Introduction

Dear student, Welcome to this course entitled “Production/Operations Management

The field of production and operations management is dynamic and very much a part of many of the good things that are happening in business organizations.

Production and operations management has seen many innovations in recent years, becoming a topic of critical importance in business today. Demands for business reengineering, quality, time-based competition, value-adding processes, and a global view have demonstrated that superior management of the operations function is vital to the survival of the firm. An understanding of production and operations management strategy and its function is a necessary part of any good business education.

The subject matter represents a blend of concepts from industrial engineering, cost accounting, general management, quantitative methods, and statistics. Production and operations activities, such as choosing a location for an office or plant, allocating resources, designing products and services, scheduling activities, and assuring and improving quality are core activities and often strategic issues in business organizations. Some of you are or will be employed directly in these areas, while others will have jobs that are indirectly related to this area. So whether this is your field of study or not, knowledge of this field will certainly benefit you and the organization you work for.

CHAPTER ONE

NATURE OF OPERATION MANAGEMENT

1.1. Introduction

Production is the creation of goods and services. The field of production management in the past focused almost exclusively on manufacturing management, with a heavy emphasis on the methods and techniques used in

operating a factory. In recent years, the scope of production management has broadened considerably. Production concepts and techniques are applied to a wide range of activities and situations *outside* manufacturing; that is, in *services* such as health care, food service, recreation, banking, hotel management, retail sales, education, transportation, and government. This broadened scope has given the field the name *production/operations management,* or more simply, **operations management**, a term that more closely reflects the diverse nature of activities to which its concepts and techniques are applied.

We can use an airline company to illustrate a production/operations system. The system consists of the airplanes, airport facilities, and maintenance facilities, sometimes spread out over a wide territory. Most of the activities performed by management and employees fall into the realm of operations management:

- ***Forecasting*** such things as weather and landing conditions, seat demand for flights, and the growth in air travel.
- ***Capacity planning***, essential for the airline to maintain the cash flow and make a reasonable profit. (Too few or too many planes, or even the right number of planes but in the wrong places, will hurt profits.)
- ***Scheduling*** of planes for flights and for routine maintenance; scheduling of pilots and flight attendants; and scheduling of ground crews, counter staff, and baggage handlers.
- ***Managing inventory*** of such items as foods and beverages, first-aid equipment, in-flight magazines, pillows and blankets, life preservers.
- ***Assuring quality***, essential in flying and maintenance operations, where the emphasis is on safety. Also important in dealing with customers at ticket counters, check-in, and telephone reservations, where the emphasis is on efficiency and courtesy.
- ***Employee motivation and training*** in all phases of operations.
- ***Location of facilities*** according to managers' decisions on which cities to provide service for, where to locate maintenance facilities, and where to locate major and minor hubs.

At first glance, it may appear that service operations don't have much in common with manufacturing operations. However, a unifying feature of these operations is that both can be viewed as transformation processes. In

manufacturing, inputs of raw materials, energy, labour, and capital are transformed into finished goods. In service operations, these same types of inputs are transformed into service outputs. Managing the transformation process in an efficient and effective manner is the task of the operations manager in any type of organization.

1.2. What is Operations Management?

Operations management is the set of activities that creates goods and services through the transformation of inputs into outputs. Activities creating goods and services take place in all organizations (firms), the production activities that create goods are usually quite obvious. In them, we can see the creation of a tangible product such as cement or cloth.

In organizations that do not create physical products, the production function may be less obvious. An example is the transformation that takes place at a bank, hospital, airline, or college. Regardless of whether the end product is good or service the production activities that go on in the organization are often referred to as operations or *operations management.*

An operation is responsible for supplying the product or service of the organization. Operations managers make decisions regarding the operations function and its connection with other functions.

Operations management is the study of decision-making in the operations function.

Three points in this definition deserve emphasis:

1. **Decisions-** Decision-making is an important element of operations management. There are four major decision responsibilities in operations management.
    - Process
    - Quality
    - Capacity
    - Inventory
2. **Function-** Operations is a major function in any organization, along with marketing and finance.
    - The operations function is responsible for supplying or producing products and services for the business.
    - In a manufacturing company, the operations function is typically called the manufacturing or production department.

- In service organizations, the operations function is called the operations department.
- In general the term “operations” refers to the function that produces goods or services.

3. **System-** The transformation systems produce goods and services. Using the systems view, we consider operations managers as managers of the conversion process in the firm.

1.3. Operations Decisions

Operations has responsibility for four major decision areas: process, quality, capacity and inventory.

1. **Process-** Decisions in this category determine the physical process or facility used to produce the product or service. The decisions include the type of equipment and technology, process flows, layout of the facility and all other aspects of the physical plant or service facility. Many of these process decisions are long range in nature and cannot be easily reversed, particularly when heavy capital investment is needed.
2. **Quality-** The operations function is responsible for the quality of goods and services produced. Quality decisions must insure that quality is designed and built into the product in all stages of operations: standards must be set, people trained, and the product or service inspected for quality to result. Operations has a particular responsibility for producing products and services that meet the defined specifications and standards.

3. **Capacity-** Capacity decisions are aimed at providing the right amount of capacity at the right place at the right time. Long-range capacity is determined by the size of the physical facilities built by the firm and its suppliers. In the short run, capacity can sometimes be augment by subcontracting, extra shifts, or rental of space. Capacity planning, however, determines not only the size of facilities but also the proper number of people in operations. The available capacity must be allocated to specific tasks and jobs in operations by scheduling people, equipment, and facilities.

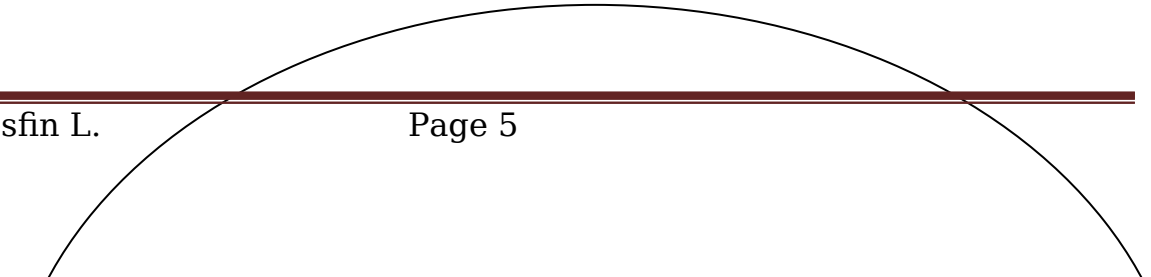
4. **Inventory-** Inventory management decisions in operations decisions determine what to order, how much to order, and when to order. Inventory control systems are used to manage materials from purchasing through raw materials, work in process, and

finished goods inventories. Inventory managers manage the flow of materials within the firm and within the supply chain.

Careful attention to the four decision areas is the key to management of successful operations. If each of the four decisions areas is functioning properly and well integrated with the other areas and functions of the firm, the operations function can be considered well managed.

1.4. Operations as a Productive System

Operations has been defined as transformation system that converts inputs into outputs. Inputs to the system include energy, materials, labour, capital and information as shown below. Process technology is then used to convert inputs into outputs. The process technology is the methods, procedures, and equipment used to transform materials or inputs into products or services.



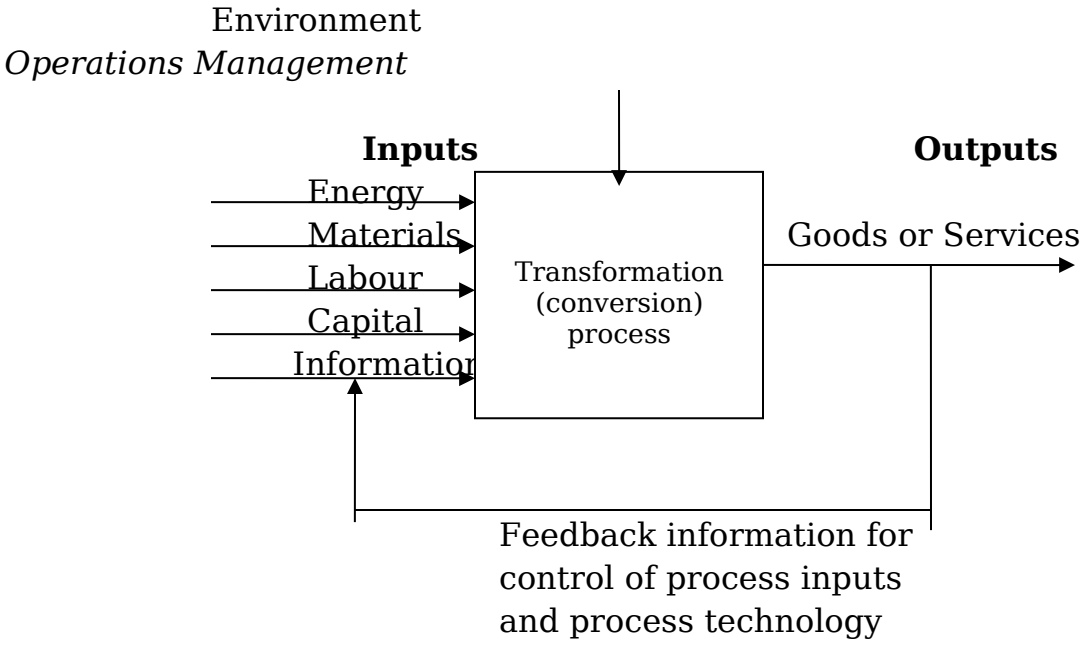


Figure 1.1
An operation as
a productive system

- The types of inputs used will vary from one industry to another e.g., operation in automobile manufacturing will differ from service industry.
- Feedback information is used to control the process technology or inputs.
- Operations managers use feedback information to continually adjust the mix of inputs and technology needed to achieve desired outputs.

The operations system is in constant interaction with its environment; internal and external environment.

- The internal environment may change policies, resource forecasts or goals.

- The external environment may change in terms of legal, political, social, economic, or technical condition thereby causing a corresponding change in the operations inputs, outputs, or transformation system. For example, a change in economic conditions may cause operations managers to revise their demand forecast and as a result hire more people and expand capacity.

Illustrations of the transformation process.

Food processor	***Inputs***	**Processing**	**Output**
	• Raw vegetables • Metal sheets • Water • Energy • Labor • Building • Equipment	• Cleaning • Making cans • Cutting • Cooking • Packing • Labeling	• Canned vegetables

Hospital	**Inputs**	**Processing**	**Output**
	• Doctors, nurses • Hospital • Medical supplies • Equipment • Laboratories	• Examination • Surgery • Monitoring • Medication • Therapy	• Healthy patients

1.5. New Operations Themes

1. Services and Manufacturing
   - Services and manufacturing are highly interrelated in today's economy. Services such as banking, insurance consulting, telecommunications, and transportation are critical for support of manufacturing, and likewise, manufactured products support all service industries.
   - The need to treat both manufacturing and service is a critical theme in operations, because of the pervasive and intertwined nature of both manufacturing and service.

2. Customer Directed Operations
   Every operation should be externally directed to meet customer requirements. This notion is consistent with the marketing concept taught in marketing courses and is now being integrated into operations courses as well.
   - A key concept is that efficiency need not be sacrificed in the pursuit of meeting customer needs. Rather, the customer can be a powerful driver for reducing waste and improving efficiency of all processes.

3. Continuous Improvement
   Continuous improvement is the key to remaining competitive in today's business world.
   - Operations can no longer be designed to meet fixed standards without emphasis on future improvements as customer needs change and better ideas are developed.
   - In some cases, process reengineering —the radical redesign of processes— is needed when continuous incremental improvement is not sufficient. Even then, continuous improvement will be needed after processes are reengineered.

4. Integration of Operations with other Functions

- Teaching of business functions has been too isolated in the past.
- The best operations are now seeking increased integration through use of cross-functional teams, information systems, management coordination, rotation of employees, and other methods of integration across functions.
- Integration is critical as a way of getting everyone pulling in the same direction.

5. Environmental Concerns
   Everyone in society must help protect the environment including those in operations. Operations have come a long way in reducing pollution of the environment, but there is still a long way to go.

6. Globalization of Operations
   - Strategies for operations should be formulated with global effects in mind and not only consider narrow national interests.
   - Facility location should be considered in view of its global implications.

1.6. Why Study Operations Management (OM)

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

Options for Increasing Contribution

	Current	Marketing Option **a**	Finance /Accounting Option **b**	OM Option **c**
Sales		Increase Sales Revenue 50%	Reduce Finance Costs 50%	Reduce Production costs 20%
	$100,000	$150,000	$100,000	$100,000
Cost of goods	-80,000	-120,000	-80,000	-64,000
Gross margin	20,000	30,000	20,000	36,000
Finance Costs	-6,000	-6,000	-3,000	-6,000
	14,000	24,000	17,000	30,000
Taxes at 25%	-3,500	-6,000	-4,250	-7,500
Contribution **d**	$10,500	$18,000	$12,750	$22,500

a. Increasing sales 50% increases contribution by $7,500 or 71% (7,500÷10, 500).
b. Reducing finance costs 50% increases contribution by $2,250 or 21% (2,250÷10, 500)
c. Reducing production costs 20% increases contribution by $12,000 or 114% (12,000÷10, 500).
d. Contribution to fixed cost (excluding finance costs) and profit.

- The above example underscores the important role of developing an effective strategy for the operations activity of a firm. It is also the approach taken by many companies as they face growing global competition.

1.7. The Productivity Challenge

- The creation of goods and service requires changing resources into goods and services. The more efficiently we make this change the more productive we are.
- *Productivity* is the ratio of outputs (goods and services) divided by the inputs (resources, such as labor and capital).
- The operations manger's job is to enhance (improve) this ratio of outputs to inputs. Improving productivity means improving efficiency.
- This improvement can be achieved in two ways:
  - a reduction in inputs while output remains constant, or
  - An increase in output while inputs remain constant.

Productivity Measurement

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

For example, if units produced =1000 and labour hours used is 250, then:

$$\text{Productivity} = \frac{\text{Units produced}}{\text{Labor-hours used}} = \frac{1000}{250} = 4 \text{ units per labor hour}$$

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

$$\text{Productivity} = \frac{\text{Output}}{\text{Labor + Material + Energy + Capital + Miscellaneous}}$$

Example

Collins Title Company has a staff of 4 each working 8 hours per day (for a payroll cost of $640 /day) and overhead expenses of $400 per day. Collins processes and closes on 8 titles each day. The company recently purchased a computerized title-search system that will allow the processing of 14 titles per day. Although the staff, their work hours, and pay will be the same, the overhead expenses are now $800 per day.

- Labor productivity with the old system = $\frac{\text{8 titles per day}}{\text{32 labor-hours}}$ = 0.25 titles per labor hour
- Labor productivity with the new system = $\frac{\text{14 titles per day}}{\text{32 labor-hours}}$ = 0.4375 titles per labor-hour
- Multifactor productivity with the old system = $\frac{\text{8 titles per day}}{640+400}$ = 0.0077 titles per dollar
- Multifactor productivity with the new system= $\frac{\text{14 titles per day}}{640+800}$ = 0.0097 titles per dollar

- Labor productivity has increased from 0.25 to 0.4375. The change is 0.4375÷0.25=1.75 or a 75% increase in labor productivity.
- Multifactor productivity has increased from 0.0077 to 0.0097. This change is 0.0097÷0.0077=1.259, or a 25.9% increase in multifactor productivity.

CHAPTER TWO

OPERATIONS STRATEGY AND COMPETITIVENESS

Each of a firm's strategies should be established in light of: (1) the threats and opportunities in the environment and (2) the strengths and weaknesses of the organization. Ultimately, every strategy is an attempt to answer the question, "How do we satisfy a customer?" within these constraints.

2.1 Identifying Missions and Strategies

An effective operations management effort must have a *mission* so it knows where it is going and a *strategy* so it knows how to get there.

Mission

Economic success, indeed survival, is the result of identifying missions to satisfy a customer's needs and wants.

Definition: We define the organization's mission as its purpose—what it will contribute to society. Mission statements provide boundaries and focus for organizations and the concept around which the firm can rally. The mission states the rationale for the organization's existence. Developing a good strategy is difficult, but it is much easier if the mission has been well defined. The mission can also be thought of as the *intent* of the strategy—what the strategy is designed to achieve.

Once an organization's mission has been decided, each functional area within the firm determines its supporting mission. By "functional area" we mean the major disciplines required by the firm, such as marketing, finance /accounting, and production/operations. Missions for each functional area are developed to support the firm's overall mission. Then within that function lower-level supporting missions are established for the operation management functions.

Figure 2.1 provides such a hierarchy of sample missions.

Sample Company Mission To manufacture and service a growing and profitable worldwide microwave communications business that exceeds our customers' expectations.	
Sample Operations Management Mission To produce products consistent with the company's mission as the worldwide low-cost manufacturer.	
Sample OM Department Mission	
Quality	To attain the exceptional value that is consistent with our company mission and marketing objectives by close attention to design, procurement, production, and field service opportunities.
Product design	To lead in research and engineering competencies in all areas of our primary business, designing and producing products and services with outstanding quality and

	inherent customer value.
Process design	To determine and design or produce the production process and equipment that will be compatible with low-cost product, high quality, and a good quality-of-work life at economical cost.
Location selection	To locate, design, and build efficient and economical facilities that will yield high value to the company, its employees, and the community.
Human resources	To provide a good quality-of-work life, with well-designed, safe, rewarding jobs, stable employment, and equitable pay, in exchange for outstanding individual contribution from employees at all levels.
Inventory	To achieve low investment in inventory consistent with high customer service levels and high facility utilization.
Scheduling	To achieve high levels of throughput and timely customer delivery through effective scheduling.
Maintenance	To achieve high utilization of facilities and equipment by effective preventive maintenance and prompt repair of facilities and equipment.

Figure 2.1. Sample Mission for a Company, the Operations Function, and Major Departments in an Operations Function

Strategy

With the mission established, strategy and its implementation can begin. Strategy is an organization's action plan to achieve the mission. Each functional area has a strategy for achieving its mission and for helping the organization reach the overall mission.

These strategies exploit opportunities and strengths, neutralize threats, and avoid weaknesses.

Firms achieve missions in three conceptual ways: (1) differentiation, (2) cost leadership, and (3) quick response. This means operations managers are called on to deliver goods and services that are (1) *better*, or at least different, (2) *cheaper,* and (3) more *responsive*. Operations managers translate these strategic concepts into tangible tasks to be accomplished. Any one or combination of these three strategic concepts can generate a system that has a unique advantage over competitors.

Strategies and Tactics

A mission statement provides a general direction for an organization and gives rise to organizational *goals*, which provide substance to the overall mission. For example, one goal of an organization may be to capture a certain percent of market share for a product; another goal may be to achieve a certain level of profitability. Taken together, the goals and the mission establish a destination for the organization.

Strategies: are plans for achieving goals. If you think of goals as destinations, then strategies are the road maps for reaching the destinations. Strategies provide *focus* for decision-making. Generally speaking, organizations have overall strategies called *organization strategies,* which relate to the entire organization, and they also have *functional strategies*, which relate to each of the functional areas of the organization. The functional strategies should support the overall strategies of the organization, just as the organizational strategies should support the goals and mission of the organization.

Tactics: are the methods and actions used to accomplish strategies. They are more specific in nature than strategies, and they provide guidance and direction for carrying out actual *operations,* which need the most specific and detailed plans and decision-making in an organization. You might think of tactics as the "how to" part of the process (e.g., how to reach the destination, following the strategy road map) and operations as the actual "doing" part of the process.

It should be apparent that the overall relationship that exists from the mission down the actual operations is *hierarchical* in nature.

Example- Rutha is a high school student in Mekelle City. She would like to have a career in business, have a good job, and earn enough income to live comfortably.

A possible scenario for achieving her goals might look something like this:

Mission: Live a good life.

Goal: Successful career, good income.

Strategy: Obtain a university education.

Tactics: Select a university and a major; decide how to finance university.

Operations: Register, buy books, take courses, study.

Operations Strategy

The organization strategy provides the overall direction for the organization.

It is broad in scope, covering the entire organization.

Operation strategy is narrower in scope, deals primarily with the operations aspect of the organization. Operations strategy relates to products, processes, methods, operating resources, quality, cost, lead times, and scheduling. Table 2.1 provides a comparison of an organization's mission, its overall strategy, and its operations strategy, tactics, and operations.

In order for operations strategy to be truly effective, it is important to link it to organization strategy; that is, the two should not be formulated independently. Rather, formulation of organization strategy should take into account the realities of operations' strengths and weaknesses, capitalizing on strengths and dealing with weaknesses. Similarly, operations strategy must be consistent with the overall strategy of the organization, and formulated to support the goals of the organization.

		Management Level	Time Horizon	Scope	Level of Detail	Relates to
The Overall Organization	Mission	Top	Long	Broad	Low	Survival, profitability
	Strategy	Senior	Long	Broad	Low	Growth rate, market share
Production/ Operations	Strategic	Senior	Moderate to long	Broad	Low	Product design, choice of location, choice of technology, new facilities
	Tactical	Middle	Moderate	Moderate	Moderate	Employment levels, output levels, equipment selection, facility layout
	Operational	Low	Short	Narrow	High	Scheduling personnel, adjusting

	output rates, inventory management, purchasing

Table 2.1 Comparison of mission, organization strategy, and operations strate

2.2. Strategy Formulation

To formulate an effective strategy, senior management must take into account the *distinctive competencies* of the organization, and they must *scan the environment.* They must determine what competitors are doing, or planning to do, and take that into account.

Distinctive competencies or **weaknesses** represent great competitive advantage or disadvantages in capturing markets. They include things like automated production technology, a skilled and dedicated work force, an ability to quickly bring new products in to production, a talented sales force, or worn-out production equipment.

In formulating a successful strategy, organizations must take into account both *order qualifiers***,** and *order winners*.

Order qualifiers are characteristics that potential customers perceive as minimum standards of acceptability to be considered as a potential for purchase.

Order winners are characteristics of an organization's goods or services that cause them to be perceived as better than the competition.

Order winning objectives:

1. Provide a crucial advantage with customers
2. Provide an important advantage with most customers
3. Provide a useful advantage with most customers

Order Qualifying objectives:

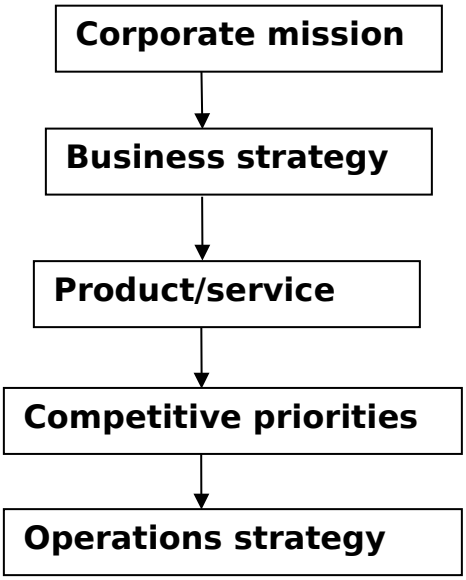
a. Need to be at least up to good industry standard;
b. Need to be around the median industry standard;
c. Need to be within close range of the rest of the industry;

In developing an operations strategy, management also needs to take other factors into consideration. These include:-

(*a*) The level of technology that is or will be available

(*b*) The required skill levels of the workers, and
(*c*) The degree of vertical integration, in terms of the extent to which outside Suppliers are used

Developing operations strategy



2.3 Competitiveness

Competitiveness refers to firm's relative position in the market in terms of how it competes with the other firms in its industry.
It is related to how effective organization is in the market place compared with other organizations that offer similar products or services. It is an important factor in determining whether a company prospers, barely gets by or fails. Business organization competes through some combination of their *marketing* and *operations* functions.

Marketing function: - includes functions like, identifying consumers' wants and needs, pricing, advertising and promotion.
Operations functions also include product and service design, cost, quality response time, flexibility, inventory and services.

Operations strategy refers to how the operations management function contributes to a firm's ability to achieve competitive advantage in that marketplace.

Operations strategies are developed from the **competitive priorities** of an organization.

2.4. Achieving Competitive Advantage through Operations

Each of the three strategies (differentiation, cost leadership, and quick response) provides an opportunity for operations managers to obtain competitive advantage.

Competitive advantage implies the creation of a system that has a unique advantage over competitors. The idea is to create customer value in an efficient and sustainable way.

The three strategies which a firm achieves competitive advantages from operations are:

1. Competing on Differentiation
2. Competing on Cost
3. Competing on flexible Response

In practice, these three concepts are often translated into six specific strategies:

1. Flexibility (in design and volume)
2. Low price
3. Delivery (time)
4. Quality
5. After-sale service, and
6. A broad product line

Through these six specific strategies, operation management can increase productivity and generate a sustainable competitive advantage.

Proper implementation of the operations decisions by operations managers will allow these strategies to be achieved.

1. Competing on Differentiation

Differentiation refers to ways in which an organization distinguishes its products and services from its competition.

For example a company could offer higher quality products or services than its competitors

Differentiation is concerned with providing *uniqueness*. A firm's opportunities for creating uniqueness are not located within a particular function or activity, but can arise in virtually everything that the firm does. Moreover, because most products include some service and most services include some product, the opportunities for creating this uniqueness are limited only by imagination.

2. Competing on Cost

Which means the ability to produce at low cost.

One driver of a low-cost strategy is an optimal facility that is effectively utilized. **Low-cost leadership** entails achieving maximum value as defined by your customer. It requires examining each of the different operation management decisions in a relentless effort to drive down costs while meeting customer expectations of value. A low-cost strategy does *not* imply low value or low quality.

3. Competing on flexibility (product or volume)

Flexibility is company environment change rapidly so company must accommodate changes by being flexible. It is the ability to change operations. Flexibility can comprise up to four aspects:

i. The ability to change the volume of production (volume flexibility).
ii. The ability to change the time taken to produce (response time).
iii. The ability to change the mix of different products or services produced.
iv. The ability to innovate and introduce new products and services.

Product flexibility: - is switching of production from one item to another.
Volume flexibility: - is ability to ramp (rise) production up and down to match market demand.

We define response time as:-

- Timely product development and delivery
- Reliable scheduling and
- Flexible performance.

Flexible response may be thought of as the ability to match changes in a market place in which design innovations and volumes fluctuate substantially.

Competitive Priorities

Competitive priorities: - How the operations function provides a firm with a specific competitive advantage. This can be thought of as the things that customers want from products or services; thus, they can be used as tools to capture market share. But all these competitive priorities can not ordinarily be used for a single product. For example, a company may not be able to provide great flexibility and at the same time provide very low cost production. Once the competitive priorities are set for a product /service, operations strategy must then determine the required production system needed to provide the priorities for the product or service.

The key to developing an effective operations strategy lies in understanding how to create or add value for customers. Specifically, value is added

through the competitive priority or priorities that are selected to support a given strategy.

Core capabilities are the means by which competitive priorities are achieved. Consequently, core capabilities must align directly with competitive priorities.
Skinner and others initially identified *four basic competitive priorities.* These were **cost, quality, delivery,** and **flexibility.** These four priorities translate directly into characteristics that are used to describe various processes by which a company can add value to the products it provides. There now exists a fifth competitive priority—**service**—and it was the primary way in which companies began to differentiate themselves in the 1990s.

I. ***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 necessarily, therefore, be the low-cost producer. But, as noted earlier, even doing this doesn't always guarantee profitability and success.

Products sold strictly on the basis of cost are typically commodity-like. (Examples of commodities include flour, petroleum, and sugar.) In other words, customers cannot easily distinguish the products made by one firm from those of another. As a result, customers use cost as the primary determinant in making a purchase.

However, this segment of the market is frequently very large and many companies are lured by the potential for significant profits, which are associated with large unit volumes of product. As a consequence, the competition in this segment is exceedingly fierce—and so is the failure rate. After all, there can only be one low-cost producer and that firm usually establishes the selling price in the market.

II. ***Quality: - is*** the ability to produce in accordance with specification and without error.

Quality can be divided into two categories: *product quality* and *process quality.*

***Product quality*: -** the level of quality in a product's design will vary as to the particular market that it is aimed to serve. One advantage of offering higher-quality products is that they command higher prices in the marketplace.

The goal in establishing the "proper level" of product quality is to focus on the requirements of the customer. Overdesigned products with too much quality will be viewed as being prohibitively expensive.

Process quality is critical in every market segment. Thus, the goal of process quality is to produce error-free products.

III. Delivery: is time related issues

- ✓ Rapid delivery
- ✓ Shorter time b/n order placement and delivery
- ✓ On time delivery

Rapid delivery: - the ability of a firm to provide consistent and fast delivery allows it to charge a premium price for its products.

Reliability: the reliability of the delivery is also important. In other words, products should be delivered to customers with minimum variance in delivery times.

Delivery Providing products quickly.

IV. Flexibility

From a strategic perspective, in terms of how a company competes, flexibility consists of two dimensions, both of which relate directly to how the firm's processes are designed.

One element of flexibility is the firm's ability to offer its customers a wide variety of products.

The greatest flexibility along this dimension is achieved when every product is customized to meet the specific requirements of each individual customer. This is often referred to as **mass customization.**

Mass customization:- Providing high volume products that are individually customized to meet the specific needs of each customer.

The other dimension of flexibility is how fast a company can change its production facilities to produce a new line of products. This dimension is growing in importance, as product life cycles become shorter and shorter. Sony provides a good example here with its ability to quickly produce new models of its Walkman. Because it has this high degree of changeover flexibility, Sony is able to easily substitute new Walkman models for those models that do not sell well.

Flexibility Providing a wide variety of products.

