ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY

B.Tech (Food Technology)

Course No.	**FDEN-323**
Course Title:	**FOOD PLANT DESIGN AND LAYOUT**
Credits:	**3 (2 + 1)**

Prepared by

Er. B. SREENIVASULA REDDY

Assistant Professor (Food Engineering)

College of Food Science and Technology

Chinnarangapuram, Pulivendula – 516390

YSR (KADAPA) District, Andhra Pradesh

DEPARTMENT OF FOOD ENGINEERING

1	Course No	:	**FDEN - 323**
2	Title	:	**Food Plant Design and Layout**
3	Credit hours	:	**3 (2+1)**
4	General Objective	:	To impart knowledge on plant layout and design of food industries
5	Specific Objectives	:	
	a) Theory	:	By the end of the course, the students will acquire knowledge on theoretical aspects to be considered for site selection, layout selection and design considerations for a food plant
	b) Practical		By the end of the course, the students will develop skills and acquaint in project preparations, estimations and cost estimates of different equipment and utilities of various food industries
	A) Theory Lecture Outlines		
1	Introduction : Plant design concepts - situations giving rise to plant design problems - differences in design of food processing and non-food processing plants		
2	General design considerations, Food Processing Unit Operations, Prevention of Contamination, Sanitation, Deterioration, Seasonal Production		
3	Flow Chart for Plant Design, Identification Stage, Looking for a need, Finding a product, Preliminary Screening of ideas		
4	Comparative rating of product ideas: Present Market, Market Growth potential, Costs, Risks		
5	Pre Selection / Pre feasibility stage, Analysis Stage: Market Analysis, Situational analysis related to market		
6	Technical analysis, Financial Analysis, Sensitivity and risk analysis, Feasibility cost estimates		
7	Break Even Analysis: Introduction, Break-Even Chart, Fixed Costs, Variable costs, Break even point calculation		
8	Plant location :Introduction, Location Decision Process, Factors involved in the plant location decision,		
9	Territory selection and Site/ community selection		
10	Subjective, Qualitative and Semi-Quantitative Techniques, Equal Weights Method, Variable Weights Method, Weight-cum-Rating Method, Another weight-cum-rating method		
11	Composite Measure method, Locational Break-Even analysis		
12	Food Plant Utilities: Process Water, Steam, Electricity, Plant Effluents		
1	Plant Size and Factors		

3	
14	The enterprise and its Environment, The total revenue function, the total cost function
15	Break-even and shutdown points, Production, economics of mass production, Production management decision
16	Plant layout : Importance, Flow Patterns
17	Basic Types of plant layouts, Product or line layout, Process or functional layout, Cellular or group layout, and Fixed position layout, Plant Layout factors, Layout design Procedure
18	General guide lines for plant layout, Typical clearances, areas and allowances, Plant layout, Layout of equipment, Space determination
19	Symbols used for food plant design and layout: Introduction, valves, line symbols, fluid handling, heat transfer, Mass transfer
20	Symbols used for food plant design and layout: Storage vessels, conveyors and feeders, separators, mixing and communition and process control and instrumentation symbols.
21	Experimentation in pilot layout : Size and structure of the pilot plant, minimum and maximum size, types and applications
22	Engineering Economy : Introduction, Terms: Time value of money, inflation, Interest, Interest rate, compound interest, rate of return, payment, receipt , cash flow, present value, Equivalence, sunk costs, opportunity costs, Asset, Life of an asset, depreciation, book value of an asset, salvage value, retirement, replacement, defender and challenger.
23	Methods of economic evaluation of engineering alternatives 1. Undiscounted cash flow methods -pay back period method 2. Discounted cash flow methods a) Net present value method b) Equivalent annual method c) Rate of return method 3.Cost- benefit analysis, Social costs, social benefits
24	Process scheduling
25	Linear Programming: Introduction, Salient features of Linear programming (Terminology)
26	Formulation of linear programming model, Advantages, limitations and applications of linear programming, solution of linear programming problems.
27	Queuing theory : Introduction, Elements of queuing system, 1) Input source, 2) Queue
2	Queuing theory: Characteristics of waiting lines, service discipline, Service

8	mechanism, system out put, customer behavior.
29	Materials of construction of Food Equipment : Characteristics of suitable construction material : Stainless steel, Aluminum, Nickel and Monel, Plastic Materials
30	Illumination and ventilation
31	Cleaning & sanitization
32	Maintenance of Food Plant Building : Safety Color Code, Roof Inspection, Care of Concrete floors

	B) Practical Class Outlines
1	Preparation of project report
2	Preparation of feasibility report
3	Layout of Food storage wares and godowns
4	Layout and design of cold storage
5	Layout of preprocessing house
6	Layout of Milk and Milk product plants
7	Design and layout of low shelf life product plant
8	Design and layout of fruits processing plants
9	Design and layout of vegetable processing plants
10	Layout of multi product and composite food plants
11	Evaluation of given layout
12	Waste treatment and management of food plant
13	Design and layout of modern rice mill
14	Design and layout of mango pulp canning industry
15	Design and layout of spices manufacturing unit
16	Design and layout of Bakery and related product plant

	References
1	M Moor, Mac Millan, Plant Layout & Design. Lames, New York.
2	H.S. Hall & Y.S. Rosen, Milk Plant Layout. FAO Publication, Rome.
3	F.W. Farrall, Dairy & Food Engineering. John Willy & Sons, New York.
4	Food Plant Design by Antonio López. Gómez
5	Food plant engineering systems by Theunis C. Robberts, CRC Press, Washington
6	Food plant economics by Zacharias B. Maroulis and George D. Saravacos published by Taylor and Francis Group, LLC
7	Fundamentals of Production Systems Engineering, G.S.Sekhon and A.S.Sachdev, Published by Dhanpat Rai and Company Private Limited, Delhi (Chapter NO. 19)
8	Operations Research by Manohar Mahajan, Published by Dhanpat Rai and

	Company Private Limited, Delhi
9	Food Process Design by Zacharias B. Maroulis published by Marcel Dekker, Inc , Cimarron Road, Monticello, New York 12701, U S A

LECTURE NO. 1

INTRODUCTION: PLANT DESIGN CONCEPTS - SITUATIONS GIVING RISE TO PLANT DESIGN PROBLEMS - DIFFERENCES IN DESIGN OF FOOD PROCESSING AND NON-FOOD PROCESSING PLANTS

INTRODUCTION

Plant design refers to the overall design of a manufacturing enterprise / facility. It moves through several stages before it is completed. The stages involved are : identification and selection of the product to be manufactured, feasibility analysis and appraisal, design, economic evaluation, design report preparation, procurement of materials including plant and machinery construction, installation and commissioning. The design should consider the **technical** and **economic factors**, **various unit operations involved, existing and potential market conditions e**tc.

Plant design specifies:

- **the equipment** to be used
- **performance requirements** for the equipment
- **interconnections and raw material flows** in terms of flow charts and plant layouts
- the **placement** of equipment, storage spaces, shop facilities, office spaces, delivery and shipping facilities, access ways, site plans and elevation drawings
- required **instrumentation and controls**, and process monitoring and control interconnections
- utility and **waste treatment requirements**, connections and facilities
- the rationale for site selection
- the basis for **selecting and sizing critical pieces of equipment**
- ways in which the design was optimized and the engineering basis for such optimization

They also often provide economic analyses of plant profitability in terms of various product demand and price and material cost scenarios.

Plant Design Situations

Plant design situations may arise due to one or more of the following:

- design and erection of a completely **new plant**
- design and erection of an **addition to the existing plant**
- the facility or plant operations and subsequent expansion restricted by a **poor site, thereby necessitating the setting up of the plant at a new site**
- **addition of some new product** to the existing range
- adoption of **some new process** /replacement of some existing equipment
- **modernization / automation** of the existing facility
- **expansion** of the plant capacity
- **relocating** the existing plant at a new site because of new economic, social, legal or political factors

Differences in the Design of Food Processing and Non-Food Processing Plants

Many of the elements of plant design are the same for food plants as they are for other plants particularly those processing industrial chemicals. However, there are many significant differences, basically in the areas of equipment selection and sizing, and in working space design. These differences stem from the ways in which the processing of foods differ from the processing of industrial chemicals.

Such differences occur because of the following considerations:

The storage life of foods is relatively limited and strongly affected by temperature, pH, water activity, maturity, prior history, and initial microbial contamination levels.

Very high and verifiable levels of product safety and sterility have to be provided.

Foods are highly susceptible to microbial attack and insect and rodent infestation.

Fermentations are used in producing various foods and bio chemicals. Successful processing requires the use of conditions, which ensure the dominance of desired strains of microorganisms growth or activity.

Enzyme-catalyzed processes are used or occur in many cases. These, like microbial growth and fermentation are very sensitive to temperature, pH, water activity and other environmental conditions.

Many foods are still living organisms or biochemically active long after harvest or slaughter.

In some cases foods (e.g. ripening cheeses) contain active living micro-organisms, which induce chemical transformations for long periods of time.

Crop-based food raw materials may only be available in usable form on a seasonal basis. Therefore, plant design may involve the modeling of crop availability.

Food raw materials are highly variable and that variability is enhanced by the ageing of raw material and uncontrollable variations in climatic conditions.

The biological and cellular nature and structural complexity of foods causes special heat-transfer, mass-transfer and component separation problems.

Foods are frequently solid. Heat and mass-transfer problems in solids have to be created in ways that are different than those used for liquid and gas streams. The kinetics of microbe and enzyme inactivation during thermally induced sterilization and blanching and heat-transfer in the solids being sterilized or blanched are strongly linked.

Food processing generates wastes with high BOD loads.

Foods are often chemically complex systems whose components tend to react with one another. Certain types of reactions, e.g. Maillard reactions, oxidative rancidification, hydrolytic rancidification and enzymatic browning tend to occur with a high degree of frequency.

The engineering properties of foods and biological material are less well known and more variable than those of pure chemicals and simple mixtures of chemicals.

Vaguely defined sensory attributes often have to be preserved, generated or modified. These require sensory testing. Raw material variation, minor processing changes and trace contaminants leached from processing equipment and packages can often cause significant changes in these attributes. Frequently, we do not have mechanistic bases for linking these attributes to processing conditions and equipment design. Much current food engineering and food science research activity at universities is designed to provide such linkages.

In the case of foods, prototype products have to be consumer tested so as to assure market acceptability before plants for large scale production are built.

Mechanical working is sometimes used to induce desired textural changes. Examples include kneading and sponge mixing during the making of bread, the calendaring of pastry dough, shearing during extrusion texturization.

Packaging in small containers is often used or required; and strong-package-product interactions exist. Packaging often requires care to maintain integrity of closure, reproducibility of fill elimination of air from head spaces and prevention of subsequent moisture and oxygen transfer. Segregation often causes problems in the packaging of powdered foods. Aseptic packaging is starting to be widely used.

Food processing techniques and formulations are sometimes constrained by standards of identity and good manufacturing practice regulations and codes.

Food processing is an art to a certain extent. Engineers and technologists are frequently uncertain as to weather portions of that art are really justified or necessary. It is sometimes difficult for them to translate the necessary portions of that art into quantifiable heat-transfer and chemical reaction processes on which rational designs can be based.

LECTURE NO. 2

GENERAL DESIGN CONSIDERATIONS, FOOD PROCESSING UNIT OPERATIONS, PREVENTION OF CONTAMINATION, SANITATION, DETERIORATION, SEASONAL PRODUCTION

General Design Considerations

Food plant designs must provide necessary levels of sanitation, means of preventing product and material contamination and means of preventing or limiting product, raw material, and intermediate product deterioration due to naturally occurring processes. Great care must be exercised to achieve high levels of product purity and preserve product integrity. A brief description of some of the design considerations follows.

Food processing unit operations

Food processing involves many conventional unit operations but it also involves many which differ greatly from those usually encountered in the production of industrial chemicals. These include: freezing and thawing and other temperature-induced phase transitions or phase transition analogs, freeze drying, freeze concentration, curd and gel formation, development of structured gels, cleaning and washing (the operation which occurs with the greatest frequency in food processing plants), leavening, puffing, and foaming, slaughtering, carcass disassembly, component excision, slicing and dicing, peeling and trimming, grading, cell disruption and maceration, pasteurization and sterilization, blanching, baking, cooking (for purposes of tenderization or textural modification), roasting (for purposes of flavour generation), radiation sterilization, mechanical expression, structure-based component separation, filling and packaging, canning and bottling, coating and encapsulation, sausage and flexible casing, stuffing, controlled atmosphere storage, fumigation and smoking, churning, artificially induced ripening, fermentation, pureeing, emulsification and homogenization, biological waste treatment, and controlled feeding of confined animals, poultry and fish.

Prevention of contamination

Prevention of contamination will involve the provision or use of filtered air, air locks, piping layouts that ensure complete drainage and present cross-stream contamination (particularly contamination of finished products by unsterilized or unpasteurized raw material and cleaning solutions), solid material and human traffic flow layouts that also prevent such contamination, suitably high curbs when pipes, conveyors or equipment pass through floors and where gangways pass over processing areas, bactericides in cooling water, culinary (i.e. contaminant-free) steam whenever direct contact between a product and steam is used, impermeable covers for insulation, dust covers over conveyors and clear plastic covers for electric lights, methods for washing bottles and containers, suitable barriers against pest entry, windowless construction, solid instead of hollow walls, or completely tight enclosure of hollow spaces in walls, air circulation system and external roof and wall insulation that prevent the formation of condensate which can drip into products or favor mold growth, ultra-violet irradiation of tank head spaces, electric light traps for flying insects, impactors for killing insect eggs, larvae, pupae and adults in grain, carbon dioxide and nitrogen fumigation of dry food storage bins, screening system to remove insects and insect parts, magnetic traps, iron screens for sieving equipment (so that screen fragments can be picked up by magnetic traps), metal detectors for rejecting packaged product that contains unwanted metal, and methods for storing and keeping track of segregated batches of raw materials and finished goods until necessary quality assurance tests have been carried out.

Sanitation

Sanitation, which helps prevent contamination, should be facilitated by providing or using: impermeable coated or tiled floors and walls, at least one floor drain per every 40 m^2 of wet processing area, special traps for such drains, pitched floors that ensure good drainage, polished vessels and equipment that do not contain dead spaces and which can be drained and automatically cleaned in place, sanitary piping, clean-in-place (CIP) systems, plate heat exchangers and other types of equipment which can be readily disassembled for cleaning if necessary, clearances for cleaning under and around equipment, grouting to eliminate crevices at the base of equipment support posts and building columns, tubular pedestals instead of support posts constructed from beams, and methods for removing solid particles which fall off conveyors. Air flow and human traffic flow patterns should be maintained to eliminate possibilities of containment transfer from dirty areas to clean ones. Very high levels of sanitation must be provided for foodstuffs that provide good substrates for the growth of micro-organisms and when processing temperatures and conditions favor such growth.

Deterioration

To minimize product and raw material deterioration, provisions should be made for: refrigerated and controlled environment storage areas, space and facilities for product inspection and for carrying out quality assurance tests, surge vessels for processed material between different operations (particularly operations which are subject to breakdown), equipment for pre-cooling material stored in such vessels, means of cooling, turning over or rapidly discharging the contents of bins and silos when excessive temperature rises, occur, and standby refrigeration and utility arrangements which are adequate to prevent product and raw material deterioration in case of power interruptions or unusual climatic conditions.

Seasonal production

Food plants have to be sized to accommodate peak seasonal flows of product without excessive delay, and in some cases, have to be highly flexible so as to handle different types of fruits and vegetables. Modeling of crop and animal growth processes can be of great help in scheduling production and adequately sizing plants.

LECTURE NO. 3

FLOW CHART FOR PLANT DESIGN, IDENTIFICATION STAGE, LOOKING FOR A NEED, FINDING A PRODUCT, PRELIMINARY SCREENING OF IDEAS

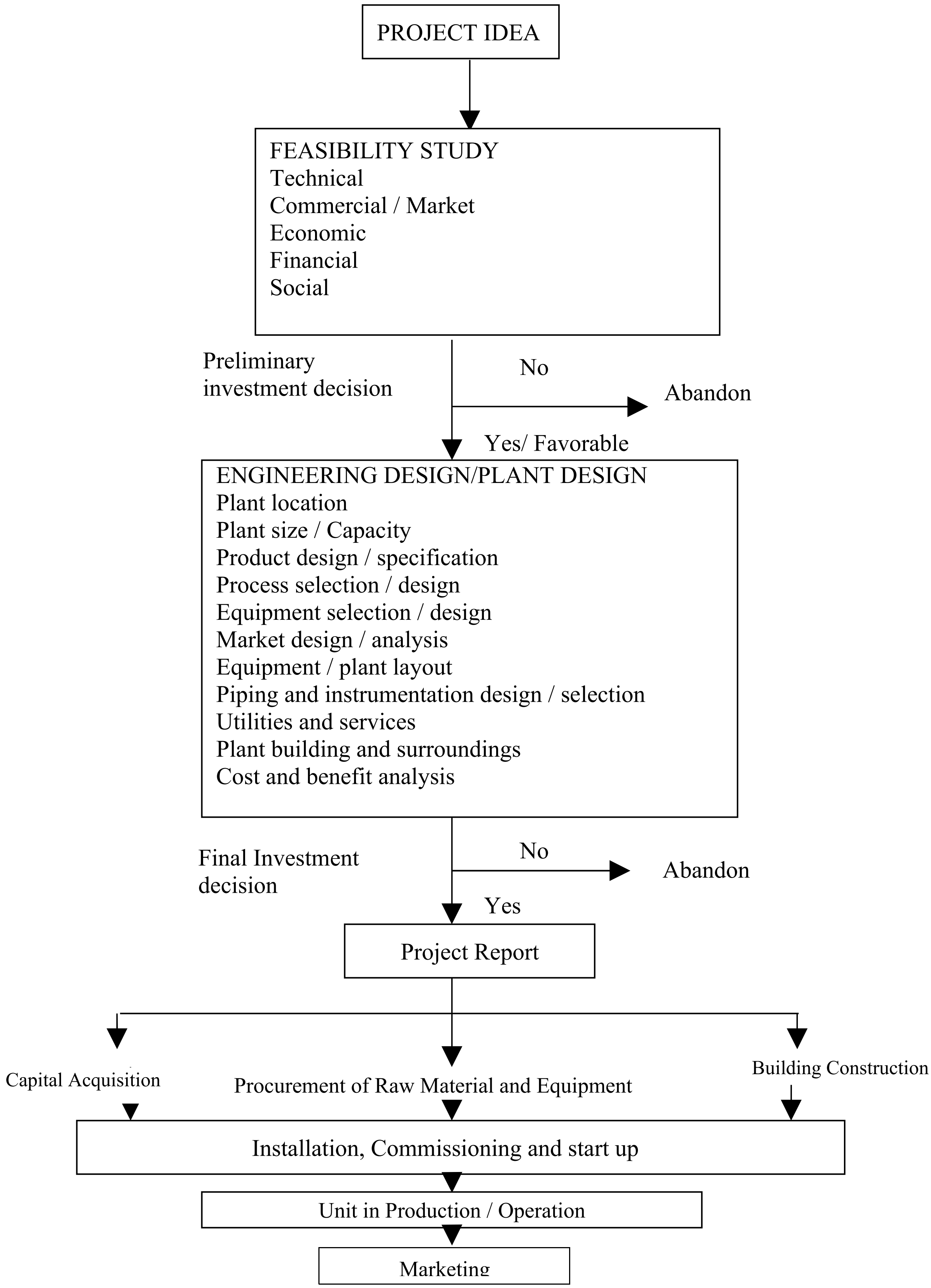


Fig. Flow chart for plant design

FEASIBILITY STUDY

The basis for the success of the design of any food processing plant is a comprehensive feasibility study and evaluation. The feasibility study involves an analysis and evaluation of the design concept from all the relevant angles. The study provides an immediate indication of the probable success of the enterprise and also shows what additional information is necessary to make a complete evaluation. It gives an insight in to: requirements of human, financial and material resources; plant and machinery, technology; and economic gains or profitability of the proposed venture.

The feasibility analysis involves a certain number of stages during which various elements of the plant design are prepared and examined to arrive at appropriate decision. The feasibility study can, therefore, be seen as a series of activities culminating in the establishment of a certain number of study elements and documents, which permit decision making. Identification stages, preliminary selection stage, analysis stage and evaluation and decision stage are the important stages.

Identification Stage

Once a product idea occurs, the starting point of analysis is the establishment of the objectives to be attained. The objective may be to prove that it is possible and desirable to manufacture a certain product or group of products, to add a piece of equipment to the existing plant or to utilize certain resources.

The ideas for new products or diversification can be generated in an informal and spontaneous manner from customers, distributors, competitors, sales people, and others, or the entrepreneur can rely on a systematic process of idea generation.

Two key approaches for product identification and selection could be:

i) Look for a need and then the product to satisfy that need, or

ii) Find a product idea and then determine the extent of the need.

Looking for a need

Venture ideas can be stimulated by information which indicates possible need. This approach requires access to data and considerable analysis. However, if the perceived need is real, the product idea has a better than average chance of leading to a successful venture. The need may be one now being served inefficiently at high cost, or it may be presently unserved. The second implies that a considerable amount of creative design and development may be required to arrive at a product that appears to satisfy the need. The following is suggested for identification of the need.

- study existing industries for backward and forward product integration to indicate input and output needs
- analyze population trends and demographic data for their affect on the market
- study development plans and consult development agencies for development needs and venture opportunities
- examine economic trends in relation to new market needs and opportunities .
- analyze social changes
- study the effects of new legislations in relation to creation of new opportunities

Finding a product

Each of the preceding suggestions for idea generation centers on the recognition of a need in order to arrive at a product idea. The suggestions that follow are product oriented. They are intended to stimulate product ideas which may meet one or more of the criteria previously discussed. Their use should result in a large number of ideas which can be subsequently examined with regard to need. The following list should be useful in conducting such an exercise.

- investigate local materials and other resources for their current utilization pattern, utilization potential and convertibility into more value added products
- examine import substitutions for indigenous production
- study local skills for production and marketing of value added products
- study implications of new technologies for improvement of existing products or to create / produce new ones
- study and analyze published sources of ideas

Preliminary Screening of Ideas

By following the above approaches, it should be possible to develop a long list of potential venture opportunities. Obviously, it would not be realistic to conduct a detailed feasibility analysis for each idea. What is needed is a preliminary screening to eliminate the many ideas that have little or no hope for success and to provide, if possible, a rank-ordering of the remaining few. The screening can be conducted as two-phase process. In the first phase venture ideas are eliminated on a go/no-go basis. A "Yes" response to any of the following should eliminate the idea from further consideration.

- Are the capital requirements excessive?
- Are environmental effects contrary to Government regulations?
- Is venture idea inconsistent with national policies, goals and restrictions?
- Will effective marketing need expensive sales and distribution system?
- Are there restrictions, monopolies, shortages, or other causes that make any factor of production unavailable at reasonable cost?

LECTURE NO. 4

COMPARATIVE RATING OF PRODUCT IDEAS: PRESENT MARKET, MARKET GROWTH POTENTIAL, COSTS, RISKS

Comparative Rating of Product Ideas

After elimination of unattractive venture ideas, it is desirable to choose the best of those remaining for further analysis. Various comparative schemes have been proposed for rating venture ideas. In this section factors that should be considered and some possible ranking methods are examined. For a product idea to lead to a successful venture, it must meet the following four requirements:

1. An adequate present market
2. Market growth potential
3. Competitive costs of production and distribution
4. Low risk in factors related to demand, price, and costs

1. Present Market:- The size of the presently available market must provide the prospect of immediate sales volume to support the operation. Sales estimates should not be based solely on an estimate of the number of potential customers and their expected individual capacity to consume. Some factors that effect sales are:

- Market size (number of potential customers)
- Product's relation to need
- Quality-price relationship compared to competitive products
- Availability of sales and distribution systems and sales efforts required
- Export possibilities

2. Market Growth Potential: There should be a prospect for rapid growth and high return on invested capital. Some indicators are:

- Projected increase in need and number of potential customers
- Increase in customer acceptance
- Product newness
- Social, political and economic trends (favorable for increasing consumption)

3. Costs (Competitive costs of production and distribution**):** The costs of production factors and distribution must permit an acceptable profit when the product is priced competitively. The comparative rating process should consider factor likely to result in costs higher than those of competitive producers should:

- Costs of raw material inputs
- Labor costs
- Selling and distribution costs
- Efficiency of production processes
- Patents and licenses

4. Risks : Obviously it is impossible to look into the future with certainty, and the willingness to assume risk is the major characteristic that sets the entrepreneur apart. However, unnecessary risk is foolhardy and, while it may be difficult or impossible to predict the future, one can examine, with considerable confidence, the possible effect of unfavorable future events on each of venture ideas. The following factors should be considered.

- Market stability in economic cycles
- Technological risks
- Import competition
- Size and power of competitors
- Quality and reliability risks (unproven design)
- Initial investment cost
- Predictability of demand,
- Vulnerability of inputs (supply and price)
- Legislation and controls
- Time required to show profit
- Inventory requirements

For purposes of preliminary screening, these factors can be subjectively evaluated.

LECTURE NO. 5

PRE SELECTION / PRE FEASIBILITY STAGE, ANALYSIS STAGE: MARKET ANALYSIS, SITUATIONAL ANALYSIS RELATED TO MARKET

Pre selection / Pre feasibility Stage

The preliminary screening may have several ideas which appear to be worthy of further study. Since a complete feasibility study is time consuming and expensive, it may be desirable to perform a pre feasibility analysis in order to further screen the possible ideas. The purpose of a pre feasibility study is to determine.

- Whether the project seems to justify detailed study
- What matters deserve special attention in the detailed study (e.g. market analysis, technical feasibility, investment costs)
- An estimate of cost for the detailed study

For many ideas the pre-feasibility analysis may provide adequate evidence of venture profitability if certain segments are more carefully verified. Emphasis depends on the nature of the product and the area of greatest doubt. In most cases market aspects and materials receive primary emphasis. The pre-feasibility study may include some or all of the following elements.

