual demand in period 6 turns out to be 39, the moving average forecast for period 7 would be:

$$MA_3 = \frac{39 + 41 + 40}{3} = 40$$

Note: In a moving average, as each new actual value becomes available, the forecast is updated by adding the newest value and dropping the oldest and then re computing the average. Consequently, the forecast "moves" by reflecting only the most recent values.

Selecting the number of period to include:

There are several conflicting effects of different period lengths. 1. The longer the moving-average period, the greater the random elements are smoothed. However, 2. The few the data in an average, the more responsive the average trends to be. Hence, if responsiveness is important, a moving average with relatively few data points should be used. Moving average based on more data points will smooth more but be less responsive to "REAL" changes. Hence, the decision maker weigh the cost of responding more slowly to changes in the data against the cost of responding to what might simply be random variations.

The advantage of moving average is that it is easy to compute and understand. Its limitations are:

- Data storage requirements can be significant
- Extensive records of data

- Can not pickup trends very well
- Increasing the size of n does smooth out fluctuations better, but it makes the method less sensitive to real changes.

ii. Weighted moving average

Weighted moving (WA) average is similar to MA, except that it assigns more weight to the most recent values in a time series. It may be expressed mathematically as:

$$\omega A = \frac{\sum_{i=1}^n \omega_i Y_i}{\sum \omega_i}$$

$$= \frac{\sum (\text{weight for period } n)(\text{demand in period } n)}{\sum \text{weights}}$$

Example 3. You are given the following data:

- Compute a weighted average forecast using a weight of 0.40 for the most recent period, 0.30 for the next most recent, 0.20 for the next, and 0.10 for the next.
- If the actual demand for period 6 is 39, forecast demand for period 7 using the same weights as in a

Period	Demand
1	42
2	40
3	43
4	40
5	41

Solution

$$\begin{aligned} \text{a) Forecast} &= 0.4 \times 41 + 0.3 \times 40 + 0.2 \times 43 + 0.1(40) \\ &= \underline{41} \end{aligned}$$

$$\begin{aligned} \text{b) Forecast} &= 0.4 \times 39 + 0.3(41) + 0.2(40) + 0.1(43) \\ &= \underline{40.2} \end{aligned}$$

Note: the advantage of WA over a simple MA is that the WA is more reflective of the most recent occurrences.

3. Exponential smoothing

It is a sophisticated weighted averaging method that is still relatively easy to use and understand. In this technique each new forecast is based on the previous forecast plus a percentage of the difference between that forecast and the actual value of the series at that point. That is:

New forecast = old forecast + α (Actual - old forecast)

Where α = (Alpha) is a percentage

i.e., smoothing constant (Actual-old forecast) represents the forecast error.

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

F_t = forecast for period t

F_{t-1} = forecast for period t -1

α = Smoothing constant

A_{t-1} = actual demand for sales for period t-1

The smoothing constant α represents a percentage of forecast error. Each new forecast is equal to the previous forecast plus a percentage of the previous error.

Example 1. Suppose the previous forecast was 42 unit, actual demand was 40 units, and $\alpha = 10\%$ what is the new forecast?

$$\begin{aligned} F_t &= 42 + 0.1(40 - 42) \\ &= \underline{41.8} \end{aligned}$$

Then, if the actual demand turns out to be 43, the next forecast would be:

$$\begin{aligned} F_t &= 41.8 + 0.1 (43 - 41.8) \\ &= \underline{41.92} \end{aligned}$$

4. Simple linear regression analysis

The following section of this unit illustrates simple linear regression method. This technique is used to predict or project the value of the dependent variable based on the actual or

predicted value of the independent variable. The cause and effect relationship of the variables is given by a linear equation: $Y = a + bx$

The variables used in the formula are defined as:

Y = dependent variable values

n = number of observations

a = vertical axis intercept

b = slope of the regression line

$\bar{Y}$ = average value of n observations of the dependent variable

$\bar{X}$ = average value of 'n' observation of the independent variable

$$b = \frac{n \sum xY - \sum x \sum Y}{n \sum x^2 - \sum (x)^2}$$

$$a = \frac{\sum Y - b \sum X}{n}$$

$$= \bar{Y} - b\bar{X}$$

If the date is a time series, the independent variable is time and the dependent variable is usually sales. The regression equation is $Y = a + bx$

Example 1. A Company produces electronic motors for the construction industry. The plant has operated at near capacity for over a years. The plant manager thinks that the growth in sales will continue and he wants to develop a long-range forecast to be used to plan facility requirements for the next three years. Sales records for the past ten years have been accumulated in the following table.