Service

With product life cycles becoming shorter and shorter, the actual products themselves tend to quickly resemble those of other companies. As a consequence, these products are often viewed as commodities in which price is the primary determinant in deciding which one to buy. A good example of this is the personal computer (PC) industry. Today, the differences in the products offered among the different PC manufacturers are relatively insignificant, so price is the prime selection criterion.
To obtain an advantage in such a competitive environment, firms are now providing "value-added" service.
Service How products are delivered and supported from these kiosks, thus avoiding a wait in line at the airport.

Summary of competitive priorities

Competitive priority	definition	some ways of creating
Low production costs	unit cost of each Product/service	- Redesign of product/services - New technology - Increase in production rates - Reduction of scrap or waste - Reduction of inventories
Delivery performance	fast delivery	- larger finished good inventories - Faster production rates - Quicker shipping methods
	On- time delivery	- more realistic promises - Better control of production of orders - Better information systems

High- quality product/service:	customers' perception of degree of excellence exhibited by Products/services	**improve** - Products/services appearance - malfunction or defect rates - Performance and function - Wear, endurance ability - After sales service
Customer service and flexibility	ability to quickly change production to other products/sv	- Change in type of processes used -use of advanced technologies - Reduction of amount of WIP through lean manufacturing Customer responsiveness -Increase in capacity

2.5 operations strategy in services

Most of what we has been discussed in previous section applies equally well both to manufacturing and services. But there are some differences. Manufactured products are tangible goods- they have physical form, they can be seen and touched, and they ordinarily must be, shipped to customers. Services however, intangible – they are usually w/t physical form. Their consumption is often simultaneous with their production.

Because manufactured products are tangible, customer demands can be anticipated and products may often be produced, transported, and held in inventory until customers need them. This allows manufacturers flexibility in deciding when to produce products. On the other hand, service can not ordinarily be produced in advance of customer demand and must be delivered to customers at the time of demand or later. This means that service operations ordinarily plan production levels to approximately equal customer demand.

Given these differences between manufactured products and services, let us now discuss the kinds of competitive priorities available to services.

Competitive priorities for services

All competitive priorities discussed above are also available to service firms. But Service Company *seldom provides* all the priorities simultaneously to customers, and for each service a set of priorities must be chosen that will provide the greatest market advantage. The trade-off b/n the cost and service quality is perhaps the most obvious. A small retailer that emphasizes close personal contact with customers may have high-quality services, but its cost may be higher than the cost of its high volume discount competitors.

Chapter three
Design of the operation system
3.1 Product and service design

Introduction

New-product development is a crucial part of business. New products serve to provide growth opportunities and a competitive advantage for the firm. Operations are greatly affected by new product introduction. New-product design greatly affects operations by specifying the products that will be made; it is a prerequisite for production to occur. New products must be defined with not only the market in mind but the production process that will be used to make the product.

Through close cooperation between operations, marketing, and other functions, the product design can be integrated with decisions regarding process, quality, capacity, and inventory. Product design is prerequisite for production, along with a forecast of production volume.

3.1. Reasons for Product or Service Design

Organizations become involved in product or service design for a variety of reasons. An obvious one is *to be competitive* by offering new products or services. Another one is *to make the business grow and increase profits*. Furthermore, the best organizations try to develop new products or services as an alternative to downsizing.

Sometimes product or service design is actually *redesign*. This, too, occurs for a number of reasons such as customer complaints, accidents or injuries, excessive warranty claims, or low demand. This desire to achieve cost reductions in labor or materials can also be a motivating factor.

Trends in product and service design

Over the last few years, the designing of products and services has increased emphasis on a number of aspects of design. Among them are the following:

1. Increased emphasis on customer satisfaction and increased pressure to be competitive.
2. Increased emphasis on reducing the time needed to *introduce* a new product or service.
3. Increased emphasis on reducing the time needed to *produce* a product or provide a service.
4. Greater attention to environmental concerns, including waste minimization, recycling parts, and disposal of worn-out products.
5. Increased emphasis on designing products and services that are user-friendly.
6. Increased effort to use less material for products (e.g., concentrated liquid detergents) and less packaging.

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

3.2. Strategies for New-Product Introduction

There are three fundamentally different ways to introduce new products.

1. **Market pull**- According to this view, the market is the primary basis for determining the products a firm should make, with little regard to existing technology.
    - A firm should make what it can sell.
    - The customer needs are determined, and processes needed to supply the customer. The market will “pull” through the products that are made.
2. **Technology push**- In this view, technology is the primary determinant of the products that the firm should make, with little regard for the market.

- This approach suggests that " you should sell what you can make". The firm should pursue a technology based advantage by developing superior technologies and products.
- The products are then pushed into the market, and the marketing's job is to create demand for these superior products.
- Since the products have superior technology, they will have a natural advantage in the market and the customers will want to buy them.

3. **Inter-functional View-** This view holds that the product should not only fit the market needs but have a technical advantage as well.
    - To accomplish this, all functions (e.g., marketing, engineering, operations, and finance) should cooperate to design the new products needed by the firm.
    - Often this is done by forming cross functional teams that are responsible for development of the new product.
    - This is the most appealing of the three views but also the most difficult to implement.
    - Cross-functional rivalry and friction must be overcome to achieve the degree of cooperation required for inter functional product development to succeed.

3.3. The Design Process

The design process begins with the *motivation* for design. For a new business or a new product, the motivation may be obvious: to achieve the goals of the organization. For an existing business, in addition to that general motivation, there are more specific factors to consider, such as government regulations, competitive pressures, customer needs, and the appearance of new technologies that have product or process applications.

Ultimately, the *customer* is the driving force for product and service design. Failure to satisfy customers can result in customer complaints, returns, warranty claims, and so on. Loss of market share becomes a potential problem if customer satisfaction is not achieved.

For the design process to occur, a business must have *ideas* for new or improved designs. These come from a variety of sources, most obviously the customer. *Marketing* can tap this source of ideas in a number of ways, such as the use of focus groups, surveys, and analyses of buying patterns.

Some organizations have *research and development departments* that also generate ideas for new or improved products and services

Competitors are another important source of ideas. By studying competitor's products or services, and how the competitor operates (e.g., pricing policies, return policies, warranties), an organization can learn a great deal about achieving design improvements.

Beyond that, some companies buy a competitor's newly designed product the moment it appears on the market. Using a procedure called **reverse engineering**; they carefully dismantle and inspect the product. This may uncover product improvements that can be incorporated in their own product. Sometimes reverse engineering can lead to a product that is *superior* to the one being examined; that is, designers conceive an improved design, which enables them to "leapfrog" the competition by quickly introducing an improved version of a competitor's product.

3.4. New-Product Development Process

The new product development process consists of the following steps.

1. **Idea Generation**- Ideas for new products can arise from a variety of sources within and external to the firm. There are two principal sources for generating ideas:
    - User needs, and
    - Technological developments.

    Manufacturers are always trying to develop new products that meet the needs of consumers, e.g. development of small cars.

    Identification of market needs can lead to the development of new technologies and products to meet those needs. New innovations can replace products based on older technologies. Research and development (R&D) plays an important role in developing new products and advancing technology. The purpose of R&D is to generate new ideas and concepts and to develop these ideas and concepts into useful products.

2. **Screening-** The purpose of screening is to eliminate ideas that do not appear to have a high potential for success and thus avoid expensive development costs. Three major criteria are used in initial screening:

- Product development –technical and operational feasibility
- Market criteria – current market and potential to grow
- Financial feasibility – contribution to overall profitability and cash flow.

Before a new product idea is put into preliminary design, it should be subjected to analysis organized around these three tests. The purpose of screening is not to reach a conclusive decision to produce and market the product. After initial development, more extensive analysis may be conducted through test markets and pilot operations before a final decision is made to introduce the product.

To assist in product analysis, several methods have been developed. One is a checklist scoring method that involves developing a list of factors along with a weight for each.
If the total score is above a certain minimum level the new product idea may be selected for further development. Alternatively, the method may be used to rank products in priority order for selection.

Screening by Checklist

Product characteristics	**Poor**	**Fair**	**Good**	**Very Good**	**Excellent**	**Weight**
Selling price		✓				15
Product quality				✓		10
Sales volume			✓			20
Operations compatibility	✓					10
Competitive advantage				✓		10
Technical capability		✓				15
Fit with strategy				✓		20
						100%

Poor = 1
Fair = 2
Good = 3 Total weighted product score
Very good = 4 = .15(2)+ .10(4)+ .20(3)+ .10(1) + .10(4)+ .15(2)+ .20(4)
Excellent = 5 = 2.9

A new product idea may also be subjected to standard financial analysis by computing an approximate return on investment. To do this, cash flows must be estimated for investments, revenues, and costs for future product sales.

3. **Preliminary product design**- This process is concerned with developing the best design for the new product idea. Preliminary product design must specify the product completely. At the end of the product design phase, the firm has a set of product specifications and engineering drawings (or computer images) specified in sufficient detail that production prototypes can be built and tested.

If the preliminary design is approved, a prototype or prototypes may be built for further testing and analysis. In the preliminary design, trade offs between cost, quality, and product performances are considered. The result should be a product design, which is competitive in the market place and produce able by operations.

4. **Prototype construction–** Several prototypes which closely resemble the final product may be made.
5. **Prototype testing**- A model is tested for its physical properties or use under actual operating conditions. Such testing is important in uncovering any problems and correcting them prior to full-scale production. Road-testing an automobile or using a consumer panel to test a new piza are some examples.
6. **Final product design** – As a result of prototype testing certain changes may be incorporated into the final design. Drawings and specifications for the product are developed. If the changes are made, the product may be tested further to ensure final product performance. An information package should be developed to ensure that the product is produce able. A great many ideas originate at the beginning but only a few are successfully introduced to the market as products.

3.5 DESIGN STRATEGIES

This section provides an overview of various approaches to product design, including, manufacturing design, remanufacturing, robust design, concurrent engineering, computer-aided design, and modular design.
Design strategies have one common characteristic, which is to achieve customer satisfaction, along with reasonable profit in a way which does not go beyond the organizations manufacturing abilities. An exaggerated example being that if an automobile car manufacturing organization's design department decides to design a truck. This would probably mean testing the organizations manufacturing capability, as the organization would not be have the infrastructure to manufacture a truck.

Some of the common design strategies are:

1. Design for Manufacturing (DFM):
2. Design for Assembly (DFA):
3. Design for Disassembly (DFD):
4. Design for Remanufacturing:
5. design for Recycling (DFR)
6. Robust Design
7. Concurrent Engineering
8. Computer-Aided Design (CAD)
9. Modular Design

1. Design for Manufacturing Design **(DFM):** The designers' consideration of the organization's manufacturing capabilities when designing a product. The more general term design for operations encompasses services as well as manufacturing.

Manufacturability is the ease of fabrication and/or assembly which is important for:

i. Cost
ii. Productivity
iii. Quality

A good design must take into account not only how a product will be fabricated, but also how it will be assembled.

2. *Design for Assembly (DFA):* focuses on reducing the number of parts in an assembly, as well as the assembly methods and sequence that will be employed.

3. *Design for Disassembly (DFD):* Design focuses on facilitating the disassembly in a logical and an exact reverse sequential manner to the assembly methods and sequence.
4. *Design for Remanufacturing:*

Remanufacturing: refers to removing some of the components of old products and reusing them in new products. This can be done by the original manufacturer, or another company. Among the products that have remanufactured components are automobiles, printers, copiers, cameras, computers, and telephones.
Remanufactured products are sold at 30 to 50% of the price of new product .e.g. Printers, copiers, cameras, PCs and Cell/Telephones. This can be done by original equipment manufacturer or a competitor or end user (in the latter case its called cannibalization)

5. *Design for Recycling (DFR):* Design for recycling is a design strategy that facilitates the recovery of materials and components of old products in the manufacture/assembly of new products.

Recycling is in simple words recovering materials for future use. The common recycling reasons are

- ❖ Cost savings
- ❖ Environment concerns
- ❖ Environment regulations

The focus here is to design components that would allow for disassembly and reuse or even *cannibalization.*

6. Robust Design
Some products will perform as designed only within a narrow range of conditions, while other products will perform as designed over a much broader range of conditions. The latter have *robust design*.
Robust Design: Design that results in products or services that can function over a broad range of conditions. The idea is to have consistent, safe and reliable operations with no excuse for environmental characteristics.
The more robust a product, the less likely it will fail due to a change in the environment in which it is used or in which it is performed.

Taguchi Approach To Robust Design

Genichi Taguchi, a Japanese Manufacturing Engineer pioneered and championed the concept of reduction in the variability factor in manufacturing process. His approach helped manufacturing organizations to isolate and eliminate waste. This approach resulted in quality improvement and cost reduction.
With the aid of the Taguchi Approach we can determine the factors that are controllable and those not controllable along with their optimal levels relative to major product advances.

The defining characteristics for the Taguchi approach include:

- Design a robust product
- Insensitive to environmental factors either in manufacturing or in use.
- Central feature is Parameter Design.

An added concept to Taguchi Approach is the Degree of Newness.
Degree of newness is an incremental enhancement of certain quality based performance features for the product.

The various ways in which degrees of newness can be achieved include:
1. Modification of an existing product/service
2. Expansion of an existing product/service
3. Clone of a competitor's product/service
4. New product/service
5. Degree of Design Change

7. Concurrent Engineering

Concurrent engineering is an approach that brings many people together in the early phase of product design in order to simultaneously design the product and the process. This type of approach has been found to achieve a smooth transition from the design stage to actual production in a shorter amount of development time with improved quality results.

The old approach to product and process design was to first have the designers of the idea come up with the exact product characteristics. Once their design was complete they would pass it on to operations that would then design the production process needed to produce the product. This was called the *"over-the-wall" approach*, because the designers would throw their design "over-the-wall" to operations that then had to decide how to produce the product.

There are many problems with the old approach.

First, it is very inefficient and costly. For example, there may be certain aspects of the product that are not critical for product success but are costly or difficult to manufacture, such as a dye color that is difficult to achieve. Since manufacturing does not understand which features are not critical, it may develop an unnecessarily costly production process with costs passed down to the customers. Because the designers do not know the cost of the added feature, they may not have the opportunity to change their

design or may do so much later in the process, incurring additional costs. Concurrent engineering allows everyone to work together so these problems do not occur. Figure 3-5 shows the difference between the “over-the-wall” approach and concurrent engineering.

A *second problem* is that the “over-the-wall” approach takes a longer amount of time than when product and process design are performed concurrently. When product and process design are made together much of the work is done in parallel rather than in sequence. In today’s markets, new product introductions are expected to occur faster than ever. Companies do not have the luxury of enough time to follow a sequential approach and then work the “bugs” out. They may eventually get a great product, but by then the market may not be there!

The third problem is that the old approach does not create a team atmosphere, which is important in today’s work environment. Rather, it creates an atmosphere where each function views its role separately in a type of “us versus them” mentality.
With the old approach, when the designers were finished with the designs, they considered their job done. If there were problems, each group blamed the other. With concurrent engineering the team is responsible for designing and getting the product to market. Team members continue working together to resolve problems with the product and improve the process.

8. Computer-Aided Design (CAD)

Computers are increasingly used for product design. *Computer-aided design* **(CAD)** uses computer graphics for product design. The designer can modify an existing design or create a new one by means of a light pen, keyboard, a joystick, or a similar device. Once the design is entered into the computer, the designer can maneuver it on the screen. The designer can obtain a printed version of the completed design and file it electronically, making it accessible to people in the firm who need this information (e.g., marketing). A major benefit of **CAD** is the increased productivity of designers. No longer is it necessary to laboriously prepare mechanical drawings of products or parts and revise them repeatedly to correct errors or incorporate revisions.

9. Modular Design

Modular design makes it possible to have relatively high product variety and low component variety at the same time. The basic idea is to develop a series of basic product components, or modules, which can be assembled into a large number of different products. To the customer, it appears there are a great number of different products. To operations, there are only a limited number of basic components and processes.
Controlling the number of different components that go into products is of great importance to operations, since this makes it possible to produce more efficiently for large volumes while also allowing standardization of processes and equipment. A large number of product variations greatly increase the complexity and cost of operations.

Modular design offers a fundamental way to change product design thinking. Instead of designing each product separately, the company designs products around standard component modules and standard processes. Common modules should be developed that can serve more than one product line, and unnecessary product frills should be eliminated. This approach will still allow for a great deal of product varieties but the number of unnecessary product variations will be reduced.

The usual way to develop products is to design each one separately without much attention to the other products in the line. Each product is optimized, but the product line as a whole is not. Modular design requires a broader view of product lines, and it may call for changes in individual products to optimize the product line in its entirety.

Application of Decision Trees to Product Design

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

1. Be sure that all possible alternatives and states of nature are included in the tree. This includes an alternative of “doing nothing.”
2. Payoffs are entered at the end of the appropriate branch. This is the place to develop the payoff of achieving this branch.
3. The objective is to determine the expected value to each course of action. We accomplish this by starting at the end of the tree (the right-hand side) and working toward the beginning of the tree (the

left), calculating values at each step and “pruning” alternatives that are not as good as others from the same node.

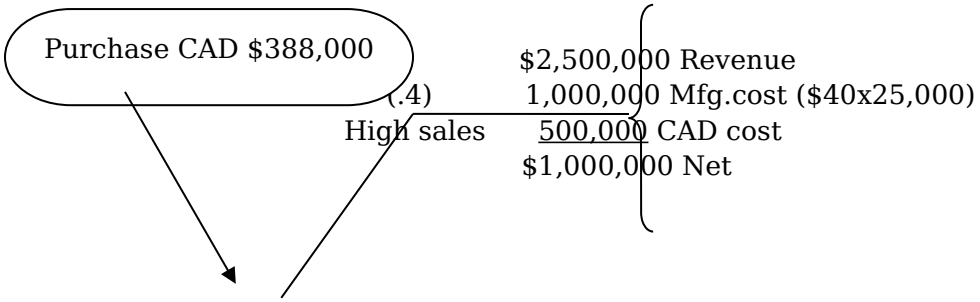
The following example shows the use of a decision tree applied to product design.

Example

Silicon, Inc., a semiconductor manufacturer, is investigating the possibility of producing and marketing a microprocessor. Undertaking this project will require either purchasing a sophisticated CAD system or hiring and training several additional engineers. The market for the product could be either favorable or unfavorable. Silicon, Inc., of course, has the option of not developing the new product at all.

With favorable acceptance by the market, sales would be 25,000 processors selling for $100 each. With unfavorable acceptance, sales would be only 8,000 processors selling for $100 each. The cost of CAD equipment is $500,000, but that of hiring and training three new engineers is only $375,000. However, manufacturing costs should drop from $50 each when manufacturing without CAD to $40 each when manufacturing with CAD.

The probability of favorable acceptance of the new microprocessor is .40; the probability of unfavorable acceptance is .60.



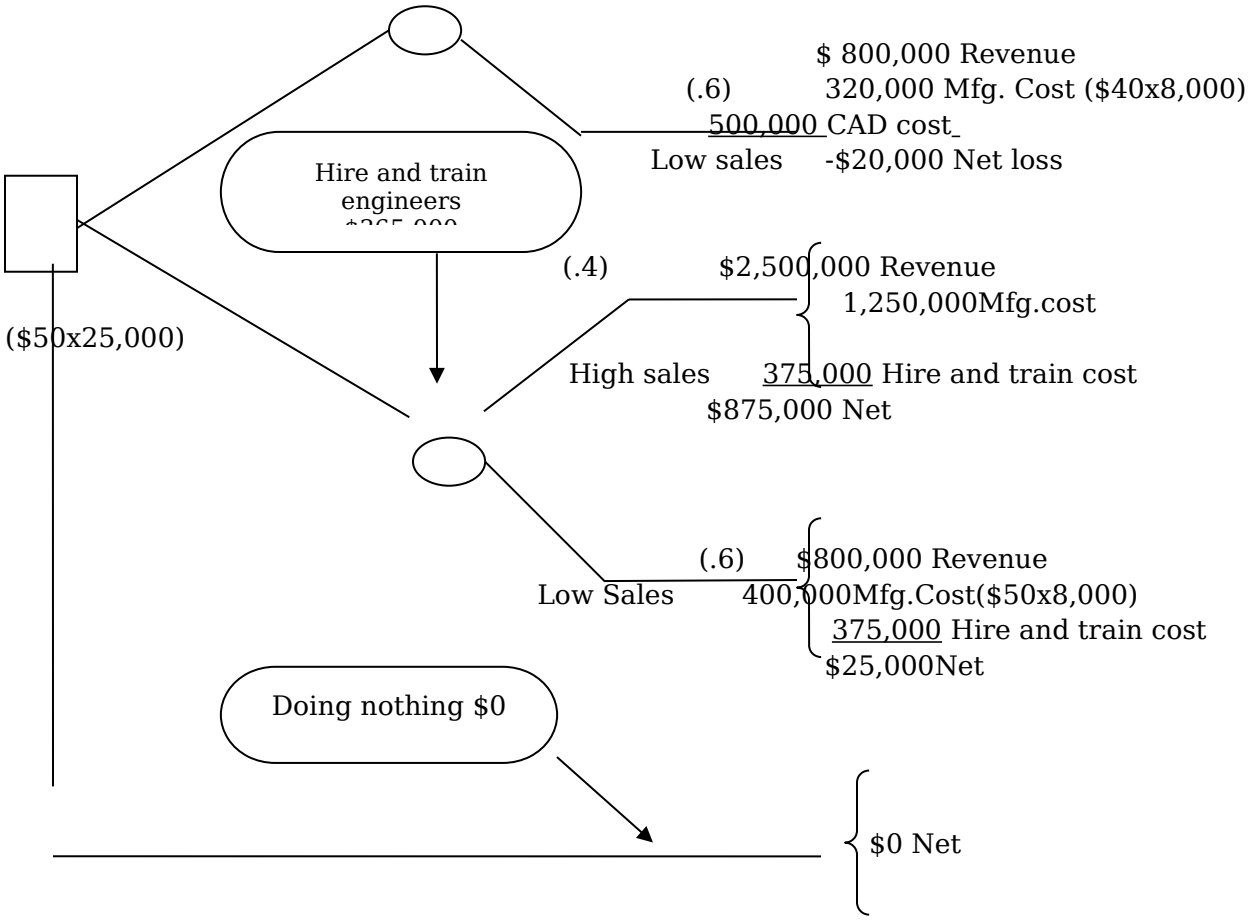


Figure 3.1. Decision Tree for Development of a New Product

The expected monetary values (EMVs) have been circled at each step of the decision tree. For the top branch:

EMV (purchase CAD system) = (.4) ($1,000,000) + (.6) (-$20,000)

=$388,000

This figure represents the results that will occur if Silicon, Inc., purchases CAD.

The expected value of hiring and training engineers is the second series of branches:

EMV (hire/train engineers) =(.4)($875,000) + (.6)($25,000)

=$365,000

The EMV of doing nothing is $0.

Because the top branch has the highest expected monetary value (an EMV of $ 388,000 vs. $365,000 vs. $0), it represents the best decision. Management should purchase the CAD System.

3.6 Service Operations Design

Service is the dominant economic force in the industrialized world today, and growth projections indicate this trend will continue. Yet, service production receives far too little emphasis in operations Management courses and business course in general.

Defining Service

Service is an intangible product, which is produced and consumed simultaneously. Therefore, a service never exists, only the results of the service can be observed. If you get a haircut, the effect is obvious, but the service itself was produced and consumed at the same time.

Simultaneous production and consumption is a critical aspect of service, because it implies that the customer must be in the production system while production takes place. The simultaneity of production and consumption indicates that service cannot be stored or transported; it must be produced at the point of consumption. For operations this means that capacity must be located at or near the customer's location and that the service cannot be produced now and placed into inventory for later consumption.

Service consists of acts and interactions that are social contacts. The interaction between the producer and customer at the time of production is a critical attribute of service. There are professional services such as medicine, law, education and architecture; and capital-intensive services; such as airlines, electric utilities; mass services such as retailing, wholesale, and fast food.

Differences between manufacturing and service

Manufacturing	*Service*
1. The product is tangible	1. The service is intangible
2. The product can be resold	2. No resale is possible
3. The product can be demonstrated before purchase	3. The product does not exist before purchase
4. The product can be stored in	4. The product cannot be stored

inventory	
5. Production precedes consumption	5. Production and consumption are simultaneous
6. Production and consumption can be spatially separated	6. Production and consumption must occur at the same location
7. The product can be transported	7. The product cannot be transported (though producers can be)
8. Indirect contact is possible between the company and the customer	8. In most cases direct contact is needed
9. The product can be exported	9. The service cannot normally be exported, but the service delivery system can be
10. Business is organized by functions, with sales and production separated	10. Sales and production cannot be separated functionally

Framework for Services

The framework (the service triangle) shown below, assumes there are four elements, which must be considered in producing services: the customer, people, strategy, and the system.

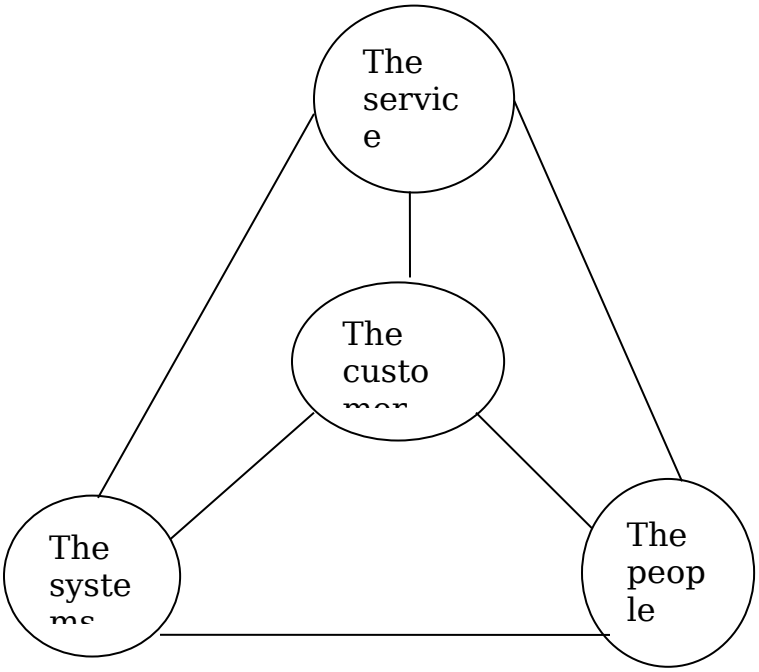


Figure 3.2. The service triangle

- The customer is (or should be) the focal point of all decisions and actions of the service organization.
- People are the employees of the service firm who serve the customer.
- The strategy is the vision or philosophy, which is used to guide all aspects of service delivery.
- The service system includes procedures, equipment, and facilities.

The line from the customer to the strategy indicates that the strategy should put the customer first, by meeting the true needs of the customer. Management should ask what goes in the customer's mind.

How does the customer think? What does the customer really want? Also, the company must communicate the service strategy to the customer. What does the company provide that is unique? Why should the customer buy from this company?

The line from customer to system indicates that the system (procedures and equipment) should be designed with the customer in mind.

- crowded seats in airplanes
- forms that cannot be understood, and
- uncomfortable restaurants do not lead to good customer service

The customer-to-people line indicates that everyone should be customer driven, not only the operations people who deliver the service, but all people in the organization. People are the most important element in delivering superior service.

The people-to-system line indicates that people depend on the system to deliver good service. Service systems should be designed to be simple, fast and efficient to operate.

The strategy-to-people line indicates that everyone in the organization should be aware of the strategy. The front-line people who deliver the service are often divorced from the strategy. Management views them as "cog in the wheel" and not in need of knowing service strategy. As a result poor service is delivered.

Service–product bundle

Most services come bundled with facilitating goods in a service-goods package. For example when customers go to a restaurant, they receive not only the food but the service, which they hope is fast, courteous, and pleasant.

- The service product bundle consists of three elements:
  1. The physical goods (facilitating goods)
  2. The sensual service provided (explicit service)
  3. The psychological service (implicit service)

Service recovery

Service recovery is an important part of the product design. When there is a service failure, service recovery is the ability to quickly compensate for the failure and restore, if possible, the service required by the customer. For example, when there is a power failure, service recovery is the time it takes for the electric company to restore power. The service recovery must be swift and appropriate in the customer's eyes.

Service guarantees

Many companies are now beginning to offer service guarantees as a way to define service and ensure its satisfactory delivery to the customer. A service guarantee is like its counterpart the product guarantee, except for one thing: the customer cannot return the service if he or she does not like it. For example, if you didn't like your haircut, you have to live with it that way, until it grows out.
The advantage of a service guarantee is it builds customer loyalty and clarifies exactly what the service process must provide.

Cycle of service

The service provided must be considered not only in light of a single service encounter but in terms of the entire cycle of service delivery. Every service is delivered in a cycle of service beginning with the point of initial customer contact and proceeding through steps or stages until the entire service is completed.
Each contact with a service system can be defined as a *moment of truth.* A moment of truth is any time that the customer comes in contact with the service system during the cycle of service delivery. It is the cumulative effect of all of the moments of truth that defines the service provided. A bad moment of truth can cancel out many positive moments. Even where service recovery is provided, it is better to prevent service failure at each moment

of truth than to recover from service failures. As a result, the entire cycle of service should be managed.
Perceived service = f (all previous moments of truth). Managing the moments of truth to achieve a positive experience is the essence of service process design.

Customer contact

With a low customer contact process, it is possible to buffer the customer from the actual process of production. Separating the customer from the service production system allows for more efficiency and greater standardization of processes. Examples of low-contact systems are catalog order processing and automatic bank teller transactions.
If customer contact is high, the customer can disrupt the production process by demanding certain types of services or special treatment. Therefore, high customer contract can lead to inefficient production process. A customer could require special consideration or more processing time and may impose unique requirements on the service provider like in dentistry and haircut.
High-contact systems have the customer in the system during the production of the service. In these systems, the customer can introduce uncertainty into the process with a resulting loss of efficiency. High-contact systems can lead to a loss of efficiency as follows:

Potential inefficiency =f (degree of customer contact)

The measure of degree of contact is the amount of time that the customer is in the system while the service is being produced. A highly efficient system is one with no customer contact, where the order can be processed away from the customer.

Characteristics of high-and low-contact services:

1. Low-contact services are used when face-to-face interaction is not required. High-contact operations are used for changing or uncertain customer demand.
2. Low-contact services require employees with technical skills, efficient processing routines, and standardization of the product and process. High-contact services require employees who are flexible, personable, and willing to work with the costumer (the smile factor).
3. High-contract services generally require higher prices and more customization due to the variable nature of the service required.

Design guidelines

A number of simple but highly effective rules are often used to guide the development of service systems. The key rules are the following:

1. Have a single, unifying theme, such as convenience or speed. This will help personnel to work together rather than at cross-purposes.
2. Make sure the system has the capability to handle any expected variability in service requirements.
3. Include design features and checks to ensure that service will be reliable and will provide consistently high quality.
4. Design the system to be user-friendly. This is especially true for self-service systems.

CHAPTER FOUR

PROCESS SELECTION AND CAPACITY PLANNING

Process Selection plays an important part in overall design of production and operations management systems. Process Selection allows an organization to offer a safe and reliable product and service through pragmatic design and effective capacity planning. With the help of process selection we can understand the different types of processing including manual, rigid, and flexible as well as various automated approaches to processing. Process selection allows an operations manager to better understand the need for management of technology. Together with capacity planning it helps an organization to develop different approaches to meet the irregular demand pattern of the customers.

Product and service choices, process selection, capacity planning, and choices about location and layout are among the most basic decisions managers must make because those decisions have long-tem consequences for the organization.
Processes transform inputs into outputs. Consequently, they are at the core of operations management. Not surprisingly, process planning plays a key role in the ability of an organization to achieve its mission.

4.1. Process Selection

Process is any part of an organization that takes input and transforms them in to output.
Process selection refers to the way an organization chooses to produce its goods or provide its services. Essentially it involves the choice of technology and related issues, and it has major implications for capacity planning, layout of facilities, equipment, and design of work systems. Process selection occurs as a matter of course when new products or services are being planned and competitive pressures. However, it also occurs periodically due to technological changes in equipment.
Process selection is based on five considerations:

1. Type of process range from intermittent to continuous
2. Flexibility of resources
3. Degree of vertical integration
4. Mix b/n capital and human resources
5. Degree of customer contact

How an organization approaches process selection is determined by the organization's process strategy.

An organizations process strategy would include:

- *Make or buy decisions*: The extent to which the organization will produce goods or provide services in-house as opposed to relying on outside organizations to produce or provide them.
- *Capital intensity:* The mix of equipment and labor that will be used by the organization.
- *Process flexibility*: The degree to which the system can be adjusted to changes in processing requirements due to such factors as changes in product or service design, changes in volume processed, and changes in technology.

Reasons to (produce in-house or outsource) Make or Buy

The very first step in process planning is to consider whether to make or

buy some or all of a product or to subcontract some or all of a service. A manufacturer might decide to purchase certain parts rather than make them; sometimes all parts are purchased, with the manufacturer simply performing assembly operations. Many firms contract out janitorial services, and some contract for repair services. If a decision is made to buy or contract, this lessens or eliminates the need for process selection.

There are *6 reasons* which are available to us in order to decide whether to develop a competence in house or hire an outside competent organization to supply that product, service or particular expertise. The latter requires that the outsourcer to be honest, ethical, competent. It also requires that outsourcing contract should be flexible yet pragmatic and carry proper levels of services.

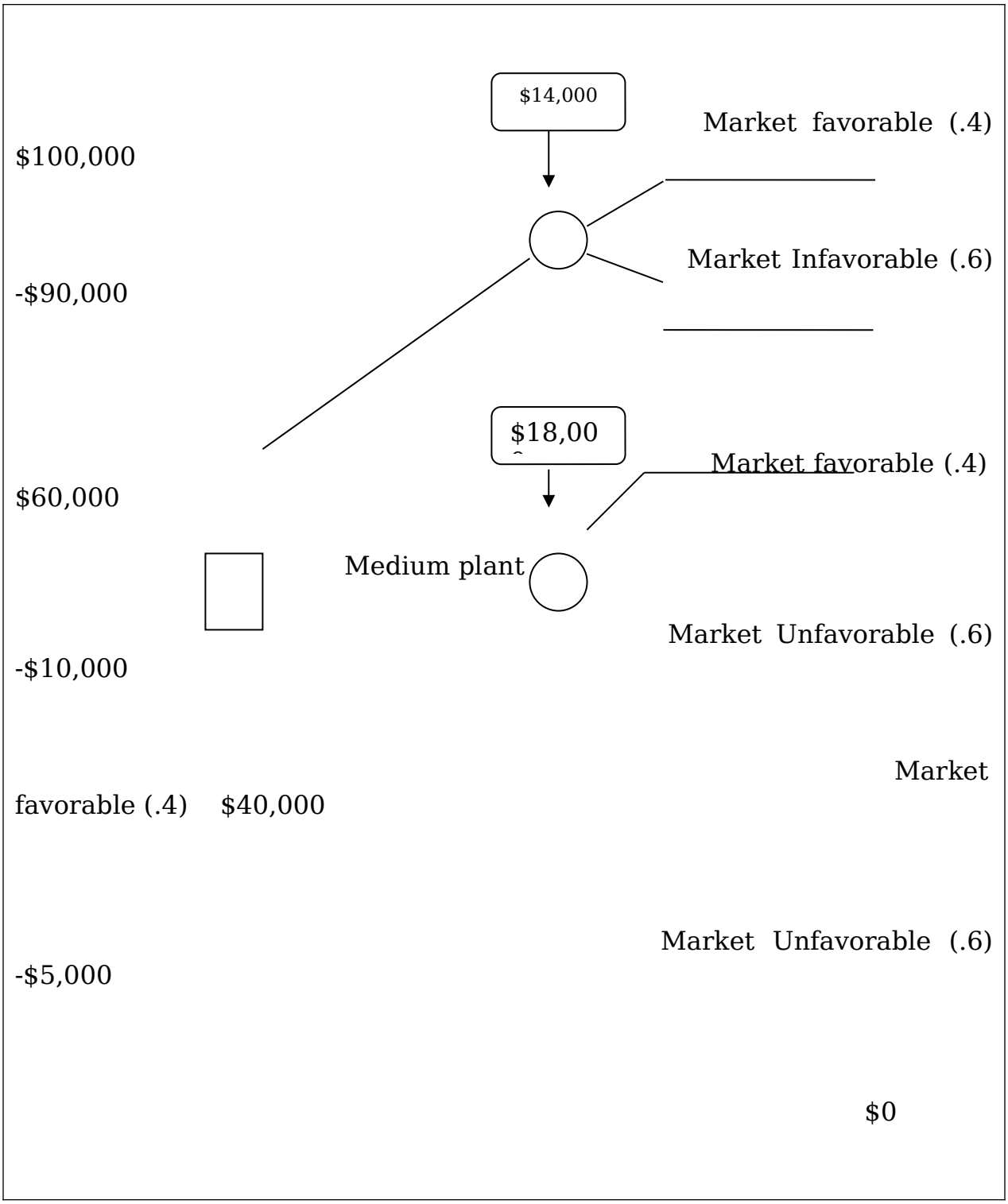
- *Available capacity*: if an organization has the equipment, necessary skills and time, it often makes sense to produce an item or perform a service in house. The additional costs would be relatively small compared with those required to buy items or subcontract them.
- *Expertise:* If a firm lacks the expertise to do a job satisfactorily, buying might be a reasonable alternative.
- *Quality considerations:* Firms that specialize can usually offer higher quality than an organization can attain itself. Conversely, special quality requirements or the ability to closely monitor quality may cause an organization to perform a job itself.
- *Nature of demand:* When demand for an item is high and steady, the organization is often better off doing the work itself. However, wide fluctuations in demand or small orders are usually better handled by specialists, who are able to combine orders from multiple sources, which results in higher volume and tend to offset individual buyer fluctuation.
- *Cost.* Any cost savings achieved from buying or making must be weighed against the preceding factors. Cost savings might come from the item itself or from transportation cost savings. If there are fixed costs associated with making an item that cannot be reallocated if the item is purchased, that has to be recognized in cost analysis.
- *Risk.* Outsourcing or buying the services carries risk; often companies retain flexibility by carrying out certain critical activities in house and repetitive menial activities through outsourcing.

Applying Decision Trees to Capacity Decisions

Decision trees require specifying alternatives and various states of nature. For capacity planning situations, the state of nature usually is future demand or market favorability. By assigning probability values to the various states of nature, we can make decisions that maximize the expected value of the alternatives. Example 1 shows how to apply decision trees to a capacity decision.

Example 1

Southern Hospital Supplies, a company that makes hospital gowns, is considering capacity expansion. Its major alternatives are to do nothing, build a small plant, build a medium plant, or build a large plant. The new facility would produce a new type of gown, and currently the potential or marketability for this product is unknown. If a large plant is built and a favorable market exists, a profit of $100,000 could be realized. An unfavorable market would yield a $90,000 loss. However, a medium plant would earn a $60,000 profit with a favorable market. A $10,000 loss would result from an unfavorable market. A small plant, on the other hand, would return $40,000 with favorable market conditions and lose only $5,000 in an unfavorable market. Of course, there is always the option of doing nothing.
Recent market research indicates that there is a .4 probability of a favorable market, which means that there is also a .6 probability of an unfavorable market. With this information, the alternative that will result in the highest expected monetary value (EMV) can be selected.



EMV (large plant) = (.4) ($100,000) + (.6) (-$90,000) =-$14,000
EMV (medium plant) = (.4) ($60,000) + (.6) (-$10,000) =+$18,000
EMV (small plant) = (.4) ($40,000) + (.6) (-$5,000) =+$13,000
EMV (do nothing) =$0

Based on EMV criteria, Southern should build a medium plant.

4.1.1. Type of Operation

The degree of standardization and the volume of output of a product or service influence the way production is organized. Output can range from high volume, highly standardized, to low volume, highly customized.

All processes can be grouped into three broad categories:

1. Continuous Processing.
    a. Repetitive (semi Continuous Processing).
2. Intermittent Processing.
    i. Batch Processing
    ii. Job Shop.
3. Automation
    a. Computer Aided Manufacturing
    b. Numerically Controlled Machines
    c. Robot
    d. Manufacturing Cell.
    e. Flexible Manufacturing System.

1. Continuous and Semi continuous Processing.

Continuous processing is employed when a highly uniform product or service is produced or rendered.

Processing of chemicals, photographic film, newsprint, and oil products are all examples of this type of product. Machines often provide continuous services, such as air-conditioning, heating, continuous cleaning, and monitoring systems. Other examples include liquid and powder detergents, and water treatment. Generally, these products are measured on a continuous basis rather than counted as discrete units. Industries that use continuous processing are sometimes referred to as *process industries.* Operations are usually performed around the clock to avoid costly shutdowns and start-ups. The output of these systems is highly uniform (standardized).

Semi continuous processing systems, known as *repetitive processing*, produce output that allows for some variety; products are highly similar but not identical.

- **Repetitive Processing***:* A production system that renders one or a few highly standardized products or services in high volume.

Examples these good include: automobiles, televisions, cafeteria, or automatic car wash, computers, calculators, cameras, and video equipment. Typically, these products are produced in discrete units. Resources are organized in a line flow to efficiently accommodate production of the product. Note that in this environment it is possible to arrange resources in a line because there is only one type of product. This is directly the opposite of what we find with intermittent operations.

To efficiently produce a large volume of one type of product these operations tend to be capital intensive rather than labor intensive. An example is “mass production” operations, which usually have much invested in their facilities and equipment to provide a high degree of product consistency. Often these facilities rely on automation and technology to improve efficiency and increase output rather than on labor skill.

The volume produced is usually based on a forecast of future demands rather than on direct customer orders.
The most common differences between intermittent and repetitive operations relate to two dimensions:
(1) The amount of product volume produced, and
(2) The degree of product standardization. Product volume can range from making a single unique product one at a time to producing a large number of products at the same time.

Skill requirements of workers are usually fairly low. Equipment tends to be highly specialized, which tends to make it expensive relative to more general purpose equipment, but the high volumes of output result in a low cost per unit. As a general rule, goods produced by these systems are made for inventory rather than customer order.

2. Intermittent Processing.

Intermittent operations are used to produce a variety of products with different processing requirements in lower volumes. Examples are an auto body shop, a tool and die shop, or a health-care facility. Because different products have different processing needs, there is no standard route that all products take through the facility. Instead, resources are grouped by function and the product is routed to each resource as needed. Think about a health-care facility. Each patient, “the product,” is routed to different

departments as needed. One patient may need to get an X ray, go to the lab for blood work, and then go to the examining room. Another patient may need to go to the examining room and then to physical therapy.

To be able to produce products with different processing requirements, intermittent operations tend to be *labor intensive* rather than *capital intensive*. Workers need to be able to perform different tasks depending on the processing needs of the products produced. Often we see skilled and semiskilled workers in this environment with a fair amount of worker discretion in performing their job and a narrower span of supervision than for most continuous systems.

Workers need to be flexible and able to perform different tasks as needed for the different products that are being produced. Equipment in this type of environment is *more general purpose* to satisfy different processing requirements. Automation tends to be less common, because automation is typically product specific. Given that many products are being produced with different processing requirements, it is usually not cost efficient to invest in automation for only one product type.

1. **Batch processing** is one form of intermittent processing.

Batch processing is used when companies need to produce moderate volumes of similar products. Food processors (e.g., bakeries, canneries) typically produce in batches. For example, an ice cream producer will produce a batch of one type of ice cream, such as vanilla, and then a second type, such as strawberry, and so on. The processing requirements and equipment are the same, but some of the ingredients vary from one batch to the next. Similarly, a canning factory might process a variety of vegetables: one run may be sliced carrots, the next green beans, and the next corn or beets. All might follow a similar process of washing, sorting, slicing, cooking, and packing, but the equipment needs to be cleaned and adjusted between runs. Batch output may be standardized (e.g., paint, ice cream, canned vegetables) or customized. An example of customized output is printing (e.g., magazines, newspapers, textbooks, user manuals).

2. **Job shops**: Job shops perform another type of intermittent processing.

A job shop is designed to handle a greater variety of job requirements than batch processing.

It is a system that renders unit or small lot production or service with varying specifications according to customer needs

A job shop maintains the ability to perform certain types of operations but

generally is not responsible for specific products. Instead, it performs to customer specifications; jobs tend to vary according to the needs of customers. Examples of job shops are organizations that do repair work (e.g., appliances, automobiles), health care, tool and die shops, and so on. Lot sizes vary from large to small, even a single unit. What distinguishes the job shop operation from batch processing is that the job requirements often vary considerably from job to job. This means that the sequence of processing steps and the job content of the steps also vary considerably. An auto repair shop is an example of a job shop. Each car is handled on an individual basis. Large repair shops may have specialists who deal in one kind of repair (e.g., brake jobs), but cars are still handled one at a time. For large jobs processing many of a single item or a few of many items, there is usually so much variety among successive jobs that the batch processing described for the canning factory would be too restrictive. Differences in job processing requirements add routing and scheduling complexities, as well as a frequent need to adjust equipment settings or make other alterations for successive jobs. Processing cost per unit is generally higher than it is under continuous or semi continuous processing.

Further examples of intermittent processing are textbook publication, bakeries, health care systems, and educational systems. In some cases, the outputs are made for inventory (clothing, automobile tires); in others, they are designed to meet customer needs (health care) or specifications (special tools, parts, or equipment). Marketing efforts in these systems are often directed toward promoting system processing capabilities or customized services.

Table 4-1a provides a summary of the characteristics of the four types of operations. The processes can be organized into a product-process matrix as shown in Table 4-1b.

Table 4-1a Type of Operation

	Job Shop	Batch	Repetitive/ Assembly	Continuous
Description	Customized goods or services	Semi-standardized goods or services	Standardized goods or services	Highly standardized goods or services
Examples of Processes Manufacturi	Machine shop	Bakery	Assembly line	Steel mill, paper mill,

ng Service	Beauty shop, barber shop	Classroom	Cafeteria line	etc. Central heating system
Examples of Goods Services	Specialty tools Hair styling	Cookies Education	Automobiles Car wash	Steel, paper, flour, sugar Heating, air conditioning
Volume	Low	Low-moderate	High	Very high
Output variety	Very high	Moderate	Low	Very Low
Equipment flexibility	Very high	Moderate	Low	Very Low
Advantages	Able to handle a wide variety of work	Flexibility	Low unit cost, high volume, efficient	Very efficient, very high volume
Disadvantages	Slow, high cost per unit, complex planning and scheduling	Moderate cost per unit, moderate scheduling complexity	Low flexibility, high cost of downtime	Very rigid, lack of variety, costly to change, very high cost of downtime

Table 4-1b matching the process with product variety, equipment flexibility, and volume requirements.

Product variety	High	Moderate	Low	Very low
Equipment flexibility	High	Moderate	Low	Very low
Low volume	Job Shop			
Moderate volume		Batch		
High volume			Repetitive assembly	
Very high volume				Continuous flow

Labor skill	high	moderate	Low	More specialized

A key concept in process selection is the need to match product requirements with process capabilities. The difference between success and failure in production can sometimes be traced to choice of process.
Table 4-1b can provide insights to managers selecting processes and managing existing operations. For new products, decision makers should make every attempt to achieve a matching of product and process requirements. For an ongoing operation, a manager should examine existing processes in light of the table to see how well processes and products are matched. Poor matches suggest the potential for improvement, perhaps with a substantial increase in efficiency and lowering of cost.
Another consideration is that products and services often go through *life cycles* that begin with low volume but which increase as products or services become better known. When that happens, a manager must know when to shift from one type of process (e.g., job shop) to the next (e.g., batch). Of course, some operations remain at a certain level (e.g., magazine publishing), while others increase (or decrease as markets become saturated) over time. Again, it is important for a manager to assess his or her products and services and make a judgment on whether to plan for changes in processing over time.

4.1.2. Process Flow analysis

Process flow analysis is a technique used for evaluating a process in terms of the sequence of steps from inputs to outputs with the goal of improving its design. One of the most important tools in process flow analysis is a process flowchart.
A **process flowchart** is used for viewing the sequence of steps involved in producing the product, and the flow of the product through the process. It is useful for seeing the totality of the operation and for identifying potential problem areas.
There is no exact format for designing a flowchart. The flowchart can be very simple or highly detailed.

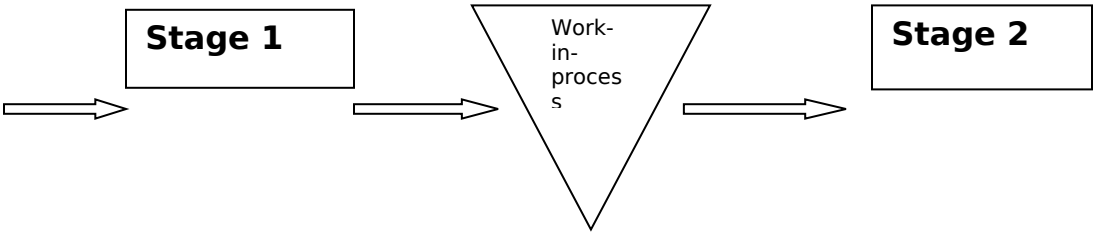
The typical symbols used in a flowchart are arrows to represent flows, triangles to represent decision points, inverted triangles to represent storage of goods, and rectangles as tasks. Let's begin by looking at some elements used in developing a flowchart, as shown in Figure 3-7. Shown first, in Figure 3-7(a), are flows between stages in a simple multistage process, which is a process with multiple activities ("stages"). You can see that the arrows indicate a simple flow of materials between the different stages.

Often multiple stages have storage areas or "buffers" between them for placement of either partially completed (work-in-process) or fully completed (finished goods) inventory, shown in Figure 3-7(b). This enables the two stages to operate independently of each other. Otherwise, the first stage would have to produce a product at the same exact rate as the second stage. For example, let's say that the first stage of a multistage process produces one product in 40 seconds and the second stage in 60 seconds. That means that for every unit produced the first stage would have to stop and wait 20 seconds for the second stage to finish its work. Because the capacity of the second stage is holding up the speed of the process, it is called a **bottleneck.**

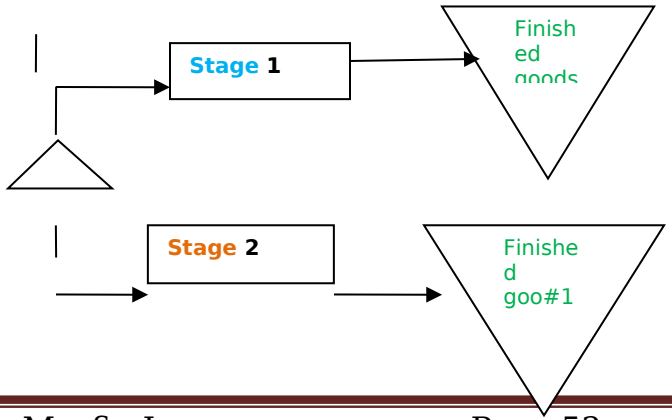
(a) Multistage process



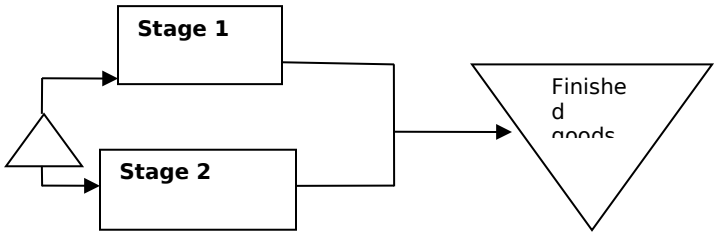
(b) Multistage process with buffers



(c) Parallel stages producing different products



(d) Parallel stages producing the same product



Now let's see what happens if the first stage takes 60 seconds to produce a product and the second stage 40 seconds. In this case the first stage becomes the bottleneck, and the second stage has to wait 20 seconds to receive a product. Obviously the best is for both stages to produce at the same rate, though this is often not possible. Inventory is then placed between the stages to even out differences in production capacity.

Often stages in the production process can be performed in parallel, as shown in Figure 3-7(c) and (d). The two stages can produce different products (c) or the same product (d). Notice that in the latter case this would mean that the capacity of the stage performed in parallel has effectively been doubled.
An important way of ensuring that a process is functioning properly is to regularly measure its performance.

Process performance metrics are measurements of different process characteristics that tell us how a process is performing. Just as accountants and finance managers use financial metrics, operations managers use process performance metrics to determine how a process is performing and how it is changing over time. There are many process performance metrics that focus on different aspects of the process. In this section we will look at some common metrics used by operations managers. These are summarized in Table 3-3.

A basic process performance metric is **throughput time,** which is the average amount of time it takes a product to move through the system. This includes the time someone is working on the product as well as the waiting time. A lower throughput time means that more products can move through the system. One goal of process improvement is to reduce throughput time. For example, think about the time spent at your last doctor's appointment. The total amount of time you spent at the facility, regardless of whether you were waiting, talking with the physician, or having lab work performed, is throughput time.

An important metric that measures how much wasted time exists in a process is **process velocity.**

Process velocity is computed as a ratio of throughput time to value added time:

$$\text{Process velocity} \quad ¿ \quad \frac{\text{Throughput time}}{\text{Value-added time}}$$

Where value-added time is the time spent actually working on the product. Notice that the closer this ratio is to 1.00, the lower the amount of time the product spends on non value adding activities (e.g., waiting). Again recall your last doctor's appointment.
What was the value-added time? What was the throughput time? Can you estimate the process velocity?
Another important metric is **productivity,** which is the ratio of outputs over inputs.
Productivity measures how well a company converts its inputs to outputs.
Utilization: which is the ratio of the time a resource is actually used versus the time it is available for use. Unlike productivity, which tends to focus on financial measures (e.g., dollars of output), utilization measures the actual time that a resource (e.g., equipment or labor) is being used.

Efficiency: is a metric that measures actual output relative to some standard of output. It tells us whether we are performing at, above, or below standard.

Frantz Title Company is analyzing its operation in an effort to improve performance. The following data have been collected:

It takes an average of 4 hours to process and close a title, with value-added time estimated at 30 minutes per title;
Each title officer is on payroll for 8 hours per day, though working 6 hours per day on average, accounting for lunches and breaks. Industry standard for labor utilization is 80 percent;
The company closes on 8 titles per day, with an industry standard of 10 titles per day for a comparable facility.

Determine process velocity, labor utilization, and efficiency for the company. Can you draw any conclusions?
Determine process velocity, labor utilization, and efficiency for the company. Can you draw any conclusions?

- **Solution**

$$\text{Process Velocity} = \frac{\text{Throughput time}}{\text{Value-added time}}$$

$$= \frac{4 \text{ hours/title}}{\frac{1}{2} \text{ hour/title}}$$

$$= 8 \text{ hours/day}$$

$$\text{Labor utilization} = \frac{6 \text{ hours/day}}{8 \text{ hours/day}}$$

$$= .75 \text{ Or } 75\%$$

$$\text{Efficiency} = \frac{8 \text{titles/day}}{10 \text{ titles/day}}$$

$$= .80 \text{ Or } 80\%$$

A process velocity of 8 indicates that the amount of time spent on nonvalue activities is 8 times that of value-added activities. Also, labor utilization and efficiency are both below standard.

3. Automation

Automation is machinery that has sensing and control devices that enable it to operate automatically.

1. Computer Aided manufacturing the use of computers in process control.
2. *Numerically Controlled Machines* that perform operations by following mathematical processing instructions
3. *Robot a machine* that consists of a mechanical arm, a power supply and a controller.

If a company decides to automate, the next question is how much. Automation can range from factories that are completely automated to a single automated operation.
Automation offers a number of advantages over human labor. It has low variability, whereas it is difficult for a human to perform a task in exactly the same way, in the same amount of time, and on a repetitive basis. In a production setting, variability is detrimental to quality and to meeting schedules. Moreover, machines do not get bored or distracted, nor do they go out on strike, ask for higher wages, or file labor grievances.

However, automation also has certain disadvantages and limitations compared with human labor. To begin with, it can be costly. Technology is expensive; usually it requires high volumes of output to offset high costs. In addition, automation is much less flexible than human labor. Once a process has been automated, there is substantial reason for not changing it. Moreover, workers sometimes fear automation because it might cause them to lose their jobs. That can have an adverse effect on morale and productivity.

Flexible Automation
1. Manufacturing Cell. one or a few N/C machines that produce a variety of parts.
2. Flexible Manufacturing System. A group of machines designed to handle intermittent processing requirements and produce a variety of similar products.
    1. Designed to handle intermittent processes
    2. Offers reduce labor costs and consistent quality.
    3. Higher Flexibility as compared to hard automation
2. **Disadvantage**.
    1. Requires longer time for planning and development
    2. Can handle only narrow range of parts variety.

Operations Strategy with respect to Process Selection

Operations strategy has the quality of being fine tuned whenever we discuss a new idea, process selection is no different, and we can formulate a process selection based operations strategy as follows.
1. Hire and Promote Managers who have both Technical and Managerial Skills. As engineers fail in managerial decisions and managers end up relying on engineers who create white elephants.
2. Flexibility as a competitive strategy to be incorporated at all levels.
3. Judicious use of Automation as unnecessary Automation causes increase

4.2. Capacity Planning

In this section, you will learn about the importance of capacity decisions, the measurement of capacity, how capacity requirements are determined, and the development and evaluation of capacity alternatives. A dictionary definition of capacity is" the ability to hold, receive, store, or accommodate".

Capacity refers to an upper limit or ceiling on the load that an operating unit, which can be a plant, department, machine, store or worker, can handle per unit of time period.

Capacity can be taken as a measure of organization's ability to provide customers with services or goods in the amount requested at the time requested. Capacity decisions should be taken by firstly identifying capacity requirements and then evaluating the alternatives capacity plans generated

In a business sense, it is most frequently viewed as the amount of output that a system is capable of achieving over specific period of time.
In a service sense, this might be the number of customers that can be handled between noon and morning.
In manufacturing, this might be the number of automobiles that can be produced in a single shift. When looking at capacity operation managers need to look at both resource inputs and product outputs.

An operation management view also emphasis the time dimension of capacity. That is capacity must be also stated relative to some period of time. This is evidenced in common distinction drawn b/n long range, intermediate-range, and short-range capacity planning.
Capacity issues are important for all organizations, and at all levels of an organization.
Capacity planning itself has different meaning to individuals at different

levels within the operations management hierarchy. The vice president of manufacturing is concerned aggregate capacity of all factories within the firm. The plant manager is concerned with the capacity of the individual plant. The plant manager must decide how best to use this capacity to meet anticipated demand for products.
The basic questions in capacity planning of any sort are the following:

1. What kind of capacity is needed?
2. How much is needed?
3. When is it needed?

The question of what kind of capacity is needed depends on the products and services that management intends to produce or provide. Hence, in a very real sense, capacity planning is governed by those choices.

The most fundamental decisions in any organization concern the products and/or services it will offer. Virtually all other decisions pertaining to capacity, facilities, location, and the like are governed by product and service choices. Thus, a decision to produce high-quality steel will necessitate certain types of processing equipment and certain kinds of labor skills, and it will suggest certain types of arrangement of facilities. It will influence the size and type of building as well as the plant location. Notice how different each of these factors would be if the choice were to operate a family restaurant, and how still different they would be if the choice were to operate a hospital.

Time duration for capacity planning

Capacity planning is viewed generally in three time durations

1. Long –range:- greater than one year
2. Intermediate range:- monthly or quarterly plans for next 6 up to 18 months here capacity, may be varied as such alternatives as hiring, layoffs, new tools, minor equipment purchase sand subcontracting.
3. Short-range –less than one month this is tied in to daily or weekly scheduling process and involves making adjustment to eliminate the variance b/n planned and actual out put. These include OT, personnel transfers, and alternative production routings.

4.2.1 Importance of Capacity Decisions

For a number of reasons, capacity decisions are among the most fundamental of all the design decisions that managers must make.

1. Capacity decisions have a real impact on the ability of the organization to meet future demands for products and services;

capacity essentially limits the rate of output possible. Having capacity to satisfy demand can allow a company to take advantage of tremendous opportunities.

2. Capacity decisions affect operating costs. Ideally, capacity and demand requirements will be matched, which will tend to minimize operating costs. In practice, this is not always achieved because actual demand either differs from expected demand or tends to vary (e.g., cyclically). In such cases, a decision might be made to attempt to balance the costs of over- and under capacity.
3. Capacity is usually a major determinant of initial cost. Typically, the greater the capacity of a productive unit, the greater its cost. This does not necessarily imply a one-for-one relationship; larger units tend to cost *proportionately* less than smaller units.
4. Capacity decisions often involve long-term commitment of resources and the fact that, once they are implemented, it may be difficult or impossible to modify those decisions without incurring major costs (irreversibility of wrongly made decisions).
5. Capacity decisions can affect competitiveness (having cloud on its competitive advantage) . If a firm has excess capacity, or can quickly add capacity, that fact may serve as a barrier against entry by other firms.

4.2.2. Types of capacity

Up to this point, we have been using a working definition of capacity. Although it is functional, it can be refined into two useful definitions of capacity:

1. *Design capacity:* the maximum output that can possibly be attained. *It is* the maximum rate of output achieved under ideal conditions.
2. *Effective capacity:* the maximum possible output given a product mix, scheduling difficulties, machine maintenance, quality factors, and so on. It is design capacity minus allowances such as personal time, maintenance and scrap.

   It is usually less than design capacity (it cannot exceed design capacity) owing to realities of changing product mix, the need for periodic maintenance of equipment, lunch breaks, coffee breaks, problems in scheduling and balancing operations, and similar circumstances.

3. *Actual out put*: is rate of output actually achieved.

Actual output cannot exceed effective capacity and is often less because of **machine breakdowns**, **absenteeism, shortages of materials**, and

quality problems, as well as **factors that are outside the control of the operations managers.**

These different measures of capacity are useful in defining two measures of system effectiveness: *efficiency* and *utilization*.

Efficiency is the ratio of actual output to effective capacity.

Utilization is the ratio of actual output to design capacity.

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}}$$

It is common for managers to focus exclusively on efficiency, but in many instances, this emphasis can be misleading. This happens when **effective capacity** is low compared with **design capacity**. In those cases, high efficiency would seem to indicate effective use of resources when it does not. The following example illustrates this point.

Given the information below, compute the efficiency and the utilization of the vehicle repair department:

Design capacity = 50 trucks per day
Effective capacity = 40 trucks per day
Actual output = 36 trucks per day

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} = \frac{\text{36 trucks per day}}{\text{40 trucks per day}} = 90\%$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}} = \frac{\text{36 trucks per day}}{\text{50 trucks per day}} = 72\%$$

Thus, compared with the effective capacity of 40 units per day, 36 units per day looks pretty good. However, compared with the design capacity of 50 units per day, 36 units per day is much less impressive although probably more meaningful. Or

The percentage of the realized efficiency (90%) seems to indicate that there is a good performance, but this has also been supported by the utilization figure (72%).

Because effective capacity acts as a lid on actual output, the real key to improving capacity utilization is to increase effective capacity by correcting quality problems, maintaining equipment in good operating condition, fully training employees, and fully utilizing bottleneck equipment.
Hence, increasing utilization depends on being able to increase effective capacity, and this requires knowledge of what is constraining effective capacity.
The following section explores some of the main determinants of effective capacity. It is important to recognize that the benefits of high utilization are only realized in instances where there is demand for the output. When demand is not there, focusing exclusively on utilization can be counterproductive, because the excess output not only results in additional variable costs, it also generates the costs of having to carry the output as inventory. Another disadvantage of high utilization is that operating costs may increase because of increasing waiting time due to bottleneck conditions.

Capacity strategy formulation

Capacity strategy for long term demand
Factors that are taken to account to formulate strategy:

- Demand pattern
- Growth rate and variability
- Facilities- operating or building costs
- Technological changes- rates and direction of technology changes
- Behavior of competitors- availability of capital and other input

Capacity planning concepts

Strategic capacity planning is an approach for determining the overall capacity level of capital intensive resources-including facilities, equipment, and overall labor force size- that best supports the company's long range competitive strategy. The capacity level selected has a critical impact on the firm's response rate, its cost structure, its inventory policies and its management and staff support requirements. If a capacity is inadequate the company may lose customers through slow service or by allowing competitors to enter the market. If the capacity is excessive, a company may have to reduce prices to stimulate demand; underlie its work force; carry excess inventory; or seek additional, less profitable to stay in business. The term capacity implies an attainable rate of out put, for example, 300 cars per day but saying nothing about how long that rate can be sustained. But we do not know for how many time periods this rate is

attained. To avoid this concept of BOL is used.

Best operating level is the level of capacity for w/c the process was designed and thus is the volume of out put at w/c average unit cost is minimized. Determining this minimum is difficult b/c it involves complex trade-off b/n the allocation of fixed overhead cost and the cost of overtime, equipment wear, defect rates, and other costs.
An important measure is the capacity utilization rate; which reveals how close a firm is to its best operating point (i.e. design capacity).

$$\text{Capacity utilization rate} = \frac{\text{capacity used}}{\text{Best operating level}}$$

During one week of production, a plant produced 83 units of a product. Its historic highest or best utilization recorded was 120 units per week. What is this plant's capacity utilization rate?

- Answer:

$$\text{Capacity utilization rate} = \frac{\text{Capacity used}}{\text{Best operating level}}$$

$$= 83/120$$

$$= 0.69 \text{ or } 69\%$$

The capacity utilization rate is expressed as a percentage and requires that the numerator and denominator be measured in the same units and time period (such as machine hour/day, barrels of oil/day, dollar of out put /day).

Economies of Scale and Diseconomies of scale

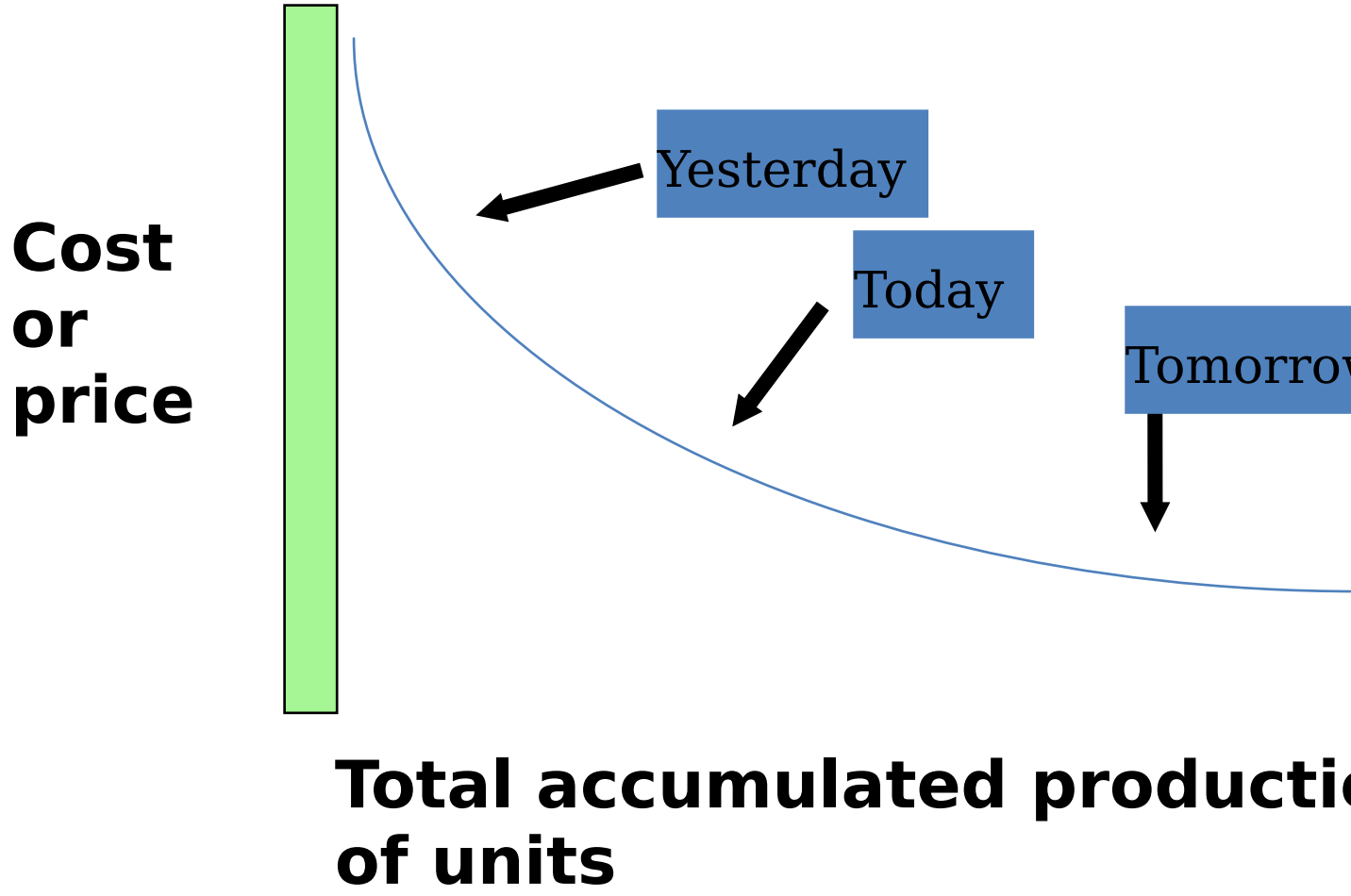
An operations manager should know what economies and diseconomies of scale are:
Economies of scale reflects a concept that states the average unit cost of a good or service can be reduced by increasing its output rate(plant gets large and volume increase), while diseconomies of scale reflects the case when the average cost per unit increases as the facility's size increases.

If the output rate is less than the optimal level, increasing output rate results in decreasing average unit costs then it reflects Economies of Scale. This is particularly due to lower operating and capital cost. Plant also gains efficiencies when they become large enough to fully utilize dedicated resource for tasks such as material handling, computer equipment and administrative support personnel. At some time the size of a plant becomes too large and diseconomies of scale become a problem. On the other hand

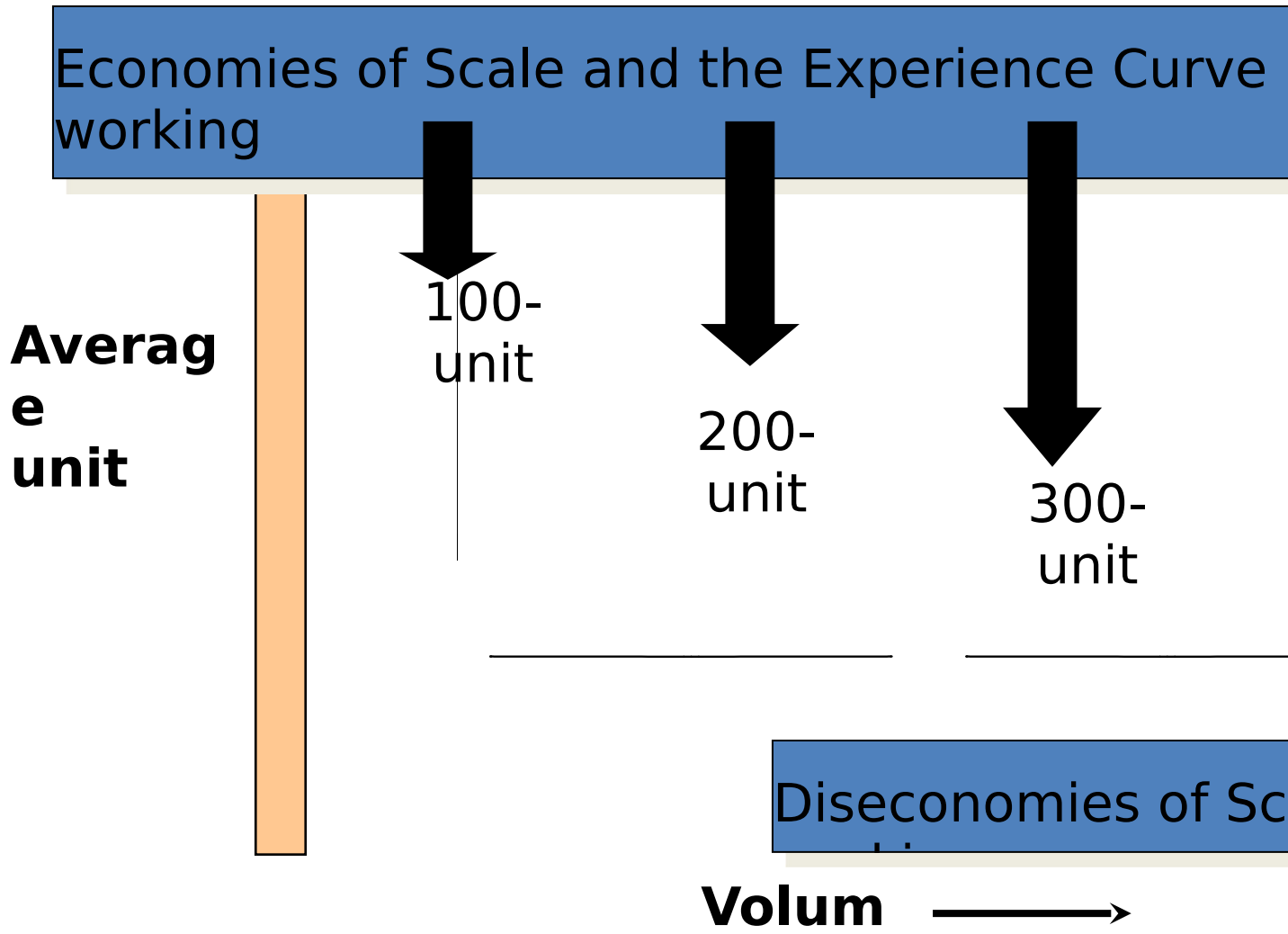
if the output rate is more than the optimal level, increasing the output rate results in increasing average unit costs

The Experience Curve

As plants produce more products, they gain experience in the best production methods and reduce their costs per unit



Larger plant can have two way cost advantages over the competitors. These include, Economies of scale and experience curve advantage



Capacity Focus

The concept of the *focused factory* holds that production facilities work best when they focus on a fairly limited set of production objectives. This means for example, that a firm should not expect to excel in every aspect of manufacturing performance: cost, quality, flexibility, new product introductions, reliability, short lead times and low investment. Rather it should select limited set of tasks that contribute the most to corporate objectives.

The capacity focus concept can also be operationalized through the mechanism of Plants within Plants (PWPs).

A focus plant may have several PWPs; each of w/c may have separate sub

organizations, equipment, process policies, workforce management policies, product control method and so forth for d/t products.

Capacity Flexibility

Capacity flexibility means having the ability to rapidly increase or decrease production levels, or to shift production capacity quickly from one product/service to another. Such flexibility is achieved through flexible plants, process and workers, as well as through strategies that use capacity of other organizations.

Flexible plants

The ultimate in plant flexibility is the *zero-changeover-time* plant. Using movable equipment, knockdown walls, and easily accessible and redoubtable utilities, such as a plant can quickly adopt to change.

Flexible processes: - are epitomized by flexible manufacturing systems, on the other hand and simple, easily set up equipment on the other.
Both of these technological approaches permit rapid low-cost switching from one product line to another, enabling what are some times referred to as economies of scope.
Economies of scope exist when multiple products can be produced at lower cost in combination than they can separately.

Flexible workers: flexible workers have multiple skills and the ability to switch from one kind of task to another.

Considerations in adding capacity

Many issues must be considered when adding capacity. The three important one include:

1. Maintaining system balance
2. Frequency of capacity additions
3. External source of capacity

1. *Maintaining system balance:* in a perfectly balanced plant, the output of stage1 provide the exact input requirement for stage 2, stage 2’ provides the exact input requirement for stage 3 and so on. In practice, however, achieving such a “perfect” design is usually both impossible and undesirable. One reason is that the best operating levels for each stage

generally differ. Another reason is that variability in product demand and the processes themselves generally leads to imbalance except in automated production lines, which in essence, just a big machine.

There are various way of dealing with imbalance

1. Add capacity to stages that are bottlenecks (scheduling equipment, leasing equipment or purchasing additional capacity through subcontracting).
2. The use of buffer inventories in front of the bottleneck stage to ensure that it always has something to work on.
3. Duplicating the facility of department

Unbalanced stages of production

Units per month

6000 7000 5000

Balanced stages of production

Units

Per
Month
6000 6000 6000

2. *Frequency of capacity additions*: there are two types of costs to consider when adding capacity.
   A. The cost of upgrading too frequently: is expensive. Direct cost includes removing and replacing old equipment and training employees on the new equipment. The new equipment musty also be purchased, often for considerably more than the selling price of the old. There are also opportunity costs of idling the plant or service during the change over period.
   B. The cost of upgrading capacity too infrequently: is also expensive. Infrequently expansion means that capacity is purchased in larger chunks.
3. *External source of capacity.* In some cases, it may be cheaper to not add capacity at all, but rather to use some existing external source of capacity. Two common strategies used by organizations are: *Outsourcing* and *Sharing capacity*.

Determining Capacity Requirements

In determining capacity requirements we must address the demand for individual product lines, individual plant capabilities and allocation of production throughout the plant net work.
Typically this is done according to the following steps:

1. Forecast sales within each individual product line
2. Calculate equipment and labor requirements to meet the product lines forecasts
3. Project equipment and labor availability over the planning horizon

Often the firm decides on some capacity cushion that will be maintained b/n the projected requirements and the actual capacity.
A capacity cushion is an amount of capacity in excess of expected demand.
When a firm's design capacity is less than the capacity required to meet its demand, it is said to have a *negative capacity cushion*.

Example:

A manufacturer produces two lines of mustard, Fancy Fine and Generic line. Each is sold in small and family-size plastic bottles.
The following table shows forecast demand for the next four years.

Year:	1	2	3	4
FancyFine				
Small (000s)	50	60	80	100
Family (000s)	35	50	70	90
Generic				
Small (000s)	100	110	120	140
Family (000s)	80	90	100	110

Production from a capacity view point:

Question: Are we really producing two different types of mustards from the standpoint of capacity requirements?

Answer: No, it's the same product just packaged differently**.**

Equipment and labor requirements:

Year:	1	2	3	4
Small (000s)	150	170	200	240
Family (000s)	115	140	170	200

- Three 100,000 units-per-year machines are available for small-bottle production. Two operators required per machine.
- Two 120,000 units-per-year machines are available for family-sized-bottle production. Three operators required per machine.

Question: What are the year 1 values of capacity, machine, and labor?

	Year:	1	2	3	4
Small family (000s)		150,000	170,000	200,000	240,000
Family (000s)		110,000	140,000	170,000	200,000
(000s)	**150,000/300,000=50%**	0	0	0	0
Small Family-size	Mach. Cap.	300,000	Labor	6	
Family-size	Mach. Cap.	240,000	Labor	6	
Small					
Percent capacity used	50.00%				
Machine requirement	1.50				
Labor requirement	3.00				
Family-size					
Percent capacity used	47.92%				
Machine requirement	0.96				
Labor requirement	2.88				

B/c the total available machine and labor capacity for small size is 300,000(3×100,000 each) and 6 respectively

Capacity used = forecasted demand = 150,000

Capacity available 300,000

0.5 Or 50% of available capacity of current year is used

Machine requirement = .5×3 = 1.5 machines

Labor requirement = .5 ×6 = 3 operators

The total available machine and labor capacity for family size is 240000(120000×2 each) and 6 respectively.

Capacity used for year 1 = 115000

240000

= 0.4792 or 47.92% of available capacity of current year is used

Machine requirement =0.4792×2 = .96 machines

Labor requirement = 0.4792×6 = 2.88 operators

Year:	1	2	3	4
Small (000s)	150	170	200	240
Family (000s)	11	14	17	20
	5	0	0	0
Small Family-size 150,000	Mach. Cap.	300,000	Labor	6
	Mach. Cap.	240,000	Labor	6
Percent capacity used	50.00%			
Machine requirement	1.5			
Labor requirement	3.0			
Percent capacity used	47.92%			
Machine requirement	0.9			
Labor requirement	2.8			

150,000/300,000=50%

At 1 machine for 100,000, it takes 1.5 machines for 150,000

Small Family-size 150,000

At 2 operators for 150,000, it takes 3 Operators for

Question: What are the values for columns 2, 3 and 4 in the table below?

Year:	1	2	3	4
Small family (000s)	150	170	200	240
Family (000s)	110	140	170	200
(000s)	50	0	0	0
Small Family-size	Mach. Cap.	300,000	Labor	6
Small Family-size	Mach. Cap.	240,000	Labor	6
Small				
Percent capacity used	50.00%	56.67%		66.67%
Machine requirement	1.50	1.70		2.00
Labor requirement	3.00	3.40		4.00
Family-size				
Percent capacity used	47.92%	58.33%		70.83%
Machine requirement	0.96	1.17		1.42
Labor requirement	2.88	3.50		4.25

Decision trees to determine capacity alternatives

A convenient way to lay out the steps of a capacity problem is through the use of decision trees.

A decision tree is a schematic model of the sequence of steps in a problem and the conditions and consequences of each step. Decision trees are composed of nodes with branches to and from them. Usually squires represent decision points, and circles represent chance events. Branches from decision points show the choices available to the decision maker; branches from chance events show the probabilities for their occurrence. In solving decision tree problems, we work from the end of the tree backward to the start of the tree. As we work back, we calculate the expected values at each step. In calculating the expected values, the time value of money is

important if the planning horizon is long. Once the calculations are made, we prune the trees by eliminating from each decision point all branches except the one with the highest payoff. This problem continues to the first decision point, and the decision problem is thereby solved.

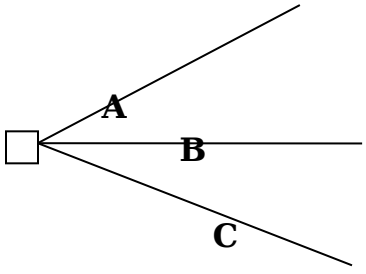
Example:
A glass factory specializing in crystal is experiencing a substantial backlog, and the firm's management is considering three courses of action:

A) Arrange for subcontracting
B) Construct new facilities
C) Do nothing (no change)

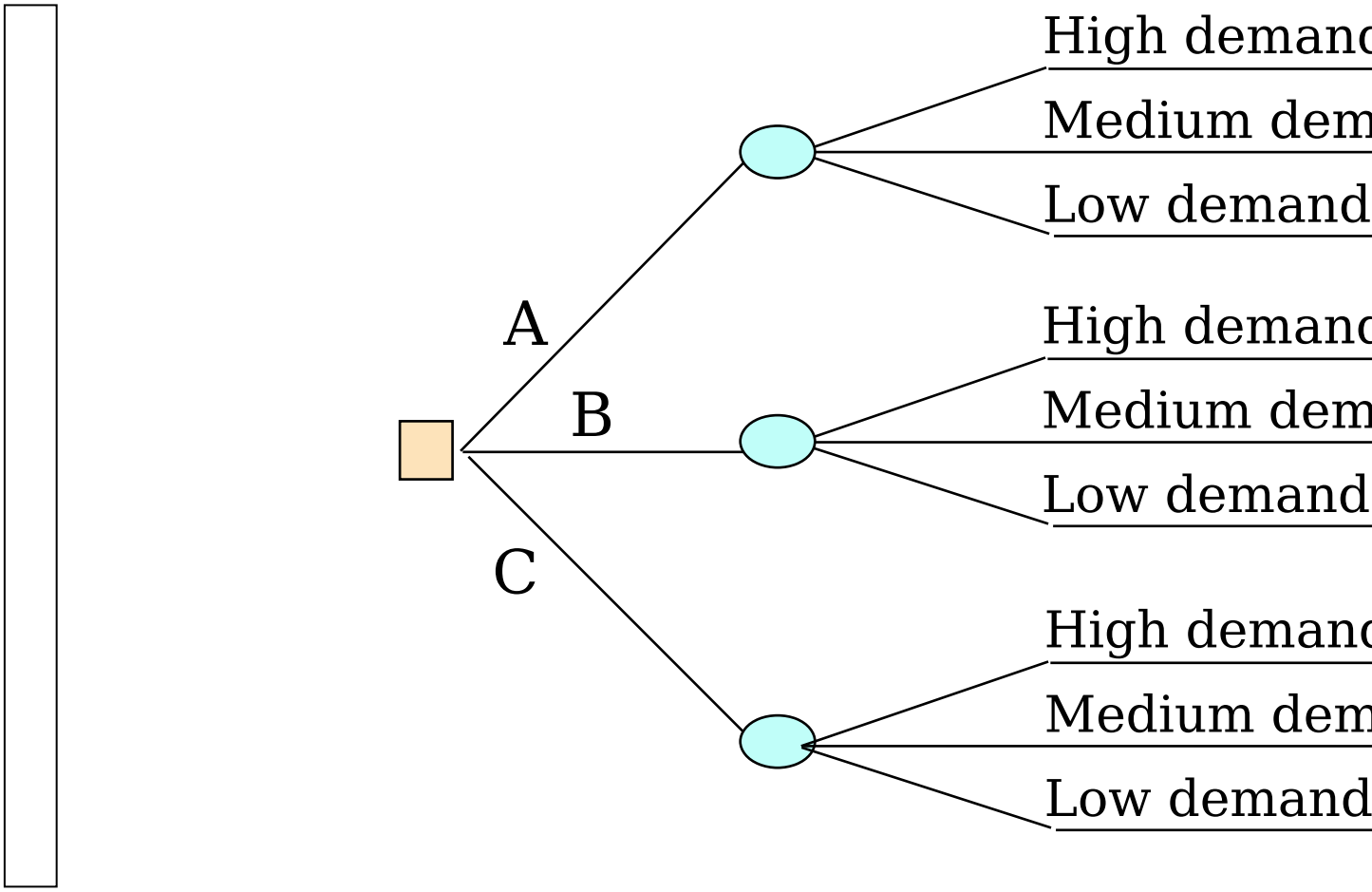
The correct choice depends largely upon demand, which may be low, medium, or high. By consensus, management estimates the respective demand probabilities as 0.1, 0.5, and 0.4.
The management also estimates the profits when choosing from the three alternatives (A, B, and C) under the differing probable levels of demand. These profits, in thousands of dollars are presented in the table below:

	0.1	0.5	0.4
	Low	Medium	High
A	10	50	90
B	-120	25	200
C	20	40	60

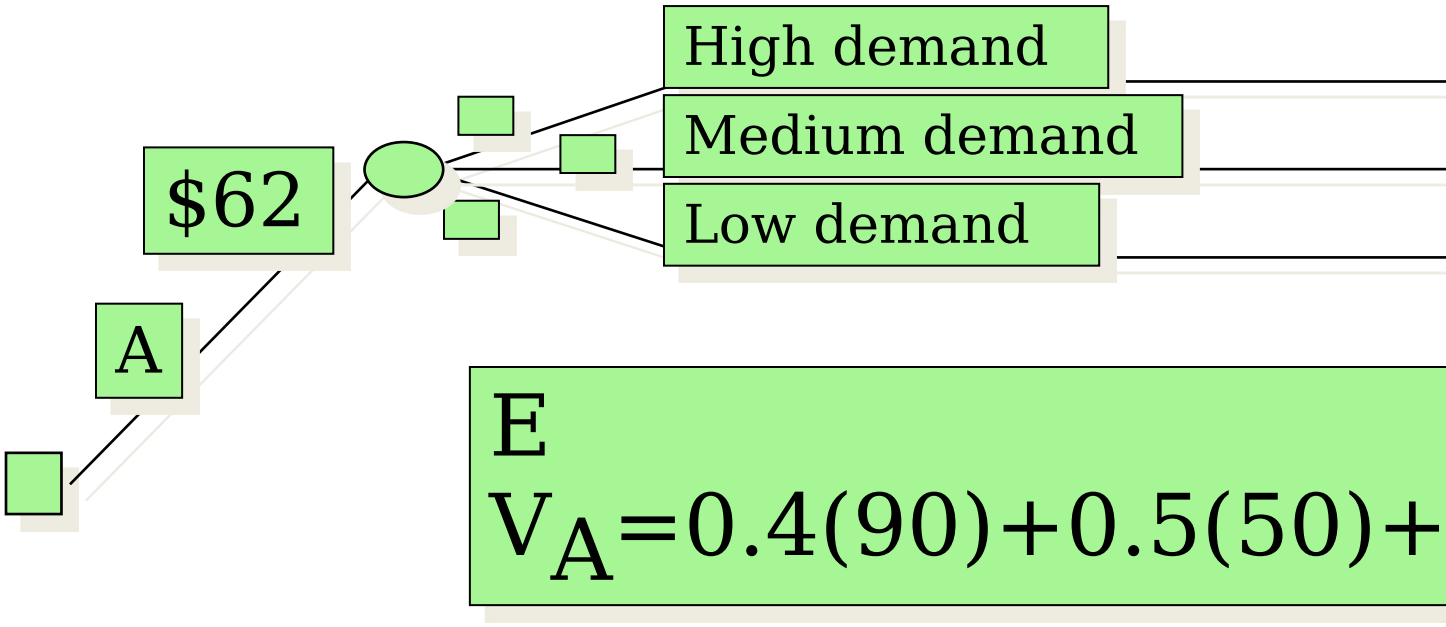
Step 1. We start by drawing the three decisions