1. Product description. The product's characteristics should be briefly described, along with possible substitutes which exist in the market place. Also, allied products should be identified, which can or should be manufactured with the product under study.

2 Description of market. The present and projected potential market and the competitive nature of the market should be delineated.

- Where is the product now manufactured?
- How many plants exist and how specialized are they?
- What are the national production, imports, and exports?
- Are there government contracts or incentives?
- What is the estimated product longevity or future consumption?
- What is the price structure?

3. Outline of technological variants. The technology choices that exist for the manufacture of the product should be described briefly. Also, the key plant location factors should be identified.

4. Availability of main production factors. Production factors such as raw materials, water, power, fuel and labor skills should be examined to ensure availability.

5. Cost estimates. Estimates should be made of the necessary investment costs and costs of operation.

6. Estimate of profit. The data gathered should include estimates of profits of firms manufacturing similar products or, if the preliminary data are extensive, an actual estimated profit for the project under study.

7. Other data. In certain cases, local attitudes toward industry; educational, recreational and civic data; and availability of local sites, may be the most important in the evaluation of the suitability of a proposed product, especially in the case of the establishment of a new firm.

Thus pre feasibility study can be viewed as a series of steps culminating in a document which permits determination of whether or not a complete detailed feasibility study should be made. It does not possess the depth the detailed study is expected to have, and the data usually are gathered in an informal manner.

Analysis Stage

At the analysis stage various alternatives in marketing, technology and capital availability need to be studied. The analysis can be conducted at different levels of effort with respect to time, budget and personnel, depending on the circumstances. The complete study is referred to as techno-economic feasibility study. In some cases such a detailed study is not necessary. For example, if the product has an assured market, in-depth market analysis is not required. In some cases, a partial study of the market or of the technologies satisfies the data requirements for decision making. The detailed analysis should include the following.

Market analysis / study

Market analysis can serve as a tool for screening venture ideas and also as a means of evaluating the feasibility of a venture idea in terms of the market. It provides:

- understanding of the market
- information on feasibility of marketing the product
- analytical approach to the decision making

In addition, it assists in analyzing the decisions already taken. **Market analysis answers questions about**.

- size of market and share anticipated for the product in terms of volume and value
- pattern of demand
- market structure
- buying habits and motives of buyers
- past and future trends
- price which will ensure acceptance in the market
- most efficient distribution channels,
- company's strong points in marketing

Market analysis involves systematic collection, recording, analysis, and interpretation of information on:

- existing and potential markets
- marketing strategies and tactics
- interaction between market and product
- marketing methods
- current or potential products

In collecting the market data, for whatever size market or type of product, it is helpful to follow an orderly procedure.

The initial step is to put down in writing a preliminary statement of objectives in as much detail as possible. A good procedure is to structure the objectives in question form. When setting objectives, always keep in mind as to how the information will be used when it is obtained. This helps in eliminating objectives that would not make a contribution to the market analysis.

Situational analysis related to Market

The situational analysis of the market involves analyzing the product's relationship to its market by using readily available information. The information reviewed and each question asked will give the analyst a feel for the situation surrounding the product. The state involves an informal investigation which includes talking to people in wholesale market, brokers, competitors, customers and other individuals in the industry. If this informal investigation produces the sufficient data to measure the market adequately, the analysis need not proceed further. Also, in some instances, where time is critical or where budget is a problem, the data gathered during the informal market analysis may be all that is available on which to base decisions.

Seldom do the data obtained during the situational analysis answer all the necessary questions. The informal analysis provides the basis for revision of the objectives and frequently indicates the most fruitful methods by which market can be studied. This also helps in preparing a comprehensive programme of market study. Such a programme should include a description of the tasks and methods by which each type of information is to be gathered. It should include not only the time schedule for each task, but also an estimate of costs likely to be incurred.

Basic steps involved in a market study for a new enterprise are outlined below:

- Define objectives of the study and specify information required
- Workout details of the study as under:
  - -identify sources of information (both secondary and primary)
  - -time and cost involvement
  - -methodology and action plan
- Select samples and decide contacts and visits
- Prepare the questionnaire as the survey instrument and field test the same
- Conduct the survey and analyze information
- Prepare the report with findings and interpretations

The analysis should generally contain:

- A brief description of the market including the market area, methods of transportation existing rates of transportation, channels of distribution, and general trade practices
- Analysis of past and present demand including determination of quantity and value of consumption, as well as identification of the major consumers of the product
- Analysis of past and present supply broken down as to source, information on competitive position of the product such as selling prices, quality, and marketing practices of the competitors
- Estimate of future demand of the product
- Estimate of the project’s share of the market considering all above factors

LECTURE NO. 6

TECHNICAL ANALYSIS, FINANCIAL ANALYSIS, SENSITIVITY AND RISK ANALYSIS, FEASIBILITY COST ESTIMATES

Technical analysis:

The technical analysis must establish whether or not the identified venture is technically feasible and, if so, make tentative choices among technical alternatives and provide cost estimates in respect of:

(i) fixed investment,

(ii) manufacturing costs and expenses, and

(iii) start-up costs and expenses.

In order to provide cost estimates, tentative choices must be made among technical alternatives such as:

(i) level of product / manufacturing technology,

(ii) raw material inputs,

(iii) equipment,

(iv) methods,

(v) organization, and

(vi) facilities location and design.

The analysis should incorporate:

- Description of the product, including specifications relating to its physical, mechanical, and chemical properties as well as the uses of the product
- Description of the selected manufacturing process showing detailed flow charts as well as presentations of alternative processes considered and justification for adopting the one selected
- Determination of plant size and production schedule, which includes the expected volume for a given time period, considering start-up and technical factors
- Selection of machinery and equipment, including specifications, equipment to be purchased and origin, quotations from suppliers, delivery dates, terms of payment, and comparative analysis of alternatives in terms of costs, reliability, performance and spare parts availability .
- Identification of plant's location and assessment of its desirability in terms of its distance from raw material sources and markets. For a new project

this part may include a comparative study of different sites, indicating the advantages and disadvantages of each.

- Design of a plant layout and estimation of the costs of erection of the proposed types of buildings and land improvements
- Study of availability of raw materials and utilities, including a description of physical and chemical properties, quantities, needed, current and prospective costs, terms of payment, source of supply and their location and continuity of supply
- Estimate of labor requirements including a breakdown of the direct and indirect labor supervision required for the manufacture of product
- Determination of the type and quantity of waste to be disposed of, description of the waste disposal method, its costs and necessary clearance from the authorities
- Estimation of the production cost for the product

The elimination of inappropriate technology alternatives for producing the identified product can be done on the basis of side effects. The factors which may be considered as side effects include:

- contribution to employment
- requirements for scarce skills
- energy requirements
- capital requirements
- need for imported equipment
- support of indigenous industry
- multiplier effect of the venture operation
- environmental effects.
- safety and health hazards,

Information concerning manufacturing processes and equipment, which may facilitate the selection and decision making, may be obtained from: (i) existing manufacturers of the product, (ii) trade publications, (iii) trade associations and organizations, and (iv) equipment manufacturers.

Financial analysis

The financial analysis emphasizes on the preparation of financial statement, so that the venture idea can be evaluated in terms of commercial profitability and the magnitude of financing required. It requires the assembly of the market and the technical cost estimates into various proforma statements. If more information on which to base an investment decision is needed, a sensitivity analysis or, possibly, a risk analysis can be conducted. The depth of analysis would depend, to a certain extent, on the venture idea and the overall objectives of the feasibility analysis.

The financial analysis should include:

- For existing companies-audited financial statements, such as balance sheets, income statements and cash flow statements
- For new companies-statements of total project costs, initial capital requirements and cash flows relative to the project time table
- For all projects-financial projections for future time periods, including income statements, cash flows and balance sheets
- Supporting schedules for financial projections, stating assumptions used as to collection period of sales, inventory levels, payment period of purchases and expenses, elements of product costs, selling, administrative and financial expenses
- financial analysis showing return on investment, return on equity, break-even volume and price analysis
- Sensitivity analysis to identify items that have a large impact on profitability or possibility of risk analysis

The analyst may obtain profitability measures for the venture being studied in several ways. Common non-time value approaches to measure profitability are the pay back period and financial statement (accounting) rates of return. These rates of return are based on some net income figure divided by some investment base. Frequently used profitability measure of this type are: net income to assets, first-year earnings to initial investment, average net income to initial investment, and average net income to average investment.

Profitability measures, which consider the time value of money, that is, discounted cash flow methods, are net present value (NPV), internal rate of return (IRR), and the discounted benefit / cost ratio. When profitability measures other than financial statement rates of return are used as the investment decision criteria, the analyst needs estimates of the following:

- the net investment, which is gross capital less any capital recovered from the sale or trade of existing assets;

- the operating cash flows, which are the after-tax cash flows resulting from the investment;
- the economic life of the venture, defined as the time period during which benefits can be obtained from the venture; and
- the appropriate discount rate.

With the relevant cash flows computed for the venture, the next step is to decide which investment decision criterion to use for the acceptance or rejection of ventures as well as their ranking. Theoretically, the net present value criterion is the best measure of profitability of the investment decision criteria used to evaluate new venture ideas, the internal rate of return appears as the technique to be of prime importance. The payback period is used primarily as a supplementary technique.

Sensitivity and risk analysis

Recognizing that the venture profitability forecast hinges on future developments whose occurrence can not be predicted with certainty, the decision-maker may want to probe further. The analyst may want to determine the impact of changes in variables such as product price, raw material costs, and operating costs on the overall results. Sensitivity analysis and risk analysis are the techniques that allow the analyst to deal with such problems.

The purpose of sensitivity analysis is to identify the variables that most affect the outcome of a venture. Sensitivity analysis is useful for determining consequences of a stated percentage change in a variable such as product price. It involves specifying the possible range for the variable, such as price, and calculating the effect of changes in this variable to profitability. With such a calculation, the analyst can determine the relative importance of each of the variables to profitability. However, only risk analysis can provide any indication of the likelihood that such events (change in product price) will actually occur.

Risk analysis takes into account the recognized fact that variables, such as product price, depend on future events whose occurrence can not be predicted with certainty. Hence, investment decision situations can be characterized with respect to certainty, risk and uncertainty. Since certainty seldom exists for future returns on investment, only risk and uncertainty are of interest. Uncertainty is used to refer to an event, such as technological breakthrough resulting in obsolescence, that is expected to take place although the probability of its occurrence cannot be forecasted during the venture's lifetime. Risk refers to a situation in which a probability distribution of future returns can not be established for the venture. The riskiness of the venture can be defined as the variability or dispersion of its future returns. In practice, there are usually several variables and the aggregate risk of the venture can not be determined easily because it is composed of numerous risks. The purpose of risk analysis is to isolate the risks and to provide a means by which various venture outcomes can be reduced to a format from which a decision can be made. A more detailed coverage can be found under profitability analysis.

Feasibility cost Estimates

A lot of guess work goes into feasibility cost estimate. Attempts are always made to collect and update historical figures with additions for escalation / inflation and local factors, based on statistics and guess work. In such a situation what is expected is a rule of thumb or an order of magnitude estimate. The order of magnitude estimate is derived from the cost reports of completed ventures. Probability of this estimates accuracy is generally between +25, and 40 percent. Preliminary control estimate is often used in the feasibility report.

This is prepared, generally, after the completion of the process design and major equipment listing. Accuracy of this estimate may vary between + 15 and 25 percent. Endeavour is usually made to achieve a +20 percent accuracy in the feasibility report estimates. For a rule of thumb, the following are the percentages of the venture cost factors:

-Project development and detailed project report (DPR) preparation - 2 %

-Engineering and design - 13 %

-Brought out materials and equipment-55 %

-Fabrication and construction- 30 %

Depending on the type of venture, sector and complexity, these can vary on either side.

LECTURE NO. 7

BREAK EVEN ANALYSIS: INTRODUCTION, BREAK-EVEN CHART, FIXED COSTS, VARIABLE COSTS, BREAK EVEN POINT CALCULATION

Break-Even Analysis

Introduction

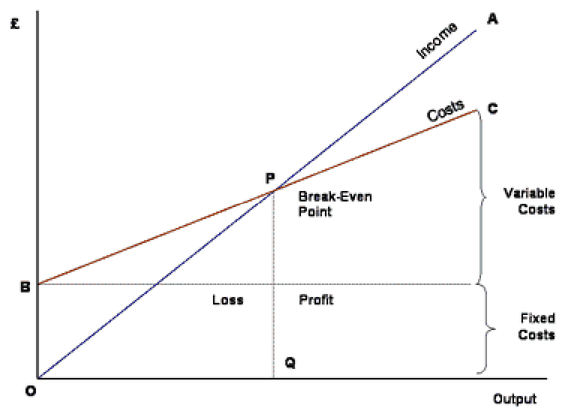
Break-even analysis is a technique widely used by production management and management accountants. It is based on categorizing production costs between those which are "variable" (costs that change when the production output changes) and those that are "fixed" (costs not directly related to the volume of production).

Total variable and fixed costs are compared with sales revenue in order to determine the **level of sales volume, sales value or production at which the business makes neither a profit nor a loss (the "break-even point").**

"A breakeven analysis **is used to determine how much sales volume your business needs to start making a profit."**

The Break-Even Chart

In its simplest form, the break-even chart is a graphical representation of costs at various levels of activity shown on the same chart as the variation of income (or sales, revenue) with the same variation in activity. The point at which neither profit nor loss is made is known as the "break-even point" and is represented on the chart below by the intersection of the two lines:



In the diagram above, the line **OA** represents the variation of income at varying levels of production activity ("output"). **OB** represents the total fixed costs in the business. As output increases, variable costs are incurred, meaning that **total costs (fixed + variable)** also increase. At low levels of output, Costs are greater than Income. At the **point of intersection, P**, costs are **exactly equal to income**, and hence neither profit nor loss is made.

Fixed Costs

Fixed costs are those business costs that are **not directly related** to the level of production or output. In other words, even if the business has a zero output or high output, the level of fixed costs will remain broadly the same. In the long term fixed costs can alter - perhaps as a result of investment in production capacity (e.g. adding a new factory unit) or through the growth in overheads required to support a larger, more complex business.

Examples of fixed costs:

- Rent and rates
- Depreciation
- Research and development
- Marketing costs (non- revenue related)
- Administration costs

Variable Costs

Variable costs are those costs which vary directly with the level of output. They represent payment output-related inputs such as raw materials, direct labour, fuel and revenue-related costs such as commission.

Break Even Point Calculation

Calculation of BEP can be done using the following formula :

$$BEP = \frac{TFC}{(SUP - VCUP)}$$

where ,

BEP = break-even point (Units of production)

TFC = total fixed costs

VCUP = variable costs per unit of production

SUP = Selling price per unit of production

For example, suppose that fixed costs for producing 100,000 widgets were $30,000 a year. Variable costs are $2.20 materials, $4.00 labour, and $0.80 overhead, for a total of $7.00. If selling price was chosen as $12.00 for each widget, then: Break even point will be $30,000 divided by ($12.00 - 7.00) equals 6000 units.This is the number of widgets that have to be sold at a selling price of $12.00 before business will start to make a profit.

Advantages of Break Even Analysis

It explains the relationship between cost, production volume and returns. The major benefit to using break-even analysis is that it indicates the lowest amount of business activity necessary to prevent losses.

Limitations of Break-even -Analysis

It is best suited to the analysis of one product at a time

LECTURE NO. 8

PLANT LOCATION: INTRODUCTION, LOCATION DECISION PROCESS, FACTORS INVOLVED IN THE PLANT LOCATION DECISION

Introduction

Plant location decisions are strategic, long term and non-repetitive in nature. Without sound and careful location planning in the beginning itself, the new plant may pose continuous operating disadvantages. Location decisions are affected by many factors, both internal and external to the organization's operations.

Internal factors include the technology used, the capacity, the financial position, and the work force required.

External factors include the economic, political and social conditions in the various localities.

Most of the fixed and some of the variable costs are determined by the location decision. The efficiency, effectiveness, productivity and profitability of the plant are also affected by the location decision. Location decisions are based on a host of factors, some subjective, qualitative and intangible while some others are objective, quantitative and tangible.

When Does a Location Decision Arise?

The impetus to embark upon a plant location study can be attributed to reasons as given below:

- It may arise when a new plant is to be established.
- In some cases, the plant operations and subsequent expansion are restricted by a poor site, thereby necessitating the setting up of the facility at a new site.
- The growing volume of business makes it advisable to establish additional facilities in new territories.
- Decentralization and dispersal of industries reflected in the industrial policy resolution so as to achieve an overall development would necessitate a location decision at a macro level.
- It could happen that the original advantages of the plant have been outweighed due to new developments.
- New economic, social, legal or political factors could suggest a change of location of the existing plant.

Some or all the above factors could force a firm or an organization to question whether the location of its plant should be changed or not.

Whenever the plant location decision arises, it deserves careful attention because of the long-term consequences. Any mistake in selection of a proper location could prove to be costly. Poor location could be a constant source of higher cost, higher investment, difficult marketing and transportation, dissatisfied and frustrated employees and consumers, frequent interruptions of production, abnormal wastage, delays and substandard quality, denied advantages of geographical specialization and so on. Once a plant is set up at a location, it is very difficult to shift later to a better location because of numerous economic, political and sociological reasons.

Raw Material

On the basis of availability, the raw materials can be categorized into:

(a) ubiquitous-to denote those available almost everywhere and

(b) localized materials, having specific locations, which are further divided into pure material which contributes nearly the total weight of it to the finished products, and gross material, which contributes only a small fraction of total weight to the finished products. It is obvious that ubiquitous hardly influence the decision of location. A material index has been proposed, which equals the weight of localized material used in the finished product divided by the weight of the finished product.

$$\text{Material Index (MI)} = \frac{\text{Weight of local material used in the finished product}}{\text{Weight of the finished product}}$$

If the material index is greater than unity, location should be nearer to the source of raw material and if it is less than unity, then a location nearer to market is advised.

Location Decision Process

Table given below lists possible formal steps in a plant location decision process. The actual approach varies with the size and scope of operations.

The objectives are influenced by, owners, suppliers, employees and customers of the organization influence the objectives. They may stem from opportunities (or concerns) with respect to any phase of the production system (i.e. inputs, processing, or outputs). The following sections describe the variables, criteria and models relevant to the location decision process.

Table Steps in a facility location decision

1	Define the location objectives and associated variables
2	Identify the relevant decision criteria * quantitative-economic * qualitative - less tangible
3	Relate the objectives to the criteria in the form of a model, or models (such as break-even, linear programming, qualitative factor analysis)
4	Generate necessary data and use the models to evaluate the alternative locations
5	Select the location that best satisfies the criteria

Factors Involved In the Plant Location Decision

Location studies are usually made in two phases namely,

I. the general territory selection phase and
II. the exact site / community selection phase amongst those available in the general locale. The considerations vary at the two levels, though there is substantial overlap as shown in the following Table.

Table Factors involved in the two stages of plant location study

Location factors	General territory selection	Selection of specific site
Market	*	
Raw material	*	
Power	*	*
Transportation	*	*
Climate and fuel	*	
Human resource and wages	*	*
Regulatory laws and taxes	*	*
Community services		*
Water and waste		*
Ecology and pollution		*
Capital availability	*	*
Site characteristics		*
Security	*	*

A typical team studying location possibilities for a large project might involve economists, accountants, town planners, marketing experts, legal experts, politicians, executives, industrial engineers, ecologists etc. It is indeed an interdisciplinary team that should be set up for undertaking location studies.

LECTURE NO. 9

TERRITORY SELECTION AND SITE/ COMMUNITY SELECTION

Territory Selection

For the general territory / region / area, the following are some of the important factors that influence the selection decision.

1. Markets: There has to be some customer / market for the product. The market growth potential and the location of competitors are important factors that could influence the location. Locating a plant or facility nearer to the market is preferred if promptness of service is required particularly if the product is susceptible to spoilage. Also if the product is relatively inexpensive and transportation costs add substantially to the cost, a location close to the market is desirable.

2. Raw materials and supplies: Sometimes accessibility to vendors/suppliers of raw materials, equipment etc. may be very important. The issue here is promptness and regularity of delivery and inward freight cost minimization.

If the raw material is bulky or low in cost, or if it is greatly reduced in bulk viz. transformed into various products and by-products or if it is perishable and processing makes it less so, then location near raw material source is important. If raw materials come from a variety of locations, the plant / facility may be situated so as to minimize total transportation costs. The costs vary depending upon specific routes, mode of transportation and specific product classifications

3. Transportation facilities: Adequate transportation facilities are essential for the economic operation of production system. For companies that produce or buy heavy bulky and low value per ton commodities, water transportation could be an important factor in location plants.

4. Manpower supply: The availability of skilled manpower, the prevailing wage pattern, living costs and the industrial relations situation influence the location.

5. Infrastructure: This factor refers to the availability and reliability of power, water, fuel and communication facilities in addition to transportation facilities.

6. Legislation and taxation: Factors such as financial and other incentives for new industries in backward areas or no-industry-district centers, exemption from certain state and local taxes, octroi etc. are important.

Site / Community Selection

Having selected the general territory / region, one would have to go in for site / community selection. Some factors relevant for this are:

1. Community facilities: These involve factors such as quality of life which in turn depends on availability of facilities like education, places of worship, medical services, police and fire stations, cultural, social and recreation opportunities, housing, good streets and good communication and transportation facilities.

2. Community attitudes: These can be difficult to evaluate. Most communities usually welcome setting up of a new industry especially since it would provide employment opportunities to the local people directly or indirectly. However, in case of polluting industries, they would try their utmost to locate them as far away as possible. Sometimes because of prevailing law and order situation, companies have been forced to relocate their units. The attitude of people as well as the state government has an impact on location of polluting and hazardous industries.

3. Waste disposal: The facilities required for the disposal of process waste including solid, liquid and gaseous effluent need to be considered. The plant should be positioned so that prevailing winds carry any fumes away from populated areas and that the waste may be disposed off properly and at reasonable costs.

4. Ecology and pollution: These days, there is a great deal of awareness towards maintenance of natural ecological balance. There are quite a few agencies propagating the concepts to make the society at large more conscious of the dangers of certain available actions.

5. Site size: The plot of land must be large enough to hold the proposed plant and parking and access facilities and provide room for future expansion.

6. Topography: -The topography, soil structure and drainage must be suitable. If considerable land improvement is required, low priced land might turn out to be expensive.

7. Transportation facilities: The site should be accessible preferably by road and rail. The dependability and character of the available transport carriers, frequency of service and freight and terminal facilities is also worth considering.

8. Supporting industries and services: The availability of supporting services such as tool rooms, plant services etc. need to be considered.

9. Land costs: These are generally of lesser importance, as they are non-recurring and possibly make up a relatively small proportion of the total cost of locating a new plant.

Generally, the site will be in a city, suburb or country location. In general, the location for large scale industries should be in rural areas, which helps in regional development also. It is seen that once a large industry is set up (or even if a decision to this effect has been taken), a lot of infrastructure develops around it as a result of the location decision. As for the location of medium scale industries is concerned, these could be preferably in the suburban / semi-urban areas where the advantages of urban and rural areas are available. For the small-scale industries, the location could be urban areas where the infrastructural facilities are already available. However, in real life, the situation is somewhat paradoxical as people, with money and means, are usually in the cities and would like to locate the units in the city itself.

Some of the industrial needs and characteristics that tend to favour each of this location are.

Requirements governing choice of a **city location** are:

- Availability of adequate supply of labour force
- High proportion of skilled employees
- Rapid public transportation and contact with suppliers and customers
- Small plant site or multi floor operation
- Processes heavily dependent on city facilities and utilities
- Good communication facilities like telephone, telex, post offices
- Good banking and health care delivery systems

Requirements governing the choice of a **suburban location** are:

- Large plant site close to transportation or population centre
- Free from some common city building zoning (industrial areas) and other restrictions
- Freedom from higher parking and other city taxes etc.
- Labour force required to reside close to the plant
- Community close to, but not in large population centre
- Plant expansion easier than in the city

Requirements governing the choice of a **rural location are**:

- Large plant site required for either present demands or expansion
- Dangerous production processes
- Lesser effort required for anti-pollution measures

- Large volume of relatively clean water
- Lower property taxes, away from Urban Land Ceiling Act restrictions
- Protection against possible sabotage or for a secret process
- Balanced growth and development of a developing or underdeveloped area
- Unskilled labour force required
- Low wages required to meet competition

LECTURE NO. 10

SUBJECTIVE, QUALITATIVE AND SEMI-QUANTITATIVE TECHNIQUES, EQUAL WEIGHTS METHOD, VARIABLE WEIGHTS METHOD, WEIGHT-CUM-RATING METHOD, ANOTHER WEIGHT-CUM-RATING METHOD

Subjective, Qualitative and Semi-Quantitative Techniques

Three subjective techniques used for facility location are Industry Precedence, Preferential Factor and Dominant Factor. In the industry precedence subjective technique, the basic assumption is that if a location was best for similar firms in the past, it must be the best for the new one now. As such, there is no need for conducting a detailed location study and the location choice is thus subject to the principle of precedence - good or bad.

However, in the case of the preferential factor, the location decision is dictated by a personal factor. It depends on the individual whims or preferences e.g. if one belongs to a particular state, he / she may like to locate his / her unit only in that state. Such personal factors may override factors of cost or profit in taking a final decision. This could hardly be called a professional approach though such methods are probably more common in practice than generally recognized.

However, in some cases of plant location there could be a certain dominant factor (in contrast to the preferential factor) which could influence the location decision. In a true dominant sense, mining or petroleum drilling operations must be located where the mineral resource is available. The decision in this case is simply whether to locate or not at the source.

