Government College of Engineering Kalahandi, Bhawanipatna

DEPARTMENT OF MECHANICAL ENGINEERING

Lecture Notes on

COMPUTER INTEGRATED MANUFACTURING AND FMS

Prepared by

Mr. Ajit Kumar Pattanaik

Asst. Professor

Mechanical Engg Department

Mr. Dilip Kumar Bagal

Asst. Professor

Mechanical Engg Department

PEME5307 COMPUTER INTEGRATED MANUFACTURING AND FMS (3-0-0)

Module I **(12 hours)**

Fundamentals of Manufacturing and Automation: Production systems, automation principles and its strategies; Manufacturing industries; Types of production function in manufacturing; Automation principles and strategies, elements of automated system, automation functions and level of automation; product/production relationship, Production concept and mathematical models for production rate, capacity, utilization and availability; Cost-benefit analysis.

Computer Integrated Manufacturing: Basics of product design, CAD/CAM, Concurrent engineering, CAPP and CIM.

Module II **(12 hours)**

Industrial Robotics: Robot anatomy, control systems, end effectors, sensors and actuators; fundamentals of NC technology, CNC, DNC, NC part programming; Robotic programming, Robotic languages, work cell control, Robot cleft design, types of robot application, Processing operations, Programmable Logic controllers: Parts of PLC, Operation and application of PLC, Fundamentals of Net workings; