Bonga University
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Operation Management Hand out

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CHAPTER ONE

NATURE OF OPERATIONS MANAGEMENT

Chapter Outline:

1.1. Introduction
- What is operations?
- What is operations Management?
- Organizing to produce goods and service
- Why study OM?

1.2. Historical Development of OM

1.3. Manufacturing Operations and Service Operations
- Manufacturing Operations
- Service Operations

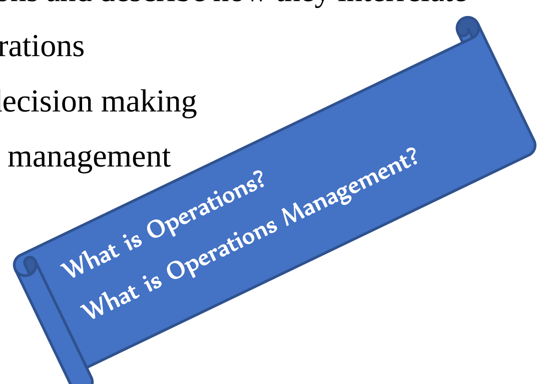
1.4. Operations Decision Making

1.5. Productivity Measurement

Learning Objectives

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

- ☑ Define operations management
- ☑ Identify the three major functional areas of organizations and describe how they interrelate
- ☑ Compare and contrast service and manufacturing operations
- ☑ Describe the key aspects of operations management decision making
- ☑ Briefly describe the historical evolution of operations management
- ☑ understand single and multifactor productivity



1.1. Introduction

1.1.1. *Definition*

Operations (production): is that part of a business organization that is responsible for producing goods and/ or services. **Goods** are physical items that include raw materials, parts, and subassemblies. **Operations** is those activities concerned with the acquisition of raw materials their conversation into finished product, and the supply of that finished product to the customer.

Services are activities that provide some combination of time, location, form, or psychological value. Operation is what the company does.

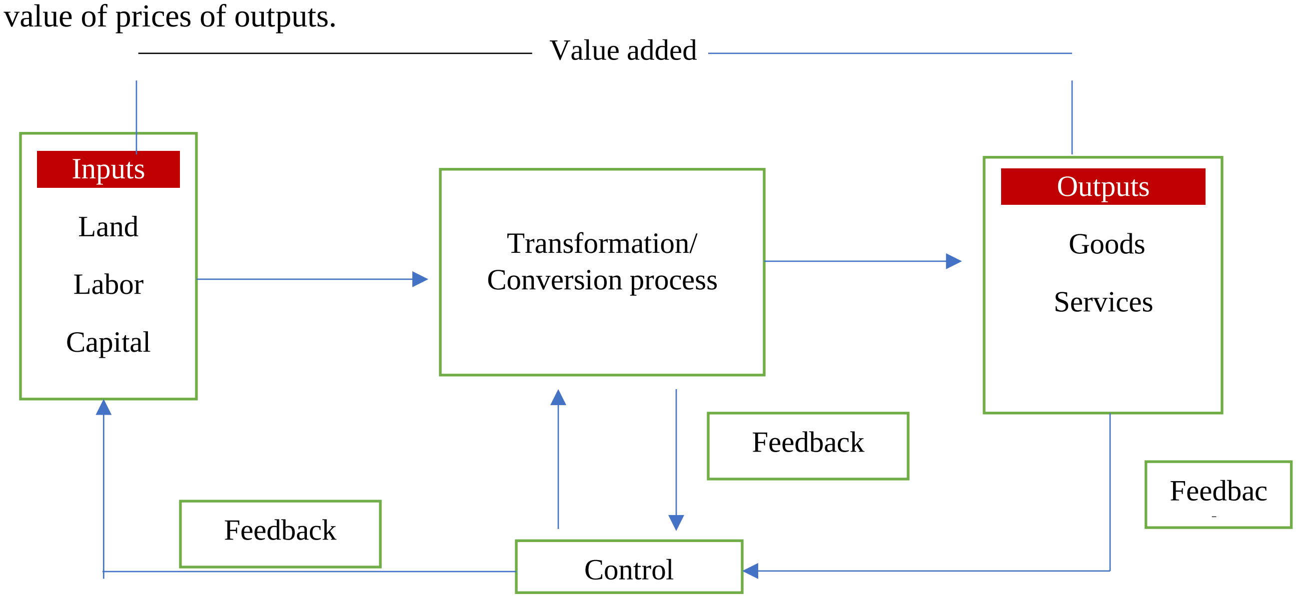
Examples: goods and services are found all around you. Every book you read, every video you watch, every e-mail you send, every telephone conversation you have, and every medical treatment you receive involves the operations function of one or more organizations. So does everything you wear, eat, travel in, sit on, and access the Internet with. The operations function in business can also be viewed from a more far-reaching perspective.

Operations management: is the set of activities that creates value in the form of goods and services by transforming inputs into outputs. In manufacturing firms, the production activities that create goods are usually quite obvious. In them, we can see the creation of a tangible product such as Sony TV or a Harley-Davidson motorcycle. In an organization that does not create a tangible good or product, the production function may be less obvious. We often call these activities services.

Operation Management: is the management of systems or processes that create goods and/or provide services. Or **Operation Management-** is the design, operation, and improvement of those systems that create and deliver the firms primary products and services, like marketing and finance.

Operation Management is functional field of business with clear line management responsibility. The business function responsible for planning, coordinating, and controlling the resources needed to produce a company's products and services. Every organization has OM function Service or Manufacturing, For profit or Not for profit.

Operation Management Adds Value which means the difference between the costs of inputs and the value of prices of outputs.



1.1.2. Organizing to produce goods and services

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

1. **Marketing:** which generates the demand, or at least takes the order for a product or service (nothing happens until there is sale).
2. **Production/operation**: which create product
3. **Finance/accounting**: which tracks how well the organization is doing, pays the bills, and collects the money.

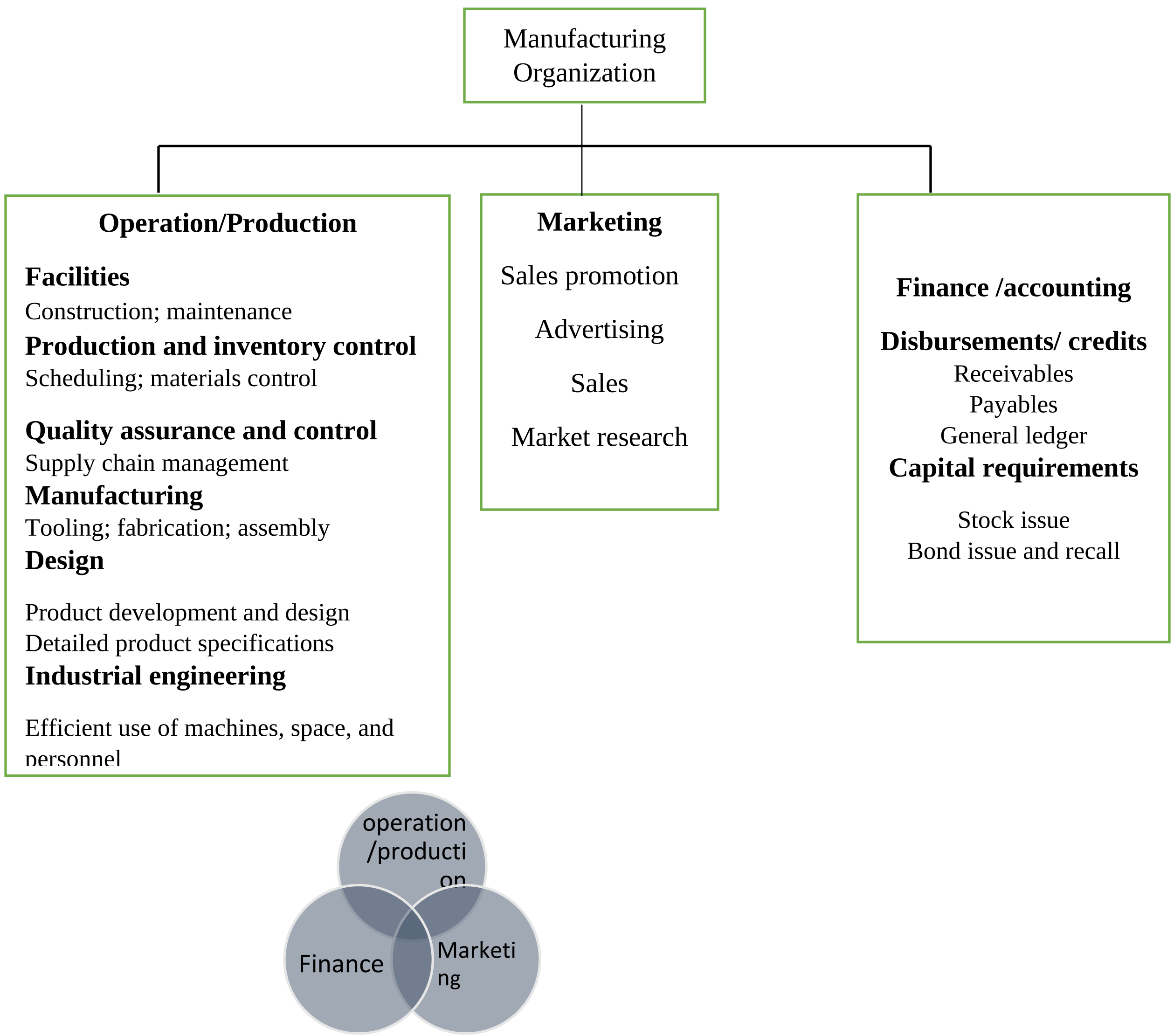


Figure 1.2: The three basic functions of business organizations

1.1.3. Why study OM?

We study OM for the following reasons:

1. OM is one of the three major functions (marketing, finance, and operations) of any organization, and it is integrally related to all the other business functions. All organization market (sell), finance (accounting), and produce (operation), and it is important to know how the OM activity functions. Therefore, we study how people organize themselves for productive enterprise.
2. We want (and need) to know how goods and services are produced.
3. We want to understand what operations managers do. By understanding what these managers do, you can develop the skills necessary to become such a manager. Operation managers have basic management function (planning, organizing, staffing, directing, and controlling This will help you explore the numerous and lucrative career opportunities in OM. These career opportunities are:
   - Operations manager
   - Production analyst
   - Production manager
   - Industrial engineer
   - Time study analyst
   - Inventory manager
   - Quality analyst
   - Quality manager
4. OM is such a costly part of an organization

Example:

Fisher technologies is a small firm that must double its dollar contribution to fixed cost and profit in order to be profitable enough to purchase the next generation of production equipment. Management has determined that if the firm fails to increase contribution, its bank will not make the loan and the equipment cannot be purchased. If the firm cannot purchase the equipment, the limitations of the old equipment will force fisher to go out of business and, in doing so, put its employees out of work and discontinue producing goods and services for its customers. Three strategic option (marketing, finance/accounting, and operations) proposed for the firm.

- The first option is a marketing option, where good marketing management may increase sales by 50%.
- The second option is a finance/ accounting option, where finance costs are cut in half through good financial management.
- The third option is an OM option, where management reduces production costs by 20%.

Which one is the best option that yield the greatest improvement in contribution***?***

Given: Current financial contribution

Sales	$100,000
Cost of Goods	– 80,000
Gross Margin	20,000
Finance Costs	– 6,000
Subtotal	14,000
Taxes at 25%	– 3,500
Contribution	$ 10,500

Solution:

Options for Increasing Contribution

		Marketing option	**Financial/ Accounting Option**	**OM Option**
	Current	**Increase Sales Revenue 50%**	**Reduce Finance Costs 50%**	**Reduce Production Costs 20%**
Sales	$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
Subtotal	14,000	24,000	17,000	30,000
Taxes at 25%	– 3,500	– 6,000	– 4,250	–7,500
Contribution	$ 10,500	$ 18,000	$ 12,750	$ 22,500

1.1.4. The Activities of Operations Management

Operations managers have some responsibility for all the activities in the organization which contribute to the effective production of goods and services. And while the exact nature of the operations function's responsibilities will, to some extent, depend on the way the organization has chosen to define the boundaries of the function, there are some general classes of activities that apply to all types of operation.

☞ **Understanding the operation's strategic objectives**. The first responsibility of any operations management team is to understand what it is trying to achieve. This means developing a clear vision of how the operation should help the organization achieve its long-term goals. It also means translating the organization's goals into their implications for the operation's performance objectives, quality, speed, dependability, flexibility and cost.

- ☞ **Developing an operations strategy for the organization**. Operations management involves hundreds of minute-by-minute decisions, so it is vital that operations managers have a set of general principles which can guide decision making towards the organization's longer-term goals. This is an operations strategy.
- ☞ **Designing the operation's products, services and processes**. Design is the activity of determining the physical form, shape and composition of products, services and processes. Although direct responsibility for the design of products and services might not be part of the operations function in some organizations, it is crucial to the operation's other activities.
- ☞ **Planning and controlling the operation**. Planning and control is the activity of deciding what the operations resources should be doing, then making sure that they really are doing it.
- ☞ **Improving the performance of the operation**. The continuing responsibility of all operations managers is to improve the performance of their operation.

1.1.5. Operation Management Critical Decisions

- ☑ **Design of goods and services:** What good or service should we offer?
  How should we design these products and services?
- ☑ **Managing quality**: How do we define quality? Who is responsible for quality?
- ☑ **Process and capacity design**: What process and what capacity will these products require? What equipment and technology is necessary for these processes?
- ☑ **Location strategy**: Where should we put the facility? On what criteria should we base the location decision?
- ☑ **Layout strategy**: How should we arrange the facility? How large must the facility be to meet our plan?
- ☑ **Human resources and job design**: How do we provide a reasonable work environment? How much can we expect our employees to produce?
- ☑ **Supply chain management**: Should we make or buy this component? Who are our suppliers and who can integrate into our e-commerce program?
- ☑ **Inventory, material requirements planning, and JIT**: How much inventory of each item should we have? When do we re-order?
- ☑ **Intermediate and short–term scheduling**: Are we better off keeping people on the payroll during slowdowns? Which jobs do we perform next?
- ☑ **Maintenance:** Who is responsible for maintenance? When do we do maintenance?

1.2. Historical Development of operation Management

The field of OM is relatively young, but it history is rich and interesting. Our lives and the OM discipline have been enhanced by the innovations and contributions of numerous individuals.

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

Frederick W. Taylor (1881), known as the father of scientific management, contributed to personnel selection, planning and scheduling, motion study, and the now popular field of ergonomics. One of his major contributions was his belief that management should be much be more resourceful and aggressive in the improvement of work methods. Taylor and his colleagues, Henry L. Gantt and Frank Lillian Gilbreth, were among the first to systematically seek the best way to produce.

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

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

By 1913, Henry Ford and Charles Sorensen combined what they knew about standardized parts with the quasi – assembly lines of the meatpacking and mail – order industries and added the revolutionary concept of the assembly line, where men stood still and material moved.

Quality control is another historically significant contribution to the field of OM. Walter Shewhart (1924) combined his knowledge of statistics with the need for quality control and provided the foundations or statistical sampling in quality control.

Table 1.1: summarize the historical development of OM.

Era	Events/Concepts	Dates	Originator
Industrial Revolution	Steam engine	1769	James Watt
	Division of labor	1776	Adam Smith
	Interchangeable parts	1790	Eli Whitney
Scientific Management	Principles of scientific management	1911	Frederick W. Taylor
	Time and motion studies	1911	Frank and Lillian Gilbreth
	Activity scheduling chart	1912	Henry Gantt
	Moving assembly line	1913	Henry Ford
Human Relations	Hawthorne studies	1930	Elton Mayo
	Motivation theories	1940s	Abraham Maslow
		1950s	Frederic Herzberg
		1960s	Douglas McGregor
Operations Research	Linear programming	1947	George Dantzig
	Digital computer	1951	Remington Rand
	Simulation, waiting line theory, decision theory, PERT/CPM	1950s	Operations research groups
Quality Revolution	JIT (just-in-time)	1970s	Taiichi Ohno (Toyota)
	TQM (total quality management)	1980s	W. Edward Deming, Joseph Juran
	Strategy and operations	1980s	Wickham Skinner, Robert Hayes
	Business process reengineering	1990s	Michael Hammer, James Champ
	Six Sigma	1990s	GE, Motorola

1.3. Manufacturing Operations and Service Operations

Production of Goods Versus Delivery of Services

- Goods are physical items that include raw materials, parts, subassemblies, and final products. E.g. Automobile, Computer, Oven, Shampoo
- Services are activities that provide some combination of time, location, form or psychological value. E.g. Air travel, Education, Haircut, Legal counsel
- Production of goods –tangible output

- Delivery of services –an act
- Service job categories-Government, Wholesale/retail, Financial services, Healthcare, Personal services, Business services, Education.

Characteristics of Goods

- Tangible product
- Consistent product definition
- Production usually separates from consumption
- Can be inventoried
- Low customer interaction

Characteristics of Service

- **Intangible product**: services are usually intangible (for example, your purchase of a ride in an empty airline seat between two cities) as opposed to a tangible good.
- **Produced and consumed at same time**: there is no stored inventory. For instance, the beauty salon produces haircut that is “consumed” simultaneously, or the doctor produces an operation that is “consumed” as it is produced. We have not yet figured out how to inventory haircuts or appendectomies.
- **Often unique**: your mix of financial coverage, such as investments and insurance policies may not be the same as anyone else’s just as the medical procedure or a haircut produced for you is not exactly like anyone else’s.
- **High customer interaction**: services are often difficult to standardize, automate, and make as efficient as we would like because customer interaction demands uniqueness.
- **Often knowledge-based**: as in the case of educational, medical, and legal services, and therefore hard to automate.
- **Frequently dispersed**: Dispersion occurs because services are frequently brought to the client/customer via local office, a retail outlet, or even a house call.

Having made the distinction between goods and services, we should point out that in many cases, the distinctions is not clear – cut. In reality, almost all services and almost all goods are a mixture of a service and a tangible product. Even services such as consulting may require a tangible report. Similarly, the sale of most goods includes a service. For instance, many products have the service components of financing and delivery (e.g., automobile sales). Many also require after – sale training and maintenance (e.g., office copiers and machinery). “service” activities may also be an integral part of production. Human resource activities, logistics, accounting, training, field service, and repair are all service activities, but they take place within a manufacturing organization. When a tangible product is not included in the service, we may call it a ***pure service***. Although there are not very many pure services, in some instances counselling may be an example. Figure 1.2 shows the range of services in a product. The range is extensive and shows the pervasiveness of service activities.