<u>Years (x)</u>	<u>Annual Sales (y)</u>	<u>Time Period X</u>	<u>X²</u>	<u>Y X</u>
1	1000	1	1	1000
2	1300	2	4	2600
3	1800	3	9	5400
4	2000	4	16	8000
5	2000	5	25	10000
6	2000	6	36	12000
7	2000	7	49	15400
8	2600	8	64	20800

9	2900	9	81	26100
10	<u>3200</u>	<u>10</u>	<u>100</u>	<u>32000</u>

$$\Sigma y = 21000 \quad \Sigma x = 55 \quad \Sigma x^2 = 385 \quad \Sigma xy = 133,300$$

$$\Sigma y = 25,000$$

$$\Sigma x = 55$$

$$\Sigma x^2 = 385$$

$$\Sigma xy = 133,300$$

$$b = \frac{n \sum xy - \sum x \sum Y}{n \sum x^2 - \sum (x)^2}$$

$$= \frac{10 \times 133,300 - 55 \times 21,000}{10 \times 385 - (55)^2}$$

$$= \frac{1,333,000 - 1,155,000}{825}$$

$$= 215.76$$

$$a = \frac{\sum Y - b \sum x}{n} = \frac{21000 - 215.8 \times 55}{10}$$

$$= \underline{\underline{913.3}}$$

Now the regression equation can be used to forecast future years' sales

$$\mathbf{Y = a+bx= 913.333+215.758x}$$

The forecast for the next three years 11, 12, 13 would be:

$$Y_{11} = 913.333 + 215.758(11) = 3299 \text{ thousand units}$$

$$Y_{12} = 913.333 + 215.758(12) = 3500$$

$$Y_{13} = 913.333 + 215.758(13) = 3720$$

Simple linear regression can also be used when the *independent variable* Y represents variable other than time. In this case linear regression representative of a class of forecasting models called *casual forecasting model*.

Example 2 The manager of an engineering corporation thinks that his firm's engineering services supplied are directly related to the amount of construction contracts.

The following data are prepared to develop a regression equation and to predict the level of demand for services for the next four quarters and how closely demand is related to the amount of construction contracts released.

<u>Year</u>	<u>Quarter</u>	<u>Sales (in thousands)</u>	<u>Amount of contact released (000')</u>
1	Q1	8	150
	Q2	10	170
	Q3	15	190
	Q4	9	170
2	Q1	12	180
	Q2	13	190
	Q3	12	200
	Q4	16	220

Solution:

Develop the totals required to perform the regression analysis

<u>Time period</u>	<u>Sales(y)</u>	<u>contracts(x)</u>	<u>X²</u>	<u>XY</u>	<u>Y²</u>
1.	8	150	22,500	1200	64
2.	10	170	28,900	1700	100
3.	15	190	36,100	2850	225
4.	9	170	28,900	1530	81
5.	12	180	32,400	2160	144
6.	13	190	36,100	2470	169
7.	12	200	40,000	2400	144
8.	<u>16</u>	<u>220</u>	<u>48,400</u>	<u>3520</u>	<u>256</u>
Total	95	1470	273,300		1183

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - \sum (x)^2} = \frac{8(17830) - (1470)(95)}{25500} = \underline{\underline{0.1173}}$$

$$a = \frac{\sum y - b \sum x}{n} = \frac{95 - 0.1173(1470)}{8} = \underline{\underline{-9.671}}$$

Therefore, the regression equation is:

$$Y = -9.671 + 0.1173x$$

Forecast the level of demand for the next four quarters. The manager prepares estimates of the next four quarters' contract releases. These were 260, 290, 300 and 270 .

$$\begin{aligned} Y_1 &= -9.671 + 0.1173(260) \\ &= \underline{\underline{20.827}} \end{aligned}$$

$$\begin{aligned} Y_2 &= -9.671 + 0.1173(290) \\ &= \underline{\underline{24.346}} \end{aligned}$$

$$\begin{aligned} Y_3 &= -9.671 + 0.1173(300) \\ &= \underline{\underline{25.519}} \end{aligned}$$

$$\begin{aligned} Y_4 &= -9.671 + 0.1173(270) \\ &= \underline{\underline{22.000}} \end{aligned}$$

The total forecast for the next year is the total of the four-quarter forecasts i.e.

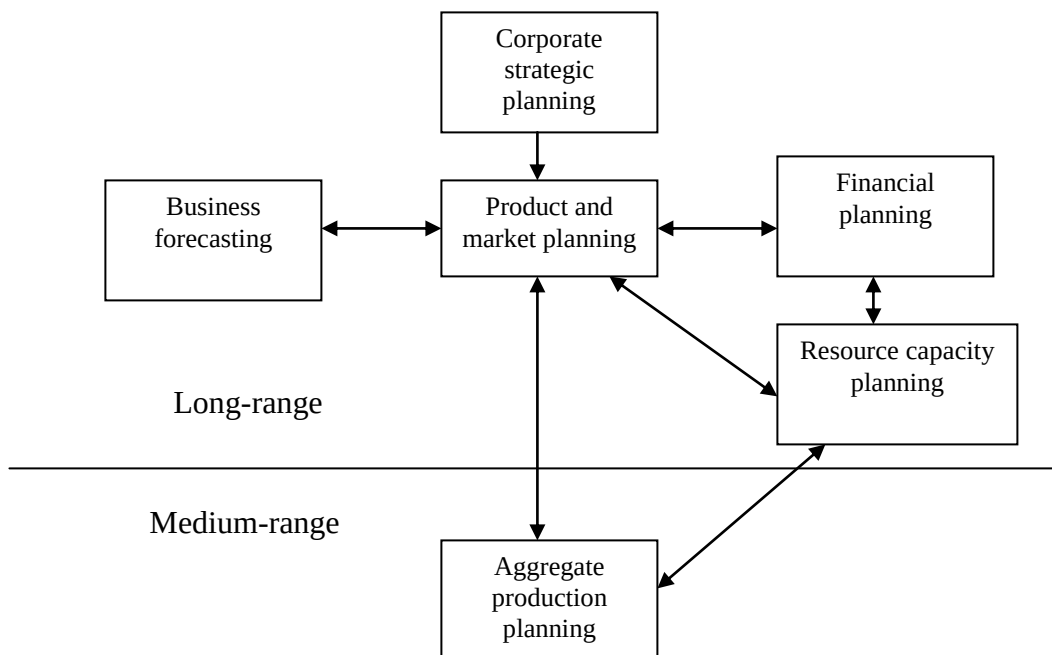
$$20.827 + 24.346 + 25.519 + 22.000 = \underline{\underline{92.7}} \text{ thousand}$$

4.3. PRODUCTION PLANNING

Firms plan their manufacturing and service operations activities at various levels and operate these as a system. Based on time dimension planning can be long range, medium range and short range.

1. Long-range planning. Begins with a statement of organizational objective and goal for the next two to ten years. It includes:

1. Corporate strategic planning articulates how these objectives and goals are to be achieved in light of the companies' capabilities and its economic and political environment as projected by its business forecasting. Elements of the strategic plan include
 - production line delineation.
 - quality and pricing level and
 - market penetration goals
2. Business forecasts
3. Product and market planning. Translates these into individual market and product line objectives and includes a long range production plan of items to be manufactured for 2years or more in the future.
4. Financial planning analyzes the financial feasibility of these objectives relative to capital requirements and return on investment goals.
5. Resource planning identifies the facilities, equipment, and personnel needed to accomplish the long range production run and thus is frequently referred to as long run capacity planning



Specific plan in long-range plans include;

i. Facility plans

- Plant location
- Layouts
- Size
- Capacities

ii. Major supplier plans

- Vertical integration plans
- Identification of components to delegate to suppliers

iii. Process plans

- Development of new production technology
- New production processes
- New system of automation

iv. Product plans

- quality
- price

2. Medium Range Planning

Usually covers the period of 6 to 18 months. With time increments that are monthly or some times quarterly. It includes aggregate production planning, item forecasting, master production scheduling, rough cut capacity planning etc.

Aggregate planning is the process of devising a plan for providing production capacity to support medium range sales forecasts. It is concerned with setting production rates by product group or other broad categories for the intermediate term.