For evaluating qualitative factors, some factor ranking and factor weight rating systems may be used. In the ranking procedure, a location is better or worse than another for the particular factor. By weighing factors and rating locations against these weights a semi-quantitative comparison of location is possible. Let us now discuss some specific methods.

Equal Weights Method

Assign equal weights to all factors and evaluate each location along the factor scale. For example, a manufacturer of fabricated foods selected three factors by which to rate four sites. Each site was assigned a rating of 0 to 10 points for each factor. The sum of the assigned factor points constituted the site rating by which it could be compared to other site.

Table Decision matrix

Factor/Potential Sites	SI	S2	S3	S4
FI	2	5	9	2
F2	3	3	8	3
F3	6	2	7	3
Site rating	11	10	24	8

Sample calculation: 11 = 2 + 3 + 6

Looking at the above Table , one can see that site S3 has the highest site rating of 24. Hence, this site would be chosen.

Variable Weights Method

The above method could be utilized on account of giving equal weight age to all the factors. Now, think of assigning variable weights to each of the factors and evaluating each location site along the factor scale. Factor **FI** might be assigned 300 points, factor **F2** 100 points and factor **F3** 50 points. The points scored, out of the maximum assigned to each of the factors, for each possible location site could be obtained and again the site rating could be derived as follows:

Table Decision matrix

Factor	Maximum points	Potential sites			
		S1	S2	S3	S4
FI	300	200	250	250	50
F2	100	50	70	80	100
F3	50	5	50	10	40
Site rating		255	370	340	190

Sample calculation: 255 = 200 + 50 + 5

Looking at the above Table, it can be seen that site S2 has the highest site rating of 370. Hence, this site would be chosen.

Weight -cum-Rating Method

This is another method of evaluating a potential location site. One can assign variable weights to each factor. A common scale for each factor then rates the locations. The location point assignment for the factor is then obtained by multiplying the location rating for each factor by the factor weight. For example, rating weights of one to five could be assigned to the three factors **F1** (human resource), **F2** (community facilities) and **F3** (power availability and reliability), as 5, 3, 2 respectively. Now for each of the factors, sites SI, S2, S3 or S4 could receive 0 to 10 points as follows and the site rating could be obtained.

Table Decision matrix

Factor	Factor rating points	Potential sites			
		S1	S2	S3	S4
FI	5	2	5	9	2
F2	3	3	3	8	3
F3	2	6	2	7	3
Site rating		31	38	83	25

Sample calculation 3l = 5 x 2 + 3 x 3 + 2 x 6

As shown in the above Table, the sample calculation should hopefully suffice to obtain the site rating. Hence, site S3 with the highest rating of 83 is chosen.

<u>Another weight-cum-rating method</u>

Another weight-cum-rating method establishes a subjective scale common to all factors. This involves assigning points against the subjective scale for each factor and assigns the factor points of the subjective rating for each factor. For example, five subjective ratings-Poor, Fair, Adequate, Good and Excellent are selected to be used in evaluating each site for each factor. For each of the factors, adequate was assigned a value zero and then negative and positive relative worth weights are assigned the subjective ratings below and above adequate for each factor as given in following Table.

Table Decision matrix

	Poor	Fair	Adequate	Good	Excellent
FI Water supply	-15	-12	0	6	10
F2 Appearance of site	-3	-1	0	1	2

The range between minimum and maximum weight assigned to a factor in effect weights that factor against all other factors in a manner equivalent to the weight-cum-rating method described previous to this one. Each location site S1 to

S4 are then rated by selecting the applicable subjective rating for each factor for each location and the equivalent points of that subjective factor rating assigned to the factor. Thus one can now obtain the following Table.

Table Decision matrix

Factor	Potential sites			
	S1	S2	S3	S4
FI	0	-12	6	0
F2	0	-3	2	-1
F3	0	0	0	0
Site rating	0	-15	8	-1

Sample calculation: -15 = (-12) + (-3) + (0)

Accordingly, site S3 with the highest rating of 8 would be chosen.

The location analyst presents to the management both the cost and the intangible data results. In such cases, management could take a decision based on a simple composite measure method illustrated below with the aid of a numerical example.

LECTURE NO. 11

COMPOSITE MEASURE METHOD, LOCATIONAL BREAK-EVEN ANALYSIS

Composite Measure Method

The steps of the composite measure method are:

- Develop a list of all relevant factors
- Assign a scale to each factor and designate some minimum
- Weigh the factors relative to each other in light of importance towards achievement of system goals. .
- Score each potential location according to the designated scale and multiply the scores by the weights.
- Total the points each location and either (a) use them in conjunction with a separate economic analysis, or (b) include an economic factors in the list of factors and choose the location on the basis of maximum points.

The following illustrates the composite measure method with a numerical example. There are three potential sites and five relevant factors like transportation costs per week, labor costs per week, raw material supply, maintenance facilities and community attitude. The costs are in rupees whereas for the last three factors, points are assigned on 0-100 scale. The data collected is shown in the following Table.

Table Payoff matrix

Factor		Potential sites		
		S1	S2	S3
Transportation cost/week Rs	FI	800	640	580
Labour cost/week, Rs.	F2	1180	1020	1160
Raw material supply	F3	30	80	70
Maintenance facilities	F4	60	20	30
Community attitude	F5	50	80	70

The location analyst has pre-established weights for various factors. This includes a standard of 1.0 for each Rs.10 a week of economic advantage. Other weights applicable are 2.0 on raw material supply, 0.5 on maintenance facilities and 2.5 on community attitudes. Also the organization prescribes a minimum acceptable score of 30 for maintenance facilities.

First of all, look at the economic factors FI and F2 for which monetary values were possible. If one totals the costs for each site, one gets the costs for sites S1, S2 and S3 as Rs.1980, RS.1660 and Rs.1740, respectively. Thus, site

S1 would be the worst cost wise. Site S2 would have an economic advantage over site S1 to the extent of RS. (1980-1660) = Rs.320. Similarly, site S3 would have an economic advantage over site SI to the extent of Rs. (1980-1740) = Rs.240. Now the monetary value in Rupees can be converted to a point scale using the fact that a standard of 1.0 is to be assigned for each Rs.10 per week of economic advantage. Thus one can get the following Table.

Table Decision matrix

Factors	Weightage	Potential sites		
		S1	S2	S3
Economic advantage (FI + F2)	1.0	0	32	24
F3	2.0	30	80	70
F4	0.5	60	20	30
FS	2.5	50	80	70
Composite site rating		215	402	354

Sample calculation: 215 = (1.0 x 0) + (2.0 x 30) + (0.5 x 60) + (2.5 x 50)

Locational Break-Even Analysis

Sometimes, it is useful to draw location break-even charts, which could aid in deciding which location would be optimal. The location of a food factory in a South Delhi site will result in certain annual fixed costs, variable costs and revenue. The 0 figures would be different for a South Mumbai site. The fixed costs, variable costs and price per unit for both sites are given below in the Table.

Table Cost data

Location site	Fixed costs	Variable Costs	Price per tonne
South Delhi (SI)	40,00,000	30,000	75,000
South Mumbai (S2)	60,00,000	24,000	82,000

Let us assume that the expected sales volume as estimated by a market research team is 95 tonnes.

Now the break-even point is defined to be the point or volume where the total costs equal total revenue. Thus for each site SI and S2, the break-even point can be determined by using a simple formula as follows:

$$\text{Break - even volume (BEP)} = \frac{\text{Fixed costs}}{(\text{Revenue per unit - Variable cost per unit})}$$

At the South Delhi Location S1

$$BEP = \frac{40,00,000}{75000 - 30000} = 88.88 = 89 \ tonnes$$

and at the South Mumbai location S2

$$BEP = \frac{60,00,000}{82,000 - 24,000} = 103.448 = 104 \ tonnes$$

Let us see what would be the profit or loss for the two sites at the expected volume of 95 tonnes. The calculations are shown in the following Table.

Table Cost comparisons

South Delhi (S1)	South Mumbai (S2)
Costs Fixed : 40,00,000 Variable: 28,50,000 Total : 68,50,000	Costs Fixed : 60,00,000 Variable : 22,80,000 Total : 82,80,000
Revenue: 75,000 x 95 = 71 ,25,000	Revenue: 82,000 x 95 = 77,90,000
Profit : = (71 ,25,000 - 68,50,000) = 2,75,000	Loss : = (77,90,000 - 82,80,000) = 4,90,000

LECTURE NO. 12

FOOD PLANT UTILITIES: PROCESS WATER, STEAM, ELECTRICITY, PLANT EFFLUENTS

FOOD PLANT UTILITIES

The principal plant utilities in a food plant **are process water, process steam**, **electric power** for motors and lighting, and **fuel**.

Process Water

Process water is required for washing the raw materials and for various cooling operations. In fruit and vegetable processing plants, water may be used for transportation (fluming) of the raw materials from receiving to processing areas. Water used in steam boilers may require ion exchange treatment to reduce its hardness. Total water requirement in fruit and vegetable processing may range from 5 to 15 m^3 / ton of raw material.

2. Steam

Steam boilers are needed in most food processing plants to provide process steam, used mainly in various operations, such as heating of process vessels, evaporators and dryers, sterilization, blanching, and peeling. A medium size food plant (80 tons / day raw material) may require a boiler producing about 10 tons/h of steam at 18 bar pressure.

Two principal types of steam boilers are used in the food processing industry, i.e. the fire-tube and the water-tube boilers. The fire tube boilers operate at relatively lower pressure (1–24 bar) and produce cleaner steam. The water-tube units operate at higher pressures (100–140 bar) and they are suited for co-generation, i.e. electrical power and exhaust steam of lower pressure for process heating. Co-generation is economical in large food plants, requiring large amounts of low-pressure steam, e.g., beet sugar plants.

A standby steam boiler of proper capacity may be necessary to provide process steam during any boiler failure or breakdown.

Steam boilers are rated in Btu/h, kW or boiler HP (1 Btu/h = 0.293 W, 1 boiler HP = 9.8 kW). The heat flux in the boiler heating surface is about 0.75 k W/ m^2. The boiler efficiency is about 85% with most of the thermal losses in the dry gases and the moisture. Steam generation is about 1.4 t/h per MW.

In order to maintain the concentration of accumulated dissolved solids in steam boilers below 3500 ppm, periodic discharge of hot water (blow down) is practiced.

Fuel is used in food plants mostly for generating process steam and process drying. Natural gas and liquefied propane (LPG) are preferred fuels in food processing, because their combustion gases are not objectionable in direct contact with food products. Fuel oil and coal can be used for indirect heating, i.e. through heat exchangers.

Culinary steam of special quality is used when steam is injected in food products. The steam must be free of objectionable chemicals used in boilers, which may be carried into the food being heated. Culinary steam is usually produced from potable water in a secondary system of a heat exchanger heated with high pressure industrial steam.

3. Electricity

Electrical power in food processing plants is needed for running the motors of the processing, control, and service equipment, for industrial heating, and for illumination. For a medium size food plant processing about 100 tons/day raw materials, the power requirement may of the order of 500 kW. A standby power generator of about 200 k VA is recommended for emergency operation of the main plant, in case of power failure or breakdown.

Single-phase or three-phase alternating current (AC) of 110 V (60 cycles) or 220 V (50 cycles) is used in food processing plants. The electrical motors are either single-phase or three-phase squirrel cage.

Energy-efficient electrical motors should be used in various food processing operations. A measure of the efficiency of electrical power is the power factor (pf), defined as pf = $\frac{k\,W}{k\,VA}$, which should be equal or higher than 0.85.

Illuminating (lighting) of industrial food plants should utilize fluorescent lamps, which can save significant amounts of energy.

4. Plant Effluents

Plant effluents consisting mainly of wastewater, but including solids and gas wastes require special handling and treatments to comply with the local laws and regulations.

Food plants should be designed and operated so that a minimum pollution is caused to the environment. The Environmental Protection Agency (EPA) in the US has issued codes and regulations that ensure the quality of natural water bodies is not damaged by effluent discharges from industrial plants. Similar regulations apply to atmospheric emissions of objectionable gases and dust. Environmental information needed to comply with EPA regulations for wastewater includes testing for pH, temperature, biochemical oxygen demand (BOD), fats oil and grease (FOG), and total suspended solids (TSS).

Large amounts of waste are produced in the processing of fruits and vegetables, as in canning, freezing, and dehydration operations. Smaller waste volumes are produced in dairy plants (with the exception of cheese and milk powder), and in dry-processing (milling) of grain (e.g., wheat flour).

A medium size fruit or vegetable processing plant handling about 100 ton/day of raw materials may discharge about 1000 m^3/day of waste water.

Treatment of food waste water may involve one or more of the following operations:

1. Simple screening out of the suspended solids,
2. Gravel filtration,
3. solids settling in sedimentation tanks,
4. biological oxidation (aeration),
5. spray irrigation,
6. discharge into the local public sewer, and
7. discharge into a waterway.

Liquid wastes (waste water) can be disposed to the local waste (sewage) treatment plants, after removing some objectionable components, such as fat, oil, and grease to an acceptable level, e.g., lower than 1000 mg/L. Pollution loads higher than 200 mg/L are common in food plant liquid wastes. It is more economical to pay pollution surcharges to the local sewage plant, whenever possible, than to build an expensive wastewater treatment facility.

Food preservation plants, located away from municipal sewage systems, dispose the process water to large storage ponds (lagoons), where a slow natural bio-oxidation of the organic waste takes place. The treated lagoon wastewater can be discharged to the land adjoining the plants.

Some solid food wastes can be sold at relatively low prices for animal feeds, either unprocessed or dried, e.g., solid citrus or sugar beet wastes. Some solid food wastes can be diverted to the land (grape pomace to vineyard), while some other can be mixed with the soil (composting).

The sanitary sewage of food plants, depending on the number of employees, should be treated in a different system than the process wastewater. It can be discharged to the local sewage system, if available. Otherwise, it is treated in septic tanks constructed near the food plant.

Relatively small amounts of gas wastes (odorous VOC) are generated by some food industries, such as bakeries (ethanol), fishmeal dryers, and edible oil refining plants. Also, odors from coffee and cocoa roasting may require some form of treatment. Treatment of objectionable gas wastes involves gas absorption equipment, such as wet scrubbers.

The design of treatment facilities for industrial wastewater, and solids/gas wastes requires the expertise of environmental engineers who are familiar with the local laws and regulations concerning environmental pollution.

LECTURE NO. 13

PLANT SIZE AND FACTORS

Plant size / capacity for any food-processing unit refers to the planned rate of production of the identified product(s). It can be expressed in terms of either **volume** or **weight** or **number produced per unit time** of the product. The **time unit** for expressing the plant size could be taken as **hour** or a **shift** or a **day** or a **year**. It is always useful to take a decision about the size/capacity in the beginning of the plant design.

Knowledge of the plant size may help in:

- assessing the type and size of the plant and machinery needed
- assessing the size and caliber of the work force needed
- determining the requirements of total land area and covered space for the plant
- deciding the type of layout
- assessing the other physical facilities needed
- determining the type of sales efforts and distribution system
- financial or economic viability calculations

The size/capacity of the plant will depend on a number of factors such as:

- raw material availability :
- market demand
- degree and nature of the market competition
- economic considerations i.e. acceptable return on investment / profitability

The interaction of each of the above factor with plant size can be assessed on the basis of information collected as part of the market study. Therefore, a comprehensive market study is a must.

Raw Material Availability

There may be adequate or unlimited demand for the product in the market with little or no competition, but the entrepreneur may not get adequate supplies of the raw material to produce the product in quantities one wishes. This would limit the size.

Market Demand

Market demand for any product is the total volume that will be bought by a **defined customer group** in defined **geographical area** in a defined **time period** and in a defined **environment**. It is possible that the **raw material is available in abundance**. One can get as much raw material as one wishes. But one can not sell all that one can produce. The **demand for the product is limited**. In this case, it is the market demand, which will determine the plant size.

Degree and Nature of the Market Competition

There is **no restriction on raw material** availability. It is available in abundance. Also, there is **enough demand** for the product in the market. *However, there exist a large number of manufacturers / processors for the product who are expected to provide stiff competition*. In this case, the plant size may be restricted to a **limit governed by the share of the market**, which the entrepreneur may capture. Depending on the product, a **10 - 15%** market share is considered to be adequate. The competition may involve price or quality or timely delivery or a combination of such features. To study the competition, the entrepreneur needs to have a list of major competitors, details of their product range, product features, output, market share and pricing.

Economic Considerations

Many times plant size is determined by the financial resources available with the entrepreneur as also by the degree of risk the entrepreneur is prepared to take. Sometimes it is also advisable to find the popular plant size of existing enterprises engaged in manufacturing/processing the product of choice.

In cases where the availability of raw material, market demand and the financial resources are not a problem, the entrepreneur may look for the size which will ensure him / her a minimum acceptable return/profit. **This size is called the minimum economically viable plant size**. However, when situation permits a plant size larger than the minimum economically viable size, a size, which will maximize profits, is selected.

The minimum acceptable return/profit viewed in two ways. In one case larger share of the capital investment may consist of the equity (entrepreneur's own capital) while in another case it may consist of the borrowed capital. In case of the former, the return/profit must be greater than the amount of interest earned if the entire capital of the entrepreneur was invested as fixed deposit in a scheduled bank. In case of the later, the return/profit must be greater than the interest paid on the borrowed capital.

While deciding the plant size/capacity one should also remember the following:

- Specify the number of days for which the proposed plant will work in a year. In general, it is customary to presume 300 working days. However, if the enterprise is to handle the seasonal product, it may work for less than 300 days.
- One shift consists of 8 hours. One shift working is the most popular pattern among small enterprises. Two and three shift working is largely limited to continuous enterprises and the medium and large-scale enterprises.

LECTURE NO. 14

THE ENTERPRISE AND ITS ENVIRONMENT, THE TOTAL REVENUE FUNCTION, THE TOTAL COST FUNCTION

The Enterprise and Its Environment

Imagine a food processing enterprise that competes with several others. The enterprise produces a single product, has some control over the price it will charge and is primarily devoted to making a profit. Imagine further that the major characteristics of the market, the competitors, and enterprises own internal technology are well known to management and essentially static in time. Under these conditions one may explore some of the major economic decisions that might be made. One may start with the environment in which the enterprise exists and work inward, eventually reaching the level of decisions at which the analyst often works.

In studying the enterprise's environment one might wish to study in detail the customers, competitors, suppliers, and the legal, political, social and geographic factors which bear upon its operations. To avoid some of the chaos this might involve, it is assumed that all these things can be expressed by the demand curve of the enterprise. The demand curve expresses a part of the relationship of the enterprise with its market by simply giving the amount of product that can be sold as a function of the price charged for it. In this simple model, price is taken to be the major determining factor in the amount the enterprise can sell; and such obvious other factors as quality, advertising, sales effort, reputation, and service are left out of the picture. Thus the relationship between the price and the amount of product that can be sold is given by:

$$P = a - b\,D \text{ for } 0 \le D \le a/b$$
$$= 0 \quad \text{otherwise}$$

Here P is the unit price, D is the amount of product sold, and a and b are positive constants. It is assumed that the amount of product, D, is a continuous variable. The straight-line example, which has been given, might have been a curve; but the point is that one usually expects large volume to be associated with low price, and small volume to be associated with high price (Figure 1).

The analyst who knows the demand curve may then decide what price one will charge, and the curve will tell how much one can sell; or, one may decide what volume to produce and the curve will indicate the highest price at which one will be able to dispose of the production. Ultimately one will make the choice so as to maximize profit, and profit may be defined simply as the difference between total revenue or gross sales (TR) and total cost (TC),

$$\text{Profit} = TR - TC$$

The total revenue resulting from any price-volume choice may be computed directly from the demand curve.

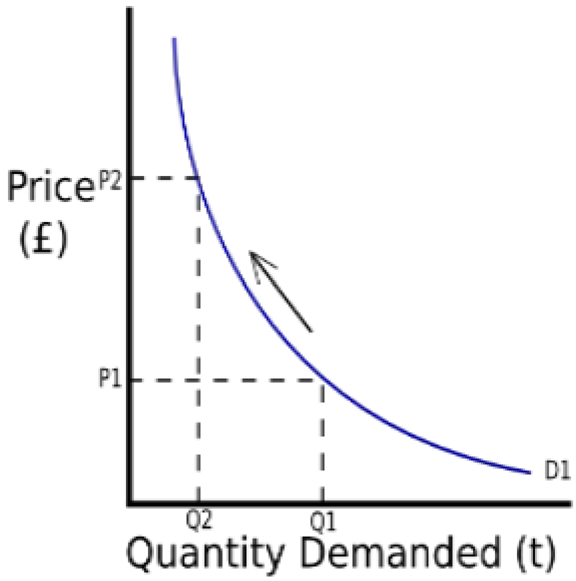


Figure 1 A Demand Curve

The Total Revenue Function

Total revenue of the enterprise is simply the amount of product sold multiplied by the unit price charged. Therefore,

$$\text{Total Revenue (TR)} = \text{(unit price) (volume)} = PD$$

Where,

P = unit price, = $(a – b\,D)$

D = amount of product sold, (Volume)

Using the demand function, total revenue can be expressed in terms of D alone,

$$TR = (a – b\,D)\,D = a\,D - b\,D^2 \text{ for } 0 \le D \le a/b$$
$$= 0 \qquad \text{otherwise}$$

Now if one were dealing with a peculiar enterprise, which has no costs at all, or has only *costs independent of the volume of production*, **then maximizing profit would be achieved by maximizing total revenue**. The volume that will maximize total revenue can be found by the usual methods of calculus (Figure - 2).

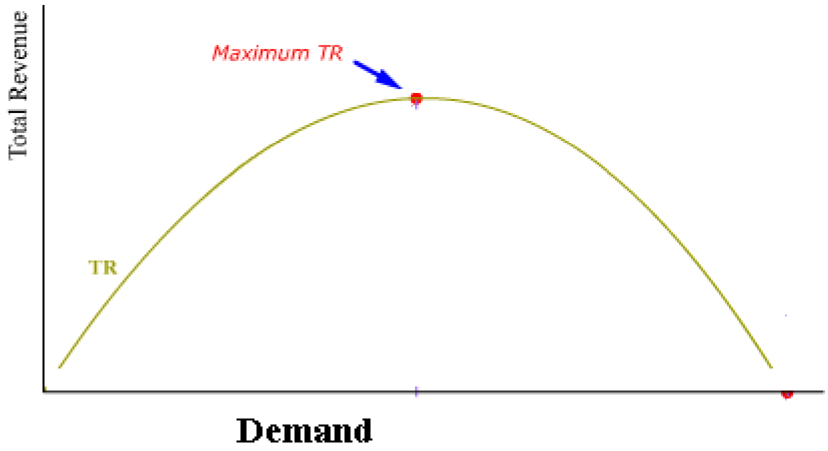


Figure 2. A total revenue function

$$\frac{dTR}{dD} = a - 2bD = (0)$$

$$D = \frac{a}{2b}$$

One may be assured of a maximum by noting that

$$\frac{d^2TR}{dD^2} = -2b$$

is negative since b is a positive constant. **It may be noted that the derivative of total revenue with respect to volume is given the name "marginal revenue".** It expresses the rate at which revenue increases with increase in the volume of sales. Most enterprises, however, would not find that maximum total revenue resulted in maximum profit, thus one must investigate the problem of total cost of production in order to compute the profit in the more usual way.

The Total Cost Function

Imagine that the analyst is able to examine the productive operations of the enterprise. At this point the analyst may be especially interested in *how total cost changes with the volume of production*. In estimating total cost it is helpful to *divide the components of this sum into two classes called fixed costs and variable costs*.

Fixed costs include all costs *independent of the volume of production*. These are the costs, which must be met irrespective of the level of production.

Variable costs include all costs which vary more or less directly with the volume of production: These costs include such things as **direct labour costs** and **raw material costs** that tend to **rise** as the number of units produced goes up. It may be difficult to discover just exactly **how variable costs do 'vary with the level of production**. Further, costs which are fixed in the short run may not be fixed in the long run. For example, if production is stopped, the enterprise may meet its fixed expenses for a short period in anticipation of renewed activity, however, this can not go on for long without resulting in liquidation or some other drastic modification of the cost structure. In spite of these difficulties, these **cost classifications** are sufficiently suggestive to give some important insights. **To clarify these**, let

TC (D) = total cost at a production level of D units

FC = fixed costs, independent of D

VC (D) = variable costs at a production level of D

TC (D) = FC + VC (D)

This is the general form of the enterprise's **total cost function.**

Consider a simple case in which the variable cost function turns out to be a simple linear function of the volume of production.

$$VC(D) = \upsilon D$$

The rate of change of the variable costs with the volume of production is called the "**marginal cost**," or sometimes the "**incremental cost**". In this case we have simply

$$\text{Marginal cost} = \frac{d\,VC\ (D)}{d\,(D)} = v$$

This implies that marginal costs are constant, and that the *cost of producing a small additional amount is always the same*. If D is taken to be a discrete variable, then the marginal cost is simply the cost of producing one additional unit of product when the production is at some given level.

$$VC(D + 1) - VC(D) = \text{marginal cost}$$

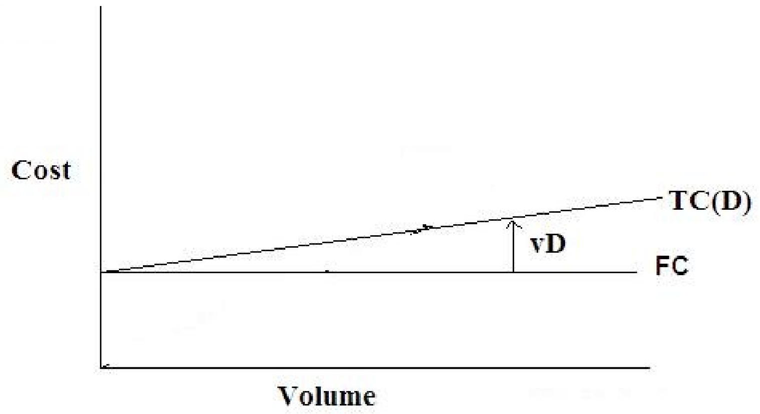


Figure 3. A total cost function

Using the simple-linear cost function (Figure - 3), the total cost function becomes

$$TC(D) = FC + \upsilon D$$

and profit is given by

$$\text{Profit} = TR(D) - TC(D) = (aD - bD^2) - (FC + \upsilon D)$$
$$= -FC + (a - \upsilon)D - bD^2 \quad \text{for } 0 \le D \le a/b$$
$$= 0 \quad \text{otherwise}$$

The-analyst who wishes to maximize profit under these conditions will then be interested in the value of D, which maximizes this function. Thus if

$$a - v \ge 0$$

$$\frac{d(profit)}{dD} = a - v - 2bD = 0$$

$$D = \frac{a - v}{2b}$$

If

$$a - v \le 0$$

the profit will be maximized for

$$D = 0$$

The situation, which confronts the analyst is shown graphically in **Figure 4**, in which it is assumed that a - v ≥ 0

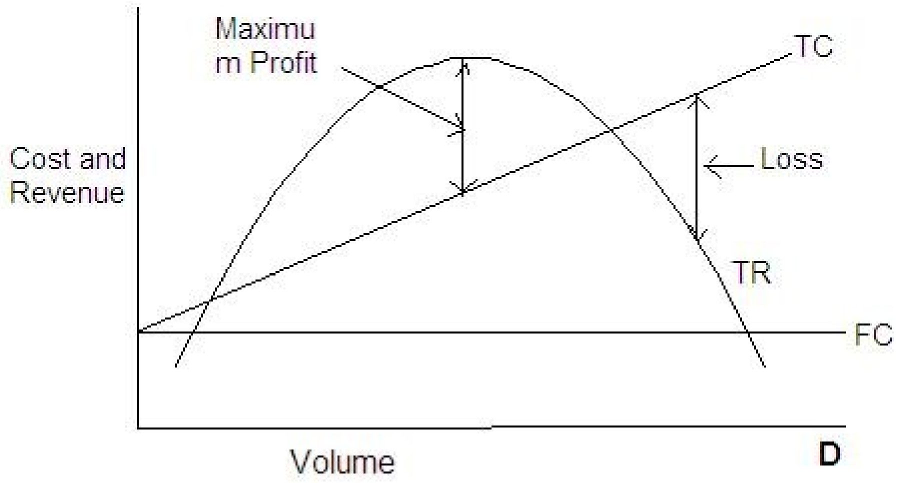


Figure 4 A profit - Loss function

An important -principle emerges here if one observes that at this level of production, marginal cost is equal to marginal revenue. For

$$D = \frac{a - v}{2b}, \quad \frac{dTR\ (D)}{dD} = a - 2bD = v \qquad (a - v \geq 0)$$

Thus one might formulate a decision rule which says, "to maximize profit, increase production as long as marginal revenue is greater than marginal cost, but stop when the two are equal". Alternatively, "*to maximize profit, increase production until the revenue from the last unit of product is just equal to the cost of producing it.*"

LECTURE NO. 15

BREAK-EVEN AND SHUTDOWN POINTS, PRODUCTION, ECONOMICS OF MASS PRODUCTION, PRODUCTION MANAGEMENT DECISION

Break-Even and Shutdown Points

From Figure 4 certain other insights may be obtained. There are two points at which *total revenue is equal to total cost, and thus profit is zero*. *These points are called the break- even points*. Between the break-even points the enterprise will make a profit, but outside of these it will suffer a loss. The lower or left-hand break-even point is of special interest to the analysts since this is the level of, production that must be reached to get the enterprise out of the red. Many of the decisions of the enterprise about its activities depend heavily on the answer to the question; "*Will the venture be able to operate at or above its break-even point*?"

Another decision that may confront the analyst is whether or not to cease production entirely when conditions force volume down below the lower break-even point. This decision might be studied using the model, although this is not essential. Suppose the analyst finds that the enterprise is forced to produce at some level lower than the break- even point; one then has the following alternatives:

a_l = stop production

a_2 = continue production at some level D_1 below the break-even point

Assuming that no uncertainty or risk is involved in the analysis of this decision, one could compute the profit associated with each alternative:

	Profit
a_1	$-FC$
a_2	$TR(D_1) - TC(D_1)$

The profit for a_2 may be computed as follows:

$$TR(D_1) - TC(D_1) = TR(D_1) - (FC + vD_1)$$

Alternative a_2 will be preferred if

$$TR(D_1) - (FC + vD_1) > -FC$$

$$TR(D_1) > vD_l$$

Thus one has the decision rule, "so long as total revenue exceeds variable costs, do not stop production." This rule must obviously apply in the short run, since the enterprise cannot go on sustaining a loss for very long.

PRODUCTION

The problems and decisions discussed so far are largely the concern of top management, since they are in the realm of major company policy. The analyst at least early in the career, is more likely to be associated with decisions specifically related to the methods of production and operation employed. Thus one may be concerned with alternative production processes, alternative designs for the product, alternative operating procedures, and so on.

Ideally all the decisions should be studied from the overall viewpoint of the enterprise, with the aim of perhaps maximizing total profit as was previously shown. For obvious practical reasons, not every decision can be approached immediately from this viewpoint and thus one uses other, more immediate criteria. Typically much effort is devoted to reducing costs through the improvement of the product, the process, or the operating procedures. Although sometimes it may be true that if costs are reduced by a rupee, profit will increase by a rupee, things are usually not so simple. Suppose, for example, the analyst can show that by refusing to disrupt production in order to push through "rush" orders, costs can be reduced. Clearly profits may not be increased by an equal amount, since the customers may take their business elsewhere. In practice many decisions are approached from the viewpoint of minimizing costs because it may be difficult to measure profit directly, and good judgment indicates that higher profits are likely to result.

ECONOMIES OF MASS PRODUCTION

Suppose that management is confronted with the following decision. If the production process and equipment are kept substantially the same, what volume of production will minimize the average unit cost of production? This is the question of the economic operating level for a plant. If we assume that under these conditions the plant's costs are given by a linear total cost function, as in Figure 1, then the average unit cost is simply given by

$$AC(D) = \frac{TC(D)}{D} = \frac{FC + vD}{D} = \frac{FC}{D} + v$$

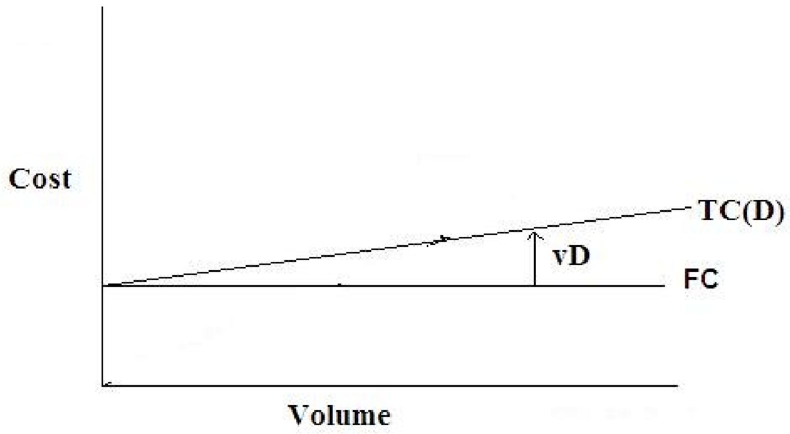


Figure 1. A total cost function

In this situation the more one produces, the lower the average unit cost. *This phenomenon is so important that it is given the name "**economics of mass production**" and forms the entire basis of much of the industrial development.* The simple linear cost function leads to the conclusion that production may be increased indefinitely, always with the result of lowering average unit cost. Recalling that the plant and production process is being held substantially constant, this conclusion does not appear realistic. As one tries to obtain more and more production from the plant, the facilities are strained to their limit, expensive overtime operation seems necessary, scrap may increase, maintenance may be neglected and average cost may go up (Figure 2).

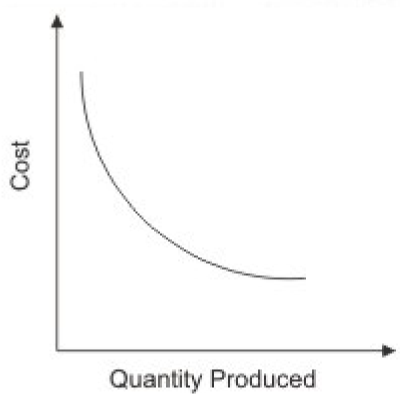


Figure 2 an average cost function

This would have been noted, one has assumed a somewhat more realistic total cost function, such as

$$TC(D) = FC + v_1 D + v_2 D^2$$

In this case average cost is given by

$$AC(D) = \frac{FC}{D} + v_1 + v_2 D$$

and will be minimized when

$$\frac{ADC\ (D)}{dD} = -\frac{FC}{D^2} + v_2 = 0$$

This yields

$$D = \sqrt{\frac{FC}{v_2}}$$

The phenomenon of rising average cost which sets in when production goes above this level suggests that we might formulate the general hypothesis: As one tries to get more and more production out of a given plant and process, the unit cost will eventually go up. Thus one has to compromise between the conflicting effects of economies of mass production and the eventual up tuning of the average cost function. The best compromise in the sense of minimizing cost is given by the result obtained above.

At this point, another helpful decision rule may be obtained. At the point where average cost is minimum, it is easy to show that

$$AC\ (D) = \text{marginal cost at } D = v_1 + 2\sqrt{FCv_2}$$

Thus one could say that average cost would come down so long as marginal cost is below it. But when marginal cost exceeds average cost, it will rise. To minimize average cost, find the level of production where it is equal to marginal cost. A little thought will confirm the common sense of this rule.

A PRODUCTION MANAGEMENT DECISION

The work of the analyst is partly that of transforming management problems into mathematical problems. If the analyst can discover or create a mathematical structure that reasonably reflects the management decision, then he / she is in a position to use the mathematical structure or model to predict the results of various managerial choices. One way, and perhaps the only way, to become acquainted with the art of model building is to study some examples. Let us take a somewhat more detailed look at production by means of an especially useful model, which may be used to capture some of the complexity of production management decisions. Instead of considering a plant in terms of a production function, we now look more closely at what is inside the plant.

Suppose we have a food processing plant, and our business consists of buying vegetables from farmers, preparing them, and packing them in cans of our own manufacture. The plant consists of three departments: the can department, which produces the containers, the preparation department, which cleans and cooks the vegetables, and the packing department, which fills and labels the cans. At the moment, farmers are offering both peas and tomatoes, either of which could be processed in our plant. Our total cost and revenue structure is so simple that we can say each can of peas yields us a profit of Rs. 5.00 and each can of tomatoes yields a profit of Rs. 8.00. These profits are the same no matter what level of production for either vegetable we decide on if we are planning for the coming week, then our profit for the week will be (in Rupees).

$$Profit = 5P + 8T$$

where, P is the number of cans of peas we turn out and T is the number of cans of tomatoes. At this point it may appear that since tomatoes are more profitable, we should entirely forsake peas and turn out all the tomatoes possible. However, usually things are not as simple as-that. First of all, we discover that the farmers in the area will have available no more than the equivalent of 20,000 cans of tomatoes and no more than the equivalent of 25,000 cans of peas. Thus our choices of P and T are limited by the availability of vegetables. It must be that

$$P \leq 25{,}000 \qquad T \leq 20{,}000$$

Next, we note that the capacity of our departments is also limited. Suppose both vegetables are packed in the same type of can, and the can department has a capacity of 30,000 cans per week. This puts another restriction on our production program.

$$P + T \leq 30{,}000$$

The preparation department, which operates 40 hours per week, requires 0.001 hours to process enough peas to fill a can and 0.002 hours to process a can of tomatoes. We then have a processing department restriction that says

$$0.001\,P + 0.002\,T \leq 40$$

or

$$P + 2T \leq 40{,}000$$

The packing department has a capacity of 50,000 cans of either type for the week, giving

$$P + T \leq 50{,}000$$

One might go on adding restrictions and conditions to make the problem more and more realistic, but at this point the decision about a production program is sufficiently complicated to suggest the difficulties that might be encountered.

The problem is still simple enough so that its solution may be graphically illustrated. Any decision as to a production program can be represented by a point on Figure 6, that is, a particular pair of values for P and T. By plotting the inequalities which express the restriction we can see exactly how our choice is limited. Because of the limited production by farmers our choice of P must lie on or below the horizontal line P = 25,000. Similarly, our choice of T must lie to the left of a vertical line T = 20,000. The other two restrictions are similarly plotted, with the result that our decision is limited in fact to P and T combinations lying in or on the edge of the shaded area in Figure 3.

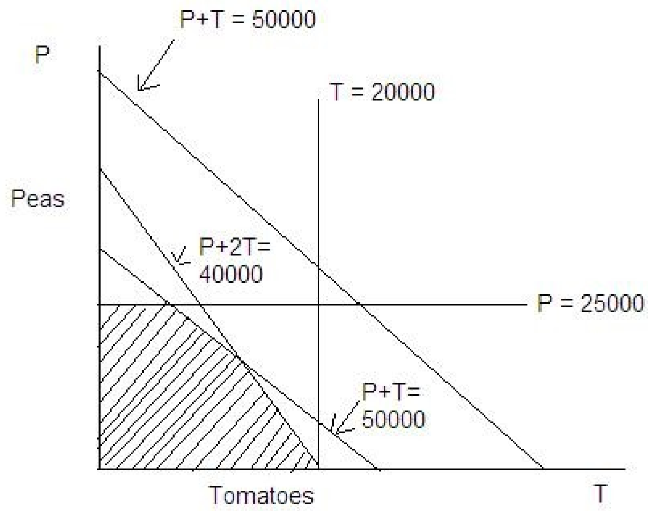


Figure 3 Possible production programmes and restrictions

The capacity of the canning department does not need to be considered in this particular decision, since the other restrictions prevent any possibility of reaching this capacity. At the moment we have more capacity than necessary in this department.

LECTURE NO. 16

PLANT LAYOUT: IMPORTANCE, FLOW PATTERNS

Importance and Function

Plant layout refers to an optimum arrangement of different facilities including human resource, plant and machinery, material etc. Since a layout once implemented **cannot be easily changed** and costs of such a change are substantial, the **plant layout is a strategic decision**. A *poor layout will result in* continuous losses in terms of higher efforts for material handling, more waste and rework, poor space utilization etc. Hence, need to analyze and design a sound plant layout can hardly be over emphasized. It is a crucial function that has to be performed both at the time of initial design of any facility, and during its growth, development and diversification.

The problem of plant layout should be seen in relation to overall plant design which includes many other functions such as product design, sales planning, selection of the production process, plant size, plant location, building, diversification etc. The layout problem occurs because of many developments including:

- change in product design
- introduction of new product
- obsolescence of facilities
- changes in demand
- market changes
- competitive cost reduction
- frequent accidents
- adoption of new safety standards
- decision to build a new plant

Plant layout problem is *defined by* **Moore (1962)** as follows: “plant layout is a plan of, or the act of planning, an optimum arrangement of facilities, including personnel, operating equipment storage space, materials handling equipment, and all other supporting services, along with the design of the best structure to contain these facilities”.

Objectives and advantages

Some of the important objectives of a good plant layout are as follows:

- **Overall simplification of production process** in terms of equipment utilization, minimization of delays, reducing manufacturing time, and better provisions for maintenance
- **Overall integration of man, materials, machinery, supporting activities and any other considerations** in a way that result in the best compromise.
- **Minimization of material handling cost** by suitably placing the facilities in the best flow sequence
- **Saving in floor space**, effective space utilization and less congestion / confusion,
- *Increased output and reduced in-process inventories*
- Better **supervision** and **control**
- **Worker convenience** and worker satisfaction
- **Better working environment**, safety of employees and reduced hazards
- **minimization of waste** and **higher** productivity
- avoid unnecessary capital investment
- **higher flexibility** and **adaptability** to changing conditions

Types of layout Problems

The plant layout problems can be classified into four types as follows:

- **Planning completely** new facility
- **Expanding or relocating** an existing facility
- **Rearrangement** of existing layout
- **Minor modifications** in present layout

Flow Patterns

According to the principle of flow, the layout plan arranges the work area for each operation or process so as to have an overall smooth flow through the production / service facility. The basic types of flow patterns that are employed in designing the layout are I-flow, L-flow, U- flow, S-flow and O - flow as shown in Figure 1. These are briefly explained below:

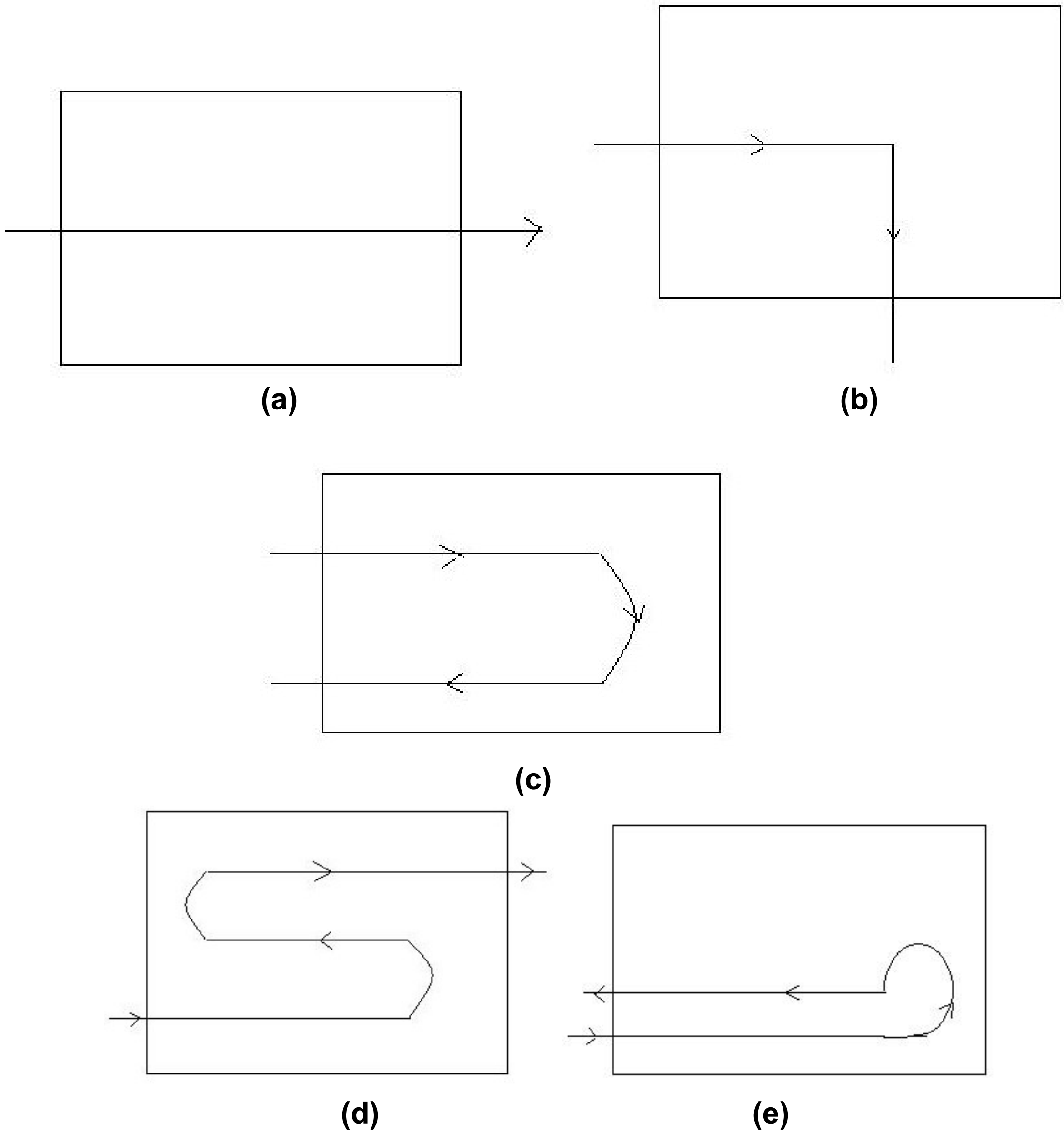


Figure-1 Basic types of flow patterns employed in designing the layout

(a) I-Flow: separate receiving and shipping area.

(b) L-Flow: when straight line flow chart is to be accommodated.

(c) U-Flow: very popular as a combination of receiving and dispatch

(d) S-Flow: when the production line is long and zigzagging on the production floor is required.

(e) O-Flow when it is desired to terminate the flow near where it is originated

LECTURE NO. 17

BASIC TYPES OF PLANT LAYOUTS, PRODUCT OR LINE LAYOUT, PROCESS OR FUNCTIONAL LAYOUT, CELLULAR OR GROUP LAYOUT, AND FIXED POSITION LAYOUT, PLANT LAYOUT FACTORS, LAYOUT DESIGN PROCEDURE

Basic Types of Plant Layouts

Depending upon the focus of layout design, the basic types of the layouts are:

Product or line layout

This type of layout is developed for product focused systems. In this type of layout only one product, or one type of product, is produced in a given area. The work centers are organized in the sequence of appearance. The raw material enters at one end of the line and goes from one operation to another rapidly with minimum of work-in-process storage and material handling. The equipment is arranged in order of their appearance in the production process.

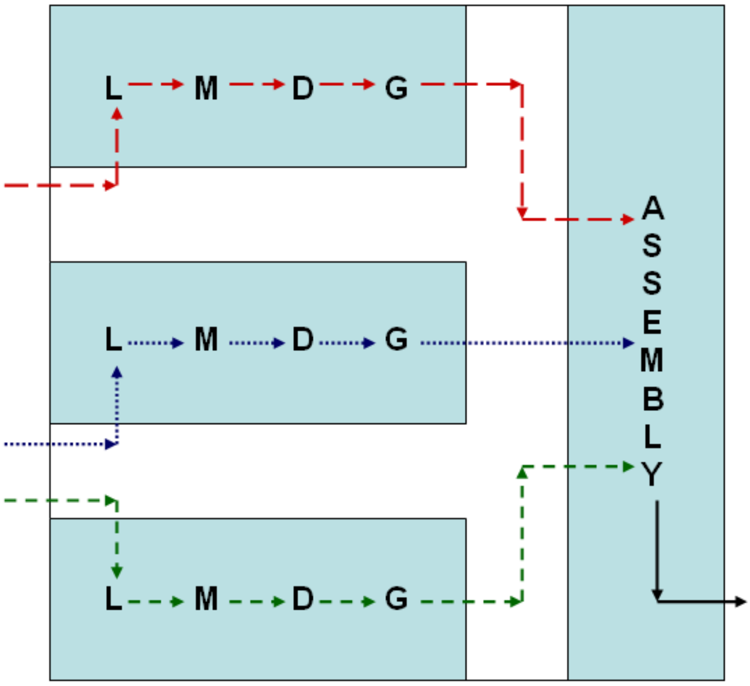


Figure 1 Product or Line Layout

The decision to organize the facilities on a product or line basis is dependent upon a number of factors and has many consequences which should be carefully weighed. Following conditions favor decision to go for a product-focused layout.

- High volume of production for adequate equipment utilization

- Standardization of product
- Reasonably stable product demand
- Uninterrupted supply of material

Some of the **major advantages** of this type of layout are:

- Reduction in material handing
- Less work-in-process
- Better utilization and specialization of labor
- Reduced congestion and smooth flow
- Effective supervision and control

The **major problem** in designing the, product-focused systems is to decide the cycle time and the sub-division of work which is properly balanced (**popularly known as line balancing)**

Process or functional layout

This type of layout is developed for process focused systems. The processing units are organized by functions into departments on the assumption that certain skills and facilities are available in each department. **Similar equipment and operations are grouped together**. The functional layout is more **suited for low-volumes of production** (*batch production*) and particularly when **the product is not standardized**. It is economical when **flexibility (**material can be rerouted in any sequence**)** is the basic system requirement. The flexibility may be in terms of the routes through the system, volume of each product and the processing requirement of the items.

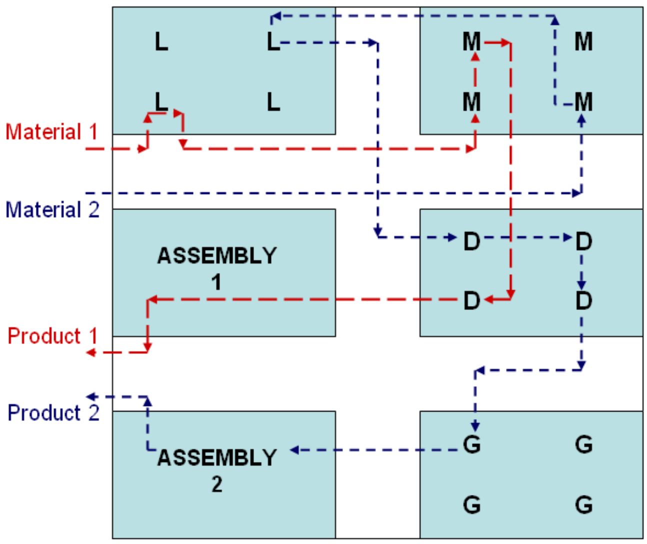


Figure 2 Process or Functional Layout

The major advantages of a process layout are:

- Better equipment utilization
- Higher flexibility
- Greater incentive to individual worker
- More continuity of production in unforeseen conditions like breakdown, shortages, absenteeism etc.

Cellular or group layout

It is a **special type of functional layout** in which the **facilities are clubbed together into cells**. This is suitable for systems designed to use the concepts, principles and approach of group technology. Such a layout offers the advantages of mass production with high degree of flexibility. We can employ high degree of automation even if the number of products is more with flexible requirements. In such a system the facilities are grouped into cells which are able to perform similar type of function for a group of products.

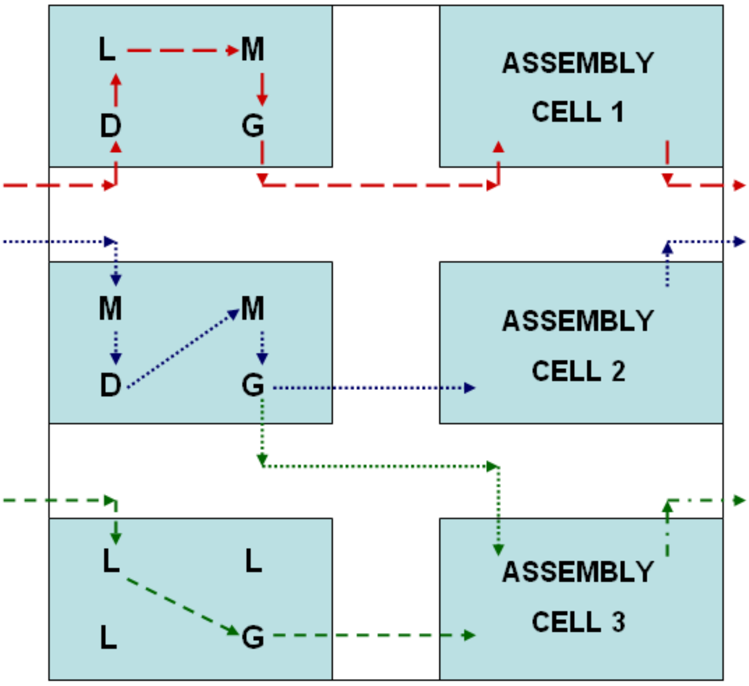


Figure 3 Cellular or Group Layout

<u>Advantages :</u>

- Also known as 'Group Technology'
- Each cell manufactures products belonging to a single family.
- Cells are autonomous manufacturing units which can produce finished parts.
- Commonly applied to machined parts.

- Often single operators supervising CNC machines in a cell, with robots for materials handling.
- Productivity and quality maximised. Throughput times and work in progress kept to a minimum.
- Flexible.
- Suited to products in batches and where design changes often occur.

'Fixed Position' Layout

This is suitable for producing single, large, high cost components or products. Here the product is static. Labour, tools and equipment come to the work site.

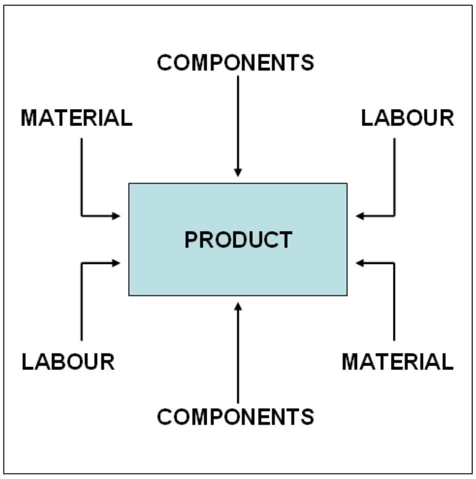


Figure 4 Fixed Position Layout

PLANT LAYOUT FACTORS

The design of any layout is governed by a number of factors and the best layout is the one that optimizes all the factors. The factors influencing any layout are categorized into the following eight groups:

- **The material factor:** includes design, variety, quantity, the necessary operations, and their sequence.
- **The main factor:** includes direct workers, supervision and service help, safety and manpower utilization.
- **The machinery factor:** includes the process, producing equipment and tools and their utilization
- **The movement factor:** includes inter and intradepartmental transport and handling at the various operations, storage and inspection, the materials handling equipment.

- **The waiting factor:** includes permanent and temporary storage and delays and their locations.
- **The service factors**: include service relating to employee facilities such as parking lot, locker rooms, toilets, waiting rooms etc.; service relating to materials in terms of quality, production control, scheduling, dispatching, waste control; and service relating to machinery such as maintenance.
- **The building factor**: includes outside and inside building features and utility distribution and equipment.
- **The change factor:** includes versatility, flexibility and expansion

Each of the above mentioned factors comprise a number of features and the layout engineer must review these in the light of his problem. Usually the layout design process is a compromise of these various considerations to meet the overall objectives in the best possible manner.

LAYOUT DESIGN PROCEDURE

The overall layout design procedure can be considered to be composed of four phases Viz.,

Phase I: Location
Phase II: General Overall Layout
Phase III: Detailed layout
Phase IV: Installation

Some important guidelines that help in the layout design are:

- Plan from whole to details
- First plan the ideal and then move to the practical aspects
- Material requirements should be central to the planning of process and machinery .
- modify the process and machinery by different factors to plan the layout

Though there is always an overlap in the different phases of layout design the **major steps that have to be followed in the layout design are outlined as follows:**

- **state the problem** in terms of its objective, scope and factors to be considered

- **Collect basic data** on sales forecasts, production volumes, production schedules, part lists, operations to be performed, work measurement, existing layouts, building drawing etc.
- **Analyze data** and present it in the form of various charts
- **Plan the production process** and its arrangement
- **Plan the material flow pattern** and develop the overall material-handling plan
- Estimate **plant** and **machinery** requirements
- Select material handling equipment
- Determine storage requirements
- Design and plan activity relationships
- **Plan auxiliary** and service facilities including their arrangement
- **Determine space requirements** and allocate activity areas
- Develop **plot plan** and **block plan** i.e. integrate all plant operations
- Develop detailed layouts and plan building along with its arrangement
- **Evaluate, modify and check** the layouts
- **Install layouts** and follow up

The Systematic Layout Planning (SLP) procedure as presented by Francis and White (1974) is shown in Figure-5. We see that once the appropriate information is gathered, a flow analysis can be combined with an activity analysis to develop the relationship diagram. Space considerations when combined with the relationship diagram lead to the construction of the space relationship diagram. Based on the space relationship diagram modifying considerations and practical limitations, a number of alternative layouts are designed and evaluated.

Data collection

The development of any layout is dependent on the quality and quantity of facts that we have about the various factors influencing it. The data collection phase is not a one-time effort but an ongoing function. The data for overall plan is to be collected at initial stages where as the data for detailed layouts may be obtained at a later stage, the facts have to be obtained regarding various materials and processes, the flow routing and sequencing, space requirements and different activities and relationships.

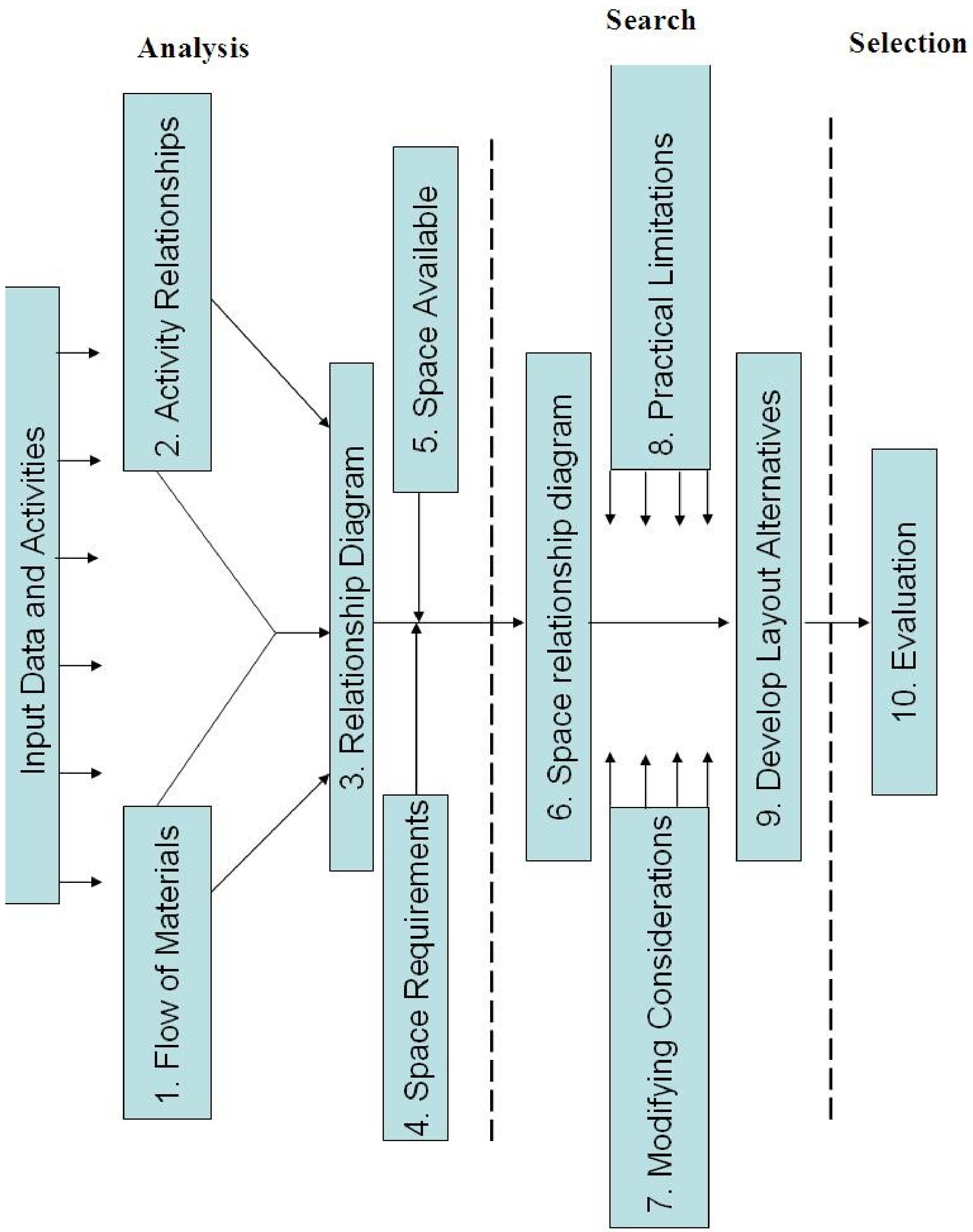


Figure-5 Systematic layout planning procedure

LECTURE NO. 18

GENERAL GUIDE LINES FOR PLANT LAYOUT, TYPICAL CLEARANCES, AREAS AND ALLOWANCES, PLANT LAYOUT, LAYOUT OF EQUIPMENT, SPACE DETERMINATION

General Guidelines / considerations

Site layout:

A good site layout provides safe and economical flow of materials and personnel. A **material sheet** for the site is therefore prepared which then allows the various processes to be positioned relative to one another. The services (e.g. boiler house, effluent plant etc.) are then added in the most convenient positions. The central buildings (administration, canteen, laboratories etc.) are placed in such a manner that the distances traveled by personnel to use them are minimized. Finally the road and rail systems are marked in. Typical sizes and clearances for the site layout are given in **Tables 1 to 3**. Having established site constraints and standards, a more detailed site layout can be made. The site layout thus prepared should then be considered to see whether the layout is consistent with safety requirements and that it assists action in any emergency as also the constraints and standards have not been violated.

Broad guidelines for preparation of the site layout are given below:

- Minimize the distance that materials have to travel to or from stores or during processing
- Separate the raw material unloading and finished product loading facilities
- Isolate the hazardous operations
- Locate storage areas close to unloading and loading facilities
- locate boiler room, power station, cooling towers, water pumping station etc. on periphery but adjacent to the area of largest use
- The usual clearances between pipes including flanges and lagging and between pipes and other objects should be 25 mm but this should be increased if hot pipes run near plastic pipes, cables etc.
- Steam and water mains, electricity and telephone cables etc. should, in general, run parallel to the road system and should avoid going through plant area

- Locate office building close to the main entrance
- Provide adequate parking facilities for vehicles waiting to load / unload, cars, scooters etc.
- Plan roads in such a manner that the vehicles do not pass through process areas. Ideally, outside of a plant should be accessible on all four sides by road
- Workshop and general stores should be located within easy access of the processing units.

Table-1 Typical Clearances between Various Units for Preliminary Site Layouts

Area	**To**	**Clearance**
Plant areas	To the adjacent unit, main roads or boundary	15 m
Boilers and furnaces		15
Blow down stacks with flares		30
Gas holders		30
Cooling towers		30
Effluent plants		15
Loading areas	To process units	15
Ware houses		30
Offices and canteens		30
Medical center		30
Garage		30
Fire station		30
Work shops		30
Main roads		12
Main roads	To building line excluding loading bays	9
		15
		15
Roads	Center line to loading bay head room	7
Paved areas and paths		4
Rail roads		5

Table-2 Typical Areas and Sizes for Preliminary Site Layouts

Administration	10 m^2	per administration employee.
Work shop	20 m^2	per workshop employee
Laboratory	20 m^2	per laboratory employee
Canteen	1 m^2	per dining place
	3.5 m^2	per dining place including kitchen and store
Medical center	0.1 - 0.15 m^2 10 m^2 minimum	per employee depending on complexity of service
Fire station (housing 1 fire, 1 crash, 1 foam, 1 generator and 1 security ,vehicle)	500 m^2	per site
Garage (including maintenance)	100 m^2	per vehicle
Main roads	10 m	wide
Side roads	7.5 m	wide
Pathways	1.2 m	wide upto 10 people /minute
	2 m	wide for 10 people / minute (near offices, canteen etc.)
Road turning circles	90^0 turn	11 m radius
	T junction	7.5 m radius
	minor roads	4 m radius
Minimum railroad curve	56 m	inside curve radius
Cooling towers per tower	0.04 m^2/ kWh	mechanical draught
	0·08 m^2/ kWh	natural draught

Table-3 Typical Constraint Allowances for Preliminary Plant Layout

Equipment	**Safety**	**Horizontal**	**Vertical**	**Construction/ Erection/ General**
Centrifuges Crushers Mills		3 m	2 m + I	5 m access corridor
Dryers		1.5 m + I	2 m + I	2.5 m to building
Columns		1.5 m		3 m between adjacent columns
Furnaces and fired heaters	15 m to hazard	3 m		2 widths (center to center adjacent heaters)
Reactors Stirred vessels	15 m to hazard	1.5 m	3 m + I	4 m access area 40 $m^2$for each 30 cm^3 reactor volume
Heat exchanger (horizontal)		1.5 m +I channel 1.5-2 m shell side	1.5 m	
Tanks	15 m to hazard	1/2 dia (avg.) between tanks	3 m	
Pumps		2 m motor end 1.5 m sides		
Filters		1.5 m + I		
Compressors		1.5 m + I	3 m + I	2 widths (center to center adjacent compressors)

I : is the length of the longest internal part of the equipment that must be removed for maintenance or operation.

Plant layout

In general, a most economical plant layout is that in which spacing of the main equipment items is such that it minimizes the interconnecting pipe work and structural steel work. As a general rule, layout should be as compact as possible with all equipment at ground level and it should conform to access and safety requirements. The major considerations are listed below:

- Equipment should be laid to give maximum economy of pipe work and supporting steel. Normally, they should be laid out in a sequence to suit the process flow, but exceptions to this arise from the desirability to group certain items such as tanks or pumps or perhaps to isolate hazardous operations.

- In general, high elevation should only be considered when ground space is limited or where gravity flow of materials is desired.
- Equipment items which are considered to be a source of hazard should be grouped together and wherever possible should be located separately from other areas of the plant.
- Provide sufficient clear space between critical and mechanically dangerous or high temperature equipment to allow safety of operating or maintenance personnel.
- The equipment needing frequent internal cleaning or replacement of internal parts should be laid out for ease of maintenance.
- Elevation to the underside of the pipe bridges and racks over paved areas should be at least 4 m.

Layout of equipment

Thought should be given to the location of equipment requiring frequent attendance by operating personnel and the relative position the control room to obtain the shortest and most direct routes for operators when on route operation. However, the control room should be in a safe area. Some important considerations involved in locating a few key equipment items are listed below:

- Mixing vessels can be laid out in a straight line, in pairs or staggered.
- In evaporators using barometric leg type condensers, barometric leg should be at least 10 mm from the vessel base. This is usually situated on the ground floor. For multiple effect evaporators, place the individual effects as close as possible to minimize vapor lines. Vapor liquid separator is accommodated without increasing the distance between effects. The layout requirements for crystallizers are similar to those for evaporators.
- Furnaces should be located at least 15 m away from other equipment. Ample room need to be provided at the firing front for the operation of the burner and burner control panel.
- Where there are a large number of heat exchangers, they are often put together in one or more groups. Location should provide a layout, which is convenient to operate and maintain. Horizontal clearance of at least 1.5 m should be left between exchangers or exchangers and piping. Floating head heat exchangers require an installation length of at least 2.5 times the

tube length. Air cooled exchangers are located adjacent to the plant section they serve.

- Pumps in general should be located close to the equipment from which they take suction. Changes in direction of the suction line should be at least 0.6 m from the pump. As far as possible, clearances and piping should provide free access to one side of the motor and pump. Clearances between pumps or pumps and piping should be at least 1.2 m for small pumps (18 kW) and 1.5 m to 2 m for large pumps. Pumps handling hot liquid (60 °C) should be at least 7.5 m from pumps handling volatile liquids.

Space Determination

In the layout planning process the space is allotted to different activities. The theoretical minimum space, a plant can occupy, is the total volume of its various components. Various constraints prevent the attainment of this minimum. Such constraints include allowing adequate clearances for access during operation and maintenance and to allow safe operation. While determining the space consideration should be given to the following.

- Operating equipment
- Storage
- Service facilities
- Operators/workers

Allowance must be made for space between adjacent equipment/machines for movement of the worker, work-in-process, maintenance personnel etc.

LECTURE NO. 19

SYMBOLS USED FOR FOOD PLANT DESIGN AND LAYOUT: INTRODUCTION, VALVES, LINE SYMBOLS, FLUID HANDLING, HEAT TRANSFER, MASS TRANSFER

Symbols Used For Food Plant Design and Layout

Process diagrams can be broken down into two major categories: process **flow diagrams** (PFDs) and **process and instrument drawings (P & IDs),** sometimes called piping and instrumentation drawings. A flow diagram is a simple illustration that uses process symbols to describe the primary flow path through a unit. A process flow diagram provides a quick snapshot of the operating unit. Flow diagrams include all primary equipment and flows.

A technician can use process design document to trace the primary flow of food materials through the unit. The flow diagram is used for visitor information and new employee training. A process and instrument drawing is more complex. The P&ID includes a graphic representation of the equipment, piping, and instrumentation. Modern process control can be clearly inserted into the drawing to provide a process technician with a complete picture of electronic and instrument systems. Process operators can look at their process and see how the engineering department has automated the unit. Pressure, temperature, flow, and level control loops are all included on the unit P&ID. Process technicians use P&IDs to identify all of the equipment, instruments, and piping found in their units.

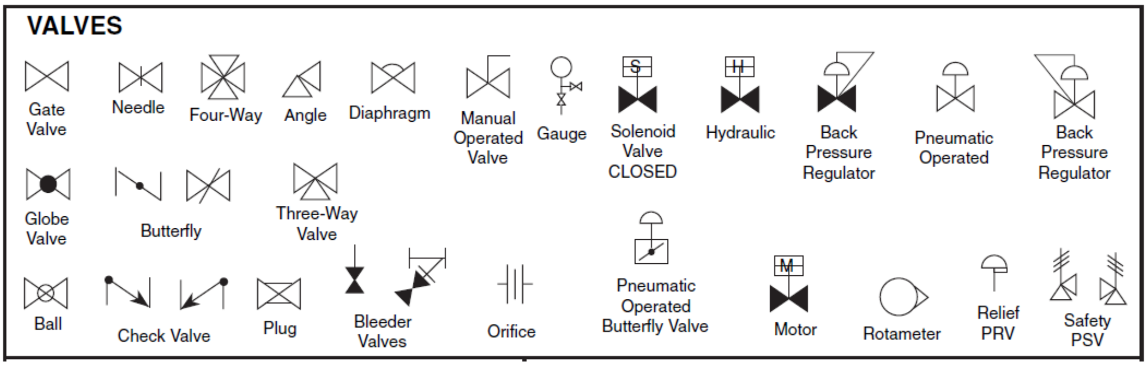


Fig. Valves

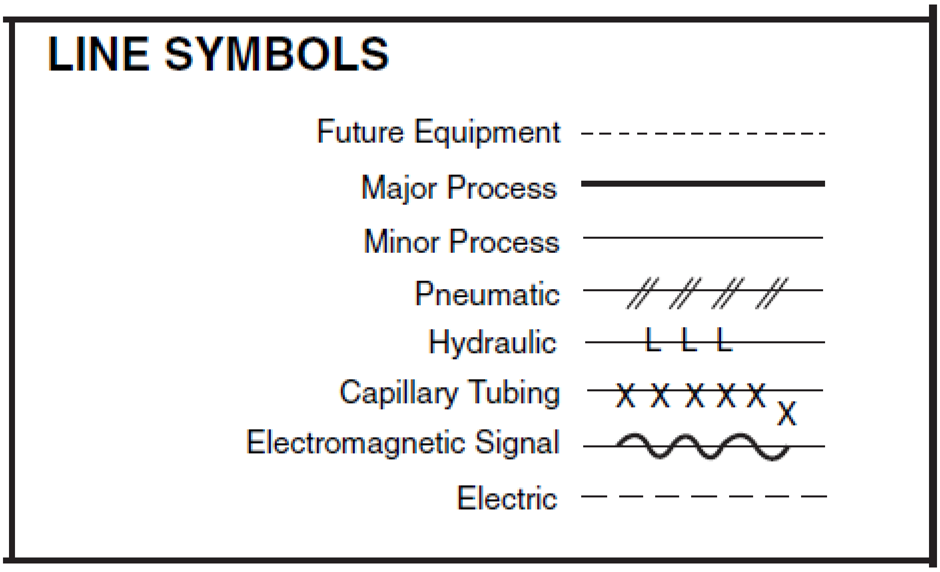


Fig. Line Symbols

FLUID HANDLING

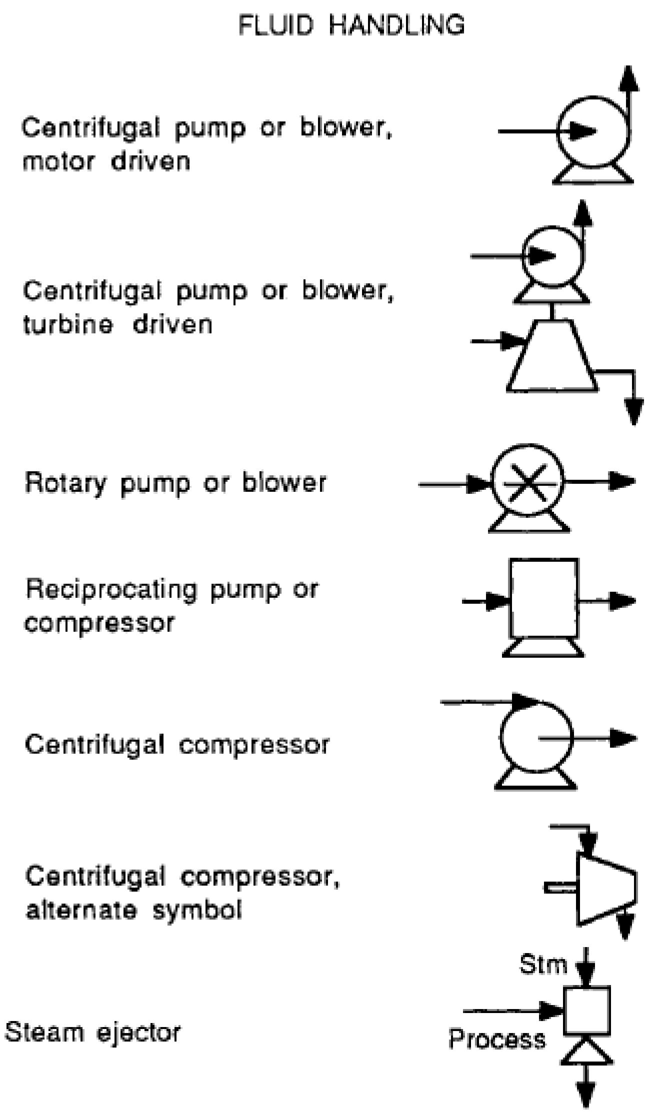
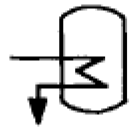


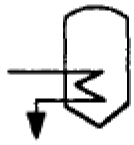
Fig. Fluid Handling

Heat Transfer

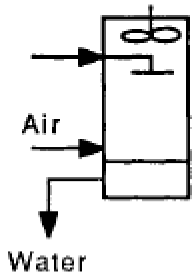
Coil in tank



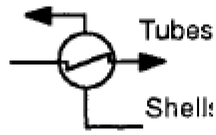
Evaporator



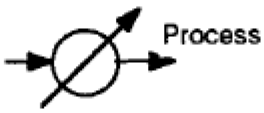
Cooling tower,
forced draft



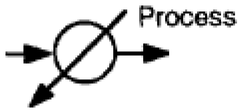
Shell-and-tube
heat exchanger



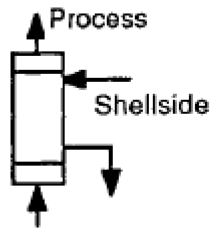
Condenser



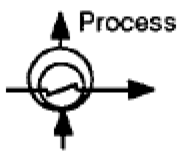
Reboiler



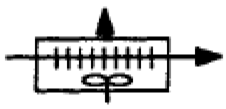
Vertical thermosiphon
reboiler



Kettle reboiler



Air cooler with
finned tubes



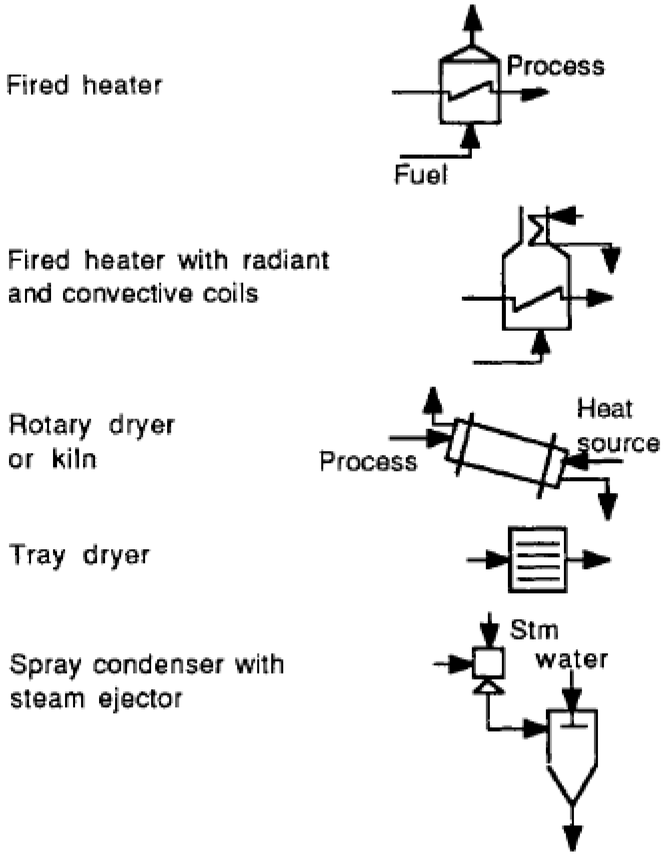
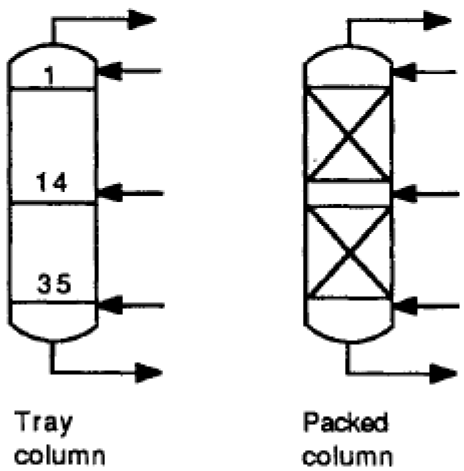


Fig. Heat Transfer

MASS TRANSFER



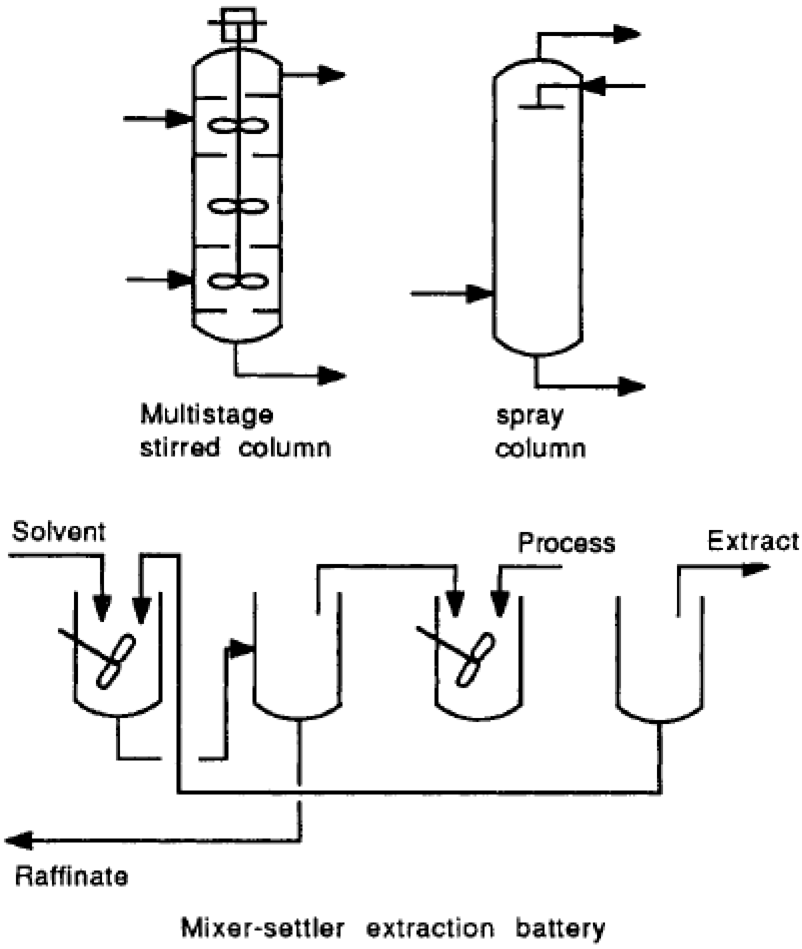


Fig. Mass Transfer

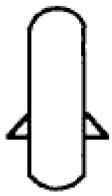
LECTURE NO. 20

SYMBOLS USED FOR FOOD PLANT DESIGN AND LAYOUT: STORAGE VESSELS, CONVEYORS AND FEEDERS, SEPARATORS, MIXING AND COMMUNITION AND PROCESS CONTROL AND INSTRUMENTATION SYMBOLS.

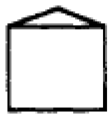
STORAGE VESSELS

Drum or tank

Drum or tank

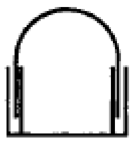


Storage tank



Open tank

Gas holder



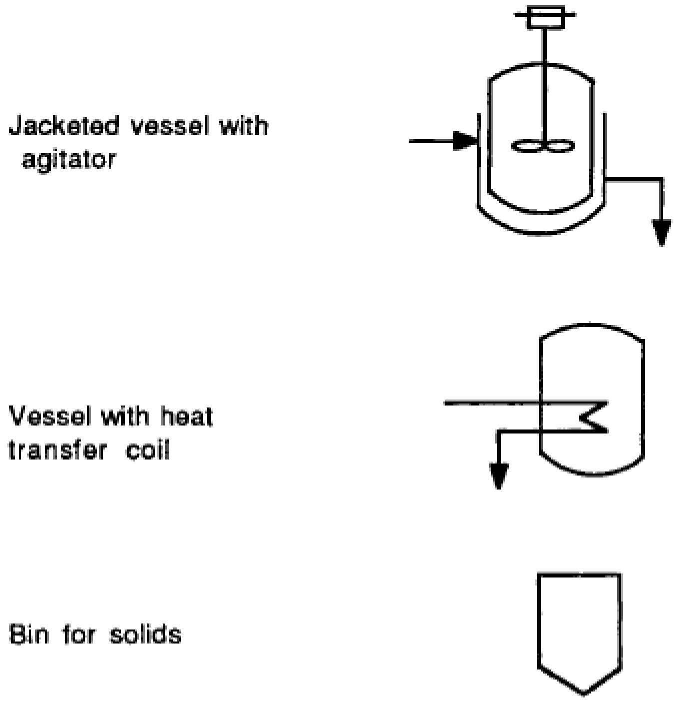


Fig. Storage Vessels

CONVEYORS AND FEEDERS

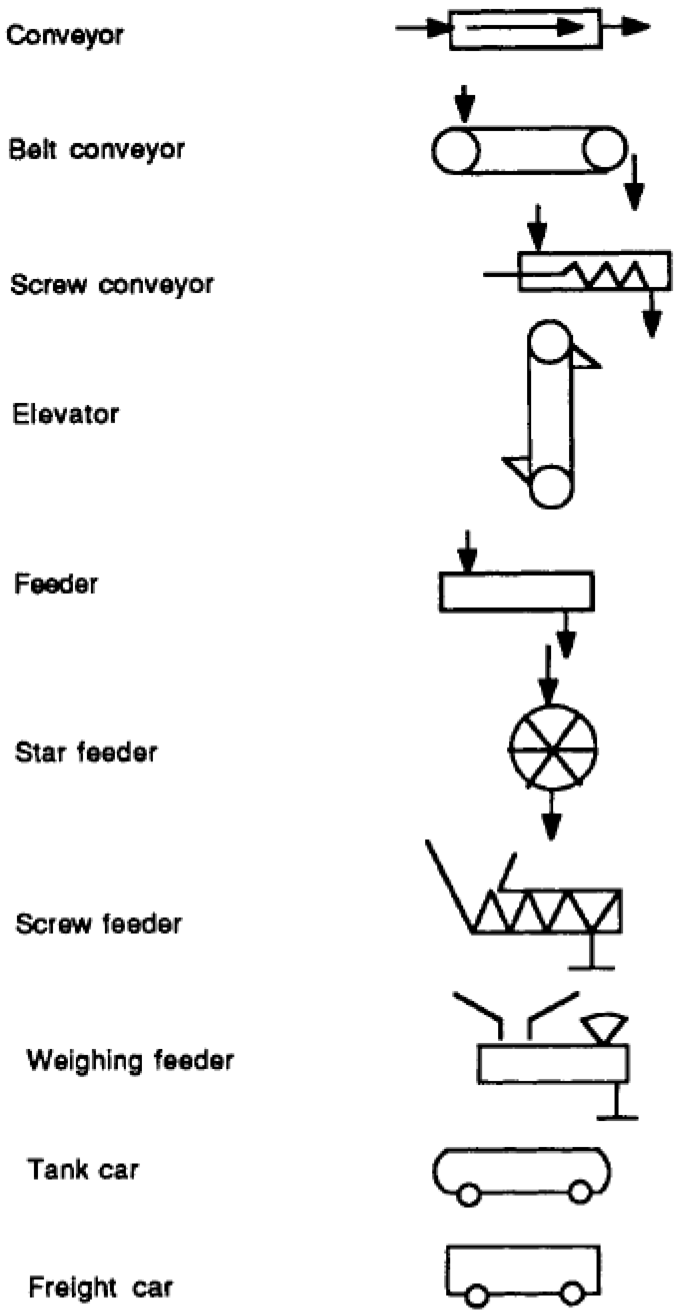
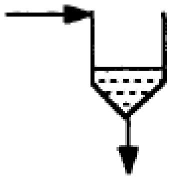


Fig. Conveyors and Feeders

SEPARATORS

Conical settling tank



Raked thickener

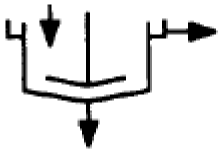
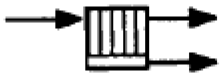
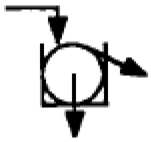


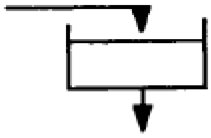
Plate-and-frame filter



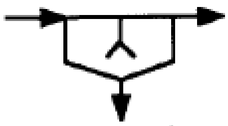
Rotary vacuum filter



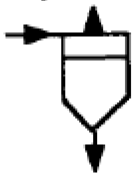
Sand filter



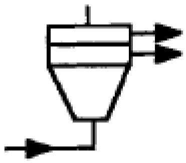
Dust collector



Cyclone separator



Centrifuge



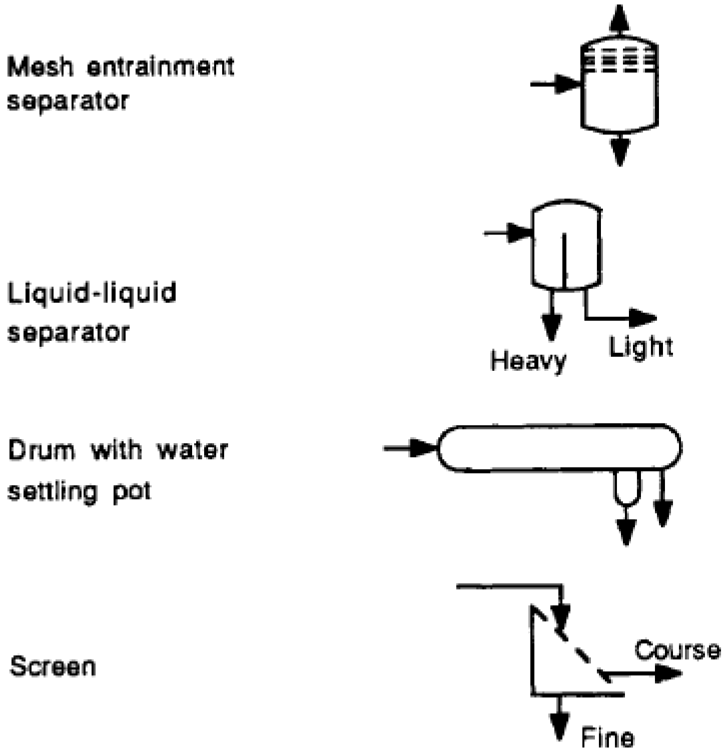


Fig. Separators

MIXING AND COMMUNITION

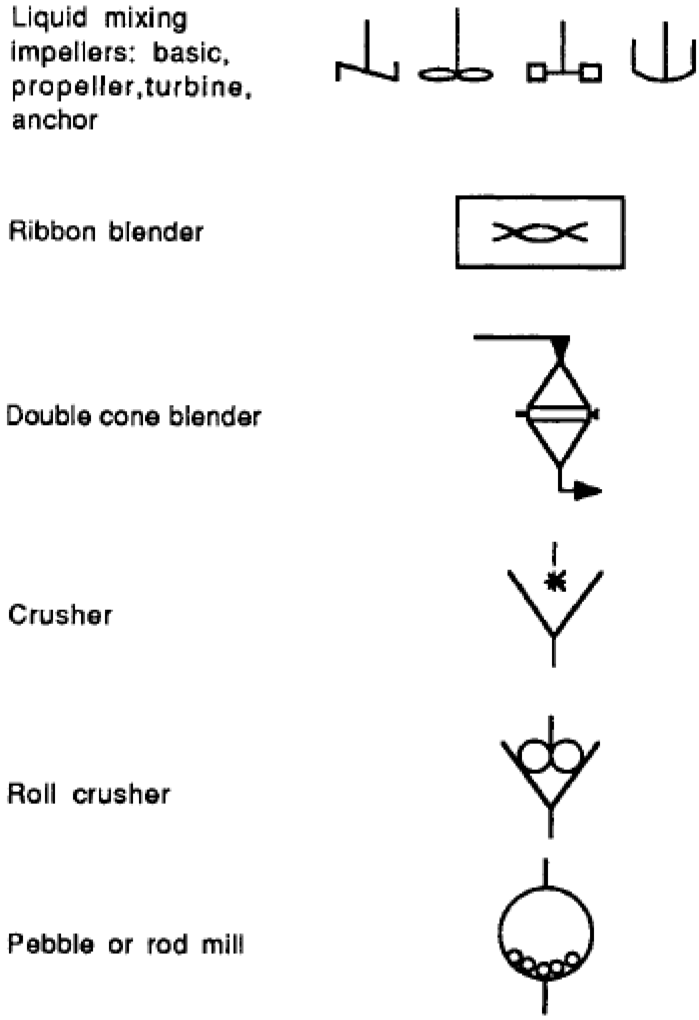


Fig. Mixing and communition

DRIVERS

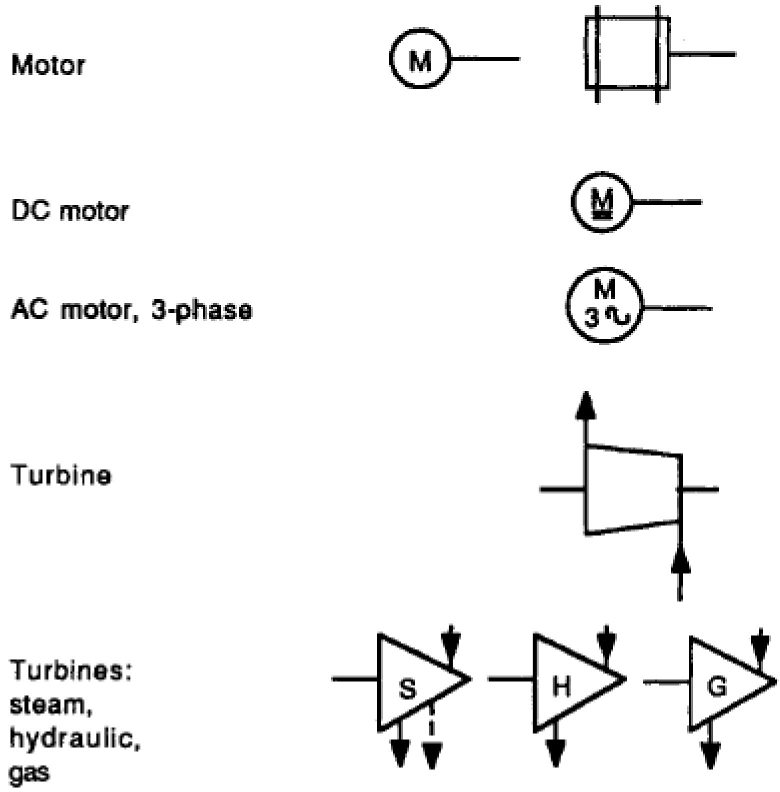
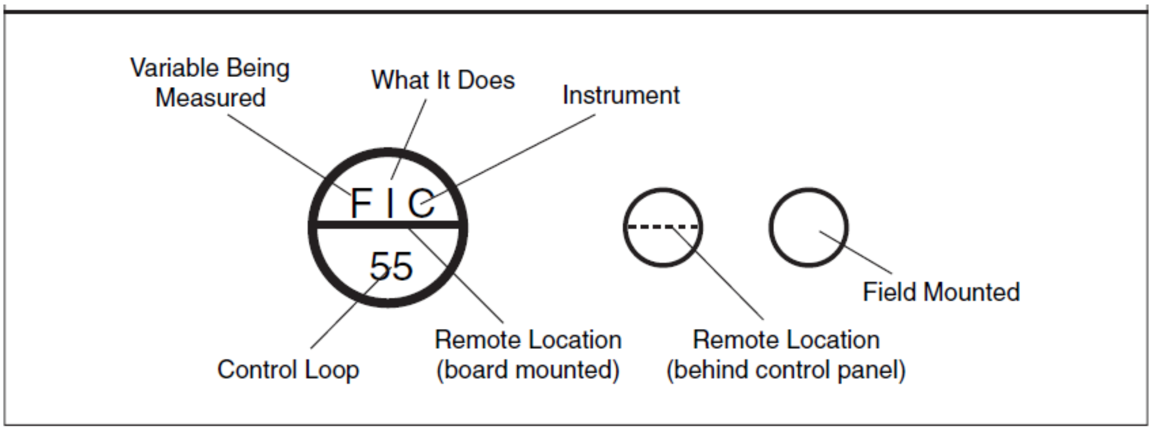


Fig. Drivers

PROCESS CONTROL AND INSTRUMENTATION SYMBOLS



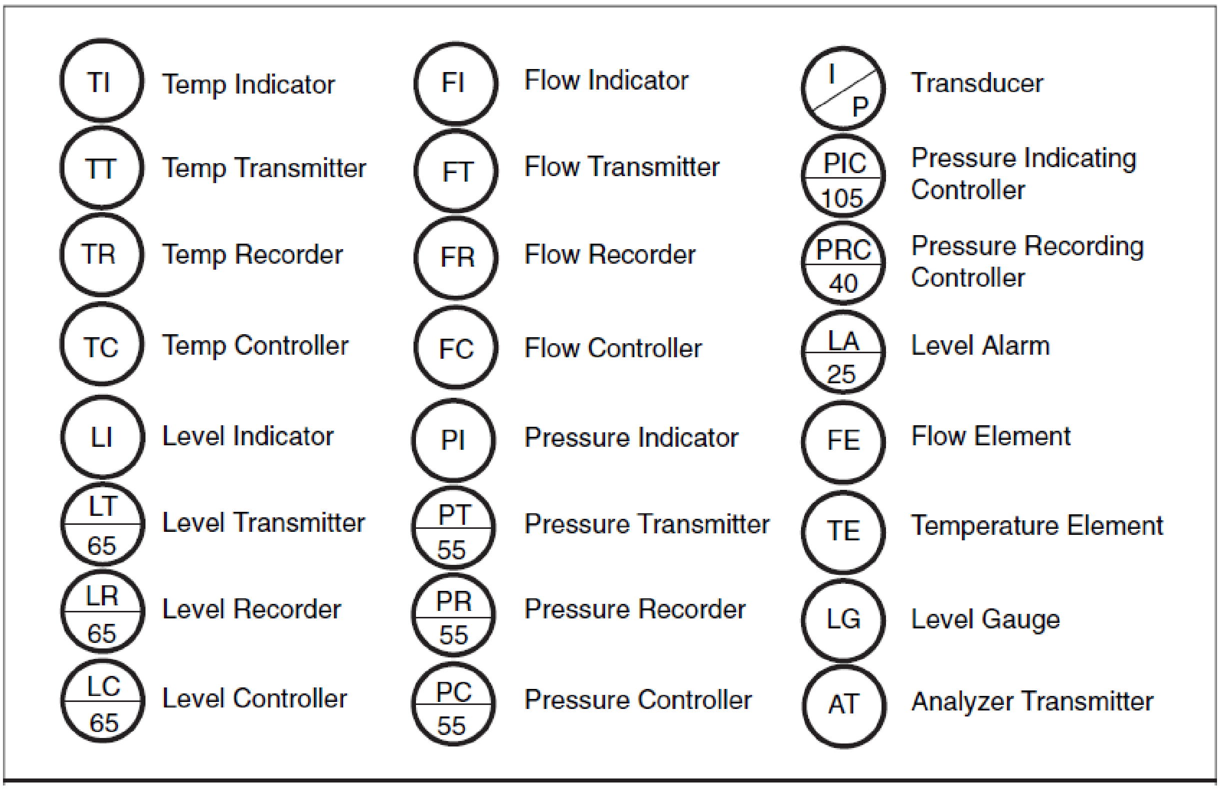


Fig. Process control and Instrumentation Symbols

LECTURE NO. 21

EXPERIMENTATION IN PILOT LAYOUT: SIZE AND STRUCTURE OF THE PILOT PLANT, MINIMUM AND MAXIMUM SIZE, TYPES AND APPLICATIONS

Experimentation in Pilot Plant

The pilot plant is a physical model and should be a “copy” of the corresponding industrial unit, with equipment scaled down in size to approximately 1/100 – 1/10 of the modeled unit.

Pilot plant experiments serve to obtain more information and data in the following areas:

1. *Market survey*: A determined new product amount can be produced in the pilot plant, to test its acceptance and to decide whether it would be economically profitable.

2. *Design data:* The behavior of a given operation or unit process can be found under conditions impossible to duplicate in the laboratory.

3. *Products and raw materials*: A pilot plant is usually needed to characterize food products and to evaluate the development of certain raw materials into specific products.

4. *Optimization data of a running plant*.

SIZE AND STRUCTURE OF THE PILOT PLANT

Basic Principles of Scaling

The most important criterion in determining the size and form of a pilot plant is the principle of similarity, a principle first formulated by Newton.

If, fluids are handled in the pilot plant, three types of similarities involved in fluid dynamics must be included:

1. ***Geometric similarity*.** Both the pilot plant and food processing plant should have the same physical form or at least the same geometric dimension relationships.
2. ***Kinematic similarity*.** The same velocity relationships should exist in both the pilot and food processing plants.
3. ***Dynamic similarity***: In both the pilot and food processing plants, the same force relationships should exist. For example, the turbulence regime should be similar on both scales when fluids are handled.

If the process simulated in a pilot plant involves chemical the following similarities apply:

1. *Thermal similarity*.
2. *Chemical and biochemical similarity*.

Minimum and Maximum Size

Several factors can affect the size of a pilot plant. In general, the m**inimum size** is set by the minimum product amount required for quality analytical control.

The **maximum size** of the pilot plant is set by the amount of processed product needed in order to test market acceptance.

Types and Applications

When product production in amounts large enough to conduct market acceptance tests is required, the pilot plant is called a semi-commercial plant.

Applications

The most common applications of a pilot plant are as follows:

1. Product studies
    - Quality characterization
    - Influence of process conditions on product quality
    - Development of new products
    - Studies of market acceptance
2. Raw material studies
    - Raw material characterization
    - Evaluation of aptitude for industrialization of different raw materials
3. Process technology and engineering studies
    - Setting the most suitable process conditions from an economic point of view (cost minimization) and a product quality point of view (to obtain a product of given quality). Process technology is optimized.
    - Study of process equipment alternatives to carry out given food processing steps or unit operations.
    - Development of new process technology.
    - Development of new process engineering or process equipment.
4. Auxiliary system requirement studies
    - Reliable evaluation of mass and energy balances and food physical properties
    - Study of energy recovery possibilities in process systems

- Improvement and evaluation of alternatives for control systems

LECTURE NO. 22

ENGINEERING ECONOMY : INTRODUCTION, TERMS: TIME VALUE OF MONEY, INFLATION, INTEREST, INTEREST RATE, COMPOUND INTEREST, RATE OF RETURN, PAYMENT, RECEIPT , CASH FLOW, PRESENT VALUE, EQUIVALENCE, SUNK COSTS, OPPORTUNITY COSTS, ASSET, LIFE OF AN ASSET, DEPRECIATION, BOOK VALUE OF AN ASSET, SALVAGE VALUE, RETIREMENT, REPLACEMENT, DEFENDER AND CHALLENGER.

Introduction

Engineering Economy is the study of quantitative techniques for the evaluation of engineering alternatives based upon financial criteria.

In production systems engineering, economic choices are required when

(a) phasing-in of new products and services, and phasing-out of existing products and services,

(b making a choice between alternative production technologies,

(c) choosing plant location and layout, and

(d) when deciding about the questions of equipment replacement etc.

Important terms of Engineering Economy

(i) Time Value of Money: Time value of money is defined as the time dependent value of money stemming both from changes in the purchasing power of money (inflation or deflation) and from the real earning potential of alternative investments over time.

The following are reasons why Rs.1000 today is "worth" **more than** Rs.1000 one year from today.

1. Inflation, 2. Risk, and 3. Cost of money

(ii) **Inflation:** It is the decrease in the purchasing power of a given sum of money with time due to complex national and international economic factors.

(iii) **Interest**: It is the money paid for the use of borrowed money. A production concern borrows money from individuals, commercial banks, insurance companies and government, and pays interest on the borrowed money.

(iv) **Interest Rate:** It is the ratio of the amount of interest paid at the end of a period or time, usually one year, to the sum of money borrowed at the beginning of that period. The sum borrowed is called the Principal. The interest rate is usually expressed as i percent per annum.

(v) Compound Interest: If a sum of money is borrowed for more than one period of time, then in compound interest, the amount of interest payable at the end of any given period of time is calculated on the total amount payable at the beginning of that period of time. In business, compound interest only is charged.

(vi) Rate of Return: If a production concern invests an amount of money in setting up production facilities, then the **ratio** of the **net profit earned** by the company **at the end of a period of time** to **the sum invested** is called the Rate of Return on investment.

***(vii)* Attractive Rate of Return**. This is the minimum rate of return which is used as a criterion by which a concern evaluates alternative investment proposals. An alternative whose expected rate of return is less than the attractive rate of return is rejected.

***(viii)* Payment:** Known also as cost, outlay, expenditure or disbursement, payment is any sum paid by a production concern for buying materials, paying wages etc.

***(ix)* Receipt (s):** Known also as return, income, profit or revenue, **receipt is any sum received by a production concern from** sales of products and services etc.

***(x)* Cash flow:** It is the series of actual or estimated **payments** and **receipts** of a production concern over a period of time. The cash flow can be represented in the form of a cash flow diagram as shown in Figure 1.

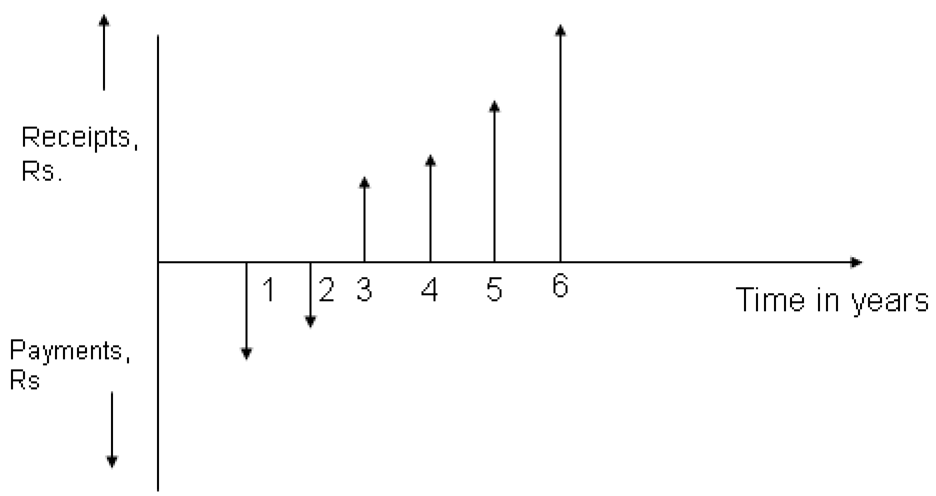


Figure 1 A typical Cash-flow diagram

***(xi)* Sunk costs**: Engineering economic analysis is concerned with making choices between engineering alternatives. For this purpose all past payments or receipts (called Sunk Costs) '**concerning the alternatives are irrelevant**, and are therefore ignored. (sunk = done for)

***(xii)* Opportunity Costs**: If a company invests certain sum of money into a certain venture (or proposal) with an element of risk, that sum is no longer available for investing in any other alternative venture**. The profits or returns lost as a result of not investing in a particular alternative is called the Opportunity Cost.**

***(xiii)* Asset**: An asset of a production concern is a valuable like land, building, machine, material etc. owned by the concern.

***(xiv)* Life of an Asset**: The life of an asset can be considered in three ways,

(a) **Actual or Technological Life** of an asset is the duration during which it can fulfill its required functions. It is determined from technological considerations. (*b)* **Accounting Life of an asset** is the duration during which the investment made in acquiring the asset is to be recovered from gross profits in the form of depreciation.

***(c)* Economic life** of an asset is the duration during which an asset performs its technological function economically. The asset is actually used by the production concern during its economic life only.

***(xv)* Depreciation**: A company invests in assets expecting to earn profits by making use of those assets. However, net profits would accrue only after the investment made in acquiring the assets is recovered. Depreciation is systematic procedure of recovering every year a portion of investment made on an asset during its accounting life. Income tax during a year is chargeable only on the net profit obtained by deducting the amount of depreciation from gross profits.

***(xvi)* Book Value of an Asset:** At any time during the accounting life of an asset, its book value is equal to its cost price minus the total amount of depreciation charged on it by that time.

***(xvii)* Salvage Value**: It is the actual or estimated value of an existing asset at which it can be sold now or at a certain date in the future.

(xx) **Retirement:** It is the disposal of an existing asset through sales or abandonment as scrap.

(xviii) **Replacement:** It means acquiring a new asset through purchase or lease to perform the same or extended service which had so far been performed by another asset which has been retired.

(xix) **Defender and Challenger:** When an economic analysis is made to decide whether or not to replace an existing asset with another, the existing asset is referred to as the Defender and the proposed replacement as the Challenger.

LECTURE NO. 23

METHODS OF ECONOMIC EVALUATION OF ENGINEERING ALTERNATIVES

1. UNDISCOUNTED CASH FLOW METHODS -PAY BACK PERIOD METHOD

2. DISCOUNTED CASH FLOW METHODS

A) NET PRESENT VALUE METHOD

B) EQUIVALENT ANNUAL METHOD

C) RATE OF RETURN METHOD

3. COST- BENEFIT ANALYSIS, SOCIAL COSTS, SOCIAL BENEFITS

Methods of Economic Evaluation of Engineering Alternatives

There are basically two kinds of methods of economic evaluation of engineering alternatives,

1. Undiscounted Cash Flow Methods and
2. Discounted Cash Flow Methods.

1. Undiscounted Cash Flow Methods: In such methods future payments and receipts are not discounted. In other words: the discount rate is considered as zero. Because in most business world, interest is charged, these methods must be considered only as approximate and rough. However, because of their simplicity they are often used as a first screening of alternatives before applying the discounted cash flow methods. The most popular undiscounted cash-flow method is the **Pay-back Period method.**

Pay-back Period Method. In this method, the time period during which the undiscounted future profits will just equal the original investment is calculated. That alternative is considered to be the best corresponding to which the payback period is the smallest.

2. Discounted Cash Flow Methods. In these methods, future payments and receipts are discounted. In other words these methods take into account the time value of money. There are three methods belonging to this category. However, all the three methods are equivalent and provide identical evaluation if investments in the various alternatives under consideration are equal.

(A) Net Present Value Method : This is also known as the Net Present Worth method. In this method, we find the net present worth (value) of all estimated receipts and payments associated with a given alternative using a discount rate equal to what the company considers an attractive rate of return. If the net present value of an alternative is positive, it means that the likely rate of return obtainable from the given alternative is greater than the attractive rate of return or *vice-versa.* That alternative is considered the best whose net present value is **algebraically the maximum.**

(B) Equivalent Annual Cost Method: In this method, the equivalent annual cost of each alternative cash flow is calculated. The equivalent annual cost of a given cash flow is that uniform series of end-of-year payments whose net present value is equal to the net present value of all the payments (and receipts) of the given ash flow, using a given attractive rate of return. That alternative is considered as the best whose equivalent annual cost is the smallest.

(C) Rate of Return Method: In this method, the expected rates of return of the various alternatives are calculated. That alternative is the best whose expected rate of return is the largest. To find the rate of return, it is usual to adopt a trial and error procedure. In this procedure, the net present value of the given alternative is calculated using a particular assumed value of discount rate. If the net present value is positive, it means that the expected rate of return is larger than the assumed discount rate, and *vice-versa.* Accordingly in the next trial, a larger discount rate is used if the previous net present value was positive, and *vice-versa.* The procedure is terminated when the net present value is sufficiently small.

Cost-Benefit Analysis

This is employed for calculating feasibility of engineering alternatives of large government projects, for example, setting up new steel plants, airports, nuclear or thermal power stations etc. In such projects, it is necessary to consider social instead of purely financial criteria. During cost-benefit analysis, that alternative is selected which is expected either

(a) to result in the largest net social benefit based on a given social rate of return (usually small) which is given by

Net social benefit =

Present worth of all social benefits - Present worth of all social costs or *(b)* to provide the largest rate of return considering the value of all social benefits and all social costs.

Social Costs: They include not only the cost of direct investments made by the government but also costs incurred by every affected member of the community. For example, if there are specific alternative sites being evaluated for setting up a steel plant, not only the costs of land, buildings, equipment, roads and railway lines are relevant, but also the cost of displacement, rehabilitation and hardship of families whose homes and farms have to be requisitioned, and costs of ecological deterioration caused by large scale human encroachment--for example, loss of wild life and picnic spots etc.

Social Benefits: The benefits include not only the revenues accruing to the government but also to all direct and indirect beneficiaries in the community as a whole. For example, the benefits of a steel plant include not only the income from sales of steel and steel products, but also increased employment to the local community, growth of ancillary industry, improvement of rail, road and communications, and modernization of the community etc.

Procedure:

(i) Identify the various project alternatives. Then for each proposal, carry out the following steps.

(ii) Identify all categories of relevant social benefits and social costs which may be expected to result from the proposal. Ideally the costs and benefits should be all inclusive, *i.e.* every possible cost and benefit should be found for every possible member of the community. However, practicability limits the numbers of persons considered.

(iii) Evaluate each item of cost and benefit on a common scale, usually money. The estimates of costs and benefits should be prepared for each year of the project's economic life.

(iv) Prepare a cash fl*ow* diagram based on the above estimates and calculate the net social benefit using a social rate of return, or preferably the expected rate of return.

(v) The alternative that yields the largest net social benefit or the largest expected rate of return is the best.

LECTURE NO. 24

PROCESS SCHEDULING

Scheduling is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment. Production scheduling aims to maximize the efficiency of the operation and reduce costs.

Production scheduling tools greatly outperform older manual scheduling methods.

Companies use backward and forward scheduling to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials.

Forward scheduling is planning the tasks from the date resources become available to determine the shipping date or the due date.

Backward scheduling is planning the tasks from the due date or required-by date to determine the start date and/or any changes in capacity required.

The benefits of production scheduling include:

- Process change-over reduction
- Inventory reduction, leveling
- Reduced scheduling effort
- Increased production efficiency
- Labor load leveling
- Accurate delivery date quotes
- Real time information

Productivity

Productivity is the relation between quantity of inputs and quantity of output.

Inputs

Inputs are plant, labor, materials, tooling, energy and a clean environment.

Outputs

Outputs are the products produced in factories either for other factories or for the end buyer. The extent to which any one product is produced within any one factory is governed by transaction cost.

Within the factory

The output of any one work area within the factory is an input to the next work area in that factory according to the manufacturing process. For example the output of the cutting room is an input to the sewing room.

For the next factory

By way of example, the output of a paper mill is an input to a print factory. The output of a petrochemicals plant is an input to an asphalt plant, a cosmetics factory and a plastics factory.

For the end buyer

Factory output goes to the consumer via a service business such as a retailer or an asphalt paving company.

Resource allocation

Resource allocation is assigning inputs to produce output. The aim is to maximize output with given inputs or to minimize quantity of inputs to produce required output.

Scheduling Algorithms

Production scheduling can take a significant amount of computing power if there are a large number of tasks. Therefore a range of short-cut algorithms (**heuristics**) (also known as **dispatching** rules) are used:

Stochastic Algorithms

- Economic Lot Scheduling Problem
- Economic production quantity

Heuristic Algorithms

- Modified due date scheduling heuristic
- Shifting bottleneck heuristic

LECTURE NO. 25

LINEAR PROGRAMMING: INTRODUCTION, SALIENT FEATURES OF LINEAR PROGRAMMING (TERMINOLOGY)

Definition of Operations Research

The Operational Research Society of India:

Operations Research is the attack of modern science on complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government and defense.

A classical definition of Operations Research (Ackoff and Arnoff):

Operations Research is the application of scientific methods, techniques and tools to problems involving the operations of systems so as to provide those in control of the system with optimum solutions to the problem".

Characteristics or Significant Features of Operations Research

The significant features of operations research can be stated as:

1. Decision Making Tool
2. Scientific Approach.
3. Inter-disciplinary Team Approach
4. System Approach
5. Operations Research largely depends on Digital Computer.
6. Objective.

MODELS IN OPERATIONS RESEARCH

Operations research expresses a problem by a model: A model is a theoretical abstraction (approximation) of a real-life problem. It can also be defined as a simplified representation of an operations or a process in which only the basic aspects or the most important features of a typical problem under investigation are considered. The object of the models is to provide means for analyzing the behavior of the system for the purpose of improving its performance.

TECHNIQUES USED IN OPERATIONS RESEARCH

1. Linear Programming. It is used in the solution of problems concerned with assignment of personnel, blending of materials, transportation and distribution, facility planning, media selection, product mix etc.

2. Dynamic Programming.

3. Queueing Theory. It is used in solving problems concerned with traffic congestion,
servicing machines subject to breakdown, air traffic scheduling, production scheduling, determining optimum number of repairment for a group of machines.

4. Inventory theory
5. CPM and PERT Techniques.
6. Game Theory (Competitive Models).
7. Replacement Models.
8. Sequencing Models
9. Decision Analysis Models.
10. Simulation.

INTRODUCTION to Linear Programming

Linear programming is one of the operations research techniques. It has its early use for military applications but it is employed widely for business problems.

Definition:

Linear programming is a mathematical technique for the purpose of allocating the limited resources in an optimum manner *(i.e.,* either maximum or minimum) to achieve the objectives of the business, which may be maximum overall profit or minimum overall cost. The word "linear" means that the relationships handled are those which can be represented by straight lines, *i.e.,* the relationships are of the form $y = ax + b$ and the word "programming" means "taking decisions systematically".

In other words, linear programming is the optimization (either maximization or
minimization) of a linear function of variables subject to constraint of linear inequalities.

Thus, linear programming involves the planning of activities to obtain an "optimal" result *i.e.,* a result that reaches the specified goal best (according to the mathematical model) among all feasible alternatives.

(i) It attempts to maximize .or minimize a linear function of decision variables.

(ii) The values of the decision variables are selected in such a way that they satisfy a set of constraints, which are in the form of linear inequality.

SALIENT FEATURES OF LINEAR PROGRAMMING (TERMINOLOGY)

Linear programming is based on the following basic concepts:

1. Decision Variables (Activities). Decision variables are the variables whose quantitative values are to be found from the solution of the model so as to minimize or maximize the objective function. For example, decision variables in a product mix manufacturing, represents the quantities of the different products to be manufactured by using its limited resources, such as men, machines, materials, money etc. The decision variables are usually denoted by x_1, x_2, ……,x_n.

2. Objective Functions. It states the determinants of the quantity either to be maximized or to be minimized. For instance, profit is a function to be maximized or cost is a function to be minimized. An objective function must include all the possibilities with profit or cost coefficient per unit of output. For example, for a firm which produces four different products *A,* B, C and D in quantities Q_1 , Q_2, Q_3 and Q_4 respectively, the objective function can be stated as :

Minimise $C = Q_l C_l + Q_2 C_2 + Q_3 C_3 + Q_4 C_4,$

where C is the total cost of production, and C_1, C_2, C3 and C_4 are unit costs of products *A, B,* C and D respectively.

3. Constraints (Inequalities). These are the restrictions imposed on decision variables. These may be in terms of availability of raw materials, machine hours, man hours etc. Suppose each of the above items *A,* B, C and D requires t_l, t_2, t_3 and t_4 machine hours respectively. The total machine hours are T hours, and this is a constraint.

Therefore it can be expressed as:

$$Q_1 t_1 + Q_2 t_2 + Q_3 t_3 + Q_4 t_4 \leq T$$

4. Non-Negative Condition. The linear programming model essentially seeks that the values for each variable can either be zero or positive. In no case it can be negative. For the products *A, B,* C and *D* the non-negative conditions can be :

$Q_1 \geq 0$ $t_1 \geq 0$
$Q_2 \geq 0$ $t_2 \geq 0$
$Q_3 \geq 0$ and also $t_3 \geq 0$
$Q_4 \geq 0$ $t_4 \geq 0$

This implies that quantity produced can be at the most zero and not below that. Similarly, the machine hours expended for each unit *A, B,* C and *D* can be at the most zero and in no case it can be negative.

5. Linear Relationship. It implies straight line or proportional relationship among the relevant variables. It means change in one variable produces proportionate change in other variables.

6. Process and its Level. Process represents to produce a particular output. If a product can be produced in two different ways, then there are two different processes or decision variables for the purpose of linear programming.

7. Feasible Solution. All such solutions which can be worked out under given constraints are called "feasible solutions" and region comprising such solution is called the "feasible region".

8. Optimum Solution. Optimum means either maximum or minimum. The object of obtaining the feasible optimum solution may be maximization of profit or minimization of cost. Optimum solution is the best of all feasible solutions.

LECTURE NO. 26

FORMULATION OF LINEAR PROGRAMMING MODEL, ADVANTAGES, LIMITATIONS AND APPLICATIONS OF LINEAR PROGRAMMING, SOLUTION OF LINEAR PROGRAMMING PROBLEMS.

Formulation of LP Model. Formulation of LP model refers to translating a problem into a format of mathematical equation.

Assumptions in Linear Programming

(i) There is a well defined objective function such as maximizing profit or minimizing cost.

(ii) There are a number of restrictions or constraints (on the amount and extent of available resources for satisfying the objective function) which can be expressed in quantitative terms. These may refer to man-hours, machine hours, raw materials, storage space, capital etc.

(iii) The parameters are subject to variation in magnitude.

*(iv)*The relationship expressed by constraints and the objective function are linear.

(v) The objective function is to be optimized w.r.t. the decision variables involved in the phenomenon. The decision variables are non-negative and represent real life situation.

Advantages, Limitations and Applications of Linear Programming

Advantages:

(i) Linear programming helps the management to make effective utilization of limited production resources.

(ii) Linear programming improves the quality of decision making by replacing rules of thumb.

(iii) It provides feasibility in analyzing a variety of multi-dimensional problems.

(iv) It highlights the bottlenecks in the production processes.

(v) It helps in re-evaluation of the basic plan to meet changing conditions in the business *(e.g.,* sales, demand etc.).

Limitations:

(i) The assumptions that all relations are linear may not hold good in many real situations.

(ii) In linear programming all coefficients and constraints are stated with certainty.

(iii) The solution many times is in fractions which may not remain optimal when rounded-off. .

(iv) When the number of variables or constraints involved are quite large then it be com necessary to use computers.

(v) It deals with only a single objective problems, whereas in real life situations there may be more than one conflicting objectives.

Applications: Some of the applications of linear programming in industry, business, and other fields are as follows:

1. ***Product Mix***. A company can produce several different products, each of which requires the use of limited resources. Linear programming helps to determine the quantity of each product to be manufactured in order to maximize profit.
2. ***Production Planning***. Linear programming helps in production planning (inventory control, manpower, equipment selection, etc.) in order to minimize total operations costs.
3. ***Assembly line Balancing.*** Linear programming techniques help to minimize. tot elapse time in assembly process.
4. ***Blending Problem.*** When a product can be made from a variety of available raw materials, each of which has a particular composition and price, linear programming technique is used to determine minimum cost blend.
5. ***Media Selection***. Linear programming helps in determining the advertising media mix so as to maximize the effective exposure at minimum cost.
6. *Traveling Salesman Problem*
7. *Physical Distribution.* It helps in selecting most economical and effective location for the manufacturing plant and distribution centers.

8. *Staffing Problem.* Linear programming helps to allocate optimum manpower to a particular job so as to minimize total over time cost and total manpower.
9. *Job Evaluation and Selection.* Selection of suitable person for a specified job and evaluation of job in organization has been done with the help of linear programming.
10. *Agriculture.* To allocate limited resources such as land, labour, water supply and working capital etc. in the way so as to improve productivity.
11. *Military.* Military applications include the problem of selecting an effective air weapon -system against enemy.
12. *Routing Problem.* To determine the most economic pattern and timings for flights so as to make the most efficient use of aircraft and crews.

Solution of Linear Programming Problems

Linear Programming Problems can be solved by following methods:

1. *Graphical method*
2. *simplex method*
3. *Transportation method*
4. *Assignment models*

The graphical method can be used only for two or three variables; where as the other methods can be used for any number of variables.

Illustrative Problems on Formulation of Linear Programming Model

Example: The manager of an oil refinery must decide on the optimal mix of two possible blending processes of which the input and output per production run are given as follows:

Process	*Input (units)*		*Output*	
	Crude A	*Crude* B	*Gasoline* X	*Gasoline* Y
1 2	5 4	3 5	5 4	8 4

The maximum amount available of crude A and B are 200 units and 150 units, respectively. Market requirements show that at least 100 units of gasoline X *and* 80 *units of gasoline* Y *must be produced. Formulate this problem as an linear* *programming model to maximize profit. The profit per production run from process* 1 *and process* 2 *are Rs. 300 and Rs. 400, respectively.*

Linear Programming Model Formulation:

Let,

Decision variables

x_1 = number of units of Gasoline from process 1

x_2 = number of units of Gasoline from process 2

Objective function, Maximize $z = 300 x_1 + 400 x_2$

Subject to constraints:

$5x_1 + 4x_2 \leq 200$

$3x_1 + 5x_2 \leq 150$

$5x_1 + 4x_2 \leq 100$

$8x_1 + 4x_2 \leq 80$

$x_1 \geq 0$ and $x_2 \geq 0$

LECTURE NO. 27

QUEUING THEORY: INTRODUCTION, ELEMENTS OF QUEUING SYSTEM, 1) INPUT SOURCE, 2) QUEUE

Queuing Theory (Waiting Lines)

INTRODUCTION

The formation of queues or waiting lines is a most common phenomenon in our every day life. It occurs where the current demand exceeds the current capacity to provide that service.

Queues are also formed even when the service rate is higher than the arrival rate due to **random pattern of arrival of customers**. The examples of the places where the queues may be formed are barber's shop, ration shop, cinema ticket window, bus stop, bank counters, railway reservation counters, telephone booth, doctor's clinic, repair shops, automobile service centers etc.

Besides these, queues are also formed in manufacturing industry in situations where in-process goods waits for next operation, or waits for getting moved to another place, machine waiting for repair parts or components waiting for assembly in assembly lines, blunt tools waiting for reground, workers waiting at the tool crib to obtain tools etc. This may increase production cycle duration which adds to the cost of the product and it may also delay the specified delivery period.

Queues may not be a physical line of customers; it may be merely a list of customers, units, orders etc. Some specified examples of such type of queues are: unconnected telephone calls waiting list of passengers for a berth etc.

The most important issue in waiting line problems is to decide the best level of service the organization should provide. Providing **too much service** would involve **excessive cost** on the other hand **inadequate service capacity** would result in long waiting lines which results in **dissatisfaction of customers** or sometimes loss of customers. Thus the ultimate goal is to achieve an economic **balance** between the **cost of service** and the **cost associated with waiting** for that service.

Queueing theory provides a large number of alternative mathematical models for describing and solving waiting line problems.

The economic balance between the cost of service and the cost associated with waiting can be achieved at either by:

(a) providing more facilities at additional cost, or

(b) replacing less efficient service facilities by more efficient ones, or

(c) changing the pattern of arrival of customers for service, or

(d) changing the pattern of providing service, or

(e) effecting method improvements to reduce service time.

Queueing problems can be solved basically either by mathematical or simulation approaches.

ELEMENTS OF QUEUEING SYSTEM

The basic queueing process (Queueing model) consists of:

(a) Input Source

(b) Queue

C) Service mechanism

The 'Customers' requiring service are ·generated over time by an "input source". These customers enter the queueing system and join the queue. At certain times a member of the queue is selected for service by some rule known as **service discipline**. The required service is then performed by the service mechanism, after which the customer leaves the queueing system.

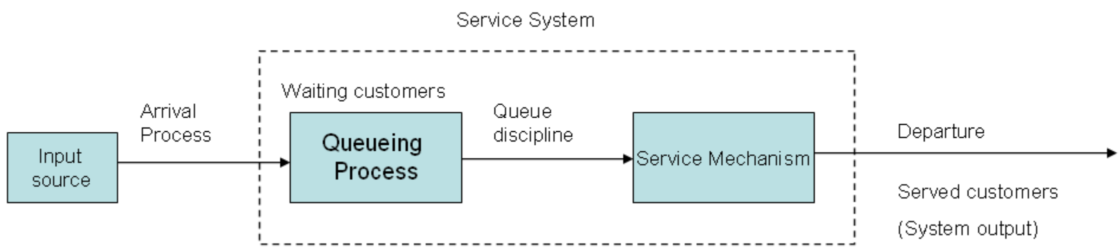


Fig. The basic queuing process

The various elements of the queueing system are:

(i) Input source *(calling population)*

(ii) Waiting line *(queue)*

(iii) Service discipline

(iv) Service mechanism

(v) System output

(vi) Customer behavior.

1. Input source

Two important characteristics of the input source are:

(i) its size and (ii) the pattern of arrival.

The size is the total number of customers that might require service from time to time. The size of the input source is generally assumed to be infinite. The railway reservation system, tax / toll both on highway etc. are the example of infinite queue.

The arrival of the customers may be either at a **constant rate or at random**. Most arrivals in a service system are at random. This is when each arrival is independent of its previous arrivals. The exact prediction of any arrival in random system is not possible. Therefore, the number of arrivals per unit time (rate of arrival) is estimated by Poisson distribution.

2. **Queue**

A queue is characterized by the maximum permissible number of customers that it contains. Units requiring service enter the system and join a queue. **In** some service systems only a limited number of customers are allowed in the system and new arrivals are not allowed to join the system unless the number becomes less than the limiting value.

LECTURE NO. 28

QUEUING THEORY: CHARACTERISTICS OF WAITING LINES, SERVICE DISCIPLINE, SERVICE MECHANISM, SYSTEM OUT PUT, CUSTOMER BEHAVIOR.

CHARACTERISTICS OF WAITING LINES

The important characteristics required to study the waiting line are:

(i) ***Waiting time:*** It is the time that a customer spends in the queue before being taken up for service.

(ii) ***Service time:*** It is the time period between two successive services. It may be either constant or variable.

(iii) ***Waiting time* in *the system:*** It implies the time spent by the Customer in the queue system.

Waiting time in the system = Waiting time + Service time

(iv) Queue length*:* It implies the number of customers waiting in the queue.

(v) System length: System length is equal to the number of customers in the queue plus those being served.

SERVICE DISCIPLINE

It refers to the order in which the customers waiting in queue are selected for service. It may be first-come-first-served, random or according to some priority procedure. The rules governing order of service may be.

(i) ***FIFO****. First-In-First-Out.* (i.e., first-come-first-served)

According to FIFO, the customers are served in the order of their arrival. Examples are bank counters, railway reservation counters etc.

(ii) ***LIFO****. Last-In-First-Out.* According to LIFO, the items arriving last are taken out first. Example, in big godowns the items arrived last are taken out first.

(iii) ***SIRO****. Service In Random Order.* (or Random and priority) Sometimes, certain

customers are given priority for service i.e., the arriving customer is chosen for service ahead of some other customers already in the queue. *Example*: Serious patients are given priority for treatment, vital machines are attended to first in the case of their breakdowns, important orders are given priority in production scheduling.

First-come-first-served (FIFO) is usually implicitly assumed by queueing models unless otherwise stated.

SERVICE MECHANISM

Service mechanism consists of one or more service facility each of which contains one or more parallel service channels.

A server may be a single individual or a group of persons, *e.g.,* a maintenance crew.

Furthermore, servers need not even be people, in many cases a server may be a machine or a piece of equipment, *e.g.,* fork lift truck.

Service mechanism may vary depending upon the number of service channels, number of servers, number of phases etc. The *four* basic structures of service mechanism are:

1. **Single Channel Single Phase (Single Queue-Single Server).** In this case the arriving units form one queue to be served by a single service facility:

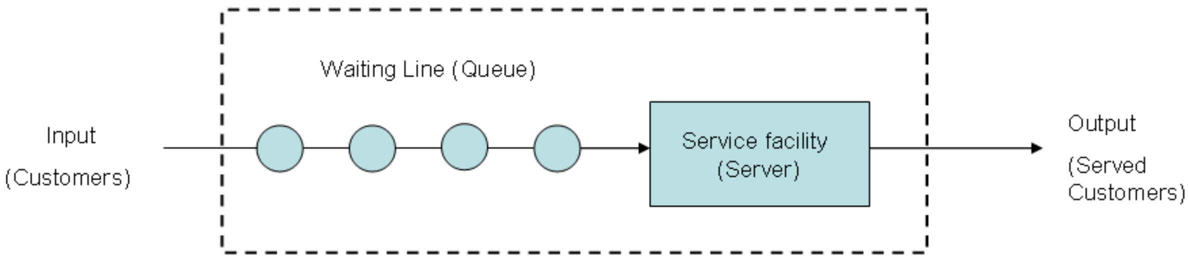


Fig Single channel, single phase system.

2. Single Channel, Multiphase (Single Queue, Multiple Servers in Series). In this case the customers are served at number of servers arranged in series. A two phase service means that once an arrival enters the service, it is served at two stations (or phases one after the other).

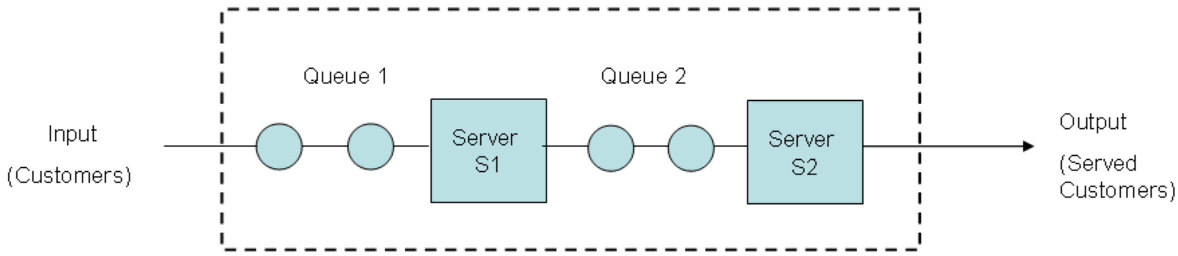


Fig. Single channel, multiphase (2-phase) system.

3. Multi Channel, Single Phase System (Single Queue, Multiple Servers in Parallel)**.** In this type there is a single queue and multiple servers arranged in parallel as shown in Figure.

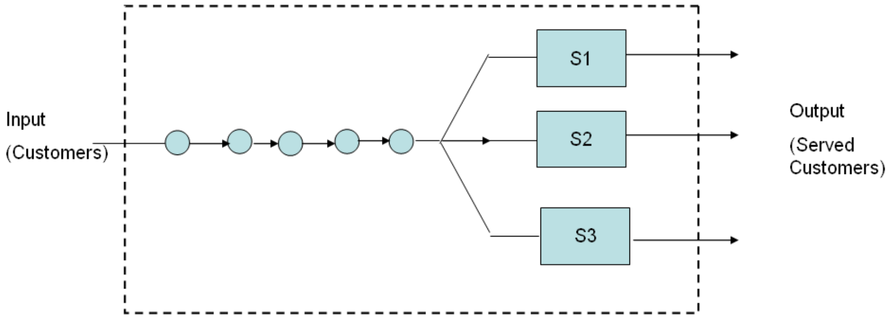


Fig. Multiple channel single phase (Single queue multiple servers in parallel).

4. Multiple Channel, Multiple Phase. In this type there are multiple channels and the customers are served at more than one server as shown in Figure.

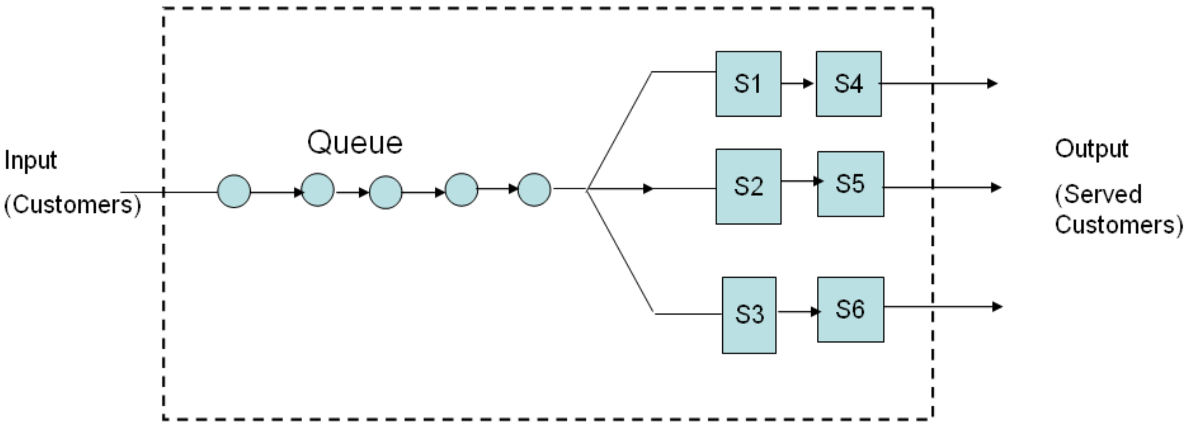


Fig. Multiple channel, multi-phase (Three channel, 2 phase).

System Output

System output refers to the **rate at which customers are rendered service**. It depends upon service time required by that facility to render service and the arrangement of service facility. The average number of customers that can be served per unit time is called **service rate.** It can be obtained by constructing service time frequency distribution. Service rate is denoted by letter 'μ'. Reciprocal of service rate is called service time *i.e.,* Service time = $\frac{1}{\mu}$.

Customer Behavior

Customer behavior implies that reactions of the typical customers about queueing system of the service mechanism. Typical tendencies of the customers are:

(i) ***Balking:*** A new customer refuses to enter the system.

(ii) ***Reneging****:* A customer may leave the queue without getting service after waiting sometime.

(iii) ***Jockeying:*** A customer may keep on switching from one queue to another, when there are more than one service counters.

(iv) Collusion: The customers in the queue may demand service on their behalf as well as on behalf of others.

LECTURE NO. 29

MATERIALS OF CONSTRUCTION OF FOOD EQUIPMENT: CHARACTERISTICS OF SUITABLE CONSTRUCTION MATERIAL: STAINLESS STEEL, ALUMINUM, NICKEL AND MONEL, PLASTIC MATERIALS

Characteristics of Suitable Construction Material

Construction materials for food processing and auxiliary system equipment that are in contact with foods or cleaning agents should have certain characteristics:

a) *Resistance to corrosive action* of foods or chemicals (cleaning and sanitation agents) that may converge with exposed surfaces of construction materials.

b) Suitable surface finish to discourage buildup of dirt that can accumulate with excessive surface rugosity

c) *Good mechanical behavior* according to performance of mechanical functions, such as structural strength, resistance to abrasion and physical or thermal shocks, and pressure charges.

TYPES OF MATERIALS AND APPLICATIONS

The most common materials used for constructing the Food Equipment

1. Stainless steel
2. Aluminium
3. Nickel and Monel
4. Plastic Materials

Stainless Steel

Stainless steel exhibits some of the most suitable characteristics of the construction materials used for food equipment. It is the most widely used material in direct contact with food found in the industry. Of the types available, AISI 304 stainless steel is the most commonly used. (AISI – American Iron Steel Institute)

Composition of the Different Types of Stainless Steel

	C	Mn	P	S	Si	Cr	Ni	Mo	Se
AISI 302	0.15 max	2.00 max	0.045 max	0.030 max	1.00 max	17.00 19.00	8.00 10.00	—	—
AISI 304	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	18.00 20.00	8.00 12.00	—	—
AISI 316	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	16.00 18.00	10.00 14.00	2.00 3.00	—

Corrosion

Under special corrosion conditions, such as handling of acidic fluid foods or foods containing SO2, AISI 316 or 316L stainless steel should be employed with preference over AISI 302 or AISI 304. AISI 302 stainless steel is used to improve the external design appearance of food equipment, but not equipment in contact with food or corrosive agents.

The corrosion resistance of stainless steel is due to the spontaneous formation of a layer of chromium oxide on the surface of the material (as a protective coating) when exposed to air. This layer can be formed artificially by treating the surface with nitric acid (20–30% at 60°C) for 30 minutes.

Aluminum

Aluminum has a high thermal conductivity, around 217 W/m. K or 187 kcal/h. m. °C, and a specific weight of 2700 kg/m3. It is corrosion resistant under normal conditions during the distillation of water, fruit juice, milk, and SO2. It does not, however, resist attack by hydrochloric and hydrofluoric acid, or caustic solutions. For this reason, alkali products must not be used with this material. Acid cleaning agents, on the other hand, are appropriate for aluminum.

Currently, aluminum is used in the construction of some parts of food process equipment. It is not as corrosion resistant as stainless steel, and it is not as resistant to abrasion from cleaning and sanitization products and foodstuffs.

Nickel and Monel

Pure nickel and monel (an alloy with 67% nickel, 28% copper, and the remainder iron and manganese) were widely used in preference over nude or tinned copper for food equipment until stainless steel proved to be the more satisfactory material.

An alloy of nickel, zinc, and copper has been used in casting pieces for valves, mainly for closing devices, since it exhibits better mechanical abrasion resistance than nickel or stainless steel.

Monel is the preferred material for common salt processing systems since it exhibits even better corrosion resistance than stainless steel. It is also employed in pumps that handle alcohol, brines, vegetal oils, and fruit juices.

Plastic Materials

Plastic materials are used in harvesting and transporting agricultural raw materials to the food processing plant, in food packaging of solid and liquid foods, and even in food process equipment (mainly processing tanks).

The most important plastics are:

- *Polypropylene*.
- *High density polyethylene*
- *Rigid PVC*
- *Polyester*
- *Epoxy resins*

LECTURE NO. 30

ILLUMINATION AND VENTILATION

Illumination of the Processing Facility

Pride in the workplace is easier to maintain in a well-illuminated plant than in a dark and dull facility. Working in an environment that is perceived to be clean promotes neat and tidy work habits. Good illumination enhances the operation of a well-run plant and promotes efficiency and safe working conditions.

Good lighting is an easy goal to reach and a quick fix to eliminate dark corners and unsafe work areas. The range of lighting hardware makes it possible to have a well-lighted plant. Industry recognizes standards that should be met or exceeded.

When a lighting system is designed, the following points should be considered:

- Distribution pattern of the light and suitability in the area involved
- Illumination output of the light hardware
- Possibility that larger lamps can be used in the same fitting when more light is required
- Design and construction of the lamp and its fitting
- Change in lamp efficiency over time and ease of periodic servicing, cleaning, and replacement
- System cost

Light is measured in luminous intensity as candela (cd) in SI units.

TABLE 1 Recommended Levels of Illumination

Offices	**Illumination (candela)**
Designing, detailed drafting	200
Bookkeeping, auditing, tabulating, rough drafting	150
Regular office work, filing, index references, mail sorting	100
Reading or transcribing handwriting in ink or medium pencil	70
Reading high-contrast or well-printed material	30
Corridors, elevators, stairways	20

LIGHT INTENSITY AND APPLICATION

In any work area, the light should be diffuse and uniformly constant. For the most efficient use of available light, the ceiling should have a minimum reflectance of 75% and the sidewalls 50 to 60%. The floor should be 20% reflective. To prevent eyestrain, glare should be avoided. The amount of light reflected off any surface is affected by the smoothness of the surface. When the surface is rough, the reflection will be scattered, and the reflected light will diffuse. When the paint surface is smooth, irregularities in the painted surface can cause glare. The color of the paint will also affect the amount of light reflected.

Because walls are normally fairly smooth, color is the dominant factor in determining reflectance and illumination. Light colors reflect high proportions of light, while dark colors absorb a lot of light. Table 2 provides reflection values for different colors of paint. There is obvious variation between shades of the same color. Human perception of color is influenced by the color of the light that illuminates it. When the dominant color in an area is cream, ivory or tan, white fluorescent lighting will be best. If the dominant colors are blue or green, the blue-type fluorescent lights will work best.

TABLE 2 Light Reflection by Different Colors of Paint

Color	Reflection (%)	Color	Reflection (%)
White gloss	84	Light blue	54
Flat white	82	Medium green	52
White, eggshell	81	Maple wood finish	42
Ivory white	79	Medium blue	35
Silver gray	75	Dark gray	30
Yellow	75	Oak wood finish	17
Cream	74	Walnut wood finish	16
Pink	72	Dark red	13
Light buff	70	Mahogany wood finish	12
Ivory tan	67	Dark brown	10
Medium yellow	65	Dark blue	8
Light green	65	Dark green	7
Medium buff	65	Black	5
Medium gray	58		

TYPES OF LAMPS

Many types of lamps are used in processing areas. In most cases, fluorescent lamps are favored because they have about 2.5 times the efficiency of incandescent lamps. They also give soft diffused light without glare. Fluorescent lamps are best suited in areas where the lamp stays on for long periods of time. In places where lamps are frequently switched on and off, fluorescent light should not be used. Frequent on and off service not only results in a short lifespan of the lighting element but places an extra load on the starting transformer. Fluorescent lamps can be used for about 2500 to 4000 h before they need to be replaced. Incandescent lamps must be replaced every 800 to 1000 h.

Most installations use fluorescent lighting in all areas possible. In some high moisture areas, including cold rooms and where explosive vapors may be present, incandescent light fittings with vapor-proof fixtures are required. In the cereal industry, cereal dust can be very explosive when mixed with the right amount of air. In these cases, light bulbs and all fittings are completely enclosed and water tight.

At loading docks, large warehouses and outside areas, where extensive coverage is required, mercury vapor lamps are used. Mercury vapor lamps are several times more efficient than fluorescent lighting.

Incandescent lamps radiate more long-wave radiation in the yellow and red ranges, while fluorescent lighting is bluer. Incandescent lamps produce light and heat. This is an obvious drawback in cold storage areas. If fluorescent lighting is used in cold rooms, the tubes must be rated to operate at temperatures below 5ºC.

The installation cost for fluorescent lighting is considerably greater than the cost for incandescent lighting. The energy savings will pay for this additional expense over time. All light bulbs should be replaced at regular intervals. Replacing them only if they are broken means that there will be one or two lights out at any given time. Lights have an average lifespan and should be replaced before they break.

VENTILATION

Ventilation is the supply of fresh, conditioned air to replace unwanted air. Conditioning can include alteration of moisture content, change of temperature, and filtering to remove particulates and organisms.

Within the processing area, ventilation will remove obnoxious odors, moisture, and heat and replace it with air that is free from contaminants and air that will increase the comfort level of workers. The amount of air is calculated as a replacement volume. Depending upon the production processes, the air can be replaced from 6 to 20 times per hour. It is also advisable to keep the processing area under a slight positive pressure. This will ensure that processing area air flows out when a door is opened.

Special air is required in areas where baby formula is handled or where aseptic operations take place. In these cases, air will be filtered through special filters that will remove organisms. The processing area must be under positive pressure at all times so that no organisms can enter from adjacent processing areas.

LECTURE NO. 31

CLEANING & SANITIZATION

Cleaning and sanitation should be considered an integral part of food process design and food processing operations. The food processing equipment should be designed to facilitate the removal and draining of all the process effluents (steam condensate, waste solids, e.g., peels). All dead ends in tanks, containers, and piping should be eliminated.

Fouling is particularly important in heat exchangers and other installations involving fluid flow (evaporators, filters, cyclones, etc.). The food processing equipment must be cleaned easily either by quick dismantling and cleaning the parts, or by Cleaning-In-Place *(CIP)* techniques. The equipment of small food processing plants is usually cleaned by periodic dismantling of the principal units, such as pumps, plate heat exchangers, filters etc. Quick dismantling and re-assembling of process piping is facilitated by various hand opening clumps.

The design and installation of *CIP* systems in large food processing plants requires specialized experience in pipe flow, sanitation, processing operations, and process control.

The *CIP* system involves the following sequential operations: 1) Pre-rinsing with cold (soft) water; 2) alkali wash (supplemented with sodium hypochlorite); 3) intermediate water rinse; 4) acid rinse; 5) final water rinse; and 6) rinse with sanitizing solution (sodium hypochlorite) or flushing with hot (90 °C) water.

The *CIP* system is actually a chemical cleaning operation, in which the chemical solution is brought into contact with all soiled surfaces. Addition of surface active substances, reducing substantially the surface tension of water, facilitates the penetration of water and aqueous cleaning solutions into crevices of the equipment. The required tanks, pumps, pipes, valves and heaters (heat exchangers or steam injection devices) are used either as single-use or re-use (re-circulation) systems. Air-operated piston or diaphragm-type pumps are used to feed the chemical solutions. For safety reasons, the pumps and the chemical supply containers are enclosed in a separate compartment of the processing plant.

Ball spray devices are used to clean process and storage tanks. Cylindrical and rectangular tanks are cleaned using liquid feed rates of 8-12 L/min m^2 internal surface, while vertical silos require liquid rates of 25-35 L/min m tank circumference. Adequate inclination (slope) of piping and process vessels is essential for self-draining of process and cleaning liquids.

Usually, food equipment must be cleaned daily, after a processing period. However, when different products are processed in the same equipment, cleaning depends also on the frequency of product changes.

Effective *CIP* requires automation of the whole system. Microprocessor controllers *(PLC)* are used in connection with on-line sensors for temperature, level, flow rate, pressure, and valve position. The concentration of cleaning agents and organic effluents can be measured with pH meters, redox potential meters, and optical density meters. The degree of surface contamination can be determined by pressure drop measurements in the pipeline.

Definition of Sanitation

The word *sanitation* comes from the Latin word *sanitas,* which means "health." In the food industry, sanitation means creating and maintaining hygienic and healthful conditions. Scientific principles are used by healthy food handlers in a hygienic environment to produce wholesome food. Sanitation can reduce the growth of microorganisms on equipment and dirt on food. This can reduce contamination of food by microorganisms that cause food borne illness and food spoilage. Sanitation is more than just cleanliness. Food or equipment can be free of visible dirt and still be contaminated with microorganisms or chemicals that can cause illness or food spoilage.

LECTURE NO. 32

MAINTENANCE OF FOOD PLANT BUILDING: SAFETY COLOR CODE, ROOF INSPECTION, CARE OF CONCRETE FLOORS

Maintenance

Painting: The task of keeping a plant and its equipment properly painted is expensive but important. **Proper painting and color selection will increase plant efficiency**. Employee morale can be improved by making the working environment more attractive. Paint, properly applied, will extend the life of most materials; wooden surfaces, structural steel, and sheet metal especially should be kept painted.

There are **special paints** for cement blocks, gypsum blocks, and concrete floors. **Equipment paint** should have **rust-inhibitive qualities** and a high degree of moisture impermeability. Where the surface is exposed to **ammonia fumes or acids or alkalis,** chemical-resistant paints should be applied. Particularly useful in this respect are paints with a rubber base. To prevent **mold growth or mildew on damp surfaces**, *copper-8-quinolinolate* (sold in a solubilized form as Cunilate) has been found effective.

No interior painting or finishing should be done until the building has been thoroughly **dried out by artificial heat**. It is important that **new plaster and concrete** be allowed to age from **60 to 90 days** under good drying conditions before painting. New and unfinished wood should be covered with three coats. All holes and cracks should be puttied after the first coat is dry.

For **best appearance**, **pleasing color combinations** should be selected. Building interiors should be painted in light colors, and eyestrain with its consequent fatigue is reduced by using those that are free from glare. Sharp color contrasts should be avoided except where they are used to improve safety conditions by making some projection or object conspicuous.

Ceilings should be **painted white**. **Walls** may be **painted light green, light gray, cream, or ivory** with the trim in a darker shade. Exterior walls should be painted in light colors with darker trim to match. For equipment, aluminum and medium gray, dark green and maroon paints have proved highly satisfactory. White is difficult to maintain. For floors, tile red or dark gray is desirable.

Moisture, washing solutions, acids, mold growth, ammonia fumes, and normal wear and abuse tend to destroy paint. All bare or badly worn sections should be "spotted in" with recommended primers or undercoats. In applying an enamel over a previously enameled surface, it is a general practice to use an enamel undercoat over the old surface. This will ensure proper adhesion, since undercoating clings to previous coats to form a good foundation.

Exterior surfaces on which the paint or previous finish is in bad condition should be scraped or burned off, taking particular care to avoid charring the surface. The surface should then be thoroughly sanded and dusted.

Safety Color Code. A safety color code has been established and should be universally adopted. **The purpose of the code is to standardize the use of various colors for identifying safety, fire protection, and medical equipment and accident hazards**. The colors and their uses are listed in the following Table.

Table : Safety color Code

Signal	***Color***	***Use***
Alert	orange	Machines or equipment that might cut, rush, otherwise injure, or electrocute a worker: interior surfaces of fuse and power boxes, machinery guards, and exposed parts such as pulleys, gears, or cutting devices.
High-visibility	Black and yellow in alternate stripes	Strike-against, tripping, or moving equipment hazards: low pipes or beams in aisles, floor elevation changes and curbing, chain-hoist blocks and low overhead conveyors, aisle obstructions and trucking equipment.
Fire-protection	Red	Fire fighting and fire protection equipment: extinguisher locations, standpipe and hose locations, controls of manually operated deluge or flooding systems, alarm stations and fire bells, fire blankets and individual deluge showers, fire doors(8-in. stripe on leading edge).
Precaution	blue	Electrical controls and also equipment that is undergoing repair: ovens, vats, boilers, valves, kilns, dryers, tanks, compressors, and scaffolding.

Signa l	***Color***	***Use***
Safety	Green cross on white background	Safety equipment and its location: stretcher boxes, first-aid cabinets, and plant hospital.
Traffic	gray, black, white, and yellow	Good-housekeeping facilities: aisle markings, corners, waste receptacles, floor areas immediately surrounding waste receptacles, and storage areas.

Roof Inspection: The roof should be inspected at least twice a year before and after the winter season and it is also advisable to make an inspection after a severe storm. The constant expansion and contraction of roofing material due to changes in temperature will eventually cause cracking. Metal roofs are subject to rust and corrosion, especially at the points where joined or nailed. Periodic inspection will reveal damaged or worn sections. Prompt repair will prevent loss from leaks and will add to the life of the roof itself.

Care of Concrete Floors. Grease may be removed from concrete floors with a mild acid or alkali cleaner. The floor is first wetted, the cleaner is sprinkled uniformly over the section to be cleaned, allowed to soak for a time, and then brushed. Either alkali or acid will attack concrete and will eventually cause pitting. After use of the cleaner, the floor should be thoroughly rinsed with hot water.

Repair. Cracked or crumbling areas in concrete floors are repaired by first removing the old floor to a depth of at least 2 inches, leaving the edges perpendicular. The cavity is then wetted liberally and cleaned by brushing. A cement wash consisting of one part of sifted sand, one part of cement, and water at the rate of 4.5 gallons per bag of cement is next applied with a stiff brush. The finish coat should be applied at once, the crack or area being filled 0.25 inches above the surrounding floor and allowed to shrink for 1 or 2 hours before smoothing and leveling. Concrete should not be permitted to dry rapidly.

Dust Control. The floor should be cleaned thoroughly with an alkaline solution to remove all grease and dirt and then rinsed. The surface should then be etched with a 10 per cent solution of either hydrochloric or sulphuric acid and again rinsed. Finally, a floor-hardening compound such as a dilute solution of sodium silicate should be applied.