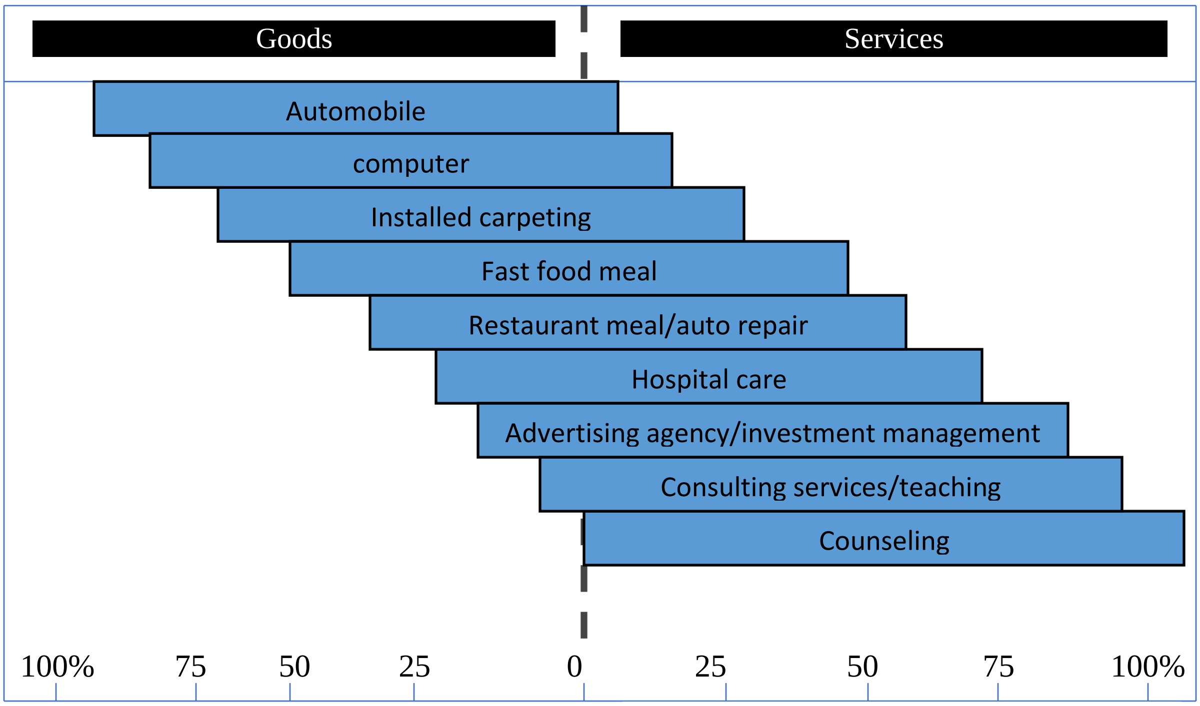


Figure 1.2 most goods contain a service, and Most services contain a Good

Attributes of goods and services

Attributes of Goods (tangible product)	Attributes of Services (intangible product)
Product can be resold	Reselling a service is unusual.
Product can be inventoried.	Many services cannot be inventoried
Some aspects of quality are measurable	Many aspects of quality are difficult to measure.
Selling is distinct from production	Selling is often a part of the service
Product is transportable	Provider, not product, is often transportable

Site of facility is important for cost	Site of facility is important for customer contact
Often easy to automate	Service is often difficult to automate.
Revenue is generated primarily from the tangible product	Revenue is generated primarily from the Service

Table 1.2 attributes of Goods and service

1.4. Operation Decision Making

Thousands of business decisions are made every day. Not all the decisions will make or break the organization. But each one adds a measure of success or failure to the operations. Hence decision-making essentially involves choosing a particular course of action, after considering the possible alternatives.

Operations decision range from simple judgments to complex analyses, which also involves judgment. Judgment typically incorporates basic knowledge, experience, and common sense. They enable to blend objectives and sub-objective data to arrive at a choice.

1.4.1. Framework for Decision-Making

An analytical and scientific framework for decision implies the following systematic steps:

☞ **Defining the problem**

Defining the problem enables to identify the relevant variables and the cause of the problem. Careful definition of the problem is crucial. Finding the root cause of a problem needs some questioning and detective work. If a problem defined is too narrow, relevant variable may be omitted. If it is broader, many tangible aspects may be included which leads to the complex relationships.

☞ **Establish the decision criteria**

Establish the decision criterion is important because the criterion reflects the goals and purpose of the work efforts. For many years' profits served as a convenient and accepted goal for many organizations based on economic theory. Nowadays organization will have multiple goals such as employee welfare, high productivity, stability, market share, growth, industrial leadership and other social objectives.

- ☞ **Formulation of a model**

Formulation of a model lies at the heart of the scientific decision-making process. Model describes the essence of a problem or relationship by abstracting relevant variables from the real-world situation. Models are used to simplify or approximate reality, so the relationships can be expressed in tangible form and studied in isolation. Modeling a decision situation usually requires both formulating a model and collecting the relevant data to use in the model. Mathematical and statistical models are most useful models for understanding the complex business of the problem. Mathematical models can incorporate factor that cannot readily be visualized. With the aid of computers and simulation techniques, these quantitative models flexible.

- ☞ **Generating alternatives**

Alternatives are generated by varying the values of the parameters. Mathematical and statistical models are particularly suitable for generating alternatives because they can be easily modified. The model builder can experiment with a model by substituting different values for controllable and uncontrollable variable.

- ☞ **Evaluation of the alternatives**

Evaluation of the alternatives is relatively objective in an analytical decision process because the criteria for evaluating the alternatives have been precisely defined. The best alternative is the one that most closely satisfies the criteria. Some models like LPP model automatically seek out a maximizing or minimizing solution. In problems various heuristic and statically techniques can be used to suggest the best course of action.

- ☞ **Implementation and monitoring**

Implementation and monitoring are essential for completing the managerial action. The best course of action or the solution to a problem determined through a model is implemented in the business world. Other managers have to be convinced of the merit of the solution. Then the follow-up procedures are required to ensure about appropriate action taken. This includes an analysis and evaluation of the solution along with the recommendations for changes or adjustments.

1.4.2. Decision Methodology

The kind and amount of information available helps to determine which analytical methods are most appropriate for modeling a given decision. The degree of certainty is classified as complete certainty, risk, and uncertainty.

1. **Decision making under certainty**: Under complete certainty conditions, all relevant information about the decision variables and outcomes is known or assumed to be known. State of nature is *known*. Some of methods which used to decision making under certainty are: Algebra, Calculus, Mathematical programming.
2. **Decision making under risk:** information about the decision variables or the outcomes is probabilistic. Several states of nature may occur and Each has a probability of occurring. Some approaches which used to decision making under risk are: Statistical analysis, queuing theory, simulation, Network analysis technique.
3. **Decision making under uncertainty**: Under extreme uncertainty, no information is available to assess the likelihood of alternative outcomes. Four possible decision criteria are *Maximin*, *Maximax*, *Laplace*, and *Minimax regret*. These approaches can be defined as follows:

- **Maximin:** Determine the worst possible pay-off for each alternative, and choose the alternative that has the "best worst." The Maximin approach is essentially a pessimistic one because it takes into account only the worst possible outcome for each alternative. The actual outcome may not be as bad as that, but this approach establishes a "guaranteed minimum."
- **Maximax**: Determine the best possible pay-off, and choose the alternative with that pay-off. The Maximax approach is an optimistic, "go for it" strategy; it does not take into account any pay-off other than the best.
- **Laplace**: Determine the average pay-off for each alternative, and choose the alternative with the best average. The Laplace approach treats the states of nature as equally likely.
- **Minimax regret**: Determine the worst regret for each alternative, and choose the alternative with the "best worst." This approach seeks to minimize the difference between the pay-off that is realized and the best pay-off for each state of nature.

Example:

ILLUSTRATION 1: Referring to the pay-off table, determine which alternative would be chosen under each of these strategies: (a) Maximin, (b) Maximax, and (c) Laplace.

	Possible future demand in Rs.		
Alternatives	Low	Moderate	High
Small facility	10	10	10
Medium facility	7	12	12
Large facility	(4)	2	16

Solution

(a) *Using Maximin*, the worst pay-offs for the alternatives are:

Small facility: Rs.10 million

Medium facility: 7 million

Large facility: –4 million

Hence, since Rs.10 million is the best, choose to build the small facility using the maximum strategy.

(b) Using Maximax, the best pay-offs are:

Small facility: Rs.10 million

Medium facility: 12 million

Large facility: 16 million

The best overall pay-off is the Rs.16 million in the third row. Hence, the Maximax criterion leads to building a large facility.

(c) For the Laplace criterion, first find the row totals, and then divide each of those amounts by the number of states of nature (three in this case). Thus, we have:

Alternatives	Raw total (Rs. Million)	Raw average (Rs. Million)
Small facility	30	10
Medium facility	31	10.33
Large facility	14	4.67

Because the medium facility has the highest average, it would be chosen under the Laplace criterion.

1.5. Productivity Measurement

Productivity is defined in terms of utilization of resources, like material and labor. In simple terms, productivity is the ratio of output to input. For example, productivity of labor can be measured as units produced per labor hour worked. Productivity is closely linked with quality, technology and profitability. Hence, there is a strong stress on productivity improvement in competitive business environment. Productivity can be improved by (a) controlling inputs, (b) improving process so that the same input yields higher output, and (c) by improvement of technology. Productivity and production are not the same thing. Productivity takes into account output in relation to input, whereas in production we consider only the output and not the input. Productivity can be measured at firm level, at industry level, at national level and at international level. Productivity ratios are used for:

- Planning workforce requirements
- Scheduling equipment
- Financial analysis
- Tracking an operating unit's performance over time
- Judging the performance of an entire industry or country

The measurement of productivity can be quite direct. Such is the case when productivity is measured by labor – hours per ton of a specific type of steel. Although labor – hours is a common measure of input, other measures such a capital (dollars invested), materials (tons of ore), or energy (kilo watts of electricity) can be used. Productivity is the relationship between the outputs generated from a system and the inputs that are used to create those outputs. An example of this can be summarized in the following equation:

$$productivity = \frac{units\ produced}{input\ used} \qquad (1\ \text{-}1)$$

✓ **Single – factor productivity (Partial Measure**): is use just one resource input to measure productivity.

$$Partial\ measure = \frac{\text{output}}{\text{machine}} \quad , \quad \frac{\text{output}}{\text{labor}} \quad , \quad \frac{\text{output}}{\text{Capital}}$$

✓ **Multifactor Productivity (multifactor measure):** includes all inputs (e.g., capital, labor, material, energy). Multifactor productivity is also known as **total factor productivity**. Multifactor productivity is calculated by combining the input units as shown here:

$$Multifactor\ \ measures = \frac{\text{output}}{\text{labor+machine}} \ , \quad \frac{\text{output}}{\text{labor+Capital+Energy}}$$

$$Total\ measures = \frac{\text{Goods or Services Produced}}{\text{All inputs used to produce them}}$$

Example1 1:

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

$$labor\ productivity = \frac{1{,}000}{250} = 4 \text{ units per labor – hour}$$

One resource input ⟶ ***single-factor productivity***

Example 2:

if 7040 Units Produced and sold for \$1.10/unit and

Cost of labor: \$1,000

Cost of materials: \$520

Cost of overhead: \$2000

What is the total factor or multifactor productivity?

Solution:

$$\text{TFP} = \frac{\text{output}}{\text{labor+material+overhead}} = \frac{(7040\text{ units})*(\$1.10)}{\$1000 + \$520 + \$2000} = 2.20$$

Multiple resource inputs ⟶ **multi-factor productivity**

Example 3:

Collins title wants to evaluate its labor and multifactor productivity with a new computerized title-search system. The company has a staff of four, 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 title each day. The new computerized title-search system will allow the processing of 14 title per day. Although the staff, their work hours, and pay are the same, the overhead expenses are now \$800 per day. Determine labor and multifactor productivity for both the old and new system.

Solution:

1. Labor productivity of old and new system

Old System:

Staff of 4 works 8 hrs/day 8 titles/day

Payroll cost = \$640/day

Overhead = \$400/day

$$labor\ productivity = \frac{8 titles/day}{32\text{ labor} - \text{hours}}$$

$$= 0.25\ titles/labor - hr$$

New System:

Staff of 4 works 8 hrs/day 14 titles/day

Payroll cost = \$640/day

Overhead = \$800/day

$$labor\ productivity = \frac{14 titles/day}{32\text{ labor} - \text{hours}}$$

$$= 0.4375\ titles/labor - hr$$

2. Multifactor Productivity

Old system:

Staff of 4 works 8 hrs/day 8 titles/day
Payroll cost = \$640/day
Overhead = \$400/day

$$multifactor\ productivity = \frac{8 titles/day}{\$640 + 400}$$

$$= .0077\ titles/dollar$$

New system :

Staff of 4 works 8 hrs/day 14 titles/day
Payroll cost = \$640/day
Overhead = \$800/day

$$multifactor\ productivity = \frac{14 titles/day}{\$640 + 800}$$

$$= .0097\ titles/dollar$$

If labor productivity growth is entirely the result of capital spending, measuring just labor distorts the results. Multifactor productivity is usually better, but more complicated. Labor productivity is the more popular measure. The multifactor productivity measures provide better information about the trade – offs among factors, but substantial ***measurement problems*** remain. Some of these measurement problems are listed here:

1. *Quality:* may change while the quantity of inputs and outputs remains constant.
2. *External elements*: may cause an increase or decrease in productivity.
3. *Precise units of measure:* may be lacking

1.5.1. Productivity Variables

Productivity increases are dependent on the three productivity variables:

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

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

Labor: improvement in the contribution of labor to productivity is the result of a healthier better – educated, and better – nourished labor force. Some increase may also be attributed to a shorter workweek. Historically, about 10% of the annual improvement in productivity is attributed to improvement in the quality of labor. Three key variables for improved labor productivity are:

- Basic education appropriate for an effective labor force.
- Diet of the labor force
- Social overhead that makes labor available, such as transportation and sanitation.

Illiteracy and poor diets are a major impediment to productivity, costing countries up to 20% of their productivity. Infrastructure that yields clean drinking water and sanitation is also an opportunity for improved productivity, as well as an opportunity for better health, in much of the world.

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

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

1.5.2. Service productivity

The service sector provides a special challenge to the accurate measurement of productivity and productivity improvement. The traditional analytical framework of economic theory is based primary goods – producing activities.

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

- Typically, labor – intensive (for example, counselling, teaching).
- Frequently focused on unique individual attributes or desires (for example, investment advice).
- Often an intellectual task performed by professionals (for example, medical diagnosis)
- Often difficult to mechanize and automate (for example a haircut).

The more intellectual and personal the task, the more difficult it is to achieve increases in productivity. Low – productivity improvement in the service sector is also attributable to the growth of low – productivity activities in the service sector. These include activities not previously a part of the measured economy, such as child care, food preparation, house cleaning, and laundry service. These activities have moved out of the home and into the measured economy as more and more women have joined the workforce.

However, in spite of the difficulty of improving productivity in the service sector, improvements are being made. and this text presents a multitude of ways to make these improvements.

CHAPTER TWO

OPERATIONS STRATEGY AND COMPETITIVENESS

After completing this unit, students will be able to:

- ☑ Define mission and strategy
- ☑ Identify and explain three strategic approaches to competitive advantage
- ☑ Identify and explain four global operations strategy options.

2.1. Developing Missions and Strategies

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

Mission

Economic success, indeed survival, is the result of identifying missions to satisfy a customer's needs and wants. 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. 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 function are developed to support the firm's overall mission. Then within that function lower – level supporting missions are established for the OM functions. The following are some of sample missions.

Table 2.1 sample mission for company, the operations functions, and major OM departments

Sample Company Mission	
To manufacture and service an innovative, 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 Missions	
Product Design	To design and produce products and services with outstanding quality and inherent customer value.

Quality management	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 operations
Process design	To determine and design or produce the production process and equipment that will be compatible with low-cost product, high quality, and good quality of work life at economical cost.
Location	To locate, design, and build efficient and economical facilities that will yield high value to the company, its employees, and the community.
Layout design	To achieve, through skill, imagination, and resourcefulness in layout and work methods, production effectiveness and efficiency while supporting a high quality of work life.
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.
Supply chain management	To collaborate with suppliers to develop innovative products from stable, effective, and efficient sources of supply.
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.

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. Operations strategy is a long term plan for the production of a company's products/rendering services and it provides a road map for what the production/operations function must do if business strategies are to be achieved. Operations strategy is the decisions which shape the long-term capabilities of the company's operations and their contribution to overall strategy through the on-going reconciliation of market requirements and operations resources.

Firms achieve missions in three conceptual ways: 1). Differentiation, 2) cost leadership, and 3). Response. This means operations managers are called on to deliver goods and services that are (1) *better*, or at least *different*, (2) *cheape*r, 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.

Operations strategy consists of goals, plans and a direction for the operations function that are linked to the business strategy and other functional strategies, leading to a competitive advantage for the firm. The approach, consistent with organization strategy, that is used to guide the operations function. The operations manager's job is to implement an OM strategy, provide competitive advantage, and increase productivity

Tactics and Operations

Tactics: is the methods and actions taken to accomplish strategies. The "how to" part of the process. **Operation**: is the actual "doing" part of the process.

2.2. Achieving Competitive Advantage Through Operations

Each of the three strategies provides an opportunity for operations manager to achieve 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. Pure forms of these strategies may exist, but operations managers will more likely be called on to implement some combination of them.

A. Competing on Differentiation

Differentiation is concerned with providing uniqueness. A firm's opportunities for creating ***uniqueness*** are not located with a particular function or activity but can arise in virtually everything 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. Indeed, differentiation should be thought of as going beyond both physical characteristics and service attributes to encompass everything about the product or service that influences the value that the customers derive from it. Therefore, effective operations managers assist in defining everything about a product or service that will influence the potential value of the customer. E.g. Convenience of product features or convenience of location distribution…

In the service sector, one option for extending products differentiation is through an *experience*. Differentiation by experience in services is a manifestation of the growing "experience economy." The idea of experience differentiation is to engage the customer – to use people's five senses so they become immersed, or even an active participant, in the product.

B. Competing on Cost

Low – cost leadership entails achieving maximum value as defined by your customer. To the companies which compete directly on price, cost will clearly be their major operations objective. The lower the cost of producing their goods and services, the lower can be the price to their customers. Even those companies which compete on things other than price, however, will be interested in keeping their costs low. Every euro or dollar removed from an operation's cost base is a further euro or dollar added to its profits. Provide the maximum value as perceived by customer. Does not imply low quality.

C. Competing on Response

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

Flexible performance: Flexibility means being able to change the operation in some way. Flexibility is matching market changes in design innovation and volumes.

Product/service flexibility: the operation's ability to introduce new or modified products and services.

Mix Flexibility: the operation's ability to produce a wide range or mix of products and services.

Volume Flexibility: the operation's ability to change its level of output or activity to produce different quantities or volumes of products and services over time.

Delivery Flexibility: the operation's ability to change the timing of the delivery of its services or products.

The second aspect of response is the ***reliability of scheduling***. Doing things in time for customers to receive their goods or services exactly when they are needed, or at least when they were promised.

The third aspect of response is ***quickness.*** is *quickness* in design, production, and delivery. The elapsed time between customers requesting products or services and their receipt of them.

2.3. Operations Strategy Issues

Operations managers consider a number of issues while developing operations strategies. These issues are examined in three ways: (1) Research, (2) preconditions, and (3) dynamics.

1. Research

Research has provided the following characteristics as impacting strategic OM decisions:

- High product quality as compared to competitors
- High capacity utilization
- High operating effectiveness (the ratio of expected to actual employee productivity)
- Low investment intensity (the amount of capital required to produce a dollar of sales)
- Low direct cost per unit (relative to competitors).

2. Preconditions

The following need to be understood in developing an effective OM strategy:

- Present and changing environment- the economic & technological environment in which the strategy is to be executed.
- Competitive demands- requires to understand about competitors' strengths and weaknesses
- Knowing the company's strategy.
- Product life cycle (PLC)-an understanding of where each product stands in the PLC

3. Dynamics

Strategies change for two reasons. First, strategy is dynamic because of changes within the organization. All areas of the firm are subject to change. Changes may occur in a variety of areas, including personnel, finance, technology, and product life. All may make a difference in an organization's strengths and weaknesses and therefore its strategy. Strategy is also dynamic because of changes in the *environment.*

2.4. Strategy Development and Implementation

One firm understands the issues involved in developing an effective strategy, they evaluate their internal strengths and weaknesses as well as the opportunities and threats of the environment. This is known as SWOT analysis (Strength, Weakness, Opportunities, and Threats). Beginning with SWOT analyses, firms position themselves, through their strategy, to have a competitive advantage. The firm may have excellent design skills or great talent at identifying outstanding locations. However, the firm may recognize limitation of its manufacturing process or in finding good suppliers. The idea is to maximize opportunities and minimize threats in the environment while maximizing the advantages of the organization's and minimize threats in the environment while maximizing the advantages of the organization's strengths and minimizing the weaknesses.