Main purpose of aggregate planning is to Specify the optimal combination of production rate, work force level, and inventory on hand. Aggregate planning is necessary in production and operations management because:

1. It facilitates fully loaded facilities and minimizes overloading and under loading, thus keeping production cost low.

2. It provides adequate production capacity to meet expected aggregate demand
3. It facilitates the orderly and systematic transition of production capacity to meet the peaks and valleys of expected customer demand and;
4. In times of scarce production resources, it enhances the probability of getting the most output for the amount of resources available.

Steps in aggregate Planning

1. Begin with a sales forecast for each product that indicates the quantities to be sold in each time period (usually weeks, months or quarters) over the planning horizon (6 to 18months)
2. Total all of the individual product or service forecasts into one aggregate demand for a factory.

If the products are not additive because of heterogeneous unit, a homogeneous unit of measurement must be selected that both allows the forecasts to be added and links aggregate outputs to production capacity.

3. Transform the aggregate demand for each time period into works, materials, machines, and other elements of production capacity required to satisfy aggregate demand.
4. Develop alternative resource schemes for supplying the necessary production capacity to support the cumulative aggregate demand.
5. Select the capacity plan from among the alternatives considered that satisfies aggregate demand and best meets the objectives of the organization.

4.3.1 Planning Strategies

There are four alternative strategies that deal with the workforce, work time, inventory and backlogs.

1. Vary the work force size by hiring and laying off employees as demand fluctuates.
2. Maintain a stable workforce, but vary the output rate by varying the number of hours worked through variable work weeks or overtime.
3. Maintain a stable workforce and constant output rate, but absorb demand fluctuations by allowing inventory to vary.

4. Allow backlogs (delivery lead time) to increase during periods of increased demand and decrease during periods of decreased demand.

The strategies can be applied independently or used in combination. This is known as mixed strategy which is common than individual strategies..

Proper Strategy is selected based on:

- 1) how much of each production resource is available
- 2) How much capacity is provided by each type of resource. The amount of resource required to produce a single unit of a particular product or service allows the translation of demand into production capacity plans.
- 3) At what step in production we determine capacity /labour hour available, or machine hour available
- 4) How much does it cost to scale capacity up or down cost of hiring, laying off, recalling/

Determining production capacity of a production system differs among the type of systems.

Product focused - capacity is determined by the gateway operation that is the first operation in a production line

- Process focused capacity is determined by bottle neck operation/operation with the least capacity for a product/
- Other systems/number of machine hour or labour hour.

How quickly production capacity can be scaled up or down and what the relative costs will determine the strategy.

Given that machine capacities are too inflexible to allow for variation in production capacities in the planning horizon for aggregate production plans here are the ways that operation managers can supply production capacity.

1. Straight – time labour

Current production of products by workers paid at

Straight –time labor rates. /increasing shift by hiring new employees /

2. Overtime labour

Current production of products or services by workers paid at overtime labor rates.

- Expensive because of worker fatigue lowered worker moral, especially if the additional capacity is planned for attended periods and premium labor rate

3. Inventory

- production in previous time periods that is held for shipment in later time periods

4. Subcontracting

- production of products or services by suppliers

Relevant costs for aggregate production planning

1. Basic production costs

Fixed and variable costs direct and indirect labour cost

2. Costs associated with changes in the production rate /hiring, training, layoff/

3. Inventory holding cost

Capital cost, storing, insurance, taxes, spoilage, obsolescence ...

4. Backlogging Costs

Cost of expediting, loss of customer goodwill, loss of sales revenues. Such cost are usually very hard to measure

4.3.2 Aggregate planning techniques

1) Matching Demand

In matching demand type aggregate plan, production capacity in each time period is varied to exactly match the forecasted aggregate demand in that time period. Such an approach varies the level of the workforce in each time period by hiring new workers, laying off workers or recalling workers.

Number of workers = unit per time period X labour standard per unit

Working day per time period per worker X hrs per day

Advantage

- Almost no inventories of finished goods inventories are needed and therefore much of the cost of carrying inventory is avoided.

Disadvantage

Labor and material costs tend to be higher because of the disruptions caused by frequently scaling the workforce and material supplies capacities up and down

2. ***Level capacity /production capacity*** is held constant over the planning horizon.