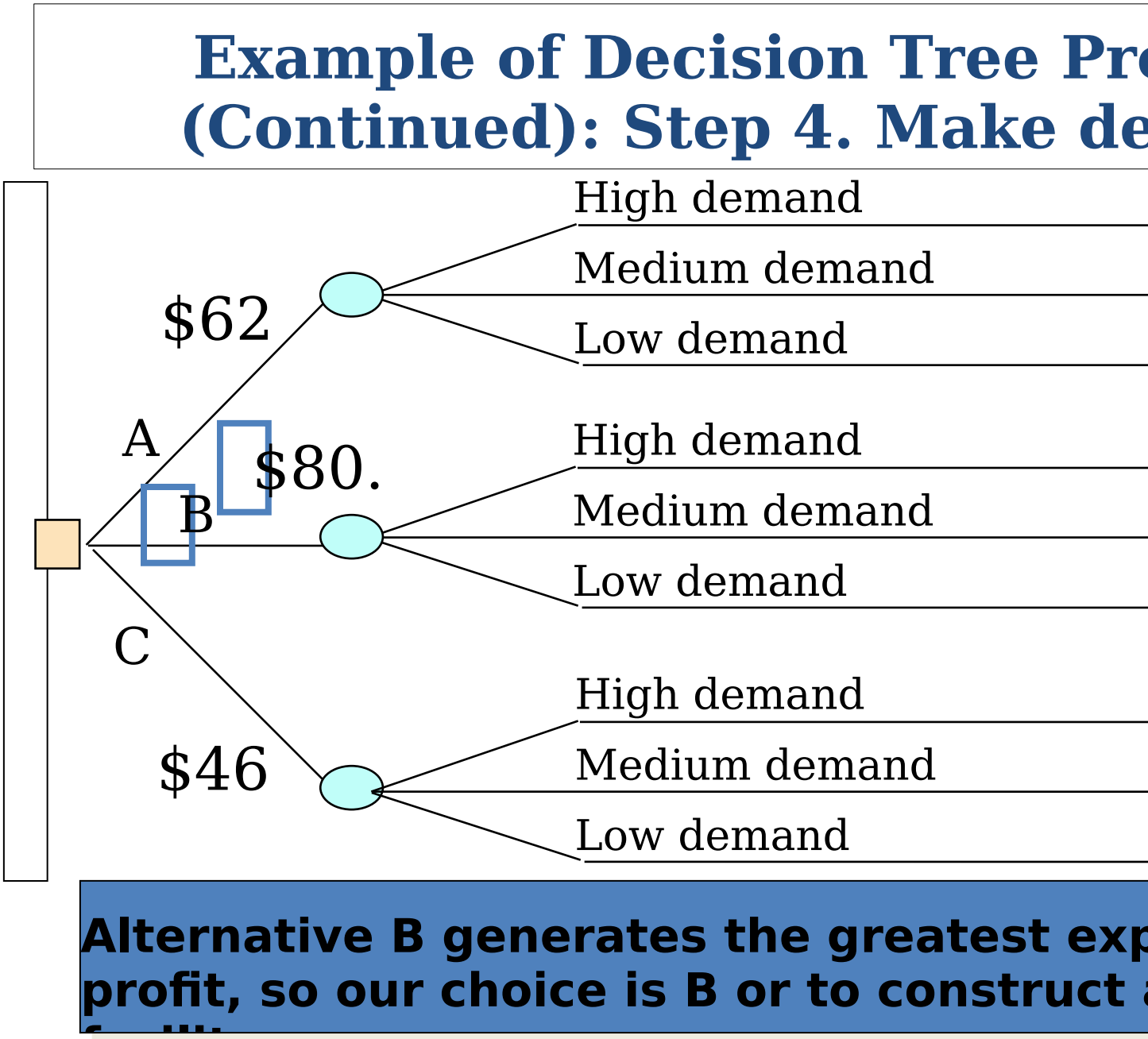


Example of Decision T
Problem (Continued): St
Add our possible state



Example of Decision Tree Problem (Co
Step 3. Determine the expected valu
decision





Example 2 The owner of Dell computer store is considering what to do with his b/s over the next five years. Sales growth over the past couples of years has been good, but sales could grow substantially if a major electronics firm is built in his area as proposed. Dells' owner sees three options. The first is to enlarge his current store, the second is to locate at a new site, and the third is to simply wait and do nothing. The decision to expand or move would take little time, and therefore, the store would not loss revenue. If nothing were done the first year and strong growth occurred, then the

decision to expand would be reconsidered. Waiting longer than one year would allow competition to move in and would make expansion no longer feasible.

The assumptions and conditions are as follows:

1. Strong growth as a result of the increased population of computer fanatics from the new electronics firm has a 55% probability.
2. Strong growth with a new site would give annual returns of birr 195,000 per year. Weak growth with a new site would mean annual returns of birr 115,000.
3. Strong growth with an expansion would give annual returns of birr190,000 per year. Weak growth with an expansion would mean annual returns of birr 100,000.
4. At the existing store with no changes, there would be returns of birr 170,000 per year. If there is Strong growth and birr 105,000 per year. If growth is weak.
5. Expansion at the current site would cost birr 87,000.
6. The move to the new site would cost birr 21000
7. If growth is Strong growth and the existing site is enlarged during the second year, the cost would still be birr 87000
8. Operating cost for all operations are equal.

Defining and Measuring Capacity

Capacity often refers to an upper limit on the *rate* of output. Even though this seems simple enough, there are subtle difficulties in actually measuring capacity in certain cases and hence, measuring capacity is not as simple as defining it.
. These difficulties arise because of different interpretations of the term *capacity* and problems with identifying suitable measures for a specific situation.
The ways production managers have to use to measure capacities make variations depending on the type of business they are in and the type of capacity, input and/or output, they tend to measure.

In selecting a measure of capacity, it is important to choose one that does not require updating. For example, dollar amounts are often a poor measure of capacity (e.g. capacity of $30 million a year) because price changes necessitate continual updating of that measure.

Where only one product or service is involved, the capacity of the

productive unit may be expressed in terms of that item. However, when multiple products or services are involved, as is often the case, using a simple measure of capacity based on units of output can be misleading. An appliance manufacturer may produce both refrigerators and freezers. If the output rates for these two products are different, it would not make sense to simply state capacity in units without reference to either refrigerators or freezers. The problem is compounded if the firm has other products.
No single measure of capacity will be appropriate in every situation. Rather, the measure of capacity must be tailored to the situation. Table 4-2 provides some examples of commonly used measures of capacity.

Table 4-2: Measures of capacity

Business	**Inputs**	**Outputs**
Auto manufacturing	Labor hours, machine hours	Number of cars per shift
Steel mill	Furnace size	Tons of steel per day
Oil refinery	Refinery size	Gallons of fuel per day
Farming	Number of acres, number of cows	Bushels of grain per acre per year, gallons of milk per day
Restaurant	Number of tables, seating capacity	Number of meals served per day
Theater	Number of seats	Number of tickets sold per performance
Retail sales	Square feet of floor space	Revenue generated per day

Determinants of Effective Capacity
Many decisions about system design have an impact on capacity. The same is true for many operating decisions. This section briefly describes some of these factors,
The main factors relate to the following:

1. Facilities
2. Operations
3. External forces
4 Human considerations
5. Product or services
6. processes

1. Facilities Factors. The design of facilities, including size and provision for expansion, is key. Locational factors, such as transportation costs, distance to market, labor supply, energy sources, and room for expansion, are also important. Likewise, layout of the work area often determines how smoothly work can be performed, and environmental factors such as

heating, lighting, and ventilation also play a significant role in determining whether personnel can perform effectively or whether they must struggle to overcome poor design characteristics.

2. Product/Service Factors. Product or service design can have a tremendous influence on capacity. For example, when items are similar, the ability of the system to produce those items is generally much greater than when successive items differ. Thus, a restaurant that offers a limited menu can usually prepare and serve meals at a faster rate than a restaurant with an extensive menu. Generally speaking, the more uniform the output, the more opportunities there are for standardization of methods and materials, which leads to greater capacity.

3. Process Factors. The quantity capability of a process is an obvious determinant of capacity. A more subtle determinant is the influence of output *quality.* For instance, if quality of output does not meet standards, the rate of output will be slowed by the need for inspection and rework activities.

***Table 4-3 Factors** that determine effective capacity*

A. Facilities
   1. Design
   2. Location
   3. Layout
   4. Environment

B. Product/Service
   1. Design
   2. Product or service mix

C. Process
   1. Quantity capabilities
   2. Quality capabilities

D. Human factors
   1. Job content
   2. Job design
   3. Training and experience
   4. Motivation
   5. Compensation
   6. Learning rates
   7. Absenteeism and labor turnover

E. Operational
   1. Scheduling
   2. Materials management
   3. Quality assurance
   4. Maintenance policies
   5. Equipment breakdowns

F. External factors
   1. Product standards
   2. Safety regulations
   3. Unions
   4. Pollution control standards

4. Human Factors. The tasks that make up a job, the variety of activities involved, and the training, skill, and experience required to perform a job all have an impact on the potential and actual output. In addition, employee motivation has a very basic relationship to capacity, as do absenteeism and labor turnover.

5. Operational Factors. Scheduling problems may occur when an organization has differences in equipment capabilities among alternative

pieces of equipment or differences in job requirements. Inventory stocking decisions, late deliveries, acceptability of purchased materials and parts, and quality inspection and control procedures also can have an impact on effective capacity.

6. External Factors. Product standards, especially minimum quality and performance standards can restrict management's options for increasing and using capacity. Thus, pollution standards on products and equipment often reduce effective capacity, as does paperwork required by government regulatory agencies by engaging employees in nonproductive activities. A similar effect occurs when a union contract limits the number of hours and type of work an employee may do. Table 4-3 presents a summary of all these factors. In general, *inadequate planning* is a major limiting determinant of effective capacity.

3.4. FACILITY LOCATION AND LAYOUT

3.4.1. Facility location

INTRODUCTION

Location decisions are concerns of not only newly launched businesses, but also the existing ones in that they need to make expansions.

Depletion of basic inputs are some of the causes for the needs to make location decisions.

Shifts in markets also force production managers to consider relocation of plant locations.

3.4.1.2. The Need or Location Decisions

Existing organizations may need to make location decisions for a variety of reasons. Firms such as banks, fast-food chains, supermarkets, and retail stores view locations 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 the *addition* of new locations to an existing system.

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

Some firms face location decisions through depletion of basic inputs. For example, fishing and logging operations are often forced to relocate due to the temporary exhaustion of fish or forests at a given location. Mining and

petroleum operations face the same sort of situation, although usually with a longer time horizon.
For other firms, a shift in markets causes them to consider relocation, or the costs of doing business at a particular location reach a point where other locations begin to look more attractive.

3.4.1.3. The Nature of Location Decisions

Location decisions for many types of businesses are made infrequently, but they tend to have a significant impact on the organization. In this section we look at the importance of location decisions, the usual objectives managers have when making location choices, and some of the options that are available to them

Importance of Location Decisions

There are two primary reasons that location decisions are a highly important part of production systems design. One is that they entail a long-term commitment, which makes mistakes difficult to overcome. The other is that location decisions often have an impact on investment requirements, operating costs and revenues, and operations. A poor choice of location might result in excessive transportation costs, a shortage of qualified labor, loss of competitive advantage, inadequate supplies of raw materials, or some similar condition that is detrimental to operations. For services, a poor location could result in lack of customers and/or high operating costs. For both manufacturing and services, location decisions can have a significant impact on competitive advantage.

Objectives of Location Decisions

As a general rule, profit-oriented organizations base their decisions on profit potential, whereas nonprofit organizations strive to achieve a balance between cost and the level of customer service they provide. It would seem to follow that all organizations attempt to identify the "best" location available. However, this is not necessarily the case.

In many instances, no single location may be significantly better than the others. There may be numerous acceptable locations from which to choose, as shown by the wide variety of locations where successful organizations can be found. Furthermore, the number of possible locations that would

have to be examined to find the best location may be too large to make an exhaustive search practical. Consequently, most organizations do not set out with the intention of identifying the one *best* location; rather, they hope to find a number of *acceptable* locations from which to choose.

Location Options

Managers generally consider four options in location planning. These are:

1. Expansion
2. Adding new location
3. Shifting
4. Doing nothing

1. Expansion of an existing facility.

This option 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.

2. *Adding new locations while retaining existing ones*.

In such cases, it is essential to take into account what the impact will be on the total system. Opening a new store in a shopping mall may simply draw customers who already patronize an existing store in the same chain, rather than expanding the market. On the other hand, adding locations can be a defensive strategy designed to maintain a market share or to prevent competitors from entering a market.

3. *Shutting down at one location and move to another (shifting)*. An organization must weigh the costs of a move and the resulting benefits against the costs and benefits of remaining in an existing location. A shift in markets, exhaustion of raw materials, and the cost of operations often cause firms to consider this option seriously.

4. Doing nothing. If 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 the status quo, at least for the time being.

General Procedure for Making Location Decisions

The way an organization approaches location decisions often depends on its size and the nature or scope of its operations. New or small organizations tend to adopt a rather informal approach to location decisions. New firms typically locate in a certain area simply because the owner lives there. Similarly, managers of small firms often want to keep operations in their backyard, so they tend to focus almost exclusively on local alternatives. Large established companies, particularly those that already operate in more than one location, tend to take a more formal approach. Moreover,

they usually consider a wider range of geographic locations. The discussion here pertains mainly to a formal approach to location decisions.
The general procedure for making location decisions usually consists of the following steps:

1. Decide on the criteria to use for evaluating location alternatives, such as increased revenues or community service.
2. Identify important factors, such as location of markets or raw materials.
3. Develop location alternatives:
   a. Identify the general region for a location.
   b. Identify a small number of community alternatives.
   c. Identify site alternatives among the community alternatives.
4. Evaluate the alternatives and make a selection.

Step (1) is simply a matter of managerial preference. Steps (2) through (4) may need some elaboration.

3.4.1.4. Factors That Affect Location Decisions

Many factors influence location decisions. However, it often happens that one or a few factors are so important that they dominate the decision. For example, in manufacturing, the potentially dominating factors usually include availability of an abundant energy and water supply and proximity to raw materials. Thus, nuclear reactors require large amounts of water for cooling, heavy industries such as steel and aluminum production need large amounts of electricity, and so on. Transportation costs can be a major factor. In service organizations, possible dominating factors are market related and include traffic patterns, convenience, and competitors' locations, as well as proximity to the market. For example, car rental agencies locate near airports and mid-city where their customers are.
Once an organization has determined the most important factors, it will try to narrow the search for suitable alternatives to one geographic region. Then a small number of community-site alternatives are identified and subjected to detailed analysis. Community and site factors are often so intertwined that it makes sense to consider them jointly,

Regional consideration/ Factors

The primary regional factors involve raw materials, markets, and labor considerations.
A. Location of Raw Materials. Firms locate near or at the source of raw materials for three primary reasons:

- ❖ Necessity: if the product needs a number of row materials or components
- ❖ Perishability, and
- ❖ Transportation costs.
- ➢ Mining operations, farming, forestry, and fishing fall under *necessity.* Obviously, such operations must locate close to the raw materials.
- ➢ Firms involved in canning or freezing of fresh fruit and vegetables, processing of dairy products, baking, and so on must consider *perishability* when considering location.
- ➢ *Transportation costs* are important in industries where processing eliminates much of the bulk connected with a raw material, making it much less expensive to transport the product or material after processing. Examples include aluminum reduction, cheese making, and paper production

B. Location of Markets(proximity to markets). Profit-oriented firms frequently locate near the markets they intend to serve as part of their competitive strategy, whereas nonprofit organizations choose locations relative to the needs of the users of their services. Other factors include distribution costs or the perishability of a finished product.

Retail sales and services are usually found near the center of the markets they serve. Examples include fast-food restaurants, service stations, dry cleaners, and supermarkets. Quite often their products and those of their competitors are so similar that they rely on convenience to attract customers. Hence, these businesses seek locations with high population densities or high traffic. The competition/convenience factor is also important in locating banks, hotels, auto repair shops, drugstores, newspaper kiosks, and shopping centers. Similarly, doctors, dentists, lawyers, barbers, and beauticians typically serve clients who reside within a limited area.
Locations of many government services are near the markets they are designed to serve. Hence, post offices are typically scattered throughout large metropolitan areas. Police and emergency health care locations are frequently selected on the basis of client needs. For instance, police patrols often concentrate on high crime areas, and emergency health care facilities are usually found in central locations to provide ready access from all directions.

C. Labor Factors. Primary labor considerations are the cost and availability of labor, wage rates in an area, labor productivity and attitudes toward work, and whether unions are a serious potential problem.

Skills of potential employees may be a factor, although some companies prefer to train new employees rather than rely solely on previous experience. Increasing specialization in many industries makes this possibility even more likely than in the past. Although most companies concentrate on the supply of blue-collar workers, some firms are more interested in scientific and technical people as potential employees, and they look for areas with high concentrations of those types of workers.
Worker attitudes toward turnover, absenteeism, and similar factors may differ among potential locations−workers in large urban centers may exhibit different attitudes than workers in small towns or rural areas. Furthermore, worker attitudes in different parts of the country or in different countries may be markedly different.

Some companies offer their current employees jobs if they move to a new location. However, in many instances, employees are reluctant to move, especially when it means leaving families and friends. Furthermore, in families with two wage earners, relocation would require that one wage earner give up a job and then attempt to find another job in the new location.

2. Other Factors. Climate and taxes sometimes play a role in location decisions.

i. Community Considerations

Many communities actively try to attract new businesses because they are viewed as potential sources of future tax revenues and new job opportunities. However, communities do not, as a rule, want firms that will create pollution problems or otherwise lessen the quality of life in the community. Local groups may actively seek to exclude certain companies on such grounds, and a company may have to go to great lengths to convince local officials that it will be a "responsible citizen." Furthermore, some organizations discover that even though overall community attitude is favorable, there may still be considerable opposition to specific sites from nearby residents who object to possible increased levels of noise, traffic, or pollution. Examples of this include community resistance to airport expansion, changes in zoning, construction of nuclear facilities, and highway construction.

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 worship, and entertainment; the quality of police, fire, and medical services; local attitudes toward the company; and the size of the community. Community size can be particularly important if a firm will be a major employer in the community; a future decision to terminate or reduce operations in that location could have a serious impact on the economy of a small community.
Other community-related factors are the cost and availability of utilities, environmental regulations, and taxes.

ii. Site-Related Factors

The primary considerations related to sites are land, transportation, and zoning or other restrictions.
Evaluation of potential sites may require consulting with engineers or architect especially in the case of heavy manufacturing or the erection of large buildings or facilities with special requirements. Soil conditions, load factors, and drainage rates can be critical and often necessitate certain kinds of expertise in evaluation.
Because of the long-term commitment usually required, land costs may be secondary to other site-related factors, such as room for future expansion, current utility and sewer capacities−and any limitations on these that could hinder future growth−and sufficient parking space for employees and customers. In addition, for many firms access roads for trucks or rail spurs are important.
Industrial parks may be worthy alternatives for firms involved in light manufacturing or assembly, warehouse operations, and customer service facilities. Typically, the land is already developed-power, water, and sewer hookups have been attended to, and zoning restrictions do not require special attention. On the negative side, industrial parks may place restrictions on the kinds of activities that a company can conduct, which can limit options for future development of a firm's products and services as well as the processes it may consider. Sometimes stringent regulations governing the size, shape, and architectural features of buildings limit managerial choice in these matters. Also, there may not be an adequate allowance for possible future expansion.

iii. Service and Retail Locations

Service and retail are typically governed by somewhat different considerations than manufacturing organizations in making location decisions. For one thing, nearness to raw materials is usually not a factor,

nor is concern about processing requirements. But customer access is usually a prime consideration.

Retail and service organizations typically place traffic volume and convenience high on the list of important factors. Specific types of retail or service businesses may pay more attention to certain factors due to the nature of their business or their customers. If a business is unique, and has its own drawing power, nearness to competitors may not be a factor. However, generally retail businesses prefer locations that are near other retailers (although not necessarily competitors) because of the higher traffic volumes and convenience to customers. Thus, large department stores tend to locate near each other, often as anchor stores in mall settings, and smaller retailers occupy spaces between the larger stores. Restaurants and specialty stores often locate in and around malls, benefiting from the high traffic.

Medical services are often located near hospitals for convenience of patients. Doctors' offices may be located near hospitals, or grouped in other, centralized areas with other doctors' offices. Available public transportation is often a consideration.
Good transportation and/or parking facilities can be vital to retail establishments. Downtown areas have a competitive disadvantage in attracting shoppers compared to malls because malls offer ample free parking and nearness to residential areas.

1. Factor Rating

A typical location decision involves both qualitative and quantitative inputs, which tend to vary from situation to situation depending on the needs of each organization. **Factor rating** is a general approach that is useful for evaluating a given alternative and comparing alternatives. The value of factor rating is that it provides a rational basis for evaluation and facilitates comparison among alternatives by establishing a composite value for each alternative that summarizes all related factors. Factor rating enables decision makers to incorporate their personal opinions and quantitative information into the decision process.

The following procedure is used to develop a factor rating:

1. Determine which factors are relevant (e.g., location of market, water supply, parking facilities, revenue potential).

2. Assign a weigh to each factor that indicates its relative importance compared with all other factors. Typically, weights sum to 1.00.
3. Decide on a common scale for all factors (e.g., 0 to 100).
4. Score each location alternative.
5. Multiply the factor weight by the score for each factor, and sum the results for each location alternative.
6. Choose the alternative that has the highest composite score.

This procedure is illustrated in the next example.

A photo-processing company intends to open a new branch store. The table below contains information on two potential locations.

Factor	Weight	Scores (out of 100)		Weighted Scores	
		Alt. 1	Alt. 2	Alternative 1	Alternative 2
Proximity to existing store	.10	100	60	.10(100)=10.0	.10(60)=6.0
Traffic volume	.05	80	80	.05(80)=4.0	.05(80)=4.0
Rental costs	.40	70	90	.40(70)=28.0	.40(90)=36.0
Size	.10	86	92	.10(86)=8.6	.10(92)=9.2
Layout	.20	40	70	.20(40)=8.0	.20(70)=14.0
Operating costs	.15	80	90	.15(80)=12.0	.15(90)=13.5
	1.00			70.6	82.7

Alternative 2 is better because it has the higher composite score.

In some cases, managers may prefer to establish minimum thresholds for composite scores. If an alternative fails to meet that minimum, they can reject it without further consideration. If none of the alternatives meets the minimum, this means that either additional alternatives must be identified and evaluated or the minimum threshold must be reevaluated.

2. The Center of Gravity Method

The center of gravity method is a method to determine the location of a distribution center that will minimize distribution costs. It treats distribution cost as a linear function of the distance and the quantity shipped. The quantity to be shipped to each destination is assumed to be fixed (i.e., will not change over time). An acceptable variation is that

quantities are allowed to change, as long as their relative amounts remain the same (e.g., seasonal variations).
The center of gravity method is a technique for locating single facilities that considers the existing facilities, the distances between them, and the volumes of goods to be shipped.

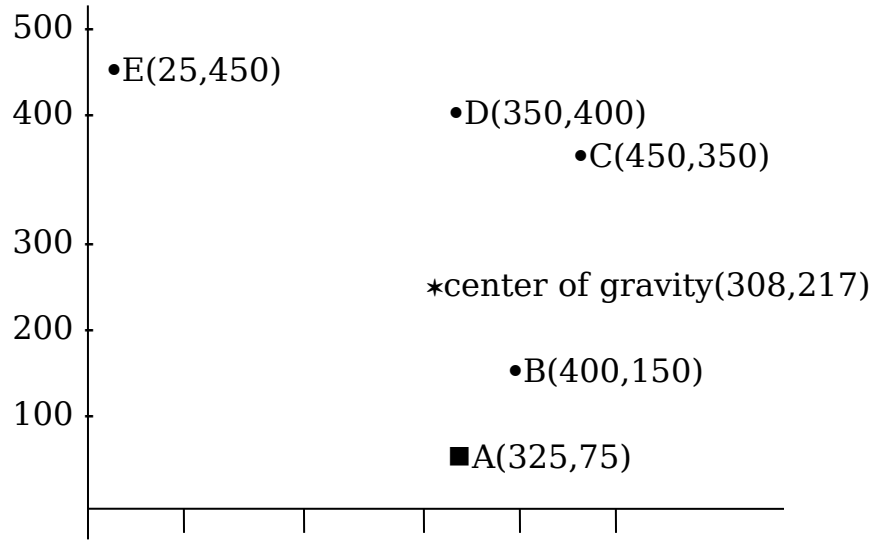
- The technique is often used to locate intermediate or distribution warehouses.
- The center of gravity method begins by placing the existing locations on a coordinate grid system.
- The purpose is to establish relative distances between locations.
- The center of gravity is found by calculating the X and Y coordinates that result in the minimal transportation cost.
- We use the formulas

$$C_x = \frac{\Sigma_{dix}\, Vi}{\Sigma Vi}$$

$$C_y = \frac{\Sigma_{diy}\, Vi}{\Sigma Vi}$$

where Cx=X Coordinate of the center of gravity
Cy=Y Coordinate of the center of gravity
dix= X coordinate of the i^{th} location
diy= Y coordinate of the i^{th} location
Vi= Volume of goods to or from the i^{th} location

Example: A refining company needs to locate an intermediate holding facility between its refining plant in place A and its major distributors. The following exhibit shows the coordinate map.



0 100 200 300 400 500

Gird Map

■ Plant

● Distributor

Shipping Volumes

Locations	A	B	C	D	E
Gallons of Gasoline per month (000,000)	1,500	250	450	350	450

In this example, for location A d_{1x}=325, d_{1y}=75, and V_1=1,500

Solution- using the above information we can calculate the coordinates of the center of gravity.

$$C_x = \frac{(325x1,500)+(400x250)+(450x450)+(350x350)+(25x450)}{1,500+250+450+350+450}$$

$$= \frac{923,750}{3,000} = 307.9$$

$$C_y = \frac{(75x1,500)+(150x250)+(350x450)+(400x350)+(450x450)}{1,500+250+450+350+450}$$

$$= \frac{650,000}{3,000} = 216.7$$

3.4.2. FACILITY LAYOUT

Introduction

Layout refers to the configuration of departments, work centers, and equipment, with particular emphasis on improvement of work (customers or materials) through the system.

Layout decisions are important for three basic reasons:

(1) They require substantial investments of money and effort,

(2) They involve long-term commitments, which make mistakes difficult to overcome, and

(3) They have a significant impact on the cost and efficiency of short-term operations. This chapter describes the main types of layout designs and the models used to evaluate design alternatives.

The Need for Layout Decisions

Layout decisions entail determining the placement of department, workgroups within the departments, workstations, machines, and stocks-holding points within the production facility.

Facility layout can be defined as the process by which the placement of departments, workgroups within departments, workstations, machines, and stock-holding points within a facility are determined

The objectives are to arrange these elements in a way that ensures a smooth workflow or a particular traffic pattern (in a service organization).

This process requires the following inputs:

- Specification of objectives of the system in terms of output and flexibility
- Estimation of product or service demand on the system
- Processing requirements in terms of number of operations and amount of flow between departments and work centers
- Space requirements for the elements in the layout
- Space availability within the facility itself

The need for layout planning arises both in the process of designing new facilities and in redesigning existing facilities. The most common reasons for redesign of layouts include:

1. Inefficient operations (e.g., high cost, bottlenecks).
2. Accidents or safety hazards.
3. Changes in the design of products or services.
4. Introduction of new products or services.
5. Changes in the volume of output or mix of outputs.
6. Changes in methods or equipment.
7. Changes in environmental or other legal requirements.
8. Morale problems (e.g., lack of face-to-face contact).

3.4.2.1. Layout Types

The three basic types of layouts are product, process, and fixed-position.

Product layouts (flow shop layout): is one in w/c equipment or work process are arranged according to the progressive steps by w/c the product is made. It is most conducive to repetitive processing.

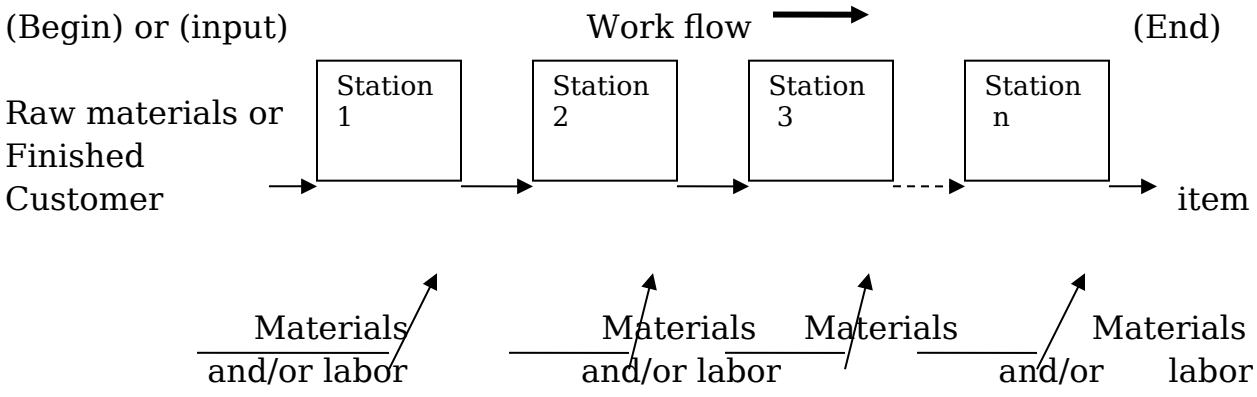
Process layouts (also called job shop or functional layout): are used for

intermittent processing, and
Fixed-position layouts: are used when projects require layouts. We will study the characteristics, advantages, and disadvantages of each layout type in this section. We'll also take a look at hybrid layouts, which are combinations of these pure types.