In the process of development and implementation of strategy, ***critical success factors are identified, build and staff the organization, and integrating OM with other activities.***

Critical Success Factors and Core Competencies

Because no firm does everything exceptionally well, a successful strategy requires determining the firm's critical success factors and core competencies. **Critical success factors (CSFs)** are those activities that are necessary for a firm to achieve its goals. Critical success factors can be so significant that a firm must get them right to survive in the industry. CSFs are often necessary, but not sufficient for competitive advantage. On the other hand, **core competencies** are the set of unique skills, talents, and capabilities that a firm does at a world – class standard. They allow a firm to set itself apart and develop a competitive advantage. A core competencies may be a subset of CSFs or a combination of CSFs. The operations manager begins this inquiry by asking:

- "what tasks must be done particularly well for a given strategy to succeed?"
- Which activities will help the OM function provide a competitive advantage?"
- Which elements contain the highest likelihood of failure, and which require additional commitment of managerial, monetary, technological, and human resources?"

Only by identifying and strengthening critical success factor and core competencies can an organization achieve sustainable competitive advantage.

Build and staff the organization

The operations manager's job is a three – step process. once a strategy and critical success factors have been identified, the second step is the group the necessary activities into an organizational structure. The third step is to staff it with personnel who will get the job done. The manager works with subordinate mangers to build plant, budgets, and programs that will successfully implement strategies that achieve missions.

Integrate OM with other activities

The operations function is most likely to be successful when the operations strategy is integrated with other functional areas of the firm, such as marketing, finance, information technology, and human resources. In this way, all of the areas support the company's objectives. The operations manager transforms inputs into outputs. The transformations may be in terms of storage, transportation, manufacturing, dissemination of information, and utility of the product or service. The operations manager's job is to implement an OM strategy, provide competitive advantage, and increase productivity.

2.5. Global Operations Strategy Options

Many operations strategies now require an international dimension. An international business is any firm that engages in international trade or investment. This is a very broad category and is the opposite of a domestic, or local, firm.

A multinational corporation (MNC) is a firm with extensive international business involvement. MNCs buy resources, create goods or services, and sell goods or services in a variety of countries. The term multinational corporation applies to most of the world large, well – known business. certainly, IBM is a good example of an MNC. It imports electronics components to the U.S. from over 50 countries, exports computers to over 130 countries.

Operations managers of international and multinational firms approach global opportunities with one of four operations strategies: International, multidomestic, global, and transnational.

A. International Strategy

an international strategy uses exports and licenses to penetrate the global arena. The international strategy is the least advantageous, with little local responsiveness and little cost advantage. There is little responsiveness because we are exporting or licensing a good from the home country. And the cost advantages may be few because we are using the existing production process at some distance from the new market. However, an international strategy is often the easiest, as exports can require little change in existing operations, and licensing agreements often leave much of the licensee.

B. Multidomestic Strategy

The multidomestic strategy had decentralized authority with substantial autonomy at each business. organizationally these are typically subsidiaries, franchises, or joint ventures with substantial independence. The advantage of this strategy is maximizing a competitive response for the local market; however, the strategy has little or no cost advantage. Many food producers, such as Heinz, use a multidomestic strategy to accommodate local tastes because global integration of the production process is not critical. The concept is one of "we were successful in the home market, let's export the management talent and processes, not necessarily the product, to accommodate another market."

C. Global Strategy

A global strategy has a high degree of centralization, with headquarters coordinating the organization to seek out standardization and learning between plants, thus generating economies of scale. This strategy is appropriate when the strategic focus is cost reduction but has little to recommend it when the demand for local responsiveness is high.

D. Transnational Strategy

A transnational Strategy exploits the economies of scale and learning, as well as pressure for responsiveness, by recognizing that core competence does not reside in just the "home" country but can exist anywhere in the organization. Transnational describes a condition in which material, people, and ideas cross – or transgress – national boundaries. These firms have the potential to pursue all three operations strategies (i.e., differentiation, low cost, and response). Such firms can be thought of as "world companies" whose country identity is not as important as its interdependent network of worldwide operations.

CHAPTER THREE
DESIGN OF OPERATIONS SYSTEM

Outline:

3.1. Product (Service) Design and Development

3.2. Process Selection

3.3. Capacity Planning

3.4. Facility Location

3.5. Facility Layout

3.6. Job Design and Work Measurement

Introduction

Products and services are often the first thing that customers see of a company, so they should have an impact. And although operations managers may not have direct responsibility for product and service design, they always have an indirect responsibility to provide the information and advice upon which successful product or service development depends. But increasingly operations managers are expected to take a more active part in product and service design. Unless a product, however well designed, can be produced to a high standard, and unless a service, however well conceived, can be implemented, the design can never bring its full benefits.

3.1. Product (Service) Design and Development

3.1.1. What is Design?

Design is the process of structuring of component parts /activities of products so that as a unit it can provide value for the customer. Product is designed in terms of size, colour, shape, content and other related dimensions. Design greatly affects operation by specifying the products that will be made and it is the prerequisite for operations to occur.

Who is responsible for design? It is not only operations department but also an interactive decision of marketing (4P's), purchasing (what materials are required to produce the products), finance (return on investment, financial liquidity), engineering, legal (warranty and liability issues), quality control (conformance with product specifications), government, top management (decision used for a long period of time) and other stakeholders, etc.

3.1.2. Objectives of Design

The objectives of design may vary from situations to situations and from organization to organization. An obvious reason includes:

- To be competent (by offering new products or services).
- To reduce cost and increase profit.

- To develop new products or services as alternatives to downsizing.
- To design products/services that have customer appeal
- To increase quality and level of customer satisfaction

NB: Sometimes product or service design is actually redesign for a number of reasons such as customer complaints, excessive warranty claims, low demand etc.

3.1.3. Product Design

Product design is *the process of defining all the features and characteristics of just about anything you can think of.* Consumers respond to a product‘s appearance, color, texture, and performance. All of its features, summed up, are the product‘s design. Someone came up with the idea of what this product will look like, taste like, or feel like so that it will appeal to you. This is the purpose of product design.

Product design is also defined as: ‘*a product‘s characteristics, such as its appearance, the materials it is made of, its dimensions and tolerances, and its performance standards*’.

3.1.3.1. Philosophies Towards Product Design and Development

There are three fundamentally different ways to introduce new products.

i. **Market pull:** the market is the primary basis for determining the products a firm should make with little regard to the existing technology. Customer’s wants and needs play the primary role for new product development and design. A firm should make what it can sell. So it is required to undertake customers’ survey and market research to determine customer’s need.

ii. **Technology push philosophy:** technology is the primary determinant of the product that the firm should make with little regard for the market. One should sell what can be produced i.e. the existing technology determine what kind of product to be produced .The assumption is that the firm should pursue a technology based advantages by developing superior technology and products. The products are pushed to the market and the marketing’s job is to create demand for these superior products.

iii. **Inter functional philosophy:** stated that product design and development is neither market pull nor technology push. Rather it is inter functional and interactive process of customers, marketing, finance, engineering and other related functional areas.

3.1.3.2. Product Development Process (Phases)

To get to a final design of a product or service, the design activity must pass through several key stages. These form an approximate sequence, although in practice designers will often recycle or backtrack through the stages. The basic stages of product/service design are the following

1. ***Idea generation***
2. ***Feasibility analysis***
3. ***Initial (Preliminary) Product Design***
4. ***Prototype development***
5. ***Prototype Testing***
6. ***Final Product Design***
7. ***Product introduction***
8. ***Follow-up evaluation***

Let's discuss each of them

1. Concept (idea) Generation

The ideas for new product or service concepts can come from sources outside the organization, such as customers or competitors, and from sources within the organization, such as staff (for example, from sales staff and front-of-house staff) or from the R&D department.

a) Ideas from customers: Marketing, the function generally responsible for identifying new product or service opportunities, may use many market research tools for gathering data from customers in a formal and structured way, including questionnaires and interviews. Listening to the customer, in a less structured way, is sometimes seen as a better means of generating new ideas. **Focus groups**, for example, are one formal but unstructured way of collecting ideas and suggestions from customers.

b) Ideas from competitor activity: All market-aware organizations follow the activities of their competitors. A new idea may give a competitor an edge in the marketplace, even if it is only a temporary one, then competing organizations will have to decide whether to imitate or alternatively to come up with a better or different idea.

Sometimes this involves *reverse engineering* that is, taking apart a product to understand how a competing organization has made it.

c) Ideas from staff: The contact staff in a service organization or the salesperson in a product-oriented organization could meet customers every day. These staff may have good ideas about what customers like and do not like.

d) Ideas from research and development: One formal function found in some organizations is research and development. Research usually means attempting to develop new knowledge and ideas in order to solve a particular problem or to grasp an opportunity. Development is the attempt to utilize and operationalize the ideas that come from research.

2. Concept Screening (Feasibility Analysis)

Not all concepts which are generated will necessarily be capable of further development into products and services. The purpose of the concept-screening stage is to take the flow of concepts and evaluate them. Evaluation in design means assessing the worth or value of each design option, so that a choice can be made between them. This involves assessing each concept or option against a number of **design criteria**. Major criteria are the following:

- **Market feasibility**: evaluate the new ideas in terms of whether the product has market or not,
- **Financial (economic) feasibility**: how well the product quality performance and costs confirm to the design objectives and,
- **Technical feasibility**: availability of technology and skilled labor.

At last, the most feasible and viable product concept is selected for the next stages.

3. Initial (Preliminary) Product Design

This stage of the product-design process is concerned with developing the best design for the new product ideas. It is the translation of ideas in to products. 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 drawing* (or computer image) specified in sufficient detail that production prototype can be built and tested. In the preliminary design tradeoffs between cost, quality and product performances are considered.

4. Prototype Construction

If the preliminary product design is approved, a prototype/s may be built for further testing and analysis. Several prototypes which closely resembles with the final products may be made by hand from some artificial materials such as plastics, mud, clay, wood etc. For example, the auto industry regularly makes clay models of new automobiles.

5. Prototype Testing:

A model is tested for its physical properties or uses under actual operating conditions. Testing of prototypes is aimed at verifying marketing and technical performance. The purpose of a test market is to gather quantitative data on customer acceptance of the new product. Prototype is also tested for technical product performance. In general, such testing is important in uncovering any problems and correcting them prior to full scale production. For example, auto manufacturer perform extensive road tests on new models; similar experiments are performed on tires, airplanes, and sports equipment.

6. **Final Product Design**

Prototype testing may indicate certain changes in the preliminary product design. If changes are made the product may be tested further to ensure final product performance. Market test is used to determine the extent of consumer acceptance. If this market test is unsuccessful, return to the design review phase (this phase is handled by marketing). During the final phase these changes are incorporated in to the design specification. Drawing and specifications for the product are to be developed at this stage. And go for full scale operations.

7. **Product Introduction:** this stage is used to promote the product; handled by marketing
8. **Follow-up Evaluation:** it helps to determines if changes are needed & refine forecasts; handled by marketing.

3.1.3.3. Issues in Product and Service Design

This sub unit addresses factors (techniques) to be considered while designing the product.

- ***Legal and Ethical Considerations***
- ***Strategies for product or service life cycle***
- ***Degree of standardization***
- ***Designing for mass customization***
- ***Reliability***
- ***Group technology (GT)***
- ***Virtual Reality technology***
- ***Value Analysis & value Engineering***
- ***Quality Function Deployment QFD***
- ***Robust Design***
- ***Cultural difference***
- ***Degree of newness***
- ***Modular Design***
- ***Concurrent Engineering***
- ***Computer-Aided Design (CAD)***
- ***Computer-Aided Manufacturing (CAM)***

Legal and Ethical Considerations

Designers are often under pressure to Speed up the design process and Cut costs. These pressures force trade-off decisions.

- **Product Liability** - A manufacturer is liable for any injuries or damages caused by a faulty product.
- **Uniform Commercial Code** – Says that products carry an implication of merchantability and fitness; i.e., a product must be usable for its intended purpose.

Designers Adhere to Guidelines

- *Produce designs that are consistent with the goals of the company*
- *Give customers the value they expect*
- *Make health and safety a primary concern*
- *Consider potential harm to the environment*

Strategies for product or service life cycle

Another factor in product design is the stage of the life cycle of the product. Most products go through a series of stages of changing product demand called the product life cycle. There are typically four stages of the product life cycle: ***introduction, growth, maturity, and decline.***

The product life cycle can be quite short for certain products, as seen in the computer industry. For other products it can be extremely long, as in the aircraft industry. A few products, such as paper, pencils, nails, milk, sugar, and flour, do not go through a life cycle. However, almost all products do, and some may spend a long time in one stage.

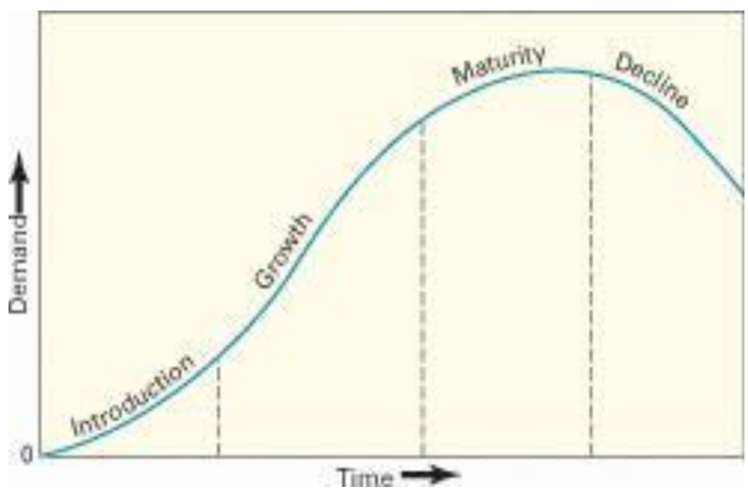
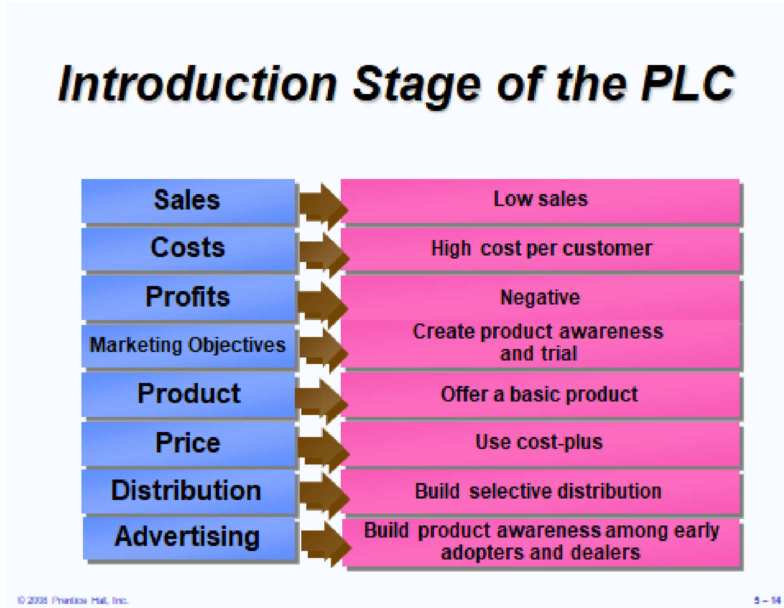


Figure 3.1: product life cycle

- ❑ ***Introduction***

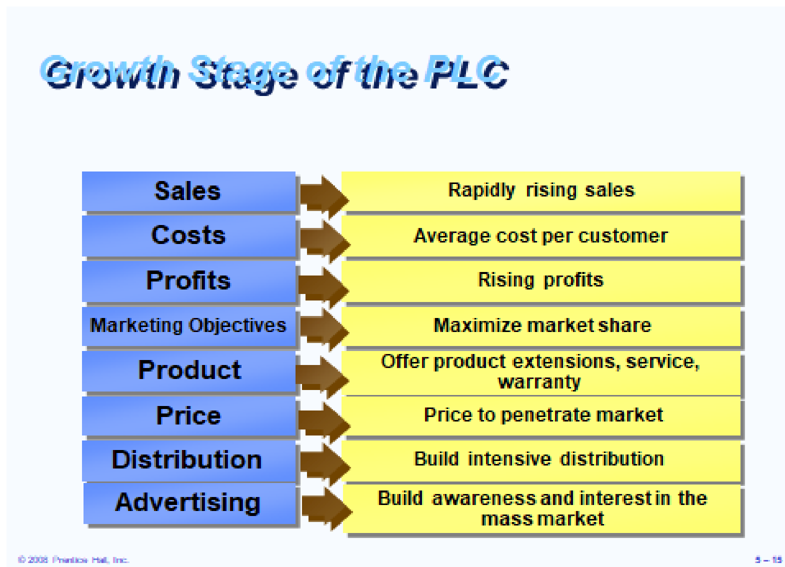
- Weigh trade-offs between eliminating ‘defects’ and getting the product or service to the market at an advantageous time

- Accurate demand forecasts are important to ensuring adequate capacity availability

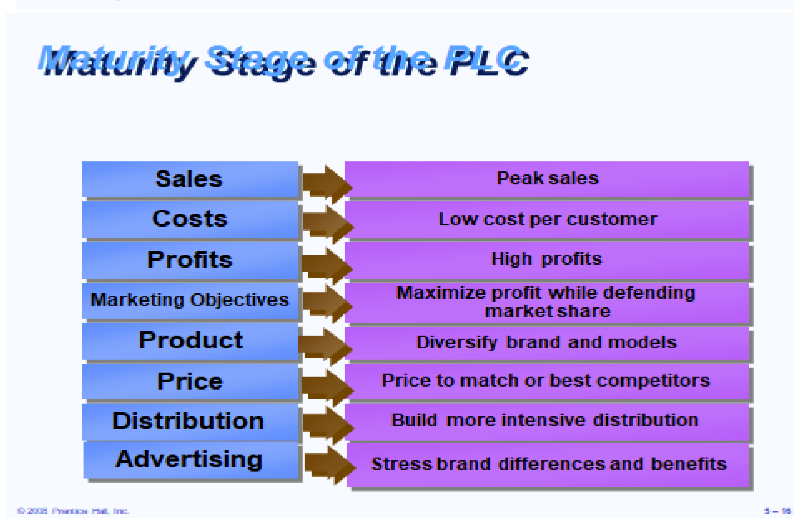


Growth

- Demand forecasts are important to ensuring a continued adequate capacity availability
- Design improvements
- Emphasis on improved product or service reliability and lower cost



- ❑ ***Maturity***
- Relatively few design changes
- Emphasis is on high productivity and low cost



❑ ***Decline***

- Continue or discontinue product or service
- Identify alternative uses for product or service
- Continued emphasis on high productivity and low cost

Design for Manufacturability (DFM)

DFM is a product development approach that explicitly considers the effectiveness with which an item can be made during the initial development of the product design. Manufacturability refers *to the ease with which the product can be manufactured*. Three concepts are closely related to designing for easy of production. These are: *simplification, specification, and standardization*.

- **Simplifications:** is a design or redesigns strategy that improves the manufacturability, serviceability, or reliability of a product or service by reducing the complexity of its design. **Specifications:** is a detail description of material, parts, or products including physical dimensions. These specifications profiled production department with precise information about the characteristics of products to be produced.
- **Standardization**: refers to a design activity that reduce variety amount a group of product or parts. Extent to which there is an absence of variety in a product, service or process. Standardized products are immediately available to customers. Standardization of groups of products or parts usually results in higher volume for each product or part model which can leads to lower production costs, higher product quality, greater ease of automation, and lower inventory investment.

Advantages of Standardization

- ✓ Fewer parts to deal with in inventory & manufacturing
- ✓ Design costs are generally lower
- ✓ Reduced training costs and time
- ✓ More routine purchasing, handling, and inspection procedures
- ✓ Orders fillable from inventory

- ✓ Opportunities for long production runs and automation
- ✓ Need for fewer parts justify increased expenditures on perfecting designs and improving quality control procedures.

Designing for mass customization

A strategy of producing standardized goods or services, but incorporating some degree of customization. Tactics make it possible are:

- **Delayed differentiation*:*** is a postponement tactic; producing but not quite completing a product or service until customer preferences or specifications are known
- **Modular Design:** is a *form of standardization in which component parts are subdivided into modules that are easily replaced or interchanged.* It allows: Easier diagnosis and remedy of failures, easier repair and replacement, simplification of manufacturing and assembly. It makes 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 in to a large number of different products..

Reliability

Reliability: The ability of a product, part, or system to perform its intended function under a prescribed set of conditions

Failure: Situation in which a product, part, or system does not perform as intended.

Normal operating conditions: The set of conditions under which an item's reliability is specified.

Range of Operating Condition

- **Robust Design:** Design that result in products or services that can function over a broad range of conditions. *Product is designed so that small variations in production or assembly do not adversely affect the product*. Typically results in lower cost and higher quality.
- **Cultural difference:** designer must take into account any differences of different country.
- **Degree of newness:** product design change can range from modification of an existing to an entirely new product.
    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

Degree of Design Change

Type of Design Change	Newness to the organization	Newness to the market
Modification	Low	Low
Expansion	Low	Low
Clone (copy)	High	Low
New	High	High

i.e. newness for organization in transition process

- ✓ Newness to the market degree of acceptance to new product
- ✓ Their effect on cost and pricing

Concurrent Engineering/ Simultaneous development

It 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*. In its narrowest sense, concurrent engineering means *bringing engineering design* and *manufacturing people* together early in the *design phase* to simultaneously develop the product and the processes for creating the product. Using concurrent engineering is preferable than *sequential/hierarchical engineering*. 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**.**

Group Technology (GT)

GT is parts or products with similar characteristics in to families, and sets aside groups of machines for their productions. Families may be based on size, shape, manufacturing, (or routing) requirement or demand. The goal is to identify a set of products with similar processing requirements and minimize machine changeovers or setups. For example all bolts might be assigned to the same family because they all require the same basic processing steps regardless of the size or shape. GT is an engineering and manufacturing strategy based on the development and exploitations of commonalities among parts, equipment, or processes.

Value Analysis and Value Engineering

The term VA and VE are used almost interchangeably but they are not identical. Value engineering focuses on pre- production design improvement while VA (even though is a related techniques) takes place during the production process when it is clear that a new product is a success. The basic objective of VE &VA is to achieve equivalent or better performance at a lower cost while maintaining all functions and quality requirements. It does this largely by identifying and eliminating hidden, invisible, and unnecessary cost. VE & VA should not be treated as a mere cost reduction techniques or cheapening of the product. It is more comprehensive and the improvement in value is attained without any sacrifices in quality, reliability, maintainability, availability, aesthetics etc.

Hence, Value Analysis focuses on design improvement during production, examination of the function of parts and materials in an effort to reduce cost and/or improve product performance and seeks improvements leading either to a better product or a product which can be produced more economically.

Computer Aided Design (CAD) & Computer Aided Manufacturing (CAM)

- ✓ **CAD** is an electronic system for *designing new parts or products or altering existing ones,* replacing drafting traditionally done by hand. The heart of CAD is a powerful computer and graphics software that allow a designer to manipulate geometric shapes and create visual display. Using the design data stored in the computer's memory, manufacturing engineers and other users can quickly obtain print outs of plan and specifications for a part or product. CAD cut the cost of product development and sharply reduces the time to market for new products. Hence Computer-Aided Design (CAD) will have the following benefits: 1) increases productivity of designers, 3 to 10 times; 2) creates a database for manufacturing information on product specifications; 3) provides possibility of engineering and cost analysis on proposed designs.
- ✓ **CAM** is an electronic system which is used to *design production process and control machine tools and material flow through programmable automation*. CAM is utilizing specialized computers and program to control manufacturing equipment. CAM is often driven by the CAD system.
- ✓ CAD /CAM integrate the design and manufacturing functions by translating final design specification in to detailed machine instruction for manufacturing an item. CAD/CAM is quicker, less error prone than human, eliminate duplications between engineering and manufacturing, allow engineers to see how the various parts of a design interact with each other without having to build a prototype.

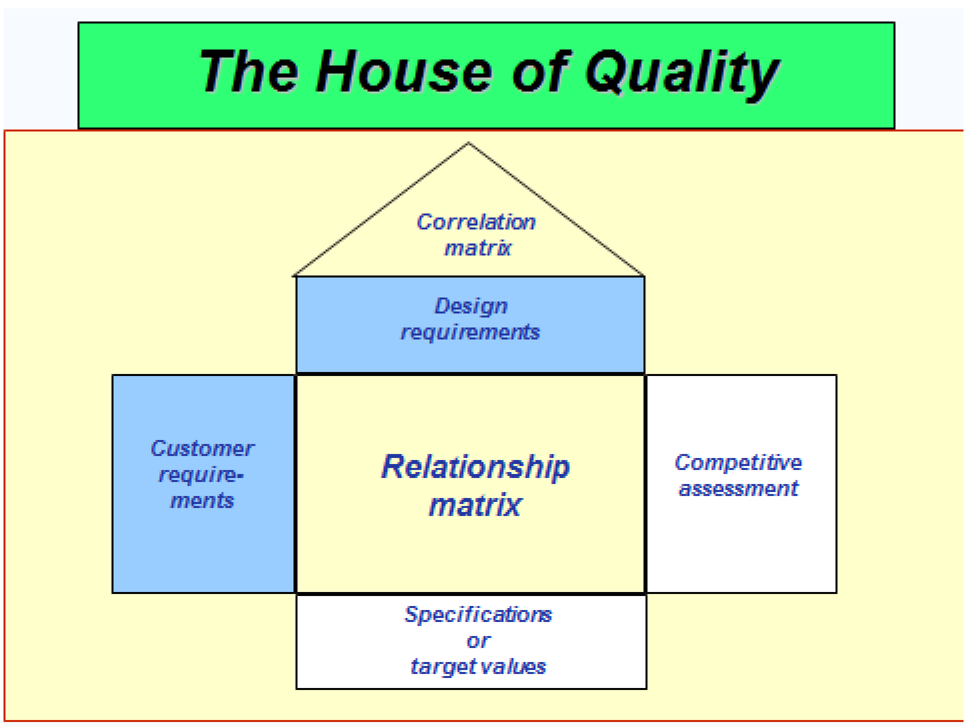
Virtual Reality Technology

Computer technology used to develop an interactive, 3-D model of a product from the basic CAD data. Allows people to see the finished design before a physical model is built. 3- D is Very effective in large-scale designs such as plant layout.

Quality Function Deployment (QFD)

The key purpose of quality function deployment is to try to ensure that the eventual design of a product or service actually meets the needs of its customers. It is a technique that was developed in Japan at Mitsubishi's Kobe shipyard and used extensively by Toyota, the motor vehicle manufacturer, and its suppliers. It is also known as the ***house of quality*'** (because of its shape) and the ***voice of the customer*'** (because of its purpose).

The technique tries to capture what the customer needs and how it might be achieved. The QFD matrix is a formal articulation of how the company sees the relationship between the requirements of the customer (what's) and the design characteristics of the new product (the how's).



Defining the relationship is the first step in building a world class production system. To build the house of quality, we perform seven basic steps:

1) ***Identify customer wants***. (What do prospective customers want in this product?)
2) ***Identify how the good/service will satisfy customer wants.*** (Identify specific characteristics, features, or attributes and show how they will satisfy customer wants).
3) ***Relate customer wants to product how's***. (Build a matrix as the following figure shows this relationship.)
4) ***Identify relationships between the firm's how's***. (How do our how's tie together?)
5) ***Developing importance ratings***. (Using the customer's importance ratings and weights for the relationships in the matrix, compute our importance ratings.)
6) ***Evaluate computing products***. (How well do competing products meet customer wants?)
7) ***Determine the desirable technical attributes***, ***your performance***, and the competitor's performance against this attributes.

3.1.4. Service Design

Service refers to an act; something is done to or for a customer. It provided by service delivery system.

- ***Service delivery system:*** the Facilities, Processes, Skills needed to provide a service.
- ***Product bundle:*** combination of goods and services provided to a customer.
- ***Service package:*** Service design involves development and refinement of the overall requirement.

- The physical resources needed
- The goods that are purchased or consumed by the customer
- Explicit services (core /essential feature of it)
- Implicit services(extra features e.g. friendliness)

3.1.4.1. Phases in Service Design

1. **Conceptualize:** Idea generation, assessment of customer wants /needs, assessment of demand potential
2. Identify **service package** components
3. Determine **performance specifications**
4. Translate performance specifications into **design specifications**
5. Translate design specifications into **delivery specifications**

3.1.4.2. Service Blueprinting

Service blueprinting is a method used in service design to describe and analyze a proposed service. It is a useful tool for conceptualizing a service delivery system. It provides a visual model of the process

Major Steps in Service Blueprinting

1. Establish boundaries for the process
2. Identify steps involved and describe them
3. Prepare a flowchart of major process steps
4. Identify potential failure points
5. Establish a time frame for service execution & an estimate of variability in process time requirement
6. Analyze profitability

Service Blueprint

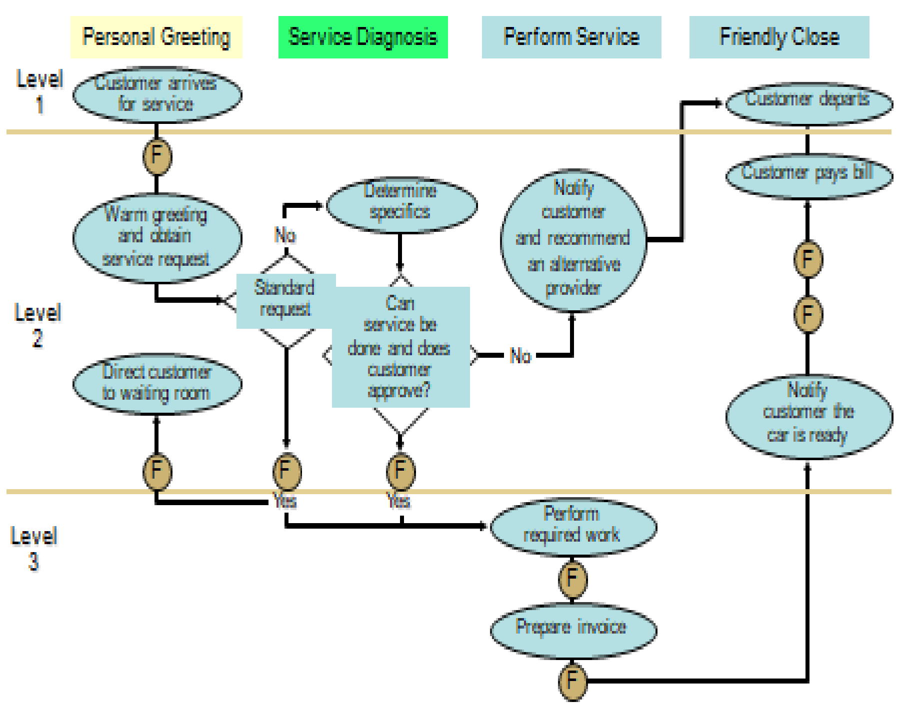


Figure 3.2: Service blueprint

3.2. PROCESS SELECTION AND CAPACITY PLANNING

Introduction

Another major decision for the operation manager is finding the best way to produce. It is clear that no product can be made and no service provided without a process, and no process can exist without a product or service. Process selection refers to the way an organization chooses to produce its goods or provide its service. Essentially it involves choice of technology and related issues, and it has major implications for capacity planning, layout of facilities, equipment and design of work systems.

A process strategy is an organization's approach to transform resources into goods and services. We use terms, process and transformation, to describe this strategy. The objective of a process strategy is to find a way to produce goods and services that meet customer requirements and product specifications within cost and other managerial constraints. The process selected will have a long term effect on efficiency and production, as well as the flexibility, cost, and quality of goods produced. This part of the course looks at the ways managers design a process.

3.2.1. Make or Buy Decision

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 contact for repair services. If a decision is made to buy or contract, this lessens or eliminates the need for process selection. In make or buy decisions, a number of factors are usually considered:

- Available capacity
- Expertise
- Quality considerations
- The nature of demand
- Cost

In some cases, a firm might choose to perform part of the work itself and let others handle the rest in order to maintain flexibility and to hedge against loss of a subcontractor. Moreover, this provides a bargaining tool in negotiations with contractors, or a head start if the firm decides later to take over the operation entirely. If the organization decides to perform some or all of the processing, then the issue of process selection is important.

3.2.2. Process Choice

One of the first decisions a manager makes in designing a well functioning process is to choose a process type that best achieves the relative importance placed on quality, time flexibility and cost. The manager has five process types, which form a continuum, to choose from:

- Project
- Job
- Batch
- Line, and
- Continuous

The figure below shows the types of processes found in manufacturing and services organizations alike. The fundamental message here is that the best choice for a process depends on the volume and the degree of customization required of the process. A process choice might apply to an entire process or just one sub process within it.

Product variety	High	Moderate	Low	Very low
Equipment flexibility	High	Moderate	Low	Very low
Low Volume	Job Shop			
Moderate Volume		Batch		
High			Repetitive	

1. ***Project Process***

A project process deals with one-of-a kind products that are tailored to the unique requirement of each customer. Projects are set up to handle complex jobs that involve unique sets of activities. Examples of a project process are building a shopping center, planning a major event, running a political campaign, doing management consulting work, or developing a new technology or product. A project process is characterized by a high degree of job customization, the large scope of each project, and the release of substantial resources once a project is completed. A project process lies at the high customization low volume end of the process choice continuum. The sequence of operations and the process involved in each are unique to the project, creating one-of-a-kind products or services made specifically to customer orders.

2. Job process

Next in the continuum of process choices is the job process. It is appropriate for manufacturers of small batches of many different products, each of which is custom designed and, consequently, requires its own unique set of processing steps, or routing, through the production process. Examples are providing emergency room care, handling special delivery mail or making customized cabinets. Customization is relatively high and volume for any one product or service is low. However, volumes are not as low as for a project process, which by definition does not produce in quantity. The work force and equipment are flexible and handle various tasks.

As with a project process, companies choosing a job process often bid for work. Typically, they make products to order and do not produce them ahead of time. A job process primarily organizes all like resources around itself; equipment and workers capable of certain types of work are located together. These resources process all jobs requiring that type of work. Because customization is high and most jobs have a different sequence of processing steps, this process choice creates jumbled flows through the operations rather than a line flow.

Characteristics of Job process

- Small production runs
- Discontinuous flow of materials
- Disproportionate manufacturing cycle time
- General purpose machines and process layout
- Highly skilled labor
- Highly competent knowledgeable supervision
- Large work-in-progress
- Limited functions of production planning and control

3. Batch Process

Batch process is a step up from job process in terms of product standardization, but it is not as standardized as line process. Example of a batch process are scheduling air travel for a group, making components that feed an assembly line, processing mortgage loans, and manufacturing capital equipment. A batch process differs from the job process with respect to volume, variety and quantity.

- The primary difference is that volumes are higher because the same or similar products or services are provided repeatedly.
- Another difference is that a narrow range of products and services is provided. Variety is achieved more through an assemble-to-order strategy than the job process's make-to-order or customized services strategy. Some of the components going into the final product or service may be processed in advance.
- A third difference is that production lots or customer groups are handled in larger quantities (or batches) than they are with job processes. A batch of one product or customer grouping is processed, and then production is switched to the next one. Eventually, the first product or service is produced again. A batch process has average or moderate volumes, but variety is still too great to warrant dedicating a separate process for each product service.

Characteristics of Batch process

- Short runs
- Skilled labor in specific trades
- Supervisor to possess knowledge of a specific process
- Limited span of control
- General purpose machines and process type of layout
- Manual materials handling
- Manufacturing cycle time affected due to queues
- Large work-in-progress
- Flexibility of production schedules
- Need to have production planning and control

4. ***Line Process***

Line Process is characterized by a linear sequence of operations used to make the product or service. Products created by a line process include automobiles, appliances and toys. Services based on a line process are fast food restaurants and cafeterias. A line process lies between the batch and continuous processes on the continuum, volumes are high, and products or services are standardized, which allows resources to be organized around a product or service. There are line flows, with little inventory held between operations. Each operation performs the same process over and over, with little variability in the products or services provided. Production orders are not directly linked to customer orders, as is the case with project and job process.

Characteristics of Line process

- Continuous flow of material
- Special purpose machines and product type layout
- Mechanized materials handling
- Low skilled labor
- Short manufacturing cycle time
- Easy supervision
- Limited work-in-progress
- Lesser flexibility in production schedules

5. ***Continuous Process***

Continuous processes systems are sometimes referred to as flow systems because of the rapid rate at which items move through the system. This form of processing is used when highly standardized products are involved. Examples are petroleum refineries, chemical plants, and plants making beer, steel, and food. Firms with such facilities are also referred to as the process industry. A continuous process is the extreme end of high volume, standardized production with rigid line flows. Its name derives from the way materials move through the process.

Characteristics of Continuous Process

- Special purpose machines with built-in controls
- Highly mechanized/automated materials handling
- Virtually zero manufacturing cycle time
- control functions
- Low skilled labor
- Supervisor to be processes specialist
- Negligible work-in-progress
- Limited production planning and

3.3. Capacity Planning

After considering the process options, managers still face a number of issues. Because determining the size of a facility is critical to a firm's success, we now investigate the concepts and techniques of capacity planning. Capacity is the maximum output of a system in a given period. It is not normally expressed as a ***rate***, such as the number of tons of steel that can be produced per week, per month, or per year. For many companies, measuring capacity can be straight forward. It is the maximum number of units that can be produced in a specific time. However, for some organization, determining capacity can be more difficult. Capacity can be measured in terms of beds (a hospital) or, active members (a church). Other organizations use total work time available as a measure of overall capacity.

Design Capacity*:* the maximum output that can possibly attained.

Effective capacity: It is the maximum output rate that can be sustained under normal conditions. These conditions include realistic work schedules and breaks, regular staff levels, scheduled machine maintenance, and none of the temporary measures that are used to achieve design capacity. Note that effective capacity is usually lower than design capacity.

Actual Output*:* the rate of output actually achieved. It cannot exceed effective capacity and is often less than effective capacity due to breakdowns, defective output, shortages of materials, and similar factors.

Capacity utilization: It simply tells us how much of our capacity we are actually using. Capacity utilization can simply be computed as the ratio of actual output over design capacity:

Designing capacity is the maximum rate of output achieved under ideal conditions. Effective capacity 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. Actual output cannot exceed effective capacity and is often less because of machine breakdowns, absenteeism, and other problems 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.

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

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.

Example: Given

Design capacity = 50 trucks/day
Effective capacity = 40 trucks/day
Actual output = 36 units/day
Required: Calculate efficiency and capacity utilization and forward your observation on these two measures of capacity tools?

Solution

$$Efficiency = \frac{Actual\ Output}{Effective\ capacity} = \frac{36}{40} = 0.90 = 90\%$$

Capacity Utilization=$\frac{\textit{Actual Output}}{\textit{Design Capacity}}$=$\frac{36}{50} = \mathbf{0.72} = \mathbf{72}\%$

Hence, utilization is much lower than efficiency implies that mangers need to work on closing the gap as much as possible.

3.3.1. Managing Demand

Option 1: When demand exceeds capacity

- ✓ Curtail/hold back demand by raising prices, scheduling longer lead time
- ✓ Long term solution is to increase capacity

Option 2: When capacity exceeds demand

- ✓ Stimulate market, Product changes, layoffs, plant closings
- ✓ Adjusting to seasonal demands
- ✓ Produce products with complementary demand patterns

- **Tactics for Matching Capacity to Demand**

1. Making staffing changes (increasing or decreasing the number of employees or shifts)
2. Adjusting equipment
3. Purchasing additional machinery
4. Selling or leasing out existing equipment
5. Improving processes to increase throughput
6. Redesigning products to facilitate more throughput
7. Adding process flexibility to meet changing product preferences
8. Closing facilities

Steps for Capacity Planning

1. Estimate future capacity requirements
2. Evaluate existing capacity
3. Identify alternatives
4. Conduct financial analysis
5. Assess key qualitative issues
6. Select one alternative
7. Implement alternative chosen
8. Monitor results

Planning Service Capacity

Three important factors in planning service capacity

1. Need to be near customers-Capacity and location are closely tied
2. Inability to store services-Capacity must be matched with timing of demand
3. Degree of volatility of demand-Peak demand periods

3.4. Facility Location and Layout

3.4.1. Facility location

The selection of location is a key-decision as large investment is made in building plant and machinery. It is not advisable or not possible to change the location very often. So, an improper location of plant may lead to waste of all the investments made in building and machinery, equipment. **Facility Location** is the process of identifying the best geographic location for a service or production facility. ***The purpose of the location study is to find an optimum location one that will result in the greatest advantage to the organization*** ***Importance of Location Decisions:***

i) Location Decision

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

ii) Need for Location Decisions

Location decisions arise for a variety of reasons:

- As part of a marketing strategy to expand markets
- Addition of new facilities
- Growth in demand that cannot be satisfied by expanding existing facilities
- Depletion of basic inputs/resources (e.g. mining & fishing)
- Cost advantage

iii) Strategic Importance of Location Decisions

Location decisions are strategically important:

- Are closely tied to an organization’s strategies
- Effect capacity and flexibility
- Represent a long-term commitment of resources/costs

- Impact competitive advantage
- Importance to supply chains
- Impact on investments, revenues, and operations

Location and Costs

- ☑ Location decisions based on low cost require careful consideration
- ☑ Once in place, location-related costs are fixed in place and difficult to reduce
- ☑ Determining optimal facility location is a good investment

Location and Innovation

When creativity, innovation, and research and development investments are critical to the operations strategy, Cost is not always the most important aspect of a strategic decision. Therefore, there are four key attributes when strategy is based on innovation

- High-quality and specialized inputs
- An environment that encourages investment and local rivalry
- A sophisticated local market
- Local presence of related and supporting industries

iv) General Procedure for Making Location Decisions

The general procedures for making formal approach to location decisions usually consist of the following steps:

1. Decide 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
4. Evaluate the alternatives and make a selection

v) Location Options

There are essentially four options that managers can consider in location planning.

1. **Expand 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. **Add new locations*:*** while retaining existing ones, as is done in many retail operations. In such case, it is essential to take into account what the impact will be on the total system.
3. **Shut down at one location and move to another:** 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.

vi) Factors that Affect Location Decisions

Many factors influence location decisions. However, if 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. In service organizations, possible dominating factors are market related and include traffic patterns, convenience, and competitors' locations, as well as proximity to the market. This section presents you a brief description of some of these important factors.

a) Regional Factors:

The primary regional factors involve **raw materials**, **markets**, and **labor** considerations.

- **Location of Raw Materials**: Firms locate near or at the source of raw materials for three primary reasons: necessity, 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.
- **Location of 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. Some firms must locate close to their markets because of the perishability of their products. Examples include bakeries, flower shops, and fresh seafood stores. Locations of many government services are near the markets they are designed to serve.
- **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 serious potential problems. Skills of potential employees may be a factor, although some companies prefer to train new employees rather than rely solely on previous experience. Workers attitude 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 and rural areas.

- **Other Factors**: Climate and taxes sometimes play a role in location decisions.

b) 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. 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. Other community-related factors are the cost and availability of utilities, environment regulations, taxes (state and local, direct and indirect).

c) Site Related Factors:

The primary considerations related to sites are land, transportation, and zoning or other restrictions. 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 firm's access roads for trucks or rail spurs are important.

d) Global Locations:

Factors relating to foreign locations are:

- Policies of foreign ownership of production facilities (local content requirements, import restrictions, currency restrictions, environmental regulations and local product standards.
- Stability issues
- Cultural differences: living circumstances for foreign workers and their dependents
- Customer Preferences: possible buy locally sentiment

Labor: level of training and education of workers, work practices, possible regulations limiting number of foreign employees and etc…

Resources: availability and quality of raw materials, energy, transportation

vii) Evaluating Location Alternatives:

There are a number of techniques that are helpful in evaluating location alternatives: factor rating method, center of gravity method, Locational cost-profit-volume analysis and transportation model.

1. Factor Rating Method:

A typical location decision involves both qualitative and quantitative inputs, which tend to vary from 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 process of selecting a new facility location involves a series of following steps:

- Determine which factors are relevant (e.g., location of market, water supply, parking, revenue potential)
- Assign a weight to each factor that indicates its relative importance compared with all other factors. Typically, weights sum to 1.00.
- Decide on a common scale for all factors (e.g., 0 to 100)
- Score each location alternative
- Multiply the factor weight by the score for each factor, and sum the results for each location alternative
- Chose the alternative that has the highest composite score

Example: Assume that a small manufacturing firm has recently decided to expand its operations to include several new lines which it hopes to produce in a separate location because of space limitations in its existing plant. The following rating sheet illustrates relevant factors and factor weightings for two alternative locations.

Factors	Weight	Scores (out of 100)		Weighted score	
		Alternative 1	Alternative 2	Alternative 1	Alternative 2
Nearness to raw materials	0.10	100	60	10	6
Labor costs	0.05	80	80	4	4
Water Supply	0.40	70	90	28	36
Transportation costs	0.10	86	92	8	9.2
Climate	0.20	40	70	8	17
Taxes	0.15	80	90	12	13.5
Total	1			70	85.7

At the weighted score of the two alternatives indicate, alternative 1 =70 and alternative 2 = 85.7. therefore, based on factor rating method, alternative 2 is selected which has the highest weighted score value.

2. *The Centre 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 center of gravity method takes into account the locations of plants and markets, the volume of goods moved, and transportation costs in arriving at the best location for a single intermediate warehouse. The center of gravity is defined to be the location that minimizes the weighted distance between the warehouse and its supply and distribution points, where the distance is weighted by the number of tones supplied or consumed. The first step in this procedure is to place the locations on a coordinate system. The origin of the coordinate system and scale used are arbitrary, just as long as the relative distances are correctly represented. This can be easily done by placing a grid over an ordinary map. The center of gravity is determined by the formula.

$$c_x = \frac{\sum D_{ix}.W_i}{\sum W_i} \qquad\qquad c_y = \frac{\sum D_{iy}.W_i}{\sum W_i}$$

Where:

C_x = *x*-coordinate of the center of gravity

C_y = *y*-coordinate of the center of gravity

D_{ix} = *x*-coordinate of location *i*

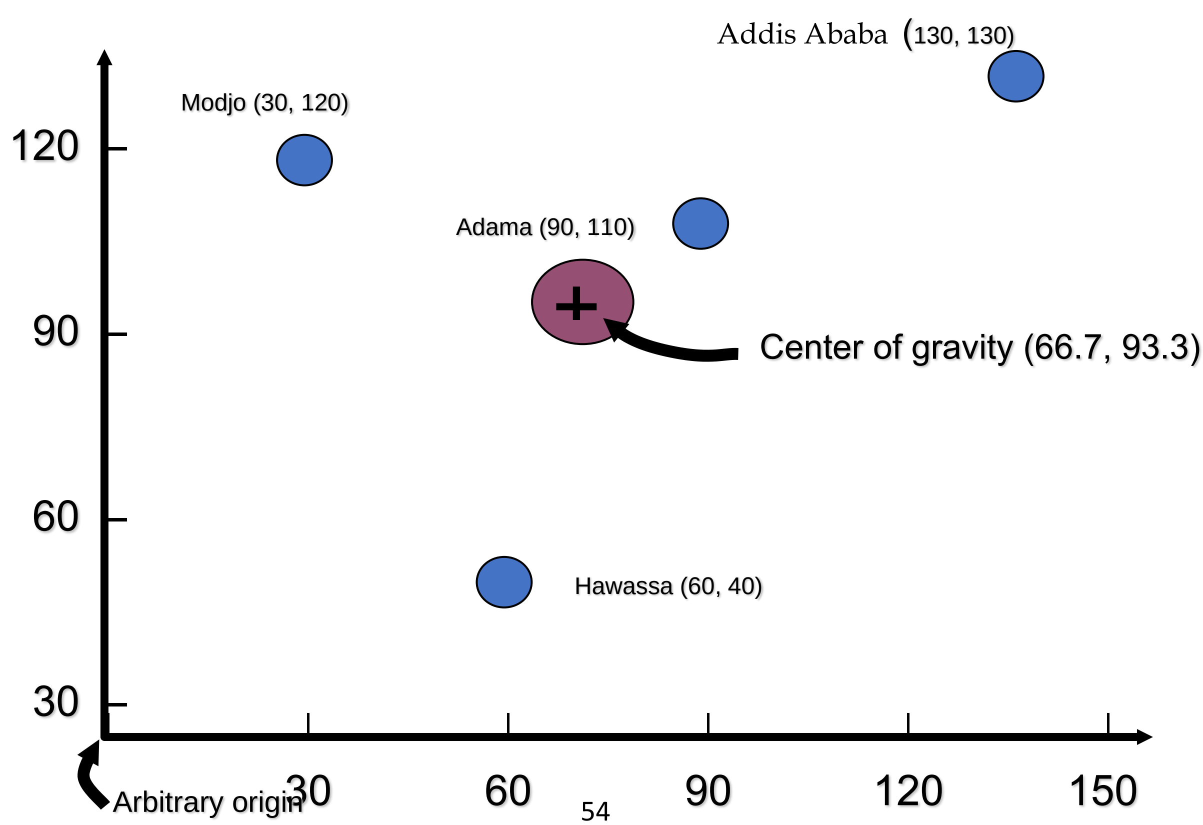
D_{iy} = *y*-coordinate of location *i*

Example: A small manufacturing facility is being planned that will feed parts to three heavy manufacturing facilities. The locations of current plants with their coordinates and volume requirements are given in the following table.

Plant Location	Coordinates (X, Y)	Volume (Parts per month)
Modjo	30, 120	2,000
Adama	90, 110	1000
Addis Ababa	130, 130	1,000
Hawassa	60, 40	2,000

$$\text{x-coordinate} = \frac{(30)(2000) + (90)(1000) + (130)(1000) + (60)(2000)}{2000 + 1000 + 1000 + 2000} = 66.7$$

$$\text{y-coordinate} = \frac{(120)(2000) + (110)(1000) + (130)(1000) + (40)(2000)}{2000 + 1000 + 1000 + 2000} = 93.3$$



3. *Location Break Even Analysis:*

Break-Even Analysis - is a technique used to compute the amount of goods that must be sold just to cover costs. The break-even point is precisely the quantity of goods a company needs to sell to break even. Whatever is sold above that point will bring a profit. At the break-even point, total cost and total revenue are equal and the equation will use those to solve for Q, which is the break-even quantity:

$$PQ = F + CQ \qquad Q = F/P - C$$

Step 1: *For Each Location, determine Fixed and Variable Costs*. Fixed costs are incurred regardless of how many units are produced and include items such as overhead, taxes, and insurance. Variable costs are costs that vary directly with the number of units produced and include items such as materials and labour. Total cost is the sum of fixed and variable costs.

Step 2: *Plot the Total Costs for each Location on one Graph*. To plot any straight line we need two points. One point is Q = 0, which is the y intercept. Another point can be selected arbitrarily, but it is best to use the expected volume of sales in the future.

Step 3: *Identify ranges of output for which each location has the lowest total cost.*

Step 4: *Solve Algebraically for the Break-Even Points over the Identified Ranges*. Select the location that gives the lowest cost for the range of output required by the new facility

Example: Fixed and variable costs for three potential plant locations are shown below:

If the selling price is = Br. 120 Expected volume = 2,000 unit

Location	Fixed cost per year	Variable cost per unit	Total cost
Hawassa	Br. 30,000	Br. 75	Br. 180,000
Dredawa	60,000	45	150,000
Addis Ababa	110,000	25	160,000

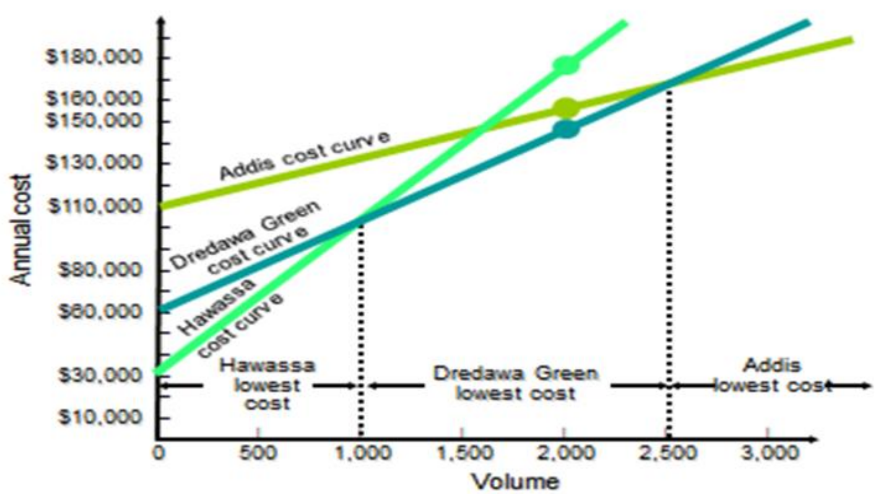


Figure 2

From the figure 2 we can understand that up to 1,000 units the best alternative is Hawassa; while from 1,000 to 2,500 units the best alternative is Dredawa and beyond 2, 500 is Addis.

3.4.2. FACILITY LAYOUT DECISIONS

Layout is defined as the most effective physical arrangement of machines, processing equipment, and service departments to have the best co-ordination and efficiency of man, machine and material in an organization. It is the spatial arrangement of physical resources used to create the product. It also means how the space needed for material movement, storage, indirect labor, etc is arranged in a factory. For a factory which is already in operation, this may mean the arrangement that is already present. However, for a new factory this means the plan of how the machines, equipment, etc will be arranged in the different sections or shops. These should be arranged in such a way that material movement cost, cost of storage in between processes, the investment on machines and equipment etc should be optimal and the product is as cheap as possible.

The **objective of layout strategy** is to develop an economic layout that will meet the firm's competitive requirements. In any cases, layout design must consider how to achieve the following:

- Higher utilization of space, equipment, and people
- Improved flow of information, materials, or people
- Improved employee morale and safer working conditions
- Improved customer/client interaction
- Flexibility (whatever the layout is now, it will need to change)

3.4.2.1. Types of layout

i. <u>Fixed Position Layout:</u>

In this, the major part of the product remains in a fixed place. All the tools, machines, workers and smaller pieces of materials are brought to it and the product is completed with the major part staying in one place. Very heavy assemblies (e.g. ship, aircraft, cranes, rail coaches, highway, a bridge, a house, an oil well, etc) requiring small and portable tools are made by this method. The techniques to deal with fixed-position layout are not well developed and are complicated by three factors:

- There is limited space at virtually all sites.
- At different stages in the process, different materials are needed; therefore, different items become critical as the project develops.
- The volume of materials needed is dynamic. For example, the rate of use of steel panels for the hull of a ship changes as the project progresses.

Because problems with fixed-position layouts are so difficult to solve on-site, an alternative strategy is to complete as much of the project as possible off-site. This approach is used in the ship-building industry when standard units (e.g., pipe-holding brackets) are assembled on a nearby assembly line (a product-oriented facility). Some ship-buildings are also experimenting with group technology to group components.

*ii. **Process-oriented or Functional Layout:***

It is a layout that deals with low-volume, high-variety production. In this type, all the machines and equipment of the same type are grouped together in one section or area or department. For example, all welding equipment are kept in one section; all drilling machines in other; all lathes in third section, and so on. It is used in intermittent (discontinuous) type of production. It is most efficient when making products with different requirements or when handling customers, patients, or clients with different needs. In this job-shop environment, each product or each small group of products undergoes a different sequence of operations. When designing a process layout, the most common tactic is to arrange departments or work centers so that the cost of material handling is minimum. For this, departments with large flows of parts or people between them should be placed next to one another.

*iii. **Repetitive or Product-Oriented Layout:***

This is also called assembly line layout because it was first used for assembling automobiles in the USA. This layout is organized around products or families of similar high-volume, low-variety products. In this type of layout, one product or one type of product is produced in a given area. This is used in case of repetitive and continuous production or mass production type industries. The machines and equipment are arranged in the order in which they are needed to perform operations on a product. The raw material is taken at one end of the line and goes from one operation to the next very rapidly with little material handling required.

Two types of product layout are fabrication and assembly lines. The fabrication line builds components on a series of machines. An assembly line puts the fabricated parts together at a series of workstations. Both are repetitive processes, and in both cases, the line must be ‘balanced’- that is, the time spent to perform work on one machine must equal or ‘balance’ the time spent to perform work on the next machine in the fabrication line.

Assembly lines can be balanced by moving tasks from one individual to another. The central problem then in product layout planning, is to balance the output at each workstation on the production line so that it is nearly the same, while obtaining the desires amount of output. A well-balanced assembly line has the advantage of high personnel and facility utilization and equity between employees’ workloads.

Assembly-line Balancing

Line-balancing is done to minimize imbalance between machines or personnel while meeting a required output from the line. For this, the management must know the tools, equipment, and work methods used. Then the time needed for each assembly task (e.g. drilling a hole, tightening a nut, or painting a part) must be determined. Management also needs to know the precedence relationship among the activities (i.e. the sequence in which different tasks must be performed). The steps in balancing an assembly line are the following:

Step 1: Specify the sequential relationships among tasks using a precedence diagram.

Step 2: Determine the required workstation cycle time(C), using the formula:

$$C = \frac{Production\ time\ per\ day}{Required\ output\ per\ day\ (in\ units)}$$

Step 3: Determine the theoretical minimum number of work stations (N)

$$N = \frac{Sum\ of\ Task\ Times\ (T)}{Cycle\ Time\ (C)}$$

Step 4: Select a primary rule by which tasks are to be assigned to workstations, and secondary rule to break ties.

Step 5: Assign tasks, one at a time, to the first workstation until the sum of the task times is equal to the work station cycle time

Step 6: Evaluate the efficiency of the balance:

$$Efficiency = \frac{Sum\ of\ Task\ Times\ (T)}{Actual\ Number\ of\ work\ stations(N)\ x\ Workstation\ Cycle\ Time\ (C)}$$

Step 7: If the efficiency is unsatisfactory, rebalance using a different decision rule.

iv. *Cellular Layouts*:

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 that require similar processing. The cells can consist of one machine, a group of machines with no conveyorized movement of parts between machines, or a flow line connected by a conveyer. In the cellular layout, machines are arranged to handle all of the operations necessary for a group of similar parts. Thus, all of the parts follow the same route, although minor variations are possible.

v. Office Layout:

The main difference between *office and factory layouts* is the importance placed on information. However, in some office environments, just in manufacturing, production relies on the flow of material. Office layout deals with grouping of workers, their equipment, and spaces/offices to provide for comfort, safety, and movement of information.

vi. Retail Layout:

Retail layouts are based on the idea that sales and profitability vary directly with customer exposure to products. Thus, most retail managers try to expose customers to as many products as possible. Studies show that the greater the rate of exposure, the greater the sales and the higher the return on investment. Once the overall layout of a retail store has been decided, products need to be arranged for sale. Many considerations go into this arrangement. However, the main objective of retail layout is to maximize profitability per square foot of floor space (or, in some stores on linear foot of shelf space). Big-ticket, or expensive, items may yield greater dollar sales, but the profit per square foot may be lower. Computerized programs are available to assist managers in evaluating the profitability of various merchandising plans.

vii. Warehousing and Storage Layouts:

The objective of warehouse layout is to find the optimum trade-off between handling cost and costs of warehouse space. So, the management's task is to maximize the utilization of the 'cubic space' of the warehouse—that is, utilize its full volume while maintaining low material handling costs, which is defined as all the costs related to the incoming transport, storage, and outgoing transport of materials to be warehoused. The cost also includes equipment, people, material, supervision, insurance, and depreciation. Effective warehouse layouts also minimize the damage and spoilage of material within the warehouse. The variety of items stored and the number of items 'picked' affect the optimum layout. A warehouse storing a few items leads itself to higher density than a warehouse storing a variety of items.

3.4.2.2. Service Layout

The major factors considered for service providers, is an impact of location on sales and customer satisfaction. Service facility layout will be designed based on degree of customer contact and the service needed by a customer. These service layouts follow conventional layouts as required. For example, for car service station, product layout is adopted, where the activities for servicing a car follows a sequence of operation irrespective of the type of car. Hospital service is the best example for adaptation of process layout. Here, the service required for a customer will follow an independent path.

3.4.3. Job design and Work Measurement

First, a company determines its objectives, and then develops an operations strategy to achieve those objectives. A Part of the operations strategy is designing a work system, which provides the structure for the productivity of the company. The work system includes: job design, work measurement, and worker compensation. The company determines the purpose of each job, what the job consists of, and the cost of the employees to do the job. A job must add value and enable the company to achieve its objectives. Objectives of job design are productivity, safety and quality of work life.

3.4.1. Job design

Job design is about how we structure each individual's job, the workplace or environment in which they work and their interface with the technology they use. Its objective is to develop job structures that meet the requirements of the organization. Job design specifies the work activities of an individual or a group in support of an organization's objectives. You design a job by answering questions such as: What is your description of the job? What is the purpose of the job? Where is the job done? Who does the job? What background, training, or skills does an employee need to do the job?

Job design involves a number of separate yet related elements which when taken together define the jobs of the people who work in the operation. The following are elements of job design that should be consider in job designing.

i. Ergonomics Environmental Design

Ergonomics is concerned primarily with the **physiological aspects** of job design – that is, with the human body and how it fits into its surroundings. This involves two aspects. First**, how a person interfaces with environmental conditions** in his or her immediate working area. By this we mean the **temperature**, **lighting**, **noise environment** and so on. Second, how the ***person interfaces with the physical aspect of his or her workplace, where the 'workplace' includes tables, chairs, desks, machines, computers***. Ergonomics is sometimes referred to as ***human factors engineering*** or just '**human factors'**.

- **a. working temperature -** Individuals vary in the way their performance and comfort vary with temperature. Nevertheless, some general points regarding working temperatures provide guidance to job designers:
- b. **Illumination levels -** The intensity of lighting required to perform any job satisfactorily will depend on the nature of the job. Some jobs which involve extremely delicate and precise movement, surgery for example, require very high levels of illumination. Other, less delicate jobs do not require such high levels.
- c. **Noise levels -** The damaging effects of excessive noise levels are perhaps easier to understand than some other environmental factors. Noise-induced hearing loss is a well-documented consequence of working environments where noise is not kept below safe limits.

d. **Ergonomics in the office -** As the number of people working in offices (or office-like workplaces) has increased, ergonomic principles have been applied increasingly to this type of work. At the same time, legislation has been moving to cover office technology such as computer screens and keyboards. Software: appropriate to task, adapted to user, no undisclosed monitoring, Screen: stable image, adjustable, readable, glare/reflection-free.

ii. Ergonomic Workplace Design

Many ergonomic improvements are primarily concerned with what are called the **anthropometric aspects of jobs** – that is, the aspects related to people's size, shape and other physical abilities. The design of an assembly task, for example, should be governed partly by the size and strength of the operators who do the job. The data which ergonomists use when doing this is called anthropometric data. we all vary in our size and capabilities, ergonomists are particularly interested in our range of capabilities.

iii. Designing task allocation – the division of labor

Division of labor is an approach to job design that involves dividing a task down into relatively small parts, each of which is accomplished by a single person or team. It was first formalized as a concept by the economist Adam Smith in his Wealth of Nations in 1746.4 Perhaps the epitome of the division of labor is the assembly line, where products move along a single path and are built up by operators continually repeating a single task.

There are some real advantages in division-of-labor principles:

- ✓ **It promotes faster learning**. It is obviously easier to learn how to do a relatively short and simple task than a long and complex one. This means that new members of staff can be quickly trained and assigned to their tasks when they are short and simple.
- ✓ **Automation becomes easier**. Dividing a total task into small parts raises the possibility of automating some of those small tasks. Substituting technology for labor is considerably easier for short and simple tasks than for long and complex ones.
- ✓ **Reduced non-productive work**. This is probably the most important benefit of division of labor. In large, complex tasks the proportion of time spent picking up tools and materials, putting them down again and generally finding, positioning and searching can be very high indeed.

There are also serious **drawbacks/** to highly divided jobs:

- ✓ **Monotony -** The shorter the task, the more often operators will need to repeat it. Repeating the same task, for example every 30 seconds, eight hours a day and five days a week, can hardly be called a fulfilling job. As well as any ethical objections, there are other, more obviously practical objections to jobs which induce such boredom. These include the increased likelihood of absenteeism and staff turnover, the increased likelihood of error and even the deliberate sabotage of the job.

- ✓ **Physical injury -** The continued repetition of a very narrow range of movements can, in extreme cases, lead to physical injury. The over-use of some parts of the body (especially the arms, hands and wrists) can result in pain and a reduction in physical capability. This is sometimes called **repetitive strain injury**.
- ✓ **Low flexibility -** Dividing a task into many small parts often gives the job design a rigidity which is difficult to adapt under changing circumstances. For example, if an assembly line has been designed to make one particular product but then has to change to manufacture a quite different product, the whole line will need to be redesigned. This will probably involve changing every operator's set of tasks, which can be a long and difficult procedure.
- ✓ **Poor robustness -** Highly divided jobs imply materials (or information) passing between several stages. If one of these stages is not working correctly, for example because some equipment is faulty, the whole operation is affected. However, if each person is performing the whole of the job, any problems will affect only that one person's output.

Eliminating Employee Boredom (Monotony)

Companies that choose highly specialized job design have several options for reducing worker boredom, including **job enlargement, job enrichment, and job rotation.**

Job Enlargement: is the horizontal expansion of a job. The job designer adds other related tasks to the job so the worker produces a portion of the final product that he or she can recognize. By reducing the level of specialization, however, job enlargement may result in some lost productivity compared to what was specified in the original job design.

Job enrichment: is the vertical expansion of a job. The job designer adds worker responsibility for work planning and/or inspection. This allows the worker some control over the workload in terms of scheduling although not in terms of how much work to do—and instills a sense of pride in the worker.

Job rotation: exposes a worker to other jobs in the work system. Rotation allows workers to see how the output from their previous assignment is used later in the production or service process. Workers see more of the big picture and have a better over- all understanding of the work system. In addition, they acquire more skills that may increase their value to the company. Job rotation provides more flexibility for the company, as its workers have upgraded skills.

iv. Designing Job Methods – scientific management

Scientific management is a school of management theory dating from the early twentieth century; more analytical and systematic than 'scientific' as such, sometimes referred to (pejoratively) as **Taylorism**, after Frederick Taylor who was influential in founding its principles. In this work he identified what he saw as the basic tenets of scientific management:

- All aspects of work should be investigated on a scientific basis to establish the laws, rules and formulae governing the best methods of working.
- Such an investigative approach to the study of work is necessary to establish what constitutes a 'fair day's work'.
- Workers should be selected, trained and developed methodically to perform their tasks.
- Managers should act as the planners of the work (analyzing jobs and standardizing the best method of doing the job) while workers should be responsible for carrying out the jobs to the standards laid down.
- Cooperation should be achieved between management and workers based on the 'maximum prosperity of both.

3.4.2. Work Measurement

Work measurement is the process of establishing the time for a ***qualified worker***, at a defined ***level of performance***, to carry out a ***specified job***. Although it is agreed that a *specified job* is one for which specifications have been established to define most aspects of the job. A ***qualified worker*** is 'one who is accepted as having the necessary physical attributes, intelligence, skill, education and knowledge to perform the task to satisfactory standards of safety, quality and quantity. ***Standard performance*** is 'the rate of output which qualified workers will achieve without over-exertion as an average over the working day provided, they are motivated to apply themselves to their work. ***Basic times* -** When a qualified worker is working on a specified job at standard performance, the time he or she takes to perform the job is called the **basic time** for the job.

Work Measurement Techniques

Commonly used work measurement techniques are

1. Stopwatch time study/time studies
2. Historical times/historical experience/ standard elemental time
3. Predetermined data/predetermined time standard
4. Work Sampling

1. Time study

Time study is 'a work measurement technique for recording the times and rate of working for the elements of a specified job, carried out under specified conditions, and for analyzing the data so as to obtain the time necessary for the carrying out of the job at a defined level of performance'.

Steps

1. ***Define the task to be studied, and inform the worker who will be studied***
2. ***Divide the task into precise elements***
3. ***Decide how many times to measure the task (number of times or cycles needed)***
4. **Time and record element times and rating of performance/time the job, and rate the worker 's performance**
5. **Compute average observed time**: (*Observed Time:* is simply the average of the recorded time).

$$Average\ observed\ time = \frac{sum\ of\ the\ times\ recorded\ to\ perform\ each\ element}{number\ of observation}$$

6. **Determine performance rating and normal time**: (*Normal Time* is the observed time adjusted for workers performance). normal time is the length of time a worker should take to perform a job if there are no delays or interruptions. It does not take into account such factors as personal delays (getting a drink of water or going to the restroom), unavoidable delays (machine adjustments and repairs, talking to a supervisor, waiting for materials), or rest breaks.

Normal time = Average Observed Time x Performance Rating Factor

7. **Add the normal times for each element to develop the total normal time for the task**
8. **Compute the standard time**: (The standard time for a job is the normal time plus an allowance for these delays.

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

Rest Allowances

- Personal time allowance: 4% - 7% of total time for use of restroom, water fountain, etc.
- Delay allowance: Based upon actual delays that occur
- Fatigue allowance: Based on our knowledge of human energy expenditure

Time Study Example 1

Average observed time = 4.0 minutes

Worker rating = 85%

Allowance factor = 13%

Normal time = (Average observed time) x (Rating factor)

= (4.0) x (.85) = 3.4 minutes

$$standard\ time = \frac{total\ normal\ time}{1 - allowance\ factor}$$

Standard time=3.4/1-0.13=3.9 minutes

Time Study Example 2

Allowance factor = 15%

Job Element	Cycle Observed (in minutes) 1	2	3	4	5	Performance Rating
(A) Compose and type letter	8	10	9	21*	11	120%
(B) Type envelope address	2	3	2	1	3	105%
(C) Stuff, stamp, seal, and sort envelopes	2	1	5*	2	1	110%

1. Delete unusual or nonrecurring observations (marked with *)
2. Compute average times for each element

Average time for A = (8 + 10 + 9 + 11)/4 = 9.5 minutes
Average time for B = (2 + 3 + 2 + 1 + 3)/5 = 2.2 minutes
Average time for C = (2 + 1 + 2 + 1)/4 = 1.5 minutes

3. Compute the normal time for each element

Normal time = (Average observed time) x (Rating)
Normal time for A = (9.5)(1.2) = 11.4 minutes
Normal time for B = (2.2)(1.05) = 2.31 minutes
Normal time for C = (1.5)(1.10) = 1.65 minutes

4. Add the normal times to find the total normal time

Total normal time = 11.40 + 2.31 + 1.65 = 15.36 minutes

5. Compute the standard time for the job

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

$$= \frac{15.36}{1 - .15} = 18.07 \text{ minutes}$$

2. Standard Elemental Times

Standard elemental times are derived from a firm's own historical time study data. Over the years, a time study department can accumulate a file of elemental times that are common to many jobs. After a certain point, many elemental times can be simply retrieved from the file, eliminating the need for analysts to go through a complete time study to obtain them. The procedure for using standard elemental times consists of the following steps:

- Analyze the job to identify the standard elements
- Check the file for elements that have historical times, and record them
- Modify the file times if necessary

- Sum the elemental times to obtain the normal time, and factor in allowances to obtain the standard time.

One obvious advantage of this approach is the potential savings in cost and effort created by not having to conduct a complete time study for each job. A second advantage is that there is little disruption of work, again because the analyst does not have to time the worker. A third advantage is that performance ratings do not have to be done; they are generally averaged in the file times. The main disadvantage of this approach is that times may not exist for enough standard elements to make it worthwhile, and the file times may be biased or inaccurate.

3. Predetermine Time Standards

Predetermined time standards involve the use of published data on standard elemental times. A commonly used system is methods-time measurement (MTM), which was developed in the late 1940s by the methods Engineering Council. The MTM tables are based on extensive research of basic elemental motions and times. To this approach, the analyst must divide the job into its basic elements (reach, move, turn, disengage), measure the distance involved; rate the difficulty of the element, and the reefer to the appropriate table of data to obtain the time for that element. The standard time for the job is obtained by adding the times of all of the basic elements. Among the advantage of predetermined time standards are the following:

- They are based on large numbers of workers under controlled conditions
- The analyst is not required to rate performance in developing the standard
- There is no disruption of the operation
- Standards can be established even before a job is done

4. Work Sampling

Work sampling is a technique for estimating the proportion of time that a worker or a machine spends on various activities. Unlike time study, work sampling doesn't require timing an activity. Instead, an observer makes brief observations of a worker or machine at random intervals and simply notes the nature of the activity. For example, a machine may be busy or idle; a secretary may be typing, filing, talking on the telephone, and so on; and a carpenter may be carrying supplies, talking measurement, cutting wood, and so on. The resulting data are counts of the number of times each category of activity or non-activity was observed.

Steps for Work Sampling

1) Select the job or group to be studied and inform the workers.
2) Take a preliminary sample to obtain an estimate of the parameter value (such as percent of time a worker is busy).

3) Compute the sample size required; for desired level of accuracy, sufficient no of observations are required. For many kinds of measurements, a level of $\pm 5\%$ accuracy is considered satisfactory. For this level of accuracy, the formula for determining the no of observations is

$$n = Z^2 \frac{p(1-p)}{h^2}$$

Where:

n = required sample size

Z = standard normal deviate for the desired confidence level

= 1 for 68 % confidence level

= 2 for 95.45 % confidence level, and

= 3 for 99.73 % confidence level

p = estimated value of sample proportion (of time the worker is observed busy or idle)

h = acceptable error level, in percent

Example:

The manager of Michigan county's welfare office, Dana Johnson, estimates her employee are idle 25% of the time. She would like to take a work sample that is accurate within 3% and want to have 95.45%confidence in the result.

Wants employees idle 25% of the time

Sample should be accurate within 3%

Wants to have 95.45% confidence in the results

$$n = Z^2 \frac{p(1-p)}{h^2} = \frac{(2)^2 .(.25)(.75)}{(.03)^2} = 833 \text{ observation}$$

CHAPTER FOUR

OPERATIONS PLANNING AND CONTROL

4.1. Aggregate Planning

Introduction:

Aggregate planning is intermediate range capacity planning that typically covers a time horizon of 2 to 12 months, although in some companies it may extend to as much as 18 months. It is particularly useful for organizations that experience seasonal or other fluctuations in demand or capacity. The goal of aggregate planning is to achieve a production plan that will effectively utilize the organization's resources to satisfy expected demand. Planners must make decisions on output rates, employment levels and changes, inventory levels and changes, back orders, and subcontracting.

4.1.1. Overview of Planning Levels

Organizations make decisions on three levels: long term, intermediate term, and short term. Long-term planning is generally done annually focusing on a horizon greater than one year. Long-term decisions relate to product and service selection (i.e. determining which products or service to offer), facility size and location, equipment decisions, and layout of facilities. The long term decisions essentially define the capacity constraints within which intermediate planning must function. Intermediate planning usually covers a period from 6 to 18 months with time increments that are monthly or sometimes quarterly. Intermediate decisions relate to general levels of employment, output, and inventories, which in turn define the boundaries within which short range capacity decisions must be made. Short-term planning covers a period from one day or less to six months with the time increment usually weekly. Thus, short-term decisions essentially consist of deciding the best way to achieve desired results within the constraint resulting from long-term and intermediate term decisions. Short-term decisions involve scheduling jobs, workers and equipment, and the like.

4.1.2. An Overview of Aggregate Planning

Aggregate planning begins with a forecast of aggregate demand for the intermediate range. This is followed by a general plan to meet demand requirements by setting output, employment, and finished goods inventory levels. Managers might consider a number of plans, each of which must be examined in light of feasibility and cost. The production plan is essentially the output of aggregate planning. Aggregate planners are concerned with the quantity and the timing of expected demand. If total expected demand for the planning period is much different from available capacity over that same period, the major approach of planners will be to try to achieve a balance by altering capacity, demand, or both. On the other hand, even if capacity and demand are approximately equal for the planning horizon as a whole, planners may still be faced with the problem of dealing with uneven demand within the planning interval. In some periods, expected demand may exceed projected capacity, and in some periods the two may be equal. The task of aggregate planners is to achieve rough equality of demand and capacity over the entire planning horizon. Moreover, planners are usually concerned with minimizing the cost of the production plan, although cost is not the only consideration.

4.1.3. The Purpose and Scope of Aggregate Planning

In this section, we examine the basic problem addressed by aggregate planning-the balancing of supply and demand- along with the purpose of aggregate planning, the primary decision variables available to planners, and associated costs. If supply and demand aren't in balance, that will cost the organization. There will be added costs of adjusting the system as well as opportunity costs.

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There are a number of important informational needs for effective aggregate planning. First, the available resources over the planning period must be known. Then, a forecast of expected demand must be available. Finally, planners must take into account any policies regarding changes in employment levels.

4.1.4. Aggregate Planning Strategies

Aggregate planning strategies can be described as ***proactive, reactive***, or ***mixed.*** Proactive strategies involve demand options: They attempt to alter ***demand*** so that it matches capacity. Reactive strategies involve ***capacity*** options: They attempt to alter capacity so that it matches demand. Mixed strategies involve an element of each of these approaches.

i. Strategies for Adjusting Capacity

If demand for a company's products or services is stable over time, then the resources necessary to meet demand are acquired and maintained over the time horizon of the plan, and minor variations in demand are handled with overtime or undertime. Aggregate planning becomes more of a challenge when demand fluctuates over the planning horizon. For example, seasonal demand patterns can be met by:

1. Producing at a constant rate and using inventory to absorb fluctuations in demand (level production)
2. Hiring and firing workers to match demand (chase demand)
3. Maintaining resources for high-demand levels
4. Increasing or decreasing working hours (overtime and undertime)
5. Subcontracting work to other firms
6. Using part-time workers

When one of these alternatives is selected, a company is said to have a ***pure strategy*** for meeting demand. When two or more are selected, a company has a ***mixed strategy***.

LEVEL PRODUCTION

The level production strategy, sets production at a fixed rate (usually to meet average demand) and uses inventory to absorb variations in demand. During periods of low demand, overproduction is stored as inventory, to be depleted in periods of high demand. The cost of this strategy is the cost of holding inventory, including the cost of obsolete or perishable items that may have to be discarded.

CHASE DEMAND

The chase demand strategy, matches the production plan to the demand pattern and absorbs variations in demand by hiring and firing workers. During periods of low demand, production is cut back and workers are laid off. During periods of high demand, production is increased and additional workers are hired. The cost of this strategy is the cost of hiring and firing workers. This approach would not work for industries in which worker skills are scarce or competition for labor is intense, but it can be quite cost-effective during periods of high unemployment or for industries with low-skilled workers. A variation of chase demand is chase supply. For some industries, the production planning task revolves around the supply of raw materials, not the demand pattern.

PEAK DEMAND

Maintaining resources for peak demand levels ensures high levels of customer service but can be very costly in terms of the investment in extra workers and machines that remain idle during low-demand periods. This strategy is used when superior customer service is important or when customers are willing to pay extra for the availability of critical staff or equipment.

OVERTIME AND UNDERTIME

Overtime and undertime are common strategies when demand fluctuations are not extreme. A competent staff is maintained, hiring and firing costs are avoided, and demand is met temporarily without investing in permanent resources. Disadvantages include the premium paid for overtime work, a tired and potentially less efficient workforce, and the possibility that overtime alone may be insufficient to meet peak demand periods. Undertime can be achieved by working fewer hours during the day or fewer days per week.

SUBCONTRACTING

Subcontracting or outsourcing is a feasible alternative if a supplier can reliably meet quality and time requirements. This is a common solution for component parts when demand exceeds expectations for the final product. The subcontracting decision requires maintaining strong ties with possible subcontractors and first-hand knowledge of their work. Disadvantages of subcontracting include reduced profits, loss of control over production, long lead times, and the potential that the subcontractor may become a future competitor.

PART-TIME WORKERS

Using part-time workers is feasible for unskilled jobs or in areas with large temporary labor pools (such as students, homemakers, or retirees). Part-time workers are less costly than full-time workers—they receive no health-care or retirement benefits—and are more flexible—their hours usually vary considerably. Part-time workers have been the mainstay of retail, fast-food, and other services for some time and are becoming more accepted in manufacturing and government jobs.

INVENTORIES

The use of finished goods inventories allows firms to produce goods in one period and sell or ship them in another period, although this involves holding or carrying those goods as inventory until they are needed. The cost includes not only storage costs and the cost of money tied up that could be invested elsewhere, but also the cost of insurance, obsolescence, deterioration, spoilage, breakage and so on. In essence, inventories can be built up during periods when production capacity exceeds demand and drawn down in periods when demand exceeds production capacity. This method is more amenable to manufacturing than to service industries since manufactured goods can be stored whereas services generally cannot.

ii. Strategies for Managing Demand

Management has a wide range of decision options at its disposal for purposes of aggregate planning. These include:

- ***Pricing**:* Pricing differentials are commonly used to shift demand from peak periods to off-peak periods. Some hotels, for example, offer lower rates for weekend stays, and some airlines offer lower fares for night travel. Movie theaters may offer reduced rates for matinees. An important factor to consider is the degree of price elasticity for the product or service; the more the elasticity, the more effective pricing will be in influencing demand patterns.
- ***Promotion**:* Advertising and other forms of promotion, such as displays and direct marketing, can sometimes be very effective in shifting demand so that it conforms more closely to capacity. Obviously, timing of these efforts and knowledge of response rates and response patterns will be needed to achieve the desired results. Unlike pricing policy, there is much control over the timing of demand; there is always the risk that promotion can worsen the condition it was intended to improve.
- ***Back orders**:* An organization can shift demand to other periods by allowing back orders. Hence, orders are taken in one period and deliveries are promised for a later period. The success of this approach depends on how willing customers are to wait for delivery. Moreover, the cost associated with the backorders can be difficult to pin down since it would include lost sales, annoyed or disappointed customers, and perhaps additional paperwork.
- ***New demand**:* Many organizations are faced with the problem of having to provide products or services for peak demand are very uneven. For instance, demand for bus transportation tends

to be more intense during the morning and late afternoon rush hours but much lighter other times. Creating new demand for buses at other times (e.g., trips by schools, clubs, and etc ….) would make use of the excess capacity during those slack times. Manufacturing firms that experience seasonal demands for certain products are sometimes able to develop a demand for a complementary product that makes use of the same production processes. They thereby achieve a more consistent use of labor, equipment, and facilities.

iii. Mixing Options to Develop a Plan

Although each of these capacity and demand options might produce an effective aggregate schedule, some combination of capacity options and demand options may be better. Many manufacturers assume that the use of the demand options has been fully explored by the marketing department and those reasonable options incorporated into the demand forecast. The operations manager then builds the aggregate plan based on that forecast. However, using the five capacity options at his command, the operations manager still has a multitude of possible plans. These plans can embody, at one extreme, a chase strategy and, at the other, a level-scheduling strategy. They may, of course, fall somewhere in between.

Techniques for Aggregate Planning

Numerous techniques help decision makers with the task of aggregate planning. Generally, they fall into one of two categories: informal trial and error techniques and mathematical techniques. In practice, informal techniques are most commonly used. A general procedure for aggregate planning consists of the following steps:

1. Determine demand for each period
2. Determine capacity (regular time, overtime, subcontracting) for each period
3. Identify company or departmental policies that are pertinent
4. Determine unit costs for regular time, overtime, subcontracting, holding inventories, backorders, layoffs, and other relevant costs.
5. Develop alternative plans and compute the cost for each
6. If satisfactory plans emerge, select the one that best satisfies objectives.

i. Informal Techniques: Trial -and -Balance using graphs

Informal approaches consist of developing simple tables or graphs that enable planners to visually compare projected demand requirements with existing capacity. Alternatives are usually evaluated in terms of their overall costs. The chief advantage of such techniques is that they do not necessarily result in the optimal aggregate plan.

Example:

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

Month	Jan.	Feb.	Mar.	Apr.	May	June	Total
Forecast	200	200	300	400	500	200	1,800

Cost Information:

Regular time = $2 per skateboard

Overtime = $3 per skateboard

Subcontract = $6 per skateboard

Inventory = $1 per skateboard per period on average inventory

Back orders = $5 per skateboard per period

They now want to evaluate a plan that calls for a steady rate of regular-time output, mainly using inventory to absorb the uneven demand but allowing some backlog. Overtime and subcontracting are not used because they want steady output. They intend to start with zero inventory on hand in the first period. Prepare an aggregate plan and determine its cost using the preceding information. Assume a level output rate of 300 units (skateboards) per period with regular time (i.e., 1,800/6 = 300). Note that the planned ending inventory is zero. There are 15 workers, and each can produce 20 skateboards per period.

Solution:

Plan1: **constant workforce (regular – time)**

Month	Jan.	Feb.	Mar.	Apr.	May	June	Total
Forecast	200	200	300	400	500	200	1,800
Output							
Regular time	300	300	300	300	300	300	1,800
Overtime	-	-	-	-	-	-	
Subcontracting	-	-	-	-	-	-	
Output - Forecasting	100	100	0	(100)	(200)	100	0

Inventory							
Beginning	0	100	200	200	100	0	
Ending	100	200	200	100	0	0	
Average	50	150	200	150	50	0	600
Backlog	0	0	0	0	100	0	100

Based on the given input and forecasting information above, the cost is calculated as follows:

Cost

Month	Jan.	Feb.	Mar.	Apr.	May	June	Total
Output							
Regular time	$600	600	600	600	600	600	$3,600
Overtime	-	-	-	-	-	-	
Subcontracting	-	-	-	-	-	-	
Inventory	$50	150	200	150	50	0	$600
Back orders	$0	0	0	0	500	0	$500
Total	$650	750	800	750	1,150	600	**$4,700**

Note that the total regular-time output of 1,800 units equals the total expected demand. If insufficient inventory exists, a backlog equal to the shortage amount appears, as in May. This is taken care of using the excess output in June. The total cost for this plan is $4,700.

very often, graphs can be used to guide the development of alternatives. Some planners prefer cumulative graphs while others prefer to see a period-by-period breakdown of a plan.

Example:

Plan 2: **using overtime**

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

Solution

Month	Jan.	Feb.	Mar.	Apr.	May	June	Total
Forecast	200	200	300	400	500	200	1,800
Output							
Regular time	280	280	280	280	280	280	1,680
Overtime	0	0	40	40	40	0	120
Subcontract	-	-	-	-	-	-	
Output - Forecasting	80	80	20	(80)	(180)	80	0
Inventory							
Beginning	0	80	160	180	100	0	
Ending	80	160	180	100	0	0	
Average	40	120	170	140	50	0	520
Backlog	0	0	0	0	80	0	80
cost							
regular time	$560	560	560	560	560	560	3,360
over time	0	0	120	120	120	0	360
subcontract	-	-	-	-	-	-	
Inventory	$40	120	170	140	50	0	$520
Backorders	0	0	0	0	400	0	$400
Total	$600	680	850	820	1,130	560	**$4,640**

overall, the total cost for this plan is $4,640, which is $60 less than the previous plan. Regular-time production cost and inventory cost are down, but there is overtime cost. However, this plan achieves savings in backorder cost, making it somewhat less costly overall than the plan in Example 1.

ii. Mathematical Techniques:

A number of mathematical techniques have been developed to handle aggregate planning. They range from mathematical programming models to heuristics and computer search models. The followings are the best-known techniques:

***Linear Programming**:* linear programming models are methods for obtaining optimal solutions to problems involving the allocation of scarce resources in terms of cost minimization and profit maximization. With aggregate [planning, the goal is usually to minimize the sum of costs related to regular labor time, overtime, subcontracting, inventory holding costs, and costs associated with changing the size of the workforce. Constraints involve the capacities of the workforce, inventories, and subcontracting.

Linear Decision Rule: seeks to minimize the combined costs of regular payroll, hiring and layoffs, overtime, and inventory using a set of cost-approximating functions.

Simulation Models: computerized models that can be tested under different scenarios to identify acceptable solution to problems.

Aggregate Planning in Services

Aggregate planning for manufacturing and aggregate planning for services share similarities in some respects, but there are some important differences- related in general to the differences between manufacturing and services:

- Services occur when they are rendered
- Demand for service can be difficult to predict
- Capacity availability can be difficult to predict
- Labor flexibility can be an advantage in services

4.2. OPERATIONS SCHEDULING

Scheduling deals with the timing of operations. Scheduling begins with capacity planning, which involves facility and equipment acquisition. In the aggregate planning stage, decisions regarding the use of facilities, inventory, people, and outside contractors are made. Then the master schedule breaks down the aggregate plan and develops an overall schedule for outputs. Short-term schedules then translate capacity decisions, intermediate planning, and master schedules into job sequences and specific assignment of personnel, materials, and machinery.

Scheduling Criteria

The correct scheduling technique depends on the volume of orders, the nature of operations, and the overall complexity of jobs, as well as the importance placed on each of four criteria. Those four criteria are:

i. *Minimize completion time:* this criterion is evaluated by determining the average completion time per job.
ii. *Maximize utilization*: this is evaluated by determining the percent of the time the facility is utilized.
iii. *Minimize work in process (WIP) inventory:* this is evaluated by determining the average number of jobs in the system.
iv. *Minimize customer waiting time:* this is evaluated by determining the average number of late days.

Good scheduling approaches should be simple, clear, easily understood, easy to carry out, flexible and realistic. Given these considerations, the objective of scheduling is to optimize the use of resources so that production objectives are met. In this part, we examine scheduling in process-focused (intermittent) production.

Scheduling Process-focused Work Centers

Process-focused facilities (also known as intermittent or job shop facilities) are high-variety, low-volume systems commonly found in manufacturing and service organizations. It is a production systems in which products are made to order. Items made under this system usually differ considerably in terms of materials used, order of processing, processing requirements, time of processing, and set up requirements. Because of these differences, scheduling can be complex. To run a facility in a balanced and efficient manner, the manager needs a production planning and control system.

Loading Jobs in Work Centers

Loading means the assignment of jobs to work or processing centers. Operations manager assign jobs to work centers so that costs, idle time, or completion time are kept to a minimum. Loading work centers takes two forms. One is *oriented capacity*; the second is related to *assigning specific jobs to work centers*. First, we examine loading from the perspective of capacity via a technique known as *input-output control*.

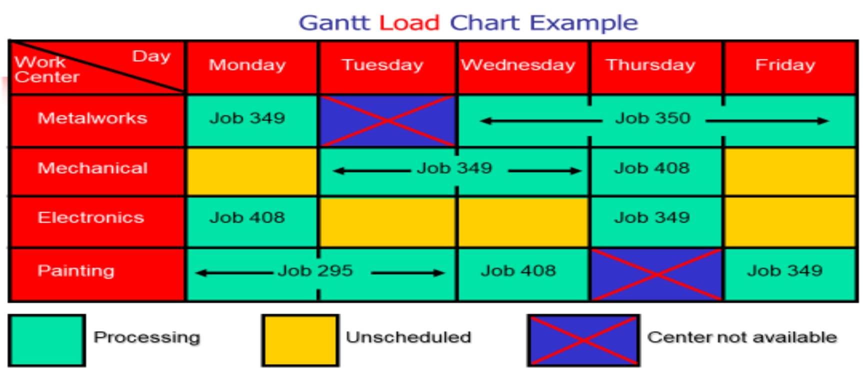
a) ***Input-output control*** is a technique that allows operations personnel to manage facility work flows. If the work is arriving faster than it is being processed, we are overloading the facility and a backlog develops. Overloading causes crowding in the facility, leading to inefficiencies and quality problems. If the work is arriving at a slower rate than jobs are being performed, we are under loading the facility and the work center may run out of work. Underloading the facility results in idle capacity and wasted resources. The options available to operations personnel to manage facility work flow include:

- Correcting performances
- Increasing capacity
- Increasing or reducing input to the work center by
- Routing work to or from other work centers
- Increasing or decreasing subcontracting
- Producing less or more

b) ***Gantt charts:*** are visual aids that are useful in loading and scheduling. The name is derived from Henry Gantt, who developed them in late 1800s. The charts help show the use of resources, such as work centers and overtime. The two most common Gantt charts that used for loading and scheduling are Load chart and Schedule chart.

When used in *loading, Gantt* charts show the loading and idle times of several departments, or facilities. They display the relative workloads in the system so that the manager knows what adjustments are appropriate. For example, when one work center becomes overloaded, employees from a low-load center can be transferred temporarily to increase the workforce.

A Gantt schedule chart is used to monitor jobs in progress. It indicates which jobs are on schedule and which are ahead of or behind schedule



The Assignment Method: involves assigning tasks or jobs to resources. Examples include assigning jobs to machines, contractors to bidders, people to projects, and salespeople to territories. The objective is to minimize total costs or time required to perform the task at hand.

One important characteristic of assignment problems is that only one job (or work) is assigned to one machine (or project).

Hungarian method is the method of assigning jobs by a one for one matching to identify the lowest cost solution.

1. Acquire the **relevant cost** information and arrange it in tabular form
2. Obtain the **Row Reduction**; this is obtained by subtracting the smallest number in each row from every number in the row. Enter the results in a new table.
3. Obtain the **Column Reduction** by subtracting the smallest number in each column of the new table from every number in the column.
4. **Test whether an optimum assignmen**t can be made. You do this by determining the minimum number of lines needed to cover (i.e.) cross out all zeros. If the **number of lines equal the numbers of row**, an **optimum assignment is possible**. In this case move to final step.
5. If the numbers of lines are **less** than the number of rows, modify the table in the following manner
   - Subtract the smallest uncovered number from every uncovered number in the table.
   - Add the smallest uncovered number to the numbers at the **intersections** of covering lines
   - Numbers crossed out but not at intersections of cross out lines carry over unchanged to the next table.
6. Repeat steps fourth and fifth unless an Optimal table is obtained
7. Make the assignments. Begin with rows or columns with **only one zero**. Match items that have zeros, using only one match for each row and each column. Cross out both the row and column for each row.

Example: Determine the optimal assignment of jobs to machines for the following data.

MACHINE				
JOB	A	B	C	D
1	8	6	2	4
2	6	7	11	10
3	3	5	7	6
4	5	10	12	9

Solution:

1. Select the Raw minimum and Subtract in each row,

MACHINE					
JOB	A	B	C	D	ROW MIN
1	8	6	2	4	2
2	6	7	11	10	6
3	3	5	7	6	3
4	5	10	12	9	5

MACHINE				
JOB	A	B	C	D
1	6	4	0	2
2	0	1	5	4
3	0	2	4	3
4	0	5	7	4
COL MIN	0	1	0	2

Subtract the smallest number in each column

& Enter the results to form a new table

MACHINE				
JOB	A	B	C	D
1	6	3	0	0
2	0	0	5	4
3	0	2	4	3
4	0	5	7	4

Determine the minimum number of lines needed to cross Out all zeros. Here we have three lines only and rows are 4, so the solution is not optimal

MACHINE				
JOB	A	B	C	D
1	~~6~~	~~3~~	~~0~~	~~0~~
2	~~0~~	~~0~~	~~5~~	~~2~~
3	0	1	4	1
4	0	4	7	2

Subtract the smallest value that has not been crossed out from every number that has not been crossed out (1 here) and add this to numbers that are at intersections of covering lines

MACHINE				
JOB	A	B	C	D
1	6+1=7	3	0	0
2	0+1=1	0	5	2
3	0	0	3	0
4	0	3	6	1

Determine the minimum number of lines needed to cross Out all 0 (4), since this equals the number of rows , we obtain the optimum assignment.

MACHINE				
Job	A	B	C	D
1	~~7~~	~~3~~	~~0~~	~~0~~
2	1	0	5	2
3	~~0~~	~~0~~	~~3~~	~~0~~
4	0	3	6	1

Step-7 Make the assignments, start with rows and columns with Only one 0.

Match jobs with machines that have 0 costs

MACHINE				
JOB	A	B	C	D
1	7	3	0	0
2	1	0	5	2
3	0	0	3	0
4	0	3	6	1

Assignments	Cost (From the original cost table)
1-C	$ 2
2-B	7
3-D	6
4-A	5
	$20

If the objective is maximization instead of minimization subtract the largest value from all values in the table and continue as usual

Sequencing Jobs in Work Centers

Scheduling provides a basis for assigning jobs to work centers. Loading is a capacity control technique that highlights overloads and under loads. Sequencing specifies the order in which jobs should be done at each center. Priority rules are the rules used in obtaining a job sequence. These can be very simple, requiring only that jobs be sequenced according to one piece of data, such as processing time, due date, or order of arrival.

The most common priority rule are the following:

- √ **FCFS –** (First Come, First Served): Jobs are processed in the order in which they arrive at a machine or work center.
- √ **SPT-** (Shortest Processing Time): Jobs are processed according to processing time at a machine or work center, shortest job first.
- √ **EDD –** (Earliest Due Date)**:** Jobs are processed according to due date, earliest due date first.
- √ **CR –** (Critical Ratio): Jobs are processed according to smallest ratio of time remaining until due date to processing time remaining.
- √ ***LCFS (Last Come, First Served):*** occurs frequently by default. As orders arrive they are placed on the top of the stack; the operator usually picks up the order on top to run first.

Assumptions of Priority Rules

1. The set of jobs is known, no new jobs arrive after processing begins and no jobs are canceled.
2. Setup time and Processing times is deterministic(static) rather than variables.
3. There will be no interruptions in processing such as machine breakdowns , accidents or worker illnesses.