The difference between the constant production rate and the varying demand rate is made up by inventory, backlog, overtime or subcontracting

- a) Buffering with inventory: An advantage of level capacity with inventory is that it usually promotes low production cost. Because:
 1. Cost of hiring and laying of workers and using overtime are practically eliminated.
 2. Cost of locating and developing new sources of material supplies is minimized.
 3. Only the most efficient production machinery is used
 4. labour and material cost per product are low as rhythmic operation of the production system has eliminated the continual startup and shut down of operation
 5. Supervision is simplified and scrap rates are low since workers are experienced in their jobs
 6. Voluntary turnover and absenteeism may be lower /life time employment /

Disadvantage

- Tying up cash and increasing the cost of carrying these inventories.

b) Buffering with Backlog

In produce-to- order firms, backlog serves the purpose of buffering the difference between varying demand rate and a constant production rate.

Advantages – services as level capacity with inventory

Disadvantage

Difficulty in developing aggregate plan. Because it is often difficult to specify the detail designs of the product before the customers orders are received

C) Buffering with overtime or subcontracting

Another approach to aggregate capacity planning is to use straight time labour to provide a production capacity that equals the minimum forecasted demand rate during the planning horizon. Then overtime or subcontracting is used to supply any demand above the minimum. This approach can be used in either produce to stock or produce to order firms.

Advantages

- 1) No finished goods inventory is carried i.e. no cost of holding inventory.
- 2) No cost of hiring, laying off, or recalling of workers i.e.,

These result in low inventory carrying cost and stable work force

Disadvantages

- 1) The amount of overtime available may be insufficient to meet demand if demand peaks are too high.
- 2) Continual use of overtime can exhaust workers which can in turn lead to deteriorating moral, problems with product and service quality, and other difficulties.

Criteria for selecting aggregate plan

- Basically comparing the cost of inventory and hiring layouts recall, overtime determine the type of aggregate plan.

4.4 MASTER PRODUCTION SCHEDULING (MPS)

The master production schedule is a disaggregating on more inclusive plan formulated from forecast and covering a short time period. The master production schedule lists the specific

production commitments by product type, size, and other variables and the time period in which the products are to be produced.

For example, an auto manufacturer can plan to produce one million cars in a year. No mention or note is made in such forecasts as to whether the cars are red, green, two door, four door and so on. MPS is a short range planning usually spans from a few weeks to months.

Time Fences in MPS

There are four sections

Section I. – frozen(includes the first few weeks)

Frozen means this early part of the MPS cannot be changed except under extra ordinary circumstances and only with authorization of highest levels. It is because it would be costly to reverse the plans to purchase materials and produce the parts that go into the product more over it will create customer dissatisfactions.

Section II. Firm (Next few weeks)

Firm means that changes can occur, but only in exceptional kind of situation customer satisfaction will be affected.

Section III Full (next few weeks)

Full means that all of the available production capacity has been allocated to orders.

Changes can be made and production costs will be only slightly affected but the effect on customer satisfaction is uncertain.

Section IV Open (the last section of a few weeks)

Open means that not all of the production capacity has been allocated. It is in this section that new orders are ordinarily slotted.

Procedures

Working from customer orders, forecasts, inventory status reports, and production capacity information, schedulers place the most urgent orders in the earliest available slot of the MPS.

1. The scheduler estimates the total demand for products from all customers
2. Assign orders to production slots.
3. Make delivery promises to customers and
4. Make the detail calculations for the MPS. This includes:
 - Determine whether the MPS under loads or overloads capacity
 - Compute the actual labour hr. required to produce the MPS for both products.
(load)
 - Compare the load to the final capacity available and total the weeks
 - Balance overloads and under loads

Once a master production schedule is complete when and how many products are to be shipped to customer is known. How a production organization plans and controls the purchase of materials, the production of parts and assemblies, and all of the other work necessary to produce the products depends on the type of production planning and control system used.

4.5 PRODUCTION CONTROL FOR JOB SHOPS

Scheduling and control in the job shop.

A schedule is a time table for performing activities, using resources or allocating facilities the purpose of operations scheduling in the job shop is to disaggregate the master production schedule into phased weekly, daily, or hourly activity, i.e. to specify the planned workload on the production system in the very short run.

Operation control entails monitoring job order progress and where necessary, expediting orders or adjusting system capacity to make sure that the master schedule is met.

In designing a scheduling and control system provision must be made for efficient performance of the following functions.

1. Allocating orders, equipment and personnel to work centers or other specified locations. /this is essentially short-run capacity planning/
2. Determine the sequence of order performance (that is establish job priorities).
3. Initiating performance of the schedule work, (dispatching of orders)
4. Shop floor control (or production activity control)
5. Revising the schedule in light of changes in order

Elements of the job shop scheduling problem-scheduling focuses on the following six elements.

1) Job arrival pattern

Jobs can arrive in a batch or over a time interval for scheduler

- static arrival

Schedule made at one time, say once a week, and does not dispatch any job until all the previous incoming orders are on hand.

- dynamic arrival

Jobs are dispatched as they arrive, and the over all schedule is updated to reflect their effect on the production facility.

2) Number and variety of machines in the shop. As the number and variety of machines increase, the more complex the scheduling problem is likely to become

3) Ratio of workers to machines in the shop

- machine limited system (more or equal number of workers than machine)
- labour limited system(more machine than workers). Concern is on labour limited system to the utilization of the worker on several machine and determination of the best way to allocate workers to machine.

4) Flow patterns to jobs through the shop flow ranges from Flow Shop (all the jobs follow the same path from one machine to the next) to a Randomly Routed job Shop (no similar pattern of movement of jobs from one machine to the next).

5) Priority Rules for allocating jobs to machines rule for selecting which job is started first on some machine or work center. It can be simply according to one piece of data (processing time, due date, or order of arrival other complex techniques).

6) Schedule Evaluation Criteria standard measures of schedule performance used to evaluate priority rules. This includes:

- meeting due dates of customers
- minimizing flow time (the time a job spends in the shop)
- minimizing work in progress
- minimizing idle time of machines and workers

4.6 PRODUCTION CONTROL FUNCTION

The role of production control in any organization producing goods or services is to separate those directly responsible for operating the production function from the none operating function of planning, scheduling, coordinating and record keeping.

The pervasive nature of the production control function can be clearly appreciated by enumerating its major responsibilities. These include the need to:

1. Initiate orders and provide authorization to produce the quantity and quality of goods required. To carry out this responsibility the production control department or group must.
 - a) Analyze orders to determine resource requirements and match these requirements with available capacity. Production control will, having made such an analysis, inform the sales department what fabrication or assembly and delivery dates are flexible for customer's orders.
 - b) Provide the production department with routing information specifying manufacturing service, machine and process setup requirements, applicable work standard and machine or processing times.

- c) Initiate production orders that authorize and direct production personnel to make the required parts or products.
- 2) Assist in the efficient utilization of material resources, people, and facilities. To achieve this objective, production control would seek to:
 - a) Provide the requisite order scheduling information to the production department on raw material, tooling, labor and machine requirements by synthesizing information obtained from process design and the mechanical and industrial engineering departments.
 - b) Maintain and control raw material inventories.
 - c) Initiate purchaser order for raw materials and parts and send them to the purchasing department.
 - d) Coordinate the transportation of raw materials or parts, in process products, and finished goods through the production system.
 - e) Make, or assist others in making, cost and time estimates for order scheduling.
 - f) Provide detailed instructions for fabricating or assembling products. Information for this would come from the design and industrial engineering departments.
- 3) Provide coordination and control for manufacturing activities. This responsibility includes monitoring production activities, analyzing production problems, and communicating any need for corrective action to production or operation person in a timely fashion.

These responsibilities specifically requires that production control.

- a) Initiate the paper controls (reports) to provide feedback information on the status of orders.
- b) Compare work accomplishments with schedule requirements to identify orders falling behind schedule or underutilization of facilities.
- c) Prepare labor, machine, and process schedules for production personnel to inform them as to what they should be doing and in what sequence and when each specific step should began and accomplished.

- 4) Assume a leadership role in providing reliable customer services with in the content of a low cost production function. This broad responsibility can be broken down in to more discrete responsibility such as:
- a) Receive orders for parts, products or services from the sales department
 - b) Assist in developing master schedules that serves to allocate the firm's production capacity to individual orders with in a specified time period.
 - c) Provide customer information on order progress or problems.
 - d) Initiate corrective action in cooperation with production personnel for orders failing behind schedule.

4.7 PAPER COMMUNICATIONS FOR AUTHORIZATION AND CONTROL

1- The production order

The actual conveyances of authority from production control to production is the production order. It is initiated by production control and is based on information taken from costumers order or by orders to replenish inventories.

The production order authorizes the production dept to start production. The actual form and content of a production order can vary but the typical production order form will provide information on: order quantity, specification, delivery date, charge codes, order number (customers and firm's) and reference to drawings and materials required

2. The Route Sheet

The route sheet provides step by step instruction to the production group assigned to produce a part or product for converting materials or parts in to the finished product. They usually originate form the engineering dept (since the task is an engineering concern)

A typical route sheet includes: order number, number units to make, part identification, reference drawing number, material requirements and specification, setup time and teardown time, operations data

- list and sequence of required operation
- description of each operation
- work center assigned to perform the operation
- machine (s) assigned
- machine settings or special instruction
- Inspection data

3. Bill of material (BOM)

Originate in the engineering department and lists the specific parts, components or subassemblies and the number of each required to make up a unit of a product. Each subassembly in turn has its own BOM.

4. The job Ticket or production card

While the production order conveys authority to the operations department to proceed with production of the items listed, and route sheet provides a detailed step by step instruction for completing the whole job, the job ticket authorizes an individual operator to produce the results requested.

The job ticket would include typically the following information for both customer orders and orders to stock

1. order number

2. operation number and description
3. quantity to be made
4. scrap allowance
5. machine to be used
6. starting date and time
7. standard time per unit
8. setup time allowance

The job ticket /production card/ may be designed to also service as an inspection ticket and as an input data source for cost control.

Some basic of production control

- routing
- scheduling
- dispatching and control

UNIT 5: TOTAL QUALITY MANAGEMENT

5.1 INTRODUCTION

Fundamental to any quality program is the determination of quality specification and the cost of achieving and not achieving those specification.

- Quality can be derived as conformance to specification. “ Fitness for use (satisfies customer needs).
- Managing the entire organization so that it excel on all dimensions of products and services that are important to customers.
- Quality management begins before products and services delivered to customers. Raw materials must meet the appropriate specification, strength, size, color, finish, appearance, chemical content and other characteristics. As the materials proceed through production, the quality of partially completed Work In Progress (WIP) products monitored to determine whether the production processes are operating as intended. The finished products and services are inspected to determine their acceptability.

5.2 DIFFERENT VIEWS OF QUALITY

In the traditional view of quality control, the way to ensure that customer receives quality products and services is to have rigorous system of inspection. The idea is if there is sufficient inspection, the defective product in will be identified and discarded, leaving only good products to be shipped to customers. In this approach the main decision is how many product to inspect and this decision is a question of economies. As more and more outputs are inspected, the cost of inspection increases while the cost of undetected defects decline. At some level of inspection and optimum trade-off is achieved when total quality controls cost are minimized.

Inspection costs include such costs as personnel training, inspection and testing labour, maintenance of testing and inspection facilities, scrap and rework. The cost of undetected defects includes such costs as customer complaints, loss of customer good will, product warranty and replacement cost, product liability suits and returned products. Operations managers are somewhat supposed to balance these costs in deciding how many products to inspect.

The fundamental wrong in this traditional view is quality can be inspected into products. Enlightened operation managers today know that superior quality is not attained through more inspection. They know that manufacturers must go back to production and make fundamental change in the way that they produce products and do it right the first time. That way, products of superior quality will be coming out of production and inspections job will shift from discarding bad products to providing feedback on how production can continue to improve product quality.

Philip B. Crosby wrote quality is defect free in 1977 and set traditional thinking about “acceptable level of defect is too high and companies should put programs into place that will move them continuously towards the goal of zero defects.

The main idea behind free quality is that the traditional trade off between the cost of improving quality and the cost of poor quality is erroneous. The cost of poor quality include all of the costs of not doing the job right the first time. Scrap, rework, lost labour hours, and machine hours, the hidden cost of customer ill will, lost sales and warranty costs. He states that the cost of poor quality is so understated that unlimited amounts can be profitably spent on improving quality.

A.V Feigenbaum developed the concept of total quality control (TQC) in 1983. Feigenbaum contended that the responsibility for quality must rest with the person who do the work. The concept is referred to as quality at the source, and means every worker, secretary, engineer and sales person must be responsible for performing his or her work with perfect quality. In

TQC where product quality is more important than production rates, workers are given the authority to stop production whenever quality problems occur.

Quality drives the productivity machine:- the traditional view of quality control was that it cost more to get higher product quality. But this is no longer the prevalent view. If production does it right the first time and produce products and services that are defect free, waste is eliminated and costs are reduced.

Quality Circle- is a small group of employees, the average number is nine – who volunteer to meet regularly to undertake work related projects designed to advance the company, improve working conditions, and spur mutual self development, all by using quality control concepts.

Continuous improvement (CI) is a management philosophy that approaches the challenge of products and process improvement as never ending process of achieving small wins. It is an integral part of total quality Management. CI seeks continual improvement of machinery, material, labour utilization and productions methods through application of suggestion and ideas from team members.

One of the techniques assisting in continuous improvement is by generating new ideas. This is achieved by 5W2H method. The 5W2H method is described below.

Type	5W2H	Description	Counter measure
Subject matter	What?	What is being done? Can this task being eliminated?	Eliminate in necessary tasks
Purpose	Why?	Why is the task necessary? Clarify the purpose	
Location	Where?	where is it being done? Does it have to be done there?	Change the sequence or
Sequence	When?	When it is the best time to doit? does it have to be done then?	

People	Who?	who is doing it? Should someone else do it? Why I am doing it?	combination
Method	how?	How is it being done? Is this the best method? Is there some other way?	Simplify the task
Cost	how much?	How much does it cost now? What will the cost be after improvement?	Select an improvement method

Other aspects of quality picture

- Product standardization :- with fewer product design and repetitive production, the same standard products are produced every day, worker job assignments are well understood, workers are familiar with their tasks, and product quality may be improved.
- Purchasing:- Suppliers should deliver perfect quality material
- Automated equipment:- it play major role in attaining superior product quality
- Preventive maintenance- minimize machine repairs.

Total Quality Management (TQM) Programs:- The underlying principle of TQM is to produce products of high quality in the first place, rather than depend on detecting defective product later through inspection . Elements of TQM include

- i.) Top management policy:- top management should issue statement about how business strategy is tied to superior quality of its products and services.
- ii.) Quality control for everyone
- iii.) Product design
- iv.) Quality material from suppliers
- v.) control in production;- production organization must be committed to produce perfect product.
- vi.) distribution, installation and use:- packaging, shipping and installation must be included in TQM.

5.3 STATISTICAL CONCEPTS IN QUALITY CONTROL (SCQC)

SCQC is divided into acceptance sampling and statistical process control. Acceptance sampling involves testing a random sample of existing goods and deciding whether to accept the entire lot based on the quality of the random sample. It is useful for purchasing and receiving.

Statistical process control - involves testing a random sample of output from a process to determine whether the process is producing items within a pre-selected range. In producing goods, the flow of products is broken into discrete batches called lots. A quality control lot has been produced under the same operating conditions.

A random sample is one which each unit in the lot has an equal chance of being included in the sample, thus the sample is likely to be representative of the lot. Either variables or attribute can be measured and compared to standard.

- Attributes are characteristics that are classified into defective and non-defective, (good or bad)
- Variables are characteristics that can be measured on a continuous scale Eg. Size of a bearing.
- What should be the size and frequency of sample? Generally, there is the argument that as the percentage of lots in sample is increased, there are two effects, 1) the sampling and testing cost increase, and (2) the quality of products going to customers increases.
- Sample size for attributes are usually larger than variables.
- When to inspect? During production process when to inspect is usually determined by following these general principles:-
 - i) Inspect after operation that are likely to produce faulty items
 - ii) Inspect before costly operation
 - iii) Inspect before operations that cover up defects
 - iv) Inspect before assembly operation that can not be undone

- v) On automatic machines, inspect first and last pieces of production runs but few in between pieces.
- vi) Inspect finished products

The reason behind these principles is largely economic.

Control Charts;- The primary purpose of control chart is to indicate when production process may have changed sufficiently to affect product quality, while the product is being produced. An investigation will then be conducted into the causes of the change. If the indications that product quality is deteriorated or is likely to deteriorate in the future, then the problem would be corrected by taking action such as replacing worn machine parts, making machine adjustment, machine overhauled, finding new material supplier and train and instruct workers.

If on the other hand, the indication is that product quality is better than the expected, then it is important to find out why so that the high quality can be maintained.