1. Product Layouts

Product layouts are used to achieve a smooth and rapid flow of large volumes of goods or customers through a system. This is made possible by highly standardized goods or services that require highly standardized (repetitive) processing operations. The work is divided into a series of standardized tasks, permitting specialization of both labor and equipment. The large volumes handled by these systems usually make it economical to invest substantial sums of money in equipment and job design. Because only one or a few very similar items are involved, it is feasible to arrange an entire layout to correspond to the technological processing requirements of the product or service. For instance, if a portion of a manufacturing operation required the sequence of cutting, sanding, and painting, the appropriate pieces of equipment would be arranged in that same sequence. And because each item follows the same sequence of operations, it is often possible to utilize fixed-path material-handling equipment such as conveyors to transport items between operations. The resulting arrangement forms a line like the one depicted in Figure 5-1.

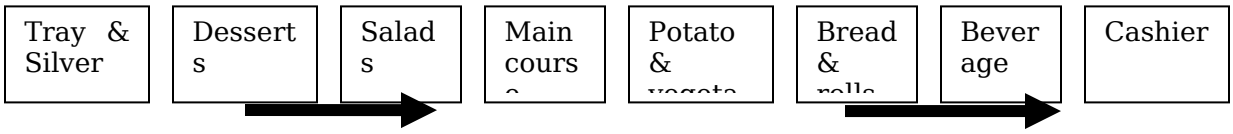
Figure 5-1 A flow line for production or service



and/or labor

In manufacturing environments, the lines are referred to as **production lines** or **assembly lines**, depending on the type of activity involved. In service processes, the term *line* may or may not be used. It is common to refer to a cafeteria line as such but not a car wash, although from a conceptual standpoint the two are nearly identical. Figure 5-2 illustrates the layout of a typical cafeteria serving line.

Figure 5-2
Cafeteria line



Examples of this type of layout are less plentiful in service environments because processing requirements usually exhibit too much variability to make standardization feasible. Without high standardization, many of the benefits of repetitive processing are lost. When lines are used, certain compromises may be made. For instance, an automatic car wash provides equal treatment to all cars—the same amount of soap, water, and scrubbing—even though cars may differ considerably in cleaning needs. As a result, very dirty cars may not come out completely clean, and relatively clean cars go through the same system with considerable waste of soap, water, and energy.

Product layouts achieve a high degree of labor and equipment utilization, which tends to offset their high equipment costs. Because items move quickly from operation to operation, the amount of work-in-process is often minimal. Consequently, operations are so closely tied to each other that the entire system is highly vulnerable to being shut down because of mechanical failure or high absenteeism. Maintenance procedures are geared to this. Preventive maintenance—periodic inspection and replacement of worn parts or those with high failure rates—reduces the probability of breakdowns during the operations. Of course, no amount of preventive activity can completely eliminate failures, so management must take measures to provide quick repair. These include maintaining an inventory of spare parts and having repair personnel available to quickly restore equipment to normal operation. These procedures are fairly

expensive; because of the specialized nature of equipment, problems become more difficult to diagnose and resolve, and spare-part inventories can be extensive.

The main advantages of product layouts are:

1. A high rate of output.
2. Low unit cost due to high volume; the high cost of specialized equipment is spread over many units.
3. Labor specialization reduces training costs and time, and results in a wide span of supervision.
4. Low material—handling cost per unit; material handling is simplified because units follow the same sequence of operations.
5. A high utilization of labor and equipment.
6. Routing and scheduling are established in the initial design of the system; they do not require much attention once the system is operating.
7. Accounting, purchasing, and inventory control are fairly routine.

The primary disadvantages of product layouts include:

1. The intensive division of labor usually creates dull, repetitive jobs that provide little opportunity for advancement and may lead to morale problems, and to repetitive stress injuries.
2. Poorly skilled workers may exhibit little interest in maintaining equipment or in the quality of output.
3. The system is fairly inflexible in response to changes in the volume of output or changes in product or process design.
4. The system is highly susceptible to shutdowns caused by equipment breakdowns or excessive absenteeism.
5. Preventive maintenance, the capacity for quick repairs, and spare-parts inventories are necessary expenses.
6. Incentive plans tied to individual output are impractical since they would cause variations among outputs of individual workers, which would adversely affect the smooth flow of work through the system.

U-Shaped Layouts.

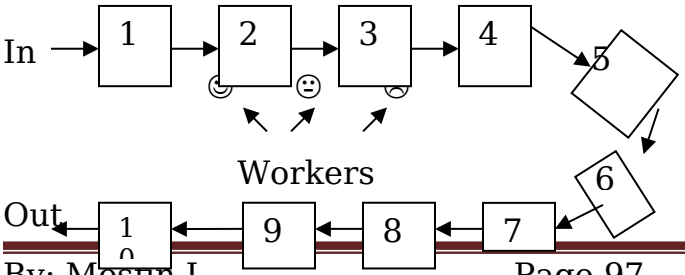


Figure 5-3 A U-shaped production line

Although a straight production line may have intuitive appeal, a U-shaped line (see Figure 5-3) has a number of advantages that make it worthy of consideration. One disadvantage of a long, straight line is that it interferes with cross travel of workers and vehicles. A U-shaped line is more compact; it often requires approximately half the length of a straight production line. In addition, a U-shaped line permits increased communication among workers on the line because workers are clustered, thus facilitating teamwork. Flexibility in work assignments is increased because workers can handle not only adjacent stations but also stations on opposite sides of the line. Moreover, if materials enter the plant at the same point that finished products leave it, a U-shaped line minimizes material handling.

Of course, not all situations lend themselves to U-shaped layouts: on highly automated lines there is less need for teamwork and communication. And entry and exit points may be on opposite sides of the building. Also, operations may need to be separated because of noise or contamination factors.

2. Process Layouts

Process layouts are designed to process items or provide services that involve a variety of processing requirements. The layouts feature departments or other functional groupings in which similar kinds of activities are performed. A manufacturing example of a process layout is the *machine shop,* which has separate departments for milling, grinding, drilling, and so on. Items that require those operations are frequently moved in lots to the departments in a sequence dictated by technical considerations. Different products may present quite different processing requirements and sequences of operations. Consequently, variable-path material-handling equipment (forklift trucks, jeeps, tote boxes) is needed to handle the variety of routes and items. The use of *general-purpose machines* provides the flexibility necessary to handle a wide range of processing requirements. Workers who operate the equipment are usually skilled or semiskilled. Figure 5-4 illustrates the departmental arrangement typical of a process layout..

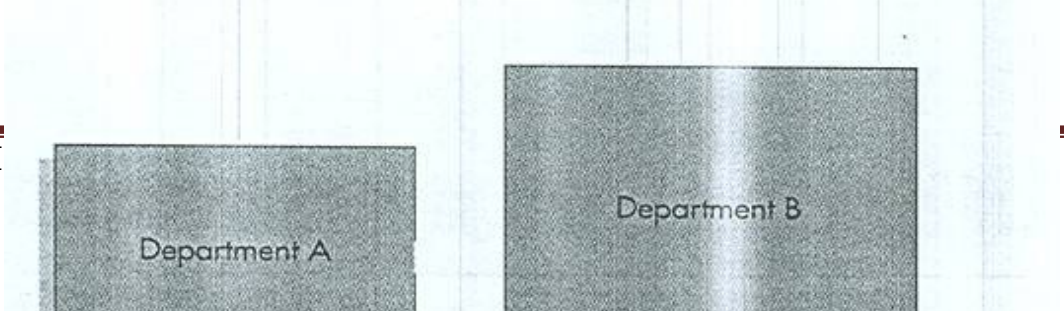


Figure 5-4 A typical process layout with departmental work centers

Process layouts are quite common in service environments. Examples include hospitals, colleges and universities, banks, auto repair shops, airlines, and public libraries. For instance, hospitals have departments or other units that specifically handle surgery, maternity, pediatrics, psychiatric, emergency, and geriatric care. And universities have separate schools or departments that concentrate on one area of study such as business, engineering, science, or math.

Because equipment in a process layout is arranged by type rather than by processing sequence, the system is much less vulnerable to shutdown caused by mechanical failure or absenteeism. In manufacturing systems especially, idle equipment is usually available to replace machines that are temporarily out of service. Moreover, because items are often processed in lots, there is considerably less interdependence between successive operations than with a product layout. Maintenance costs tend to be lower because the equipment is less specialized than that of product layouts, and the grouping of machinery permits repair personnel to become skilled in handling that type of equipment. Machine similarity reduces the necessary investment in spare parts. On the negative side, routing and scheduling must be done on a continual basis to accommodate the variety of processing demands typically imposed on these systems. Material handling is

inefficient, and unit handling costs are generally much higher than in product layouts. In-process inventories can be substantial due to batch processing. Furthermore, it is not uncommon for such systems to have equipment utilization rates under 50 percent because of routing and scheduling complexities related to the variety of processing demands being handled.

In sum, process layouts have both *advantages* and *disadvantages.* The *advantages of process layouts* include:

1. Systems can handle a variety of processing requirements.
2. Systems are not particularly vulnerable to equipment failures.
3. General-purpose equipment is often less costly than the specialized equipment used in product layouts and is easier and less costly to maintain.
4. It is possible to use individual incentive systems.

The *disadvantages of process layouts* include:

1. In-process inventory costs can be high if batch processing is used in manufacturing systems.
2. Routing and scheduling pose continual challenges.
3. Equipment utilization rates are low.
4. Material handling is slow and inefficient, and more costly per unit than in product layouts.
5. Job complexities often reduce the span of supervision and result in higher supervisory costs than with product layouts.
6. Special attention necessary for each product or customer (e.g., routing, scheduling, machine setups) and low volumes result in higher unit costs than with product layouts.
7. Accounting, inventory control, and purchasing are much more involved than with product layouts.

3. Fixed-Position Layouts

In fixed-position layouts, the item being worked on remains stationary, and workers, materials, and equipment are moved about as needed. This means the product remains at one location.

This is in marked contrast to product and process layouts. Almost always, the nature of the product dictates this kind of arrangement: weight, size, bulk, or some other factor makes it undesirable or extremely difficult to move the product. Fixed-position layouts are used in large construction projects (buildings, power plants, and dams), shipbuilding, and production

of large aircraft and space mission rockets. In those instances, attention is focused on timing of material and equipment deliveries so as not to clog up the work site and to avoid having to relocate materials and equipment around the work site. Lack of storage space can present significant problems, for example, at construction sites in crowded urban locations. Because of the many diverse activities carried out on large projects and because of the wide range of skills required, special efforts are needed to coordinate the activities, and the span of control can be quite narrow. For these reasons, the administrative burden is often much higher than it would be under either of the other layout types. Material handling may or may not be a factor: in many cases, there is no tangible product involved (e.g., designing a computerized inventory system). When goods and materials are involved, material handling often resembles process-type, variable-path, general purpose equipment. Projects might require use of earth-moving equipment and trucks to haul materials to, from, and around the work site, for example.

Fixed-position layouts are widely used for farming, firefighting, road building, home building, remodeling and repair, and drilling for oil. In each case, compelling reasons bring workers, materials, and equipment to the "product's" location instead of the other way around.

4. Combination Layouts

The three basic layout types are ideal models, which may be altered to satisfy the needs of a particular situation. It is not hard to find layouts that represent some combination of these pure types. For instance, supermarket layouts are essentially process layouts, and yet we find most use fixed-path material-handling devices such as roller-type conveyors both in the stockroom, and belt-type conveyors at the cash registers. Hospitals also use the basic process arrangement, although frequently patient care involves more of a fixed-position approach, in which nurses, doctors, medicines, and special equipment are brought to the patient. By the same token, faulty parts made in a product layout may require off-line reworking, which involves customized processing. Moreover, conveyors are frequently observed in both farming and construction activities.

Process layouts and product layouts represent two ends of a continuum from small batches to continuous production. Process layouts are conducive to the production of a wider range of products or services than product layouts, which is desirable from a customer standpoint where customized products are often in demand. However, process layouts tend to be less

efficient and have higher unit production costs than product layouts. Some manufacturers are moving away from process layouts in an effort to capture some of the benefits of product layouts. Ideally, a system is flexible and yet efficient, with low unit production costs. Cellular manufacturing, group technology, and flexible manufacturing systems represent efforts to move toward this ideal.

Product and process layouts compared

	Product Layout	**Process Layout**
Description	A sequential arrangement of personnel and/or equipment designed to provide standardized processing.	A functional arrangement of personnel and/or equipment designed to handle a variety of processing requirements.
Focus of layout	Balance operations to avoid bottlenecks, and attain a smooth flow of work.	Arrange equipment or departments to minimize transportation costs and /or congestion.
Processing Examples of:: goods services Product or service variety	Repetitive or continuous. Automobiles, video tapes. Car wash, cafeteria line. Low	Job shop or batch. Furniture, baked goods. Auto repair, health care. Moderate to high.
Typical processing worker skill levels	Low, semiskilled.	Semiskilled to highly skilled.
Flexibility	Very low.	Moderate to high.
Volume	High.	Low to moderate.
Work-in-process inventory levels	Low.	High.
Material handling	Fixed path (e.g., conveyors).	Variable path (e.g., forklifts).
Primary approach to equipment maintenance	Preventive.	As needed.
Benefits	Low cost per unit, high productivity.	Can handle a variety of processing requirements.

5. Cellular Layouts

Cellular Manufacturing

Cellular manufacturing is a type of layout in which machines are grouped into what is referred to as a *cell.* Groupings are determined by the operations needed to perform work for a set of similar items, or *part families,* which require similar processing. The cells become, in effect, miniature versions of product layouts. The cells may have no conveyorized movement of parts between machines, or may have a flow line connected by a conveyor (automatic transfer

Figure 5-5 Comparison of functional and cellular manufacturing layout

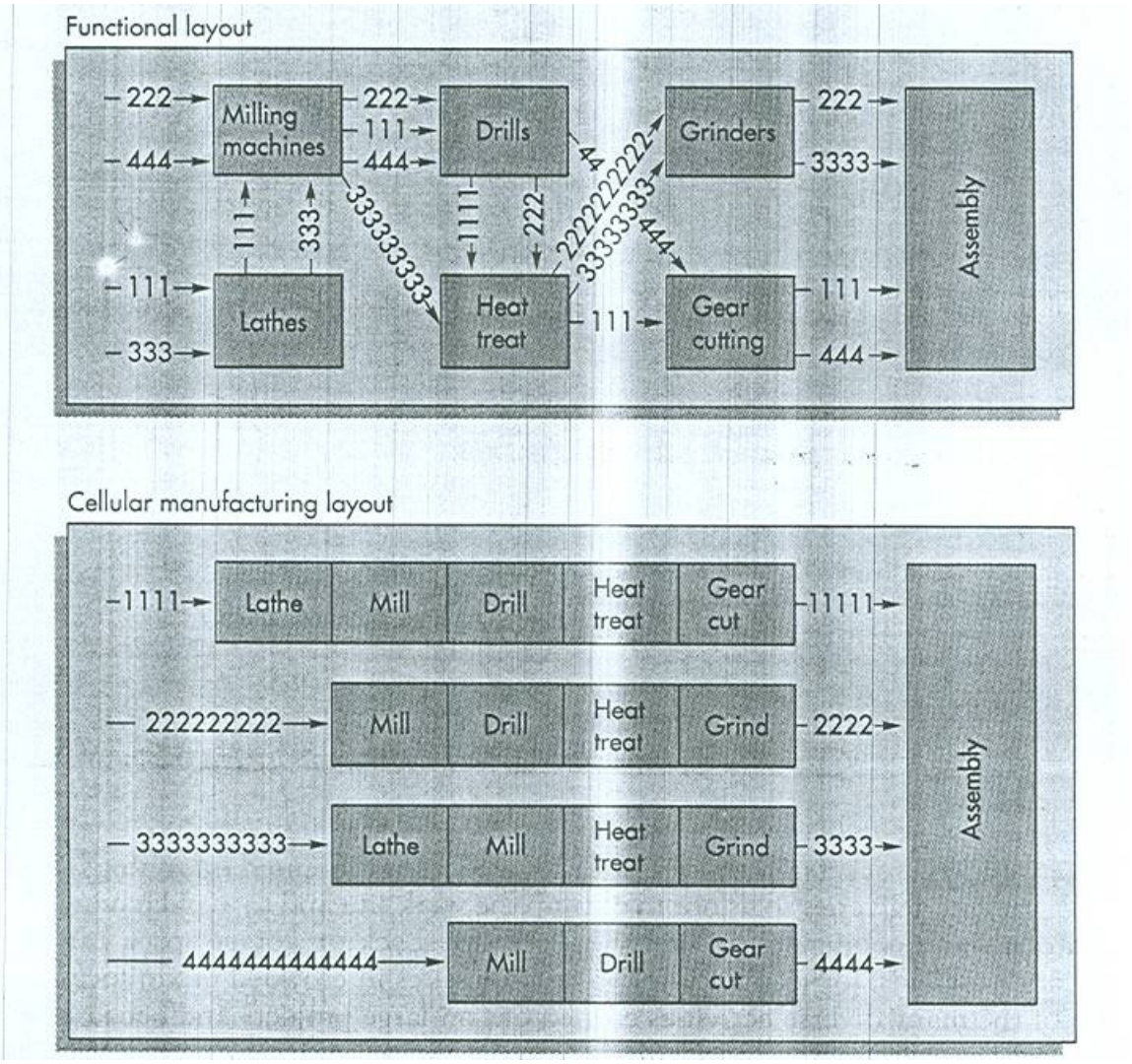


Figure 5-5 compares a typical functional (process) layout and a cellular manufacturing layout.

Observe that in the cellular layout, machines are arranged to handle all of the operations necessary for a group (family) of similar parts. Thus, all parts follow the same route although minor variations (e.g., skipping an operation) are possible. In contrast, the functional layout involves multiple paths for parts. Moreover, there is little effort or need to identify part families; the distinction in the figure is merely for purposes of comparison.

There are numerous benefits of cellular manufacturing. These relate to the grouping of equipment and include faster processing time, less material handling, less work-in process inventory, and reduced setup time.

Group Technology

Effective cellular manufacturing must have groups of identified items with similar processing characteristics. The grouping process is known as group technology and involves identifying items with similarities in either *design characteristics* or *manufacturing characteristics,* and grouping them into part families. Design characteristics include size, shape, and function; manufacturing or processing characteristics involve the type and sequence of operations required. In many cases, design and processing characteristics are correlated, although this is not always the case.
Conversion to cellular manufacturing can involve costly realignment of equipment. Consequently, a manager must weigh the benefits of a switch from a process layout to a cellular one against the cost of moving equipment as well as the cost and time needed for grouping parts.

6. Other Service Layouts

In addition to the layouts already described, there are other layouts found in service environments, such as warehouse, retail, and office layouts.

A. Warehouse and Storage Layouts

The design of storage facilities presents a different set of factors than the design of factory layouts. Frequency of order is an important consideration; items that are ordered frequently should be placed near the entrance to the facility, and those ordered infrequently should be placed towards the rear of the facility. Any correlations between items are also significant (i.e., item A is usually ordered with item B), suggesting that placing those two items close together would reduce the cost and time of *picking* (retrieving) those items. Other considerations include the number and widths of aisles, the height of storage racks, rail and/or truck loading and unloading, and the need to periodically make a physical count of stored items.

B. Retail Layouts

The objectives that guide design of manufacturing layouts often pertain to cost minimization and product flow. However, with retail layouts such as department stores, supermarkets, and specialty stores, designers must take into account the presence of customers, and the opportunity to influence sales volume and customer attitudes through carefully designed layouts. Traffic patterns and traffic flow are important factors to consider.

C. Office Layouts

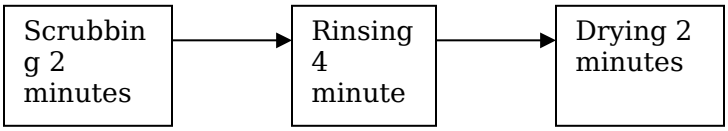
Office layouts are undergoing transformations as the flow of paperwork is replaced with the increasing use of electronic communications. That means there is less need to place office workers in a layout that optimizes the physical transfer of information or paper work. Another trend is to project an image of openness, and office walls are giving way to low-rise partitions and glass walls.

3.4.2.3. Designing Product Layouts: Line Balancing

The process of deciding how to assign tasks to workstations is referred to as line balancing. The goal of line balancing is to obtain task groupings that represent approximately equal time requirements. This minimizes the idle time along the line and results in a high utilization of labor and equipment. Idle time occurs if task times are not equal among workstations; some stations are capable of producing at higher rates than others. These "fast" stations will experience periodic waits for the output from slower stations or else be forced into idleness to avoid buildups of work between stations. Unbalanced lines are undesirable in terms of inefficient utilization of labor and equipment and because they may create morale problems at the slower stations for workers who must work continuously.

Lines that are perfectly balanced will have a smooth flow of work as activities along the line are synchronized to achieve maximum utilization of labor and equipment. The major obstacle to attaining a perfectly balanced line is the difficulty of forming task bundles that have the same duration. One cause of this is that it may not be feasible to combine certain activities into the same bundle, either because of differences in equipment requirements or because the activities are not compatible (e.g., risk of contamination of paint from sanding). Another cause of difficulty is that differences among elemental task lengths cannot always be overcome by grouping tasks. A third cause of an inability to perfectly balance a line is that a required technological sequence may prohibit otherwise desirable

task combinations. Consider a series of three operations that have durations of two minutes, four minutes, and two minutes, as shown in the following diagram. Ideally, the first and third operations could be combined at one workstation and have a total time equal to that of the second operation. However, it may not be possible to combine the first and third operations. In the case of an automatic car wash, scrubbing and drying operations could not realistically be combined at the same workstation due to the need to rinse cars between the two operations.

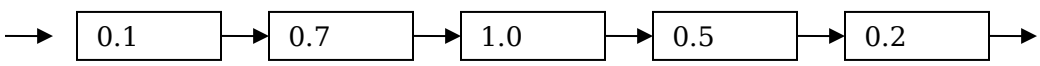


Line balancing involves assigning tasks to workstations. Usually, each workstation has one worker who handles all of the tasks at that station, although an option is to have several workers at a single workstation. For purposes of illustration, however, all of the examples and problems in this chapter have workstations with one worker. A manager could decide to use anywhere from one to five workstations to handle five tasks. With one workstation, all tasks would be done at that station; with five stations, one task would be assigned to each station. If two, three, or four workstations are used, some or all of the stations will have multiple tasks assigned to them. How does a manager decide how many stations to use?

The primary determinant is what the line's cycle time will be. The cycle time is the *maximum* time allowed at each workstation to perform assigned tasks before the work moves on. The cycle time also establishes the output rate of a line. For instance, if the cycle time is two minutes, units will come off the end of the line at the rate of one every two minutes.

We can gain some insight into task groupings and cycle time by considering a simple example.

Suppose that the work required to fabricate a certain product can be divided up into five elemental tasks, with the task times and precedence relationships as shown in the following diagram.



The task times govern the range of possible cycle times. The *minimum* cycle

time is equal to the *longest* task time (1.0 minute), and the *maximum* cycle time is equal to the sum of the task times (0.1 + 0.7 + 1.0 + 0.5 + 0.2 = 2.5 minutes). The minimum cycle time would apply if there were five workstations. The maximum cycle time would apply if all tasks were performed at a single workstation. The minimum and maximum cycle times are important because they establish the potential range of output for the line, which we can compute using the following formula:

$$\text{Output capacity} = \frac{OT}{CT}$$

Where, ***OT = Operating time per day***
CT = Cycle time
Assume that the line will operate for eight hours per day (480 minutes). With a cycle time of 1.0 minute, output would be

$$\frac{\text{480 minutes per day}}{\text{1.0 minute per unit}} = \text{480 units per day}$$

With a cycle time of 2.5 minutes, the output would be

$$\frac{\text{480 minutes per day}}{\text{2.5 minute per unit}} = \text{192 units per day}$$

Assuming that no parallel activities are to be employed (e.g., two lines), the output selected for the line must fall in the range of 192 units per day to 480 units per day.
As a general rule, the cycle time is determined by the desired output; that is, a desired output level is selected, and the cycle time is computed. If the cycle time does not fall between the maximum and minimum bounds, the desired output rate must be revised. We can compute the cycle time using this formula:

$$CT = \frac{OT}{D}$$

Where
D = Desired output rate
For example, suppose that the desired output rate is 480 units. Using the above formula the necessary cycle time is

$$\frac{\text{480 minutes per day}}{\text{480 units per day}} = \text{1.0 minute per unit}$$

The number of workstations that will be needed is a function of both the

desired output rate and our ability to combine elemental tasks into workstations. We can determine the *theoretical minimum* number of stations necessary to provide a specified rate of output as follows:

$$N_{min} = \frac{\Sigma_t}{C} \quad \text{or} \quad \frac{T}{D}$$

Where N_{min} = Theoretical minimum number of stations

D = Desired output rate

Σ_t = Sum of task times

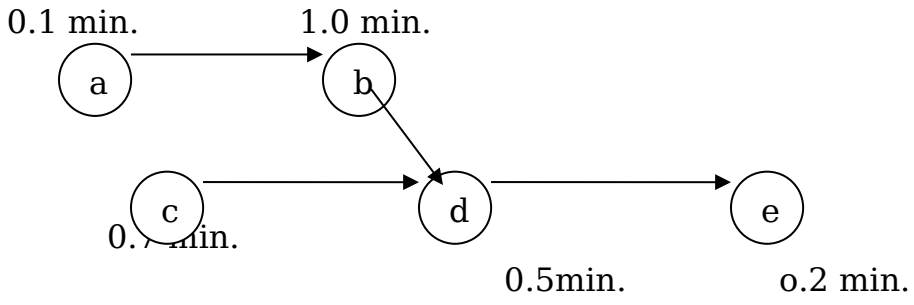
Suppose the desired rate of output is the maximum of 480 units per day. (This will require a cycle time of 1.0 minute.) The minimum number of stations required to achieve this goal is:

$$N_{min} = \frac{\text{2.5 minutes per unit}}{\text{1 minute per unit per station}} = 2.5 \text{ stations}$$

Because 2.5 stations is not feasible, it is necessary to *round up* (because 2.5 is the minimum) to three stations. Thus, the actual number of stations used will equal or exceed three, depending on how successfully the tasks can be grouped into work bundles.

A very useful tool in line balancing is a precedence diagram. Figure 5-6 illustrates a simple precedence diagram. It visually portrays the tasks that are to be performed along with the *sequential* requirements, that is, the *order* in which tasks must be performed. The diagram is read from left to right, so the initial task(s) are on the left and the final task is on the right. In terms of precedence requirements, we can see from the diagram, for example, that the only requirement to begin task b is that task a must be finished. However, in order to begin task d, tasks b and c must *both* be finished. Note that the elemental tasks are the same ones that we have been using.

Figure 5-6
A simple precedence diagram



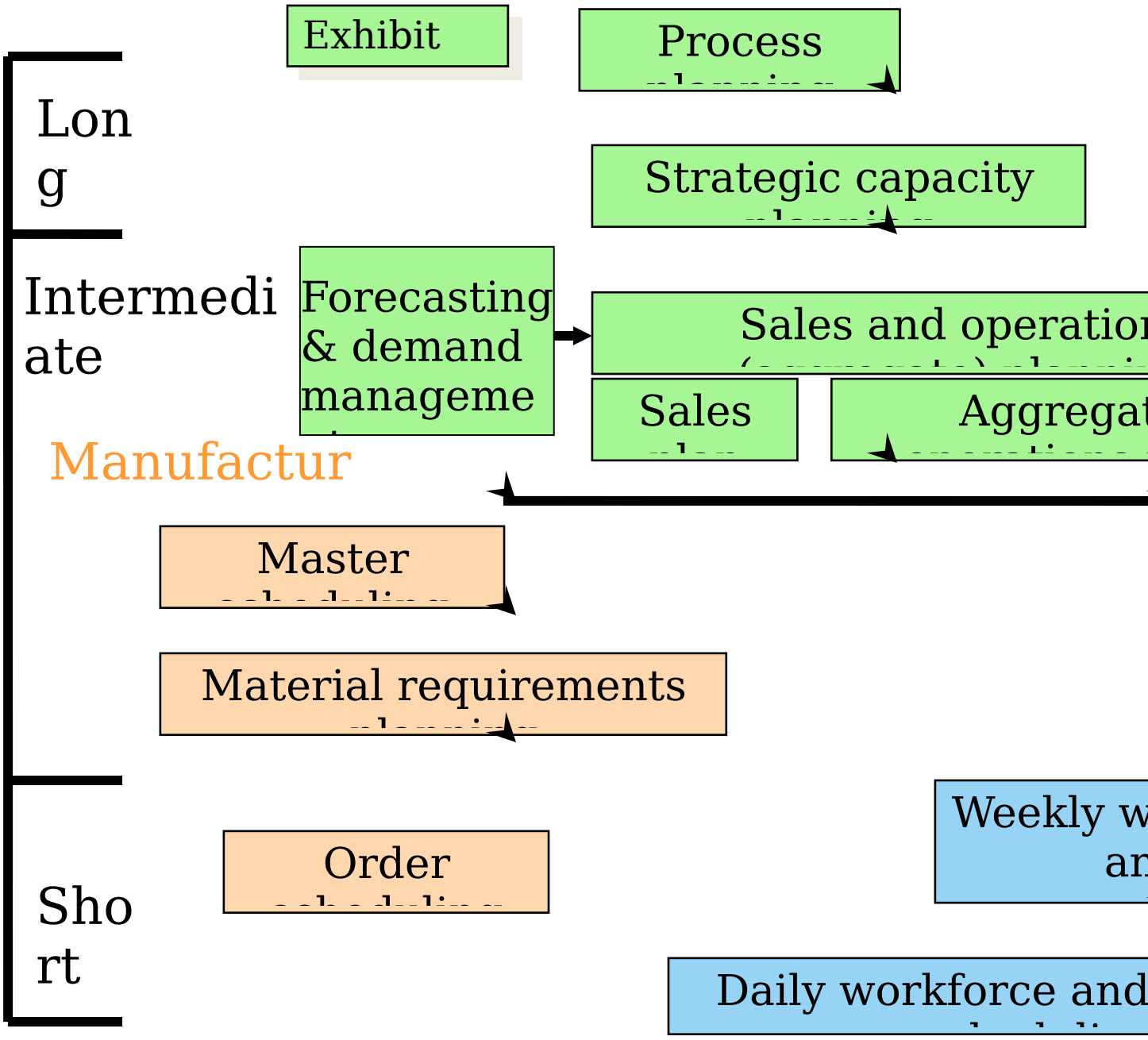
CHAPTER FOUR

OPERATION PLANNING AND CONTROL

4.1 Aggregate Sales and production planning

It is the types of plan w/c translates annual and quarterly business plan into broad labor and out put plans for the intermediate (3- 18 months).
Its objective is to minimize the cost of resources required to meet demand over that period.
Sales and operation planning is a process to help give better customer service, lower inventory, shorter customer lead-times, stabilize production rates, and give top management handle on the business.

Fig. 4.1Overview of major production planning



Sales and Operations Planning Activities

1. Long-range planning
   - Greater than one year planning horizon
   - Usually performed in annual increments
2. Medium-range planning
   - Six to eighteen months
   - Usually with weekly, monthly or quarterly increments

3. Short-range planning
    - One day to less than six months
    - Usually with weekly or daily increments

The Aggregate Operations Plan

Main purpose:

- Specify the optimal combination of production rate (units completed per unit of time)
- **Workforce level (number of workers needed for production)**
  prodn.= PR × WF
- **inventory on hand (unused inventory carried from previous period)**

Product group or broad category (Aggregation)

This planning is done over an intermediate-range planning period of 3 to18 months

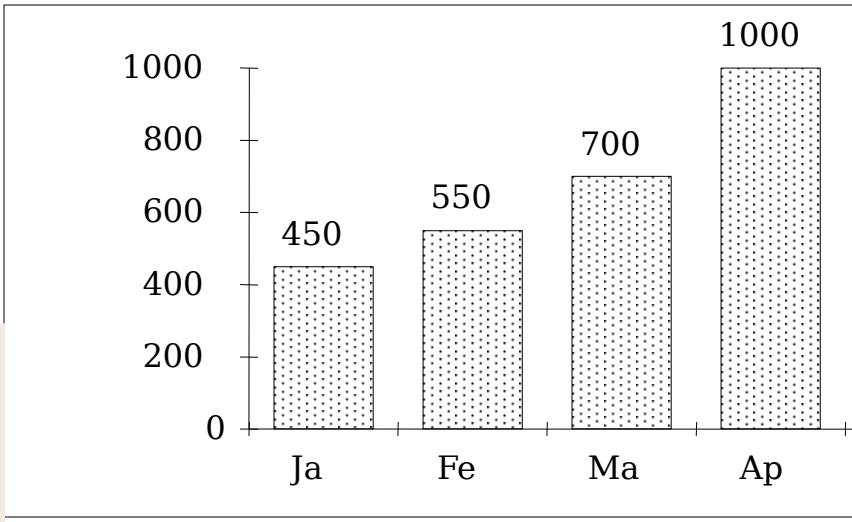
Balancing Aggregate Demand and Aggregate Production Capacity

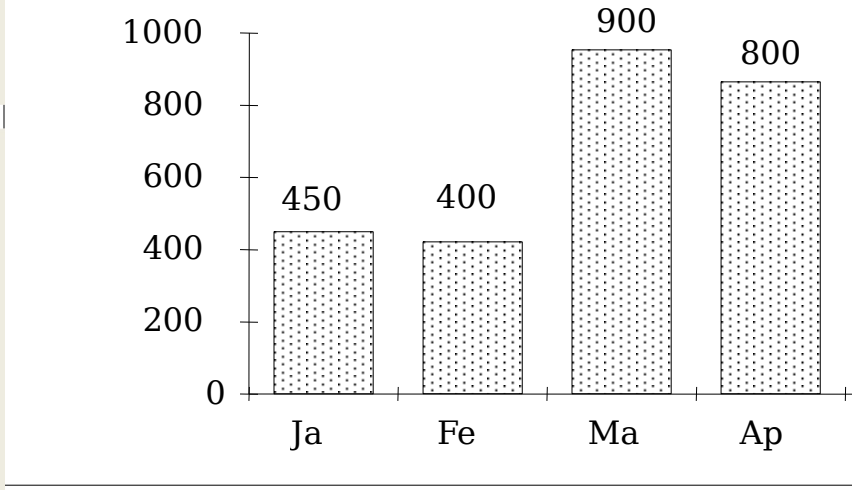
Balancing Aggregate Demand and Aggregate Production Capa

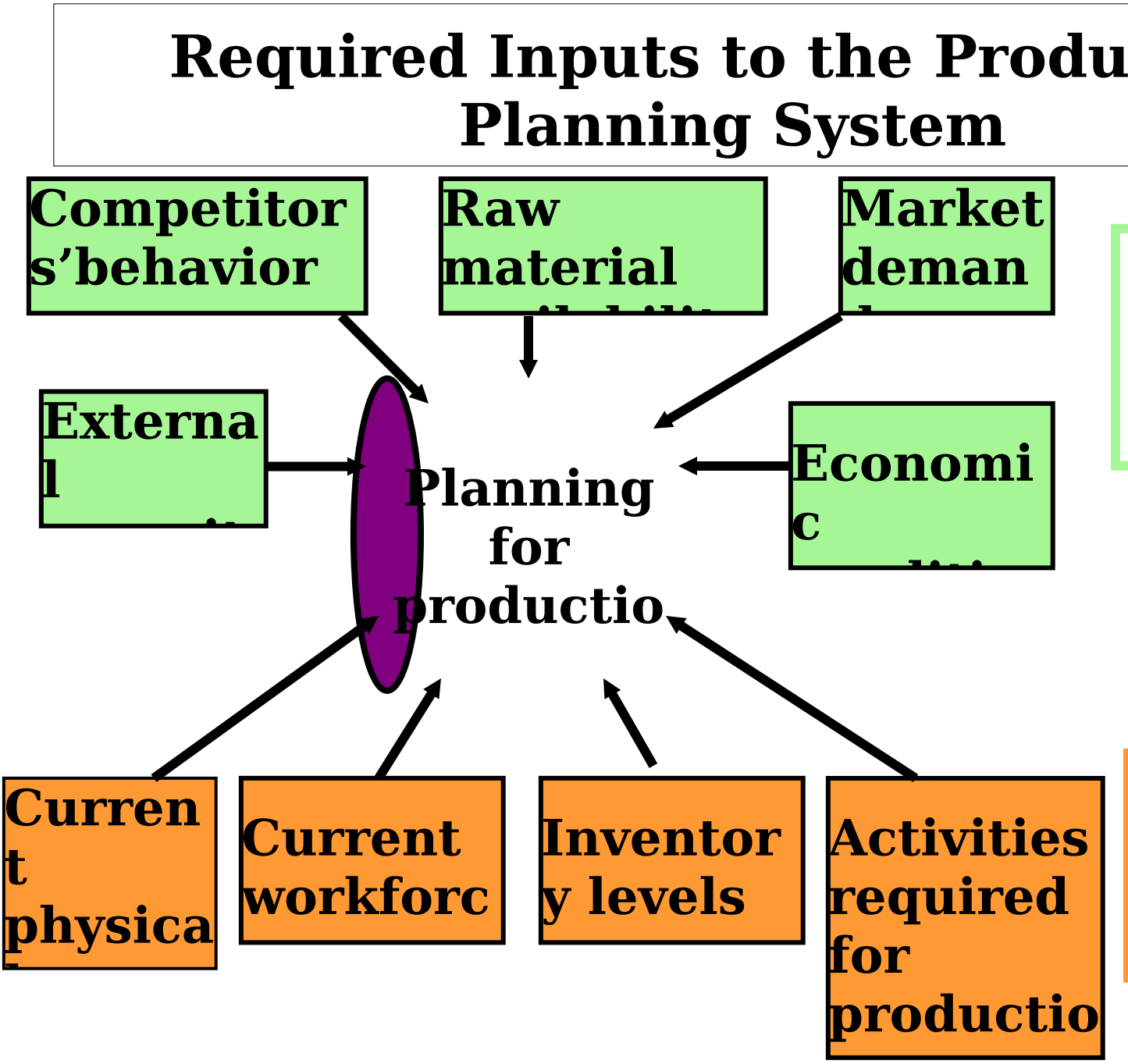
Suppose the figure to the right represents forecast demand in units

Now suppose this lower figure represents the aggregate capacity of the company to

What we want to do is balance out the production rate, workforce levels, and inventory to make these figures







Production planning Strategies
There are essentially three production planning strategies for meeting demand

- Chase: match the production rate to the order rate by hiring and layoff employees as the order rate varies.
- Level : maintain a stable workforce working at a constant output rate

- Stable work force- variable work hours: vary out put by varying the number of hours worked through flexible work schedule or over time

Aggregate Planning relevant Costs

1. Basic production costs; these are the fixed and variable costs incurred in producing a given product type in a given time period. Includes direct material, direct labor and overhead cost.
2. Cost associated with change in production rate: includes costs associated with hiring, firing and training personnel.
3. Inventory holding costs: include costs of capital tied up in inventory and other costs like storage, insurance, taxes spoilage obsolescence.
4. Backordering costs : include costs of expediting, loss of customer goodwill, and loss of sales revenue resulting from back ordering

Examples:
Suppose we wish to setup the production plan for ABC Company for the next six months we are given the following demand and Cot data.

Demand/mo	Jan	Feb	Mar	Apr	May	Jun
	4500	5500	7000	10000	8000	6000

Materials	$5/unit
Holding costs	$1/unit per mo.
Marginal cost of stockout	$1.25/unit per mo.
Hiring and training cost	$200/worker
Layoff costs	$250/worker
Labor hours required	.15 hrs/unit
Straight time labor cost	$8/hour
Beginning inventory	250 units
Productive hours/worker/day	7.25
Paid straight hrs/day	8

Cut-and-T
Straight

**Given the dema
are the aggrega
dollars/worker?**

Demand/mo	Ja
4500	5

Productive hou
Paid straight h

22x8hrsx$8=$
1408

Hrs/worker/mo	
Units/worker	1
$/worker	$

Chase Strategy (Hiring & Firing to meet demand)

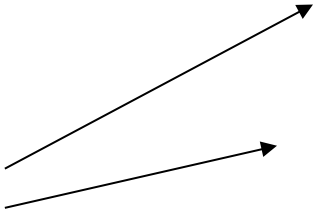
	Jan
Days/mo	22
Hrs/worker/mo	159.5
Units/worker	1,063.33
$/worker	$1,408
	Jan
Demand	4,500
Beg. inv.	250
Net req.	4,250
Req. workers	3.997
Hired	

for

Let's assume our current workforce is 7 workers.
First, calculate net requirements

Production or 4500-250=4250 units

- Then, calculate number of workers needed to produce the net requirements,



or 4250/1063.33=3.997 or 4 workers

- Finally, determine the number of workers to hire/fire. In this case we only need 4 workers; we have 7, so 3 can be fired.

Below are the complete calculations for the remaining months in the six month planning horizon

	Jan	Feb	Mar	Apr	May	Jun
Days/mo	22	19	21	21	22	20
Hrs/worker/mo	159.5	137.75	152.25	152.25	159.5	145
Units/worker	1,063	918	1,015	1,015	1,063	967
$/worker	$1,408	1,216	1,344	1,344	1,408	1,280
	Jan	Feb	Mar	Apr	May	Jun
Demand	4,500	5,500	7,000	10,000	8,000	6,000
Beg. inv.	250					
Net req.	4,250	5,500	7,000	10,000	8,000	6,000
Req. workers	3.997	5.989	6.897	9.852	7.524	6.207
Hired		2	1	3		
Fired	3				2	1
Workforce	4	6	7	10	8	7
Ending inventory	0	0	0	0	0	0

Below are the complete calculations for the remaining months in the six month planning horizon with the other costs included

	Jan	Feb	Mar	Apr	May	Jun	
Days/mo	22	19	21	21	22	20	
Hrs/worker/mo	159.5	137.75	152.25	152.25	159.5	145	
Units/worker	1063.33	918.33	1015	1015	1063.33	966.67	
$/worker	$1,408	1,216	1,344	1,344	1,408	1,280	
	Jan	Feb	Mar	Apr	May	Jun	
Demand	4,500	5,500	7,000	10,000	8,000	6,000	
Beg. inv.	250						
Net req.	4,250	5,500	7,000	10,000	8,000	6,000	
Req. workers	3.997	5.989	6.897	9.852	7.524	6.207	
Hired		2	1	3			
Fired	3				2	1	
Workforce	4	6	7	10	8	7	
Ending inventory	0	0	0	0	0	0	

	Jan
Demand	4,500
Beg. inv.	250
Net req.	4,250
Workers	6
Production	6,380
Ending inventory	2,130
Surplus	2,130
Shortage	

Below are the complete calculations for the remaining months in the six month planning horizon

	Jan	Feb	Mar	Apr	May	Jun
Demand	4,500	5,500	7,000	10,000	8,000	6,000
Beg. inv.	250	2,130	2,140	1,230	-2,680	-1,300
Net req.	4,250	3,370	4,860	8,770	10,680	7,300
Workers	6	6	6	6	6	6
Production	6,380	5,510	6,090	6,090	6,380	5,800
Ending inventory	2,130	2,140	1,230	-2,680	-1,300	-1,500
Surplus	2,130	2,140	1,230			
Shortage				2,680	1,300	1,500

Note, if we recalculate this sheet with 7 workers we would have a surplus
Below are the complete calculations for the remaining months in the six month planning horizon with the other costs included

Note, total c

this strategy

Chase at $26

Jan	Feb	Mar	Apr	May	Jun		
4,500	5,500	7,000	10,000	8,000	6,000		
250	2,130	10	-910	-3,910	-1,620		
4,250	3,370	4,860	8,770	10,680	7,300		
6	6	6	6	6	6		
6,380	5,510	6,090	6,090	6,380	5,800		
2,130	2,140	1,230	-2,680	-1,300	-1,500		
2,130	2,140	1,230					
			2,680	1,300	1,500		
Jan	Feb	Mar	Apr	May	Jun		
$8,448	$7,296	$8,064	$8,064	$8,448	$7,680	$48,000.00	
31,900	27,550	30,450	30,450	31,900	29,000	181,250.00	
2,130	2,140	1,230				5,500.00	
			3,350	1,625	1,875	6,850.00	
						$241,600.00	

Labor
Material
Storage
Stockout

4.2 Operations Scheduling

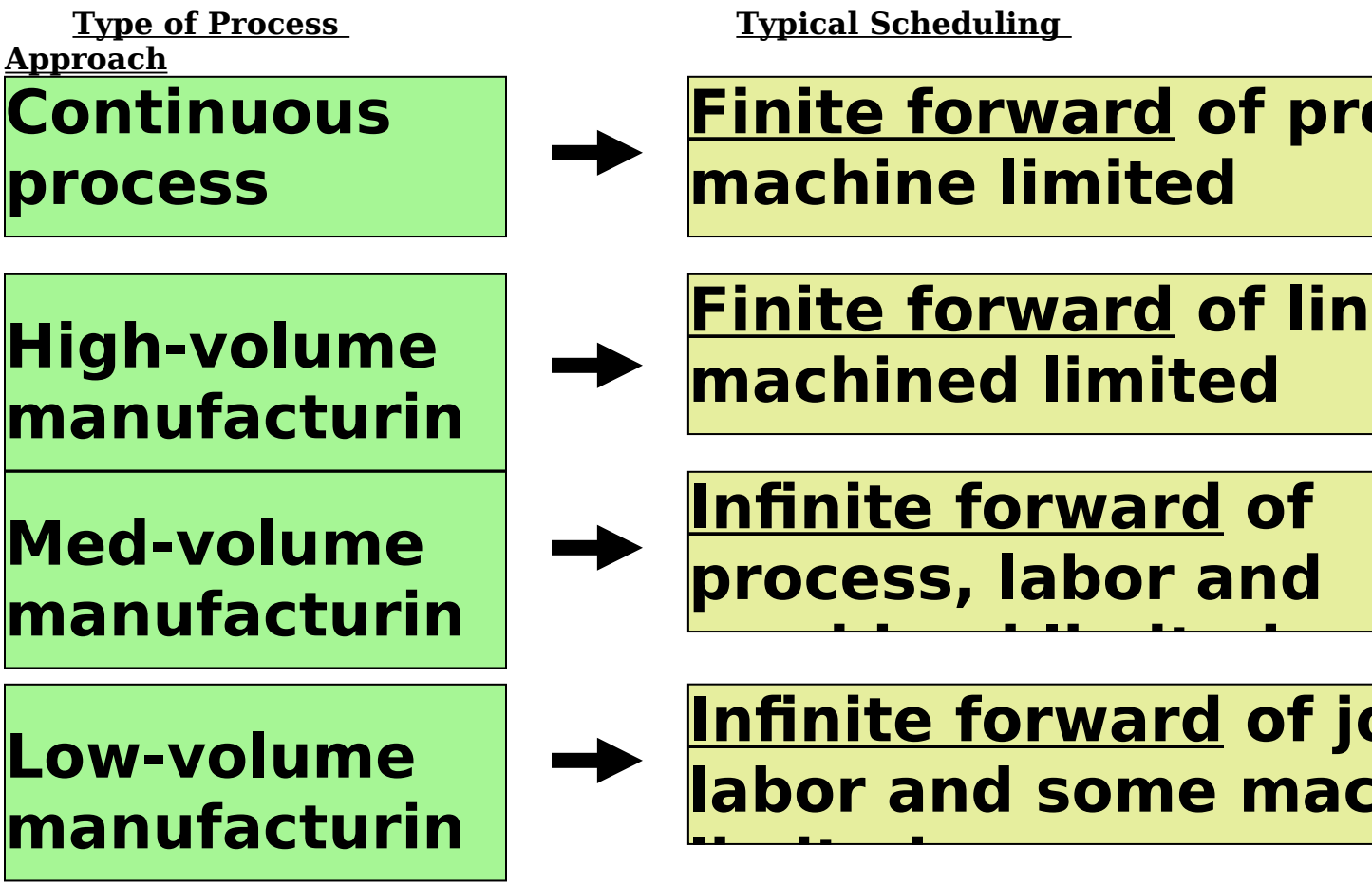
A work center is an area in a business in which productive resources are organized and work is completed

Can be a single machine, a group of machines, or an area where a particular type of work is done

Capacity and Scheduling

- Infinite loading (Example: MRP)
- Finite loading
- Forward scheduling
- Backward scheduling (Example: MRP)
-

Types of Manufacturing Scheduling Processes and Scheduling Approaches



Typical Scheduling and Control Functions

- Allocating orders, equipment, and personnel
- Determining the sequence of order performance
- Initiating performance of the scheduled work
- Shop-floor control

Work-Center Scheduling Objectives

- Meet due dates
- Minimize lead time
- Minimize setup time or cost
- Minimize work-in-process inventory
- Maximize machine and labor utilization

Priority Rules for Job sequencing (scheduling n jobs on one machine)

1. First-come, first-served **(FCFS)**
2. Shortest operating time **(SOT**)
3. Earliest due date first **(D Date)**
4. Slack time remaining (**STR**) first
5. Slack time remaining per operation **(STR/OP**)
6. Critical ratio **(CR)** $$CR = \frac{(\text{Due date-Current date})}{\text{Number of days remaining}}$$
7. Last come, first served **(LCFS)**
8. Random order or whim

Example of Job Sequencin
Shortest Operating Time

Suppose you have the four jobs to the right arrive for processing on

Jobs (in order of arrival)	Processing Time (days
A	4
B	7
C	3
D	1

What is the SOT schedule?

Do all the jobs ge

Answer: Shortest Operating Time Schedule

Jobs (in order of arrival)	Processing Time (days)	Due Date (days hence)	Flow Time (days)
D	1	4	1
C	3	6	4
A	4	5	8
B	7	10	15

N ar ge la

Example of Job Sequenci First-Come First-Serve

Suppose you have the four jobs to the right arrive for processing on

Jobs (in order of arrival)	Processing Time (days)
A	4
B	7
C	3
D	1

What is the FCFS schedule?

Do all the jobs ge

N a g

Answer: FCFS

Jobs (in order of arrival)	Processing Time (days)	Due Date (days hence)	Flow Time (days)
A	4	5	4
B	7	10	11
C	3	6	14
D	1	4	15

TFT = 4+11+14+15= 44 days
MFT = TFT/n = 44/4 = 11days

delay time = 4+11+14 = 29
MDT = 29/4 = 7.25

Example of Job Sequencin
Earliest Due Date First

Suppose you have the four jobs to the right arrive for processing on

Jobs (in order of arrival)	Processing Time (days)
A	4
B	7
C	3
D	1

What is the earliest due date first schedule?

Do all the jobs get

Answer: Earliest Due Date

Jobs (in order of arrival)	Processing Time (days)	Due Date (days hence)	Flow Time (days)
D	1	4	1
A	4	5	5
C	3	6	8
B	7	10	15

N a g la

Example of Job Sequencing: C
Ratio Method

Suppose you have the four jobs to the right arrive for processing on

Jobs (in order of arrival)	Processing Time (days)
A	4
B	7
C	3
D	1

What is the CR schedule?

Do all the jobs ge

In order to do this schedule the CR's have be calculated for each job. If we let today be Day 1 and allow a total of 15 days to do the work. The resulting CR's and order schedule are:
CR(A)=(5-4)/15=0.06 (Do this job last)
CR(B)=(10-7)/15=0.20 (Do this job first, tied with C and D)
CR(C)=(6-3)/15=0.20 (Do this job first, tied with B

N th th ti fi tw

Example of Job Sequenci
Last-Come First-Serve

Suppose you have the four jobs to the right arrive for processing on

Jobs (in order of arrival)	Processing Time (days)
A	4
B	7
C	3
D	1

What is the LCFS schedule?

Do all the jobs get

Answer: Last-Come First-Served Schedule

Jobs (in order of arrival)	Processing Time (days)	Due Date (days hence)	Flow Time (days)
D	1	4	1
C	3	6	4
B	7	10	11
A	4	5	15

N a g la

Scheduling n jobs on two machines

Johnson's rule (method): is to minimize the flow time from the beginning of the first job until the finish of the last.

Johnson's rule consists of the following steps

1. List the operation time for each job on both machines
2. Select the shortest operating time.

3. If the shortest time is for the first machine; do the job first; if it is for the second machine, does the job last. In the case of a tie, do the job on the first machine.
4. Repeat step 2&3 for each remaining jobs until the schedule is complete.

Example of Job Sequenci
Johnson's Rule (Part 1)

Suppose you have the following five job
time requirements in two stages of pro
What is the job sequence using Johnson

Jobs	Time in Hours Stage 1	Stage 2
A	1.50	1.25
B	2.00	3.00
C	2.50	2.00
D	1.00	2.00

Example of Job Sequencing: John
(Part 2)

First, select the job with the smallest time in either stage.

That is Job D with the smallest time in the first stage. Place that job as early as possible in the unfilled job sequence

Jobs	Time in Stage 1	
A	1.50	1.25
B	2.00	3.00
C	2.50	2.00
D	1.00	2.00

Drop D out, select the next smallest time (Job A), and place sequence.

Drop A out, select the next smallest time. There is a t stages for two different jobs. In this case, place the jo smallest time in the first stage as early as possible in

Then place the job with the smallest time in the secon late as possible in the unfilled sequence.

Job Sequence	1	2	3	4
Job Assigned	D	B	C	A

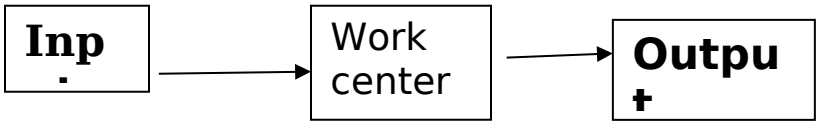
Shop-Floor Control:

Major Functions

1. Assigning priority of each shop order
2. Maintaining work-in-process quantity information
3. Conveying shop-order status information to the office
4. Providing actual output data for capacity control purposes

5. Providing quantity by location by shop order for WIP inventory and accounting purposes
6. Providing measurement of efficiency, utilization, and productivity of manpower and machines

Input/output Control



- Planned input should never exceed planned output
- Focuses attention on bottleneck work centers

Principles of Work Center Scheduling

1. There is a direct equivalence between work flow and cash flow
2. The effectiveness of any job shop should be measured by speed of flow through the shop
3. Schedule jobs as a string, with process steps back-to-back
4. A job once started should not be interrupted
5. Speed of flow is most efficiently achieved by focusing on bottleneck work centers and jobs
6. Reschedule every day
7. Obtain feedback each day on jobs that are not completed at each work center
8. Match work center input information to what the worker can actually do
9. When seeking improvement in output, look for incompatibility between engineering design and process execution
10. Certainty of standards, routings, and so forth is not possible in a job shop, but always work towards achieving it

Personnel Scheduling in Services

- ✓ Scheduling consecutive days off
- ✓ Scheduling daily work times
- ✓ Scheduling hourly work times

CHAPTER 5

QUALITY MANAGEMENT AND CONTROL

5.1. MEANING AND NATURE OF QUALITY

Introduction

High-quality products are reliable, dependable, and satisfying, they do the job they were designed for and meet customer requirements. Why do managers seek to control and improve the quality of their organization's products? There are two reasons: First, customers usually prefer a higher-quality product to a lower-quality product. So an organization that is able to provide, for the same price, a product of higher quality than a competitor's product is serving its customers better-it is being more responsible to its customers.

The second reason for trying to boost product quality is that higher product can increase efficiency and thereby lower operating costs and boost profits. Higher product quality means that less employee time is wasted in making defective products that must be discarded or in providing substandard services, and less time has to be spent in fixing mistakes. This translates into higher employee productivity, which means lower costs. Dear students it is with this in mind that we are trying to study this chapter. Are you satisfied with our country's industry products? Why?

5.1.1 Meaning of Quality

The notion of quality has been defined in different ways by various authors. Garvin divided the definition of quality into five categories-namely: transcendent, product-based, user-based, manufacturing-based, and value-based. Furthermore, he identified a framework of the following eight attributes that may be used to define quality. These are performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. According to Crosby quality is conformance to requirements or specifications and Juran defined quality as fitness for use. Dear readers how do you define quality?

For our purpose quality, generally, can be defined as the quality of a product or service is the fitness of the product or service for meeting or

exceeding its intended use as required by customer. Fitness for use is related to benefits received by the customer and to customer satisfaction. Only the customer, not the producer, can determine it (Schroeder, 2000).

According to Schroeder (2000), customer satisfaction is a relative concept that varies from one customer to another. Also, a customer may be satisfied, with today's products but not satisfied in the future. Hence, from the producer's view point, variation from specifications cannot be tolerated. The producer must specify quality attributes of the product or service as carefully as possible and then strive to meet these specifications while improving the process over time. Whether the resulting product meets the customer's requirements or not will then be judged by the customer.

Determinants of Quality

Question

From your experience, what major factors do you use to evaluate the quality of organization's products (say cloths)?

The degree to which a product or a service successfully satisfies its intended purpose has four primary determinates (Stevenson, 1999).

These are:

1. Design
2. How well it conforms to the design
3. Ease of use
4. Service after delivery

Quality of design is determined before the product is produced. This determination is usually the primary responsibility of a cross-functional product design team, including members from marketing, engineering, operations, and other functions (Schroeder, 2000). Design involves decisions about the specific characteristics of a product or service such as size, shape, and location. Quality of design refers to the intention of designers to include or exclude certain features in a product or service. How automobiles are different in their models of design? They differ in size, appearance, roominess, fuel economy, comfort, and materials used. These differences reflect choices made by designers that determine the quality of design. Design decisions must take into account customer wants, production or service capabilities, safety and liability (both during production and after delivery), costs and other similar considerations.

Quality of Conformance refers to the degree to which goods and services conform to the intent of the designer. This is affected by factors such as the capability of equipment used, the skills, training, and motivation of workers, the extent to which the design lends its self to production, the monitoring process to assess conformance, and the taking of corrective action (eg. through problem solving) when necessary.

Ease of Use

The determination of quality does not stop once the product or service has been sold or delivered. Ease of use and user instructions are important. They increase the chances but do not guarantee, that a product will be used for its intended purposes and in such a way that it will continue to function properly and safely. Much of the same reasoning can be applied to services. Customers, patients, clients, or other users must be clearly informed on what they should or should not do; otherwise, there is a danger that they will take some action that will adversely affect quality. Dear students what will happen if a doctor fails to specify a medication should be taken before meals and not with orange juice? Have you ever faced such mistakes on you? Yes, this is what we mean ease of use.

Service after Delivery

Suppose you bought TV /television/ from your nearby dealer and fail to work after one week. The dealer rejects your request to repair the TV or to get warranty. What will be your reaction? This implies quality represents warranty and repair or replacement of the product after it has been sold. Service represents promptness, competence, and integrity. The customer expects that any problems will be corrected quickly, in a satisfactory manner, and with a high degree of honesty and courtesy.

In general failure to conform to the aforementioned quality determinants may affect the organization in terms of loss of business, product liability, productivity and increased costs.

The Costs of Quality

Any serious attempt to deal with quality issues must take into account the costs associated with quality. These costs can be classified in to four categories:

- ***Internal failure costs*** – costs related to defective products or services before they are delivered to customers. Example, rework costs, problem solving, material and product losses, scrap, and downtime.

- ***External failure costs***- costs related to delivering substandard products or services to customers. Example, returned goods, reworking costs, warranty costs, loss of goodwill, liability claims, and penalties.
- ***Appraisal costs*** – costs related to measuring, evaluating, and auditing materials, parts, products, and services to assess conformance with quality standards. Example inspection equipment, testing, labs, inspectors, and the interruption of production to take samples.
- ***Prevention costs*** – costs related to reducing the potential for quality problems. Example, quality improvement programs, training, monitoring data collection and analysis and design costs. Any way your effort should be targeted toward achieving the optimal quality level-unlike the traditional view-a level that will balance the costs of allowing some poor quality to exist and the cost associated with achieving that degree of quality-the current view of achieving zero defects. In the later view, no matter how high the level of quality, unless it is perfect, the cost of achieving an even higher level will be less than the gain realized by doing so.

Quality Circles and Quality Improvement Teams

In the previous sections we have tried to discuss what the meaning of quality and the quality attributes as well as the associated costs with quality. This section devotes on the contribution of groups or work teams in managing quality.

A quality circle is a typical informal group of people that consists of operators, supervisors, managers, and so on, who get together to improve ways to make the product or deliver the service. The concept behind the quality circle is that, in most cases, the people who are closest to an operation are in a better position to contribute ideas that will lead to an improvement in it. A quality circle tries to overcome barriers that may exist within the prevailing organizational structure so as to foster an open exchange of ideas.

A quality circle can be effective productivity improvement tool, because it generates new ideas and implements them. Key to its success is its participative style of management. The group members are actively involved in the decision making process and therefore develop a positive attitude towards creating a better product or service.

The quality improvement team is cross-functional in nature and involves people from various disciplines and organized to identify feasible solutions to quality problems. A key advantage of such a team is that it promotes

cross disciplinary flow of information in real time as it solves the problem. When design change is made the feasibility of equipment and tools in meeting the new requirements must be analyzed. It is thus essential for information to flow between design, engineering, and manufacturing.

International Quality Documentation Standards (Documentation Standards)

ISO 9000:

The purpose of the international organization for standards (ISO) is to promote worldwide standards that will improve operating efficiency, improve productivity and reduce costs. Have you every heard or read an organization which prized the ISO 9000 series certificate? What do you imagine the advantage of this certificate? Well the ISO 9000 series is a set of international standards on quality management and quality assurance. These standards are critical to doing business internationally, particularly in Europe. They must go through a process that involves documenting quality procedures and on-site assessment. The process often takes 12 to 18 months. With certification comes registration in an ISO directory that companies seeking suppliers can refer to for a list of certified companies.

A key requirement for registration is that a company review, refine, and map functions such as process control, inspection, purchasing, training, packaging, and delivery. The review process involves considerable self-appraisal, resulting in problem identification and improvements. Registered companies face an ongoing series of audits, and they must be registered every three years. Well are you ready to register your organization like the case in Dashen Beer Factory?

ISO 9000 actually consists of five documents: ISO 9000-9004. ISO 9000 is an over view document which provides guidelines for selection and use of the other standards. ISO 9001 is a standard that focuses on 20 aspects of a quality program for companies that design, produce, install, and service products. These aspects include management responsibility, quality system documentation, purchasing, product design, inspection, training, and corrective action. It is the most comprehensive and difficult standard to attain. ISO 9002 covers the same areas as ISO 9001 for companies that produce to the customer’s designs or have their design and service activities at another location. ISO 9003 is the most limited in scope and addresses only the production process. ISO 9004 contains guidelines for interpreting the other standards.

ISO 14000- An Environmental Management System

Have you heard an organization, which obtained the ISO 14000 quality certificate in our country? If so, good. The ISO 14000 documentation standards require participating companies to keep track of their raw materials use and their generation, treatment, and disposal of hazardous wastes. ISO 14000 covers a number of areas, including the following:

- ***Environmental Management System.*** Requires a plan to improve performance in resources use and pollutant output.
- ***Environmental Performance Evaluation.*** Specifies guidelines for the certification of companies.
- ***Environmental Labeling.*** Defines terms such as recyclable, energy efficient, and safe for the Ozone layer.
- ***Life*-cycle assessment.** Evaluates the lifetime environmental impact form the manufacture, use, and disposal of a product.

In general to maintain their certification, companies must be inspected by outside, private auditors on a regular basis.

5.2 Total Quality Management (TQM)

So far we have discussed few things about the ISO 9000 standards. Do you understand the basics of the standards? Another related concept is TQM. TQM is a philosophy of perpetual improvement. It is the foundation for activities which include:

- Meeting customer requirements
- Reducing development cycle times
- Just in time/demand flow manufacturing
- Improvement teams
- Reducing product and service costs
- Improving administrative systems training

TQ M has the following main principles:

1. Quality can and must be managed.
2. Everyone has a customer and is a supplier
3. Processes, not people are the problem
4. Every employee is responsible for quality
5. Problems must be prevented, not just fixed.
6. Quality must be measurable and measured
7. Quality improvements must be continuous
8. The quality standard is defect free
9. Goals are based on requirements, not negotiated.
10. Life cycle costs, not front end costs.

11. Management must be involved and lead
12. Plan and organize for quality improvement

Dear reader, are you ready to apply these principles in your organization? In general for effective and efficient quality management, managers must provide training to employees on quality management and control measure and review process performance and improve process performance with the help of those who use the process. Wish you a nice preparation to utilize the basic concepts on quality management in your organization.

5.3 Continuous Improvement and Quality control

5.3.1 Continuous Improvement

So far we have discussed on techniques that can bring a stable process in the production of goods, but how we can achieve a continuous improvement in the production of these products? This is the aim of continuous improvement (CI).

The aim of continuous improvement is to reduce variability of the product or process. This generally requires problem solving or changes in the design of the product or process itself. Such changes make it possible to make a more consistent product or service with less variation from one unit to the next.

Three techniques for continuous improvement will be discussed here briefly: Pareto analysis, cause-and-effect diagrams and benchmarking.

Using Pareto analysis, data can be collected on the various modes of failure of the product or service produced. The data are then tabulated to identify the most frequent modes of failure. As a result, the most important problems can be attacked first.

The next step in the analysis is to take one of these failure modes and to analyze the causes of failure. This is done by use of the cause and effect diagram (CE). Once we identify the major causes, next each of the major causes is then broken down into more detailed cause, giving rise to more causes. For example if loose connections is found to be the major reason for hydraulic leaks, the major causes for the loose connections can be workers, inspection problems, poor system of the material connectors or problems in tools and soon. Further effort is required to find out the specific causes for the major causes and finally management is required to bring solutions for the identified causes.

1. **Benchmarking for CI**

- The CI approaches described so far are more or less inward looking: they seek to make improvements by analyzing in detail the current practices of the company itself.
- Benchmarking, however, goes outside the organization to examine what industry competitors and excellent performers outside the industry are doing.
- Its basic objective is simple: Find the best practices that lead to superior performance and see how you can use them.
- Benchmarking basically involves the following steps:
  1. Identify those processes needing improvement
  2. Identify a firm that is the world leader in performing the process. For many processes, this may be a company that is not in the same industry.
  3. Contact the managers of that company and make a personal visit to interview managers and workers.
  4. Analyze data. This entails looking at gaps between what your company is doing and what the benchmark company is doing.

5.3.2 QUALITY CONTROL

Quality control may generally be defined as a system that is used to maintain a desired level of quality in a product or service. This task may be achieved through different measures such as planning, design use of proper equipment and procedures, inspection, and taking corrective action in case a deviation is observed between the product, service or process output and a specified standard.

5.3. Quality Control and Improvement

5.3.1 Design of Quality Control Systems

All quality control must start with the process itself. A process can be an individual machine, a group of machines, or any of the many clerical and administrative processes that exist in the organization. Each of these processes has its own internal customers and its own products or services that are produced. For example in the Faculty of Business and Economics the registrar office is the customer of the various departments as well as it is the customer of the accounts and budget sections of the campus. Students become their common customers.

After identifying each of the processes that need to be controlled, critical control points can be identified where inspection or measurement should

take place. The control points can be the inputs, work in process and/or the outputs of the production system.

The next step will be to decide on the type of measurement to be used at each inspection point. There are two options: measurement based either on variables or on attributes.

Variable measurement utilizes a continuous scale for such factors as length, height and weights. Example of variables measurements are the dimensions of parts the viscosity of liquids, and the time that it forces to wait on tables in a restaurant.

Attribute measurement uses a discrete scale by counting the number of defective items or the number of defects per unit. When the quality specifications are complex, it will be usually be necessary to use attribute measurements (Schroeder, 2000). In this case, a complicated set of criteria can be used to define a defective unit or a defective. For example, a color TV set may be classified as defective if any of a number of functional tests fail or if the appearance of the cabinet is not satisfactory.

The next step in defining the quality control system is to decide on the amount of inspection to use-whether to inspect samples or 100 percent inspection (entire lot). The final step will be deciding who should do the inspection-shall we inspect using our task force or outside consultants? Any way these are the major steps required in designing a quality system in an organization. Now let us return in discussing the main classifications of the process quality control techniques:

5.4. STATISTICAL QUALITY CONTROL

We now focus on the idea of Quality Control in terms of Statistical Process Control, for this we need to define:

- *Statistical Process Control*: Statistical evaluation of the output of a process during production
- *Quality of Conformance:* A product or service conforms to specifications
- Which Characteristics can be controlled: Only those characteristics which can be counted or measured.
- Main Task of QC: is to distinguish random from non random variability, because non random variability indicates that the process is out of control

Control Chart

Control Chart: A time ordered plot representative sample statistics obtained from an on going process (e.g. sample means)

- ✓ Purpose*:* to monitor process output to see if it is random
- ✓ Upper and lower control limits define the range of acceptable variation

CONTROL CHART & STATISTICAL PROCESS CONTROL

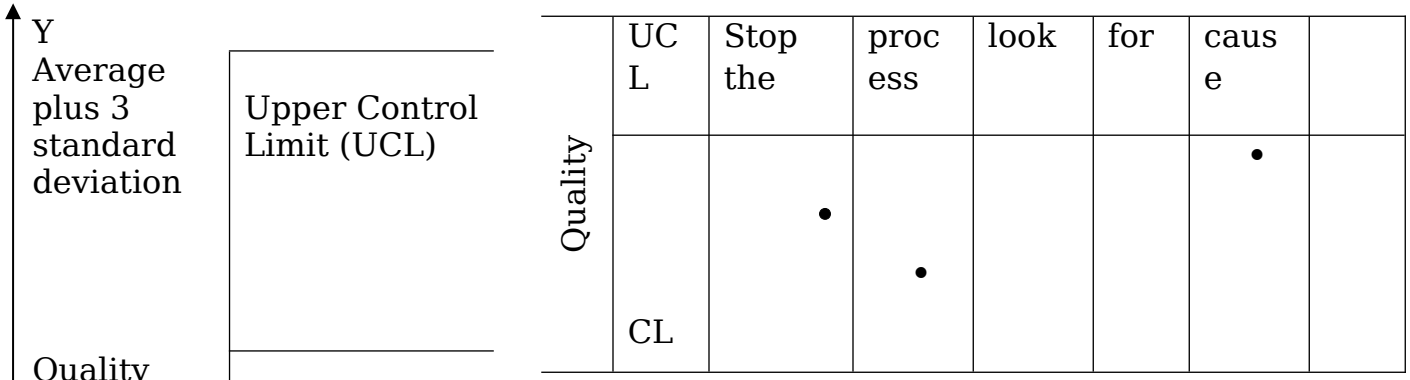
Statistical Process Control

- ➢ The essence of statistical process control is to assure that the output of a process is random so that *future output* will be random.
- ➢ Statistical Process Control
- ➢ The Control Process consists of the following important stages.
    1. Define
    2. Measure
    3. Compare
    4. Evaluate
    5. Correct
    6. Monitor results

5.5 Process Quality Control

Process quality control utilizes inspection (or testing) of the product or service while it is being produced. Periodic samples of the output of a production process are taken. When, after inspection of the sample, there is reason to believe that the process quality characteristics have changed, the process is stopped and a search is made for an **assignable cause**. This cause could be a change in the operator, the machine, or the material. When the cause has been found and corrected, the process is started again.

A process can be brought to **a state of control** and can be maintained in this state through the use of quality control charts/also called process charts/ as shown below:



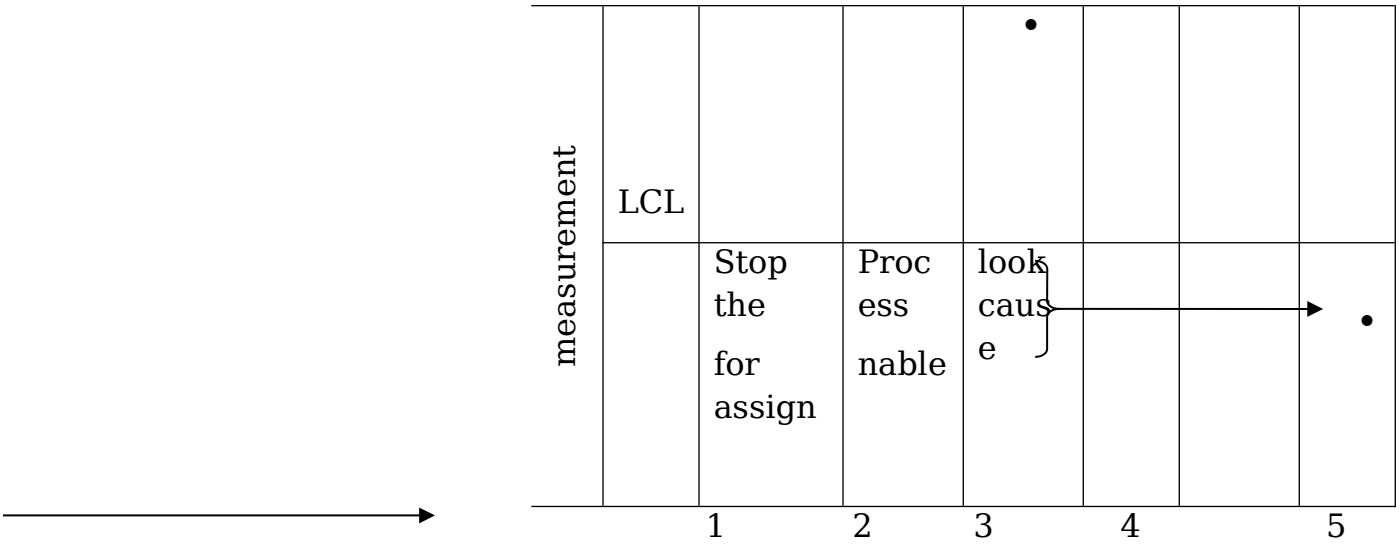


Figure 7.1. Quality control chart

Figure7.2. Quality control chart sample.

In the control chart shown in Figure 7.1., the Y-axis represents the quality characteristics that are being controlled, while the X-axis represents time or a particular sample taken from the process.

The **centerline** of the chart is the average quality characteristic being measured. The **upper control limit** represents the maximum acceptable random variation, and the **lower control limit** indicates the minimum acceptable random variation when a state of control exists. Generally speaking, the upper and control limits are set $\pm$ three standard deviation from the mean. If a normal probability distribution is assumed, these control limits will include 99.74 percent of the random variations observed.

After a process has been brought to steady state operation, periodic samples are taken and plotted on the control chart (as shown in Figure 7.2 above) .when the measurement falls within the control limits, the process is continued. If the measurement faces outside the control limits, the process is stopped and a search is made for an assignable cause. Through this procedure, the process is maintained in a constant state of statistical control and there is only natural random variation in the process's output.

Control Charts for Attributes

Dear readers there are two charts commonly used for quality measures based on product or service attributes. These are the P-and C- chart.

P-charts. The P-chart is used for controlling the proportion of defective products or services generated by the process. The quality characteristic is counted rather than measured, and the entire item or service can be

declared good or defective. The method involves selecting a random sample, inspecting each item in it, and calculating the sample proportion defective, P, which is the number of defective units divided by the sample size and we can get the value P**. This value of** P **is** used as the centerline, since it represents the best available estimate of the true average percent defective of the process. We also use the value of P to compute upper and control limits as follows:

$$UCL = \overline{P} + 3\sqrt{\frac{\overline{P}(1 - \overline{P})}{n}}$$

$$LCL = \overline{P} - 3\sqrt{\frac{\overline{P}(1- P)}{n}}$$

Example 1.

The operation manager of Good Bahri Bank (hypotetical) is concerned about the number of wrong customer account numbers recorded by the bank's personnel. Each week a random sample of 2,500 deposits is taken, and the number of incorrect account numbers is recorded. The results for the past 12 weeks are shown in the following table. Is the process out of control?

Sample number	**Wrong account number**	**Sample number**	**Wrong account number**
1	15	8	7
2	12	9	10
3	19	10	17
4	2	11	15
5	19	12	3
6	4		Total 147
7	24		

Solution

Step 1. construct the P-chart, using past data to calculate P.

$\overline{P}$ = Total defectives

Sample size X to the number of observations

= 147 = 0.0049

$$UCLP = \bar{P} + \sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$$

$$= 0.0049 + 3\sqrt{\frac{0.0049\,(1-0.0049)}{2,5000}}$$

$$= \underline{0.0091}$$

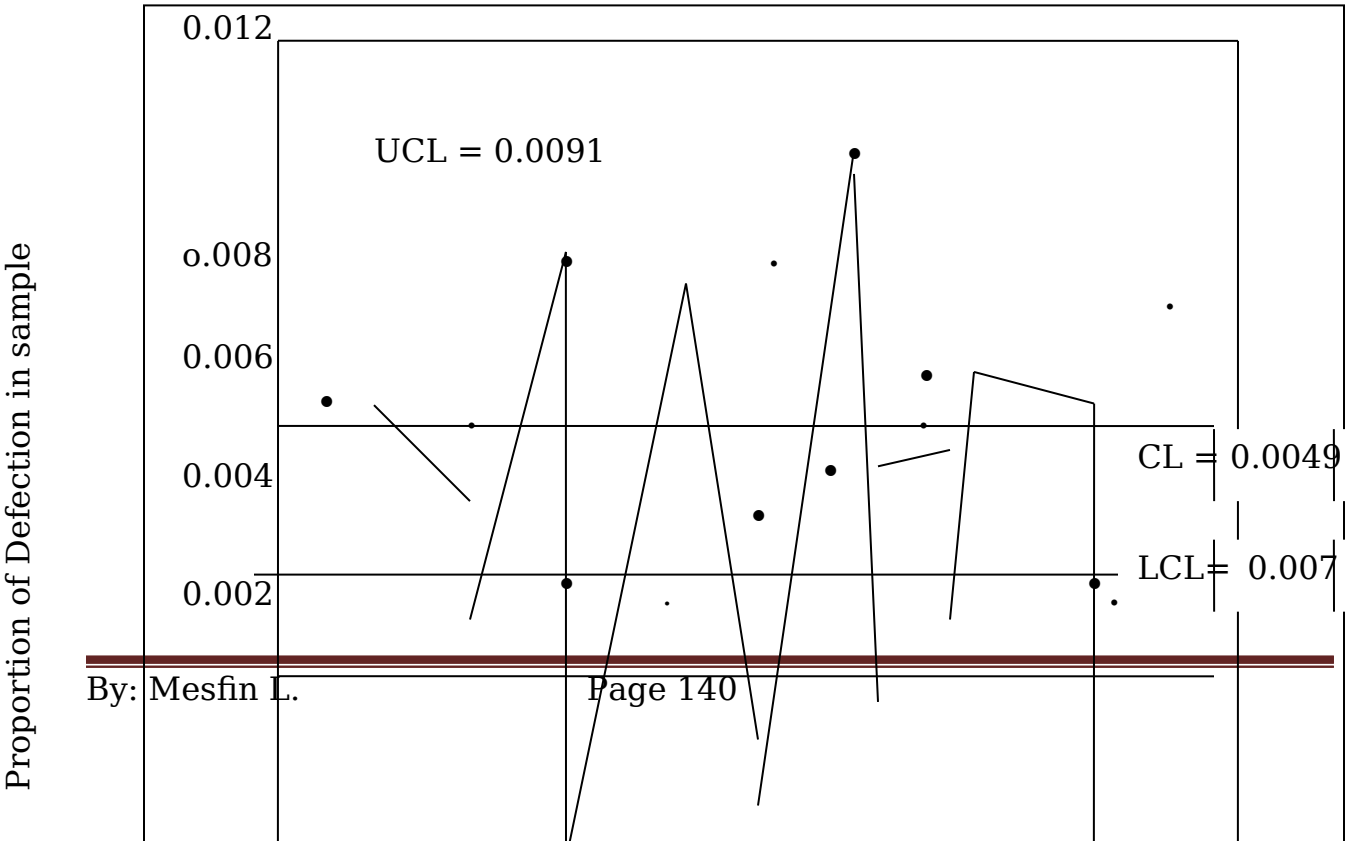
$$LCLp = \bar{p} - 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$$

$$= 0.0049 - 3\sqrt{\frac{0.0049\,(1-0.0049)}{2,500}}$$

$$= \underline{0.0007}$$

Step 2. Calculate the sample proportion defective. For sample 1, the proportion of defectives is 15/2500 = 0.0060

Step 3. Plot each sample proportion defective on the chart, as shown in Figure 5.3 below:



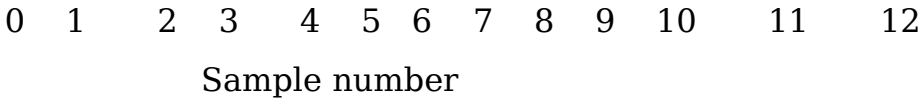


Figure 5.3. The P – chart for wrong account numbers showing that sample 7 is out of control.

Decision

Sample 7 exceeds the upper control limit, thus, the process of is out of control and the reasons for the poor performance of that week should be determined.

C- Charts. The C- chart is used for controlling the number of defects when more than one defect can be present in a product or service. It is constructed based on the assumption that defects occur over a continuous region and that the probability of two or more defects at any one location is negligible. The mean of the distribution is C and the standard deviation is $\sqrt{C}$. A useful tactic is to use the normal approximation to the Poisson so that the central line of the chart is **C** and the control limits are:

$$UCL = \bar{C} + Z\sqrt{C} \qquad \text{and} \qquad LCL_{\bar{c}} = \bar{C} - Z\sqrt{C}$$

Example X Company produces paper for the newspaper industry. As a final step in the process, the paper passes through a machine that measures various quality characteristics. When the process is in control, it averages 20 defects per roll.

a. Set up a control chart for the number of defects per roll. For this example, use two sigma control limits

b. Five rolls had the following number of defects: 16, 21, 17, 22 and 24, respectively. The sixth roll, using pulp from a different supplier, had 5 defects. Is the process in control?

Solution

a. The average number of defects per roll is 20. Therefore,

$$UCL_c = \bar{C} + z\sqrt{\bar{C}} = 20 + 2\sqrt{(20)} = 28.94$$

$$LCLc = \bar{C} - z\sqrt{\bar{C}} = \sqrt{20} - 2(20) = 11.06$$

The control chart is shown in Figure 5.4 below:

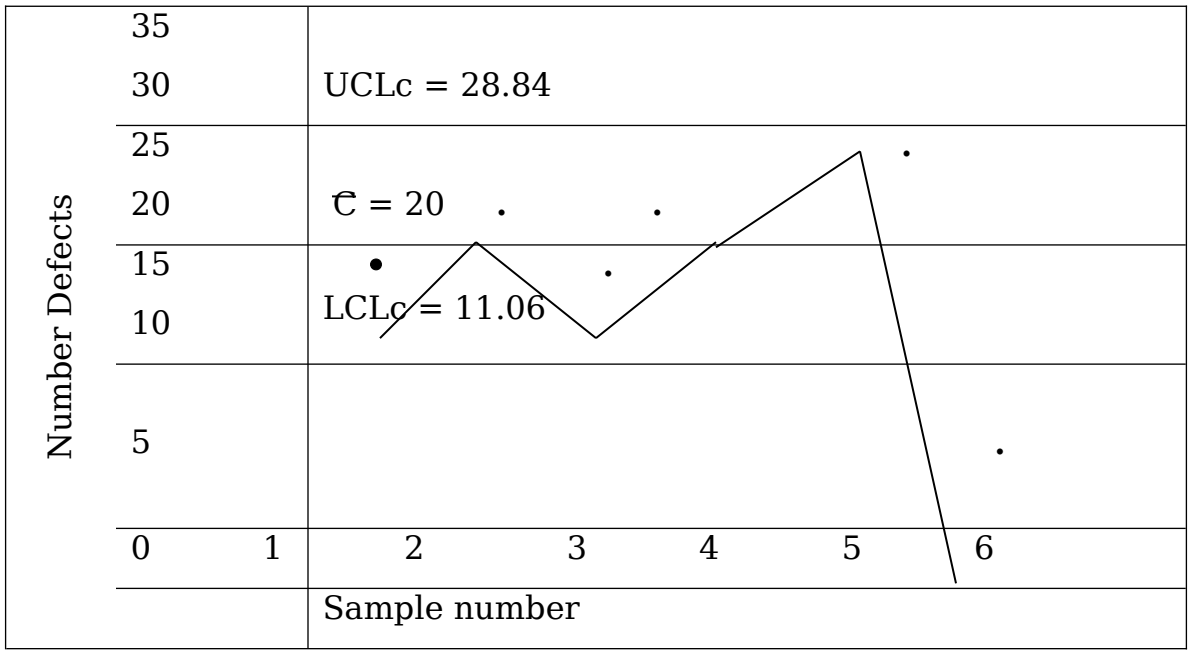


Figure 5.4. The C-chart for defects per roll of paper B – Because of the first roll had only 16 defects, or less than the upper control limit, the process is still in control. Five defects, however, is less than the lower control limit, and therefore, the process is technically “out of control”.

5.3.2.1 Variables Control

Control charts are used for measurements of variables. In this case, a measurement of a continuous variable is made when each item is inspected. As a result, two values are computed from the sample. A measure of central tendency (usually the average) and a measure of variability (the range or the standard deviation) with these values, two control charts are developed one for the central tendency and the second for variability of the process. Where the process is found to be out of control on either of these charts, it is stopped and a search for an assignable cause is made.

Suppose that the average X and range R are computed each time a sample is taken. Then a control chart for average and a chart for range will be used. The control limits for the average chart are computed as follows:

$$CL = \bar{\bar{X}}$$

$$UCL = \bar{\bar{X}} + A2\,\bar{R}$$

$$LCL = \bar{\bar{X}} - A2\,\bar{R}$$

Where $\bar{\bar{X}}$ is the grand average of several past X averages and $\bar{R}$ is the average of several past R values. In the above formulas, A2 is a constant that includes three standard deviations in terms of the range. Table 5.4., provides values of A2 for various sample sizes.

The control limits for the range chart are computed as follows:

$$CL = \bar{R}$$

$$UCL = D_4\,\bar{R}$$

$$LCL = D_3\,\bar{R}$$

The constants D_3 and D_4 provide three standard deviation limits for the range. Values for these constants are also given in Table 5.4. the example below illustrates how to compute control limits and how to determine whether or not a sample is in control.

Table 5.1. Control Chart Constants

Sample size n	A2	D3	D4
2	1.880		3.267
3	1.023	0	2.575
4	0.729	0	2.282
5	0.577	0	2.115
6	0.483	0	2.004
7	0.419	0.076	1.924
8	0.373	0.136	1.864

9	0.337	0.184	1.816
10	0.308	0.223	1.777
12	0.266	0.284	1.716
14	0.235	0.329	1.671
16	0.212	0.364	1.608
28	0.194	0.392	1.586
20	0.180	0.414	1.566
22	0.167	0.434	1.548
24	0.157	0.452	

Example MIE would like to control the quality of the bolts produced by its automatic screw machines. Each machine produces 100 bolts per hour and is controlled by a separate control chart. Every hour a random sample of six bolts is selected form the output of each machine and diameter of each sample bolt is measured. From each six diameters an average and range are computed. For example, one sample produced the following six measurements: 0.536, 0.507, 0.530, 0.525, 0.530, and 0.520. The average of these measurements is $\bar{X} = 0.513$ and the grand average range is $\bar{R} = 0.020$. From these grand averages, the control chart parameters are computed as follows (see Table 7.1. for control constants with n = 6)

$\bar{X}$ chart	$\bar{R}$ chart
CL = 0.513	CL = 0.020
UCL = 0.513 + 0.483 (0.020) = 0.523	UCL = 2.004 (0.020) = 0.040
LCL = 0.513 – 0.483 (0.020) = 0.503	LCL = 0.(0.020) = 0

On the basis of these control limits, the sample of six bolts is found to be out of control on average measurement and in control on range. (Note: $\bar{X} = 0.525$ is outside the upper control limit on the $\bar{X}$ chart). We should therefore stop the process and look for an assignable cause that would tend to produce bolts, which are too large in diameter