Performance Measures

The effectiveness of any given sequence is frequently **judged** in terms of one or more *performance measures*:

- √ **Job Flow Time**: The length of time a job is in the shop at a particular workstation or work center (cumulative value of processing time).

$$\textbf{Average flow time (completion time)} = \frac{\text{Total flow time}}{\text{Number of Jobs}}$$

- √ **Job Lateness**: This is the length of time the job completion date is **expected to exceed** the date the job was due or promised to a customer.

$$\textbf{Average job tardiness} = \frac{\textbf{total late days}}{\text{Number of Jobs}}$$

- √ **Makespan (total processing time)**: This is the **total time needed to complete a group of jobs**. It is the length of time between the start of the first job in the group and the completion of the last job in the group.
- √ **Average Number of Jobs**: Jobs that are in a shop are considered to be work-in-process inventory. The average work-in-process for a group of jobs can be computed as:

$$\text{Average Number of Jobs} = \frac{\text{Total flow time}}{\text{Makespan}}$$

- √ Utilization of facility = $\frac{\text{makespan}}{\text{sum of job flow time}}$

√ The objective of the scheduler to minimize processing time, job lateness, number of work in process , while maximizing utilization of facilities

Example: Processing times (including setup times*) and due dates for six jobs waiting to be processed at a work center are given in the following table. Determine the **sequence of jobs**, **the average flow time**, **average tardiness**, and **average number of jobs at the work center**, for each of these rules: FCFS, SPT, EDD. Assume jobs arrived in the order shown

Job	Processing Time (days)	Due Date (days)
A	2	7
B	8	16
C	4	4
D	10	17
E	5	15
F	12	18

Solution:

a) (FCFS) sequence A-B-C-D-E-F

Job Sequence	Processing Time (days) (1)	Flow Time (cumulative processing time) (2)	Due Date (3)	Days Tardy (0 if negative) (2)-(3)
A	2	2	7	0
B	8	10	16	0
C	4	14	4	10
D	10	24	17	7
E	5	29	15	14
F	12	41	18	23
	41	120		54

$Average\ Flow\ time = \frac{\text{Total flow time}}{\text{Number of Jobs}} = \frac{120}{6}$

= 20days

Average Tardiness=54/6=9 days

The makespan =41 days

Average Number of Jobs at workstation= 120/41=2.93 jobs per workstation

Utilization = 41/120= 0.34 0r 34 %

b) STP sequence is **A-C-E-B-D-F**

Job Sequence	Processing Time(days) (1)	Flow Time (cumulative processing time) (2)	Due Date (3)	Days Tardy (0 if negative) (2)-(3)
A	2	2	7	0
C	4	6	4	2
E	5	11	15	0
B	8	19	16	3
D	10	29	17	12
F	12	41	18	23
	41	108		40

Average Flow time =

Total Flow Time/Number of Jobs =108/6 =18 days

Average Tardiness = 40/6 = 6.67days

The makespan = 41 days

Average Number of Jobs at workstation =108/41=2.63 jobs per workstation

Utilization = 41/ 108 = 0.379 0r 38%

c) (EDD) sequence is **C-A-E-B-D-F.**

Job Sequence	Processing Time (days) (1)	Flow Time (cumulative processing time) (2)	Due Date (3)	Days Tardy (0 if negative) (2)-(3)
C	4	4	4	0
A	2	6	7	0
E	5	11	15	0
B	8	19	16	3
D	10	29	17	12
F	12	41	18	23
	41	110		38

Average Flow time=

Total Flow Time/Number of Jobs=110/6=18.33 days

Average Tardiness=38/6=6.33 days

The makespan =41 days

Average Number of Jobs at workstation=110/41=2.68 jobs per workstation

Utilization = 41/ 110 = 0.372 0r 37%

CHAPTER FIVE

5 QUALITY MANAGEMENT AND CONTROL

5.1. Meaning and Nature of Quality

Different meaning could be attached to the word quality under different circumstances. The word quality does not mean the quality of manufactured product only. It may refer to the quality of the process (*i.e.*, men, material, and machines) and even that of management. Where the quality manufactured product referred as or defined as "Quality of product as the degree in which it fulfils the requirement of the customer. It is not absolute but it judged or realized by comparing it with some standards".

Quality begins with the design of a product in accordance with the customer specification further it involved the established measurement standards, the use of proper material, selection of suitable manufacturing process etc., quality is a relative term and it is generally used with reference to the end use of the product.

Crosby defined as "Quality is conformance to requirement or specifications". Juran defined as "Quality is fitness for use". "The Quality of a product or service is the fitness of that product or service for meeting or exceeding its intended use as required by the customer." According to American Society for Quality "Quality is the totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs."

51.1. The Dimensions of Quality

The dimensions of quality primarily for manufactured products a consumer looks for in a product include the following:

- ***Performance****:* The basic operating characteristics of a product; for example, how well a car handles or its gas mileage.
- ***Features*****:** The "extra" items added to the basic features, such as stereo CD or a leather interior in a car.
- ***Reliability****:* The probability that a product will operate properly within an expected time frame; that is, a TV without repair for about 7 years.
- ***Conformance****:* The degree to which a product meets pre established standards.
- ***Durability****:* How long the product lasts; its life span before replacement.
- ***Serviceability****:* The ease of getting repairs, the speed of repairs, and the courtesy and competence of the repair person.
- ***Aesthetics****:* How a product looks, feels, sounds, smells, or tastes.

- ***Safety*****:** Assurance that the customer will not suffer injury or harm from a product; an especially important consideration for automobiles.
- ***Other perceptions***: Subjective perceptions based on brand name, advertising and the like.

These quality characteristics are weighed by the customer relative to the cost of the product. In general, consumers will pay for the level of quality they can afford. If they feel they are getting what they paid for, then they tend to be satisfied with the quality of the product.

The dimensions of quality for a service differ somewhat from those of a manufactured product. Service quality is more directly related to time, and the interaction between employees and the customer. Evans and Lindsay identify the following dimensions of **service quality**.

- ***Time and timeliness***: How long a customer must wait for service, and if it is completed in time. For example, is an overnight package delivered overnight?
- ***Completeness*****:** Is everything the customer asked for provided? For example, is a mail order from a catalogue company complete when delivered?
- ***Courtesy****:* How customers are treated by employees. For example, are catalogue phone operators nice and are their voices pleasant?
- ***Consistency*****:** Is the same level of service provided to each customer each time? Is your newspaper delivered on time every morning?
- ***Accessibility and convenience****:* How easy it is to obtain the service. For example, when you call BPL Mobile, does the service representative answer quickly?
- ***Accuracy****:* Is the service performed right every time? Is your bank or credit card statement correct every month?
- ***Responsiveness****:* How well the company reacts to unusual situations, which can happen frequently in a service company. For example, how well a telephone operator at a catalogue company is able to respond to a customer's questions about a catalogue item not fully described in the catalogue.

All the product and service characteristics mentioned previously must be considered in the design process to meet the consumer's expectations for quality. This requires that a company accurately assess what the consumer wants and needs.

5.1.2. The Costs of Quality

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

Failure costs*:* are incurred by defective parts or products, or faulty services. Internal failures are those discovered during the production process; external failures are those discovered after delivery to the customers. Internal failures occur for a variety of reasons, including defective material from vendors, incorrect machine settings, faulty equipment, incorrect methods, and etc..the cost of internal failures include lost production time, scrap and rework, investigation costs, possible equipment damage, and possible employee injury. External failures are defective or poor services that go undetected by the producer. Resulting costs include warranty work, handling of complaints, replacements, liability/litigation, payment to customers or discount used to offset the inferior quality, loss of customer goodwill, and opportunity costs related to lost sales.

Appraisal Costs*:* relate to inspection, testing, and other activities intended to uncover defective products or services, or to assure that there are no defectives. They include the cost of inspectors, testing, test equipment, labs, quality audits, and field testing.

Prevention Costs*:* relate to attempts to prevent defects from occurring. They include costs such as planning and administration systems, working with vendors, training, quality control procedures, and extra attention in both the design and production phases to decrease the probability of defective workmanship.

5.1.3. International Quality Standards

Quality is so important globally that a number of quality standards have been developed. Japan, the European Community, and the United States have each developed their own quality standards.

Japan's Industrial Standard: the Japanese specification for quality management is published as industrial Standard Z8101 – 1981. It emphasizes continuous improvement and stresses the role of organization-wide coordination and commitment.

Europe's ISO Standard: the European community has developed quality standards called ISO 9000, 9001, 9003, and 9004. The focuses of the EC standard are to force the establishment of quality management procedure, through detailed documentation, on firms doing business in EC.

ISO 9000*:* The purpose of the International Organization for Standardization (ISO) is to promote worldwide standards that will improve operating efficiency, improve productivity, and reduce costs. The ISO is composed of the national standards bodies of 91 countries. The work of the ISO is conducted by some 180 technical committees. ISO 9000 is the work of the Quality Management and Quality Assurance Committee. The ISO 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. A key requirement for registration is that a company review, refine, and map functions such as process control, inspection, purchasing, training, packaging, and delivery.

5.2. TOTAL QUALITY MANAGEMENT

As the 20th century ends, business organizations are involved in what has become a "quality revolution." It began in Japan and has now spread to North America and other parts of the world. It involves an entirely new way of thinking about, and dealing with, quality that encompasses the entire organization. This new approach has been given a variety of names, but the one we shall use is total quality management, or TQM.

The term TQM refers to a quest for quality that involves everyone in an organization. There are two key philosophies in this approach. One is a never-ending push to improve, which is referred to as *continuous improvement*; the other is a goal of *customer satisfaction*, which involves meeting or exceeding customer expectations. We can describe the TQM approaches as follows:

- ✓ Find out what customers want
- ✓ Design a product or service that will meet or exceed what customer want
- ✓ Design a production process that facilitates doing the job right the first time. Determine where mistakes are likely to occur and try to prevent them. Strive to make the process "mistake-proof"
- ✓ Keep track of results, and use those to guide improvement in the system. Never stop trying to improve.
- ✓ Extend these concepts to suppliers and to distribution
- ✓ Successful TQM programs are built through the dedication and combined efforts of everyone in the organization. As noted, top management must be committed and involved.

5.2.1. The Major Elements of TQM

- √ ***Continual Improvement****:* the philosophy that seeks to make never ending improvements to the process of converting inputs into outputs. The Japanese use the term kaizen to refer to continuous improvement.
- √ ***Competitive Benchmarking***: this involves identifying companies or other organizations that are the best at something and studying how they do it to learn how to improve your operation. The company need not be the same line of business.
- √ ***Employee Empowerment****:* giving workers the responsibility for improvements and the authority to make changes to accomplish them provides strong motivation for employees.
- √ ***Team Approach****:* the use of teams for problem solving and to achieve consensus takes advantage of group synergy, gets people involved, and promotes a spirit of cooperation and shared values among employees.
- √ ***Decisions based on facts rather than opinion***: management gathers and analyzes data as a basis for decision making.

√ ***Knowledge of Tools****:* employees and managers are trained in the use of quality tools.

√ ***Supplier Quality****:* suppliers must be included in quality assurance and quality improvements efforts so that their processes are capable of delivering quality parts and materials in a timely manner.

QUALITY TOOLS

A major cornerstone of the commitment to quality improvement prescribed by Deming and the other early quality gurus is the need to identify and prevent the causes of quality problems, or defects. These individuals prescribed a number of "tools" to identify the causes of quality problems that are still widely used today. These are :

1. ***Check Sheets****:* is a fact-finding tool used to collect data about quality problems. A typical check sheet for quality defects tallies the number of defects for a variety of previously identified problem causes. When the check sheet is completed, the total tally of defects for each cause can be used to create a histogram or a Pareto chart.
2. ***Flowchar****t:* is a visual representation of a process. It helps investigators in identifying possible points in a process where problems occur.
3. ***Scatter Diagram****:* a graph that shows the degree and direction of relationship between two variables.
4. ***Histogram****:* a chart of an empirical frequency distribution. It can be useful in getting a sense of the distribution of observed values.
5. ***Pareto Analysis****:* technique for classifying problem areas according to degree of importance, and focusing on the most important.
6. ***Control Chart****:* a statistical chart of time-ordered values of a sample statistic. It can help detect the presence of correctable causes of variation. It can also indicate when a problem occurred and give insight into what caused the problem.
7. ***Cause-and-Effect Diagram****:* offers a structured approach to the search for the possible cause(s) of a problem. It is also known as a fishbone diagram.

5.3. STATISTICAL PROCESS CONTROL

Quality control is concerned with the quality of conformance of a process: Does the output of a process conform to the intent of design? Variations in characteristics of process output provide the rationale for process control. Statistical process control (SPC) is used to evaluate process output to decide if a process is "in control" or if corrective action is needed.

The best companies emphasize designing quality into the process, thereby greatly reducing the need for inspection or control efforts. Quality assurance that relies primarily on inspection after production is referred to as acceptance sampling. Quality control efforts that occur during production are referred to as statistical process control.

Process Control

Quality control is concerned with the quality of conformance of a process of a process: Does the output of a process conform to the intent of design? Toward that end, managers use statistical process control to evaluate the output of a process to determine its acceptability. To do this, they take periodic samples from the process and compare them with a predetermined standard. If the samples results are not acceptable, they stop the process and take corrective action. If the samples results are acceptable, they allow the process to continue. Two statistical tools are used for quality control: control charts and run tests.

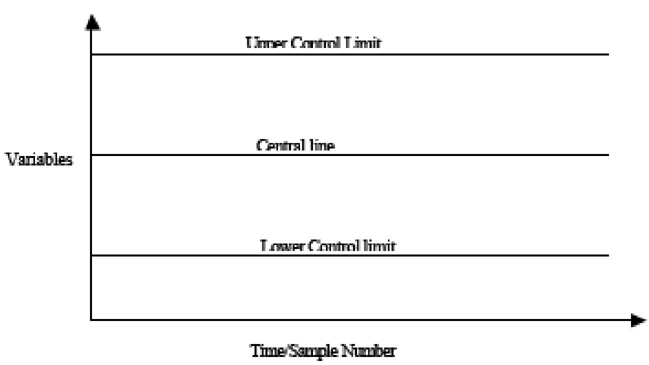
Control Charts:

There are two basic categories of variation in output: Common Causes and Assignable Causes

Common causes of variation are purely random, unpredictable sources of variation that are unavoidable with the current process. For example, a machine that fills cereal boxes will not put exactly the same amount of cereal in each box.

The second category of variation, assignable causes of variation, also known as special causes, includes any variation –causing factors that can be identified and eliminated. Assignable causes of variation include an employee needing training, or a machine needing repair.

Control charts are used to control in-process quality. Acceptance sampling plans are aimed to control the quality of incoming raw material, semi-finished products and finished products.



Above figure shows the generalized representation of control chart. The x-axis shows the observation number in sequence. The y-axis shows the sample values of the observations.

There are three lines, namely upper control limit (UCL), lower control limit (LCL) and central line. The central line is with respect to the average of the observations.

The UCL and LCL jointly specify the range over which each sample observation can lie. After plotting all the sample observations on the chart, we should look for the pattern of those plots. If any sample observation is outside of these two limits, then we can conclude that the process is out of control and definitely requires corrective action.

Control limits are the boundaries within which sample statistic can be expected to vary due simply to the randomness of the sample used. They are computed from the relatively tight sampling distributions and are typically set at 3 (or possibly 2) standard errors away from the process average. When a process is "in control," 99.7 % of the sample average should be within ±3 standard errors of the centre line. If the sample average fall outside the control limit limits, some assignable cause is probably responsible and corrective action should be taken.

Control Charts for Variables:

As the name indicates, these charts will use the variable data of a process. $\bar{X}$ Chart gives an idea of the central tendency of the observations. These charts will reveal the variations between sample observations. R chart gives an idea about the spread (dispersion) of the observations. This chart shows the variations within the samples.

Mean Chart: A mean control chart, sometimes referred to as an $\bar{X}$ ("x-bar") chart, can be constructed in one of two ways. The choice depends on what information is available. Although the value of the standard deviation of a process, σ, is often unknown, if a reasonable estimate is available, one can compute control limits using these formulas:

$$\text{Upper control limit (UCL): } = \bar{\bar{X}} + z\sigma_{\bar{X}}$$

$$\text{Lower control limit (LCL): } = \bar{\bar{X}} - z\sigma_{\bar{X}}$$

Where:

$\sigma_{\bar{X}} = \sigma / \sqrt{n}$

$\sigma_{\bar{X}}$ = standard deviation of distribution of sample means

σ = Process standard deviation

n = Sample size

z = Standard normal deviate

$\bar{\bar{X}}$ = Average of sample means

The following example illustrates the use of these formulas.

Example: A quality inspector took five samples, each with four observations, of the length of time to process a loan application at a credit union. The analyst computed the mean of each sample and then computed the grand mean. All values are in minutes. Use this information to obtain three-sigma (i.e. z = 3) control limits for means of future times. It is known from previous experience that the standard deviation of the process is 0.02 minutes.

Observation	Sample				
	1	2	3	4	5
1	12.11	12.15	12.09	12.12	12.09
2	12.10	12.12	12.09	12.10	12.14
3	12.11	12.10	12.11	12.08	12.13
4	12.08	12.11	12.15	12.10	12.12
Mean	12.10	12.12	12.11	12.10	12.12

Solution:

X = (12.10 + 12.12 + 12.11 + 12.10 + 12.12)/5 = 12.11

With z = 3, n = 4 observations per sample, and = 0.02, we find

UCL: 12.11 + 3(0.02/√4) = 12.14

LCL: 12.11 - 3(0.02/√4) = 12.08

If one applied these control limits to this data, one would judge the process to be in control because the entire sample means have values that fall within the control limits. The fact that some of the individual measurements fall outside of the control limits is irrelevant.

A second approach is to use the sample range as a measure of process variability. The appropriate formulas for control limits are:

UCL = X = A2R

LCL = X – A2R

Where:

R = Average of sample ranges

Example: Twenty samples of n = 8 have been taken from a cleaning operation. The average sample range for the 20 samples was 0.016 minutes, and the average mean was 3 minutes. Determine three-sigma control limits for this process.

Solution:

X = 3 cm   R = 0.016 A2 = 0.37 for n = 8

UCL = 3 + 0.37(0.016) = 3.006 minutes

LCL = 3 + 0.37(0.016) = 2.994 minutes

Note that this approach assumes that the range is in control.

Range Charts: Range control charts (R- Charts) are used to monitor process dispersion; they are sensitive to changes in process dispersion. Although the underlying sampling distribution is not normal, the concepts for use of range charts are much the same as those for use of mean charts. Control limits for range charts are found using the average sample range in conjunction with these formulas:

UCLR = D4R

LCLR = D3R

Example: Twenty-five samples of n = 10 observations have been taken from a milling process. The average sample range was 0.01 centimeter. Determine upper and lower control limits for sample ranges.

Solution:

R = 0.01 cm, n = 10

UCLR = 1.78(0.01) = 0.0178 or 0.018

LCLR = 0.22(0.01) = 0.0022 or 0.002

Mean control charts and range control charts provide different perspective on a process. As we have seen, mean charts are sensitive to shifts in the process mean, whereas range charts are sensitive to changes in process dispersion. Because of this difference in perspective, both types of charts might be used to monitor the same process. Once control charts have been set up, they can serve as a basis for deciding when to interrupt a process and search for assignable causes of variation. To determine initial control limits, one can use the following procedure.

- ✓ Obtain 20 to 25 samples. Compute the appropriate sample statistics for each sample.
- ✓ Establish preliminary control limits using the formulas, and graph them.
- ✓ Plot the sample statistics on the control chart(s)
- ✓ If you find no out-of-control signals, assume that the process is in control. If not, investigate and correct assignable causes of variation. Then resume the process and collect another set of observations upon which control limits can be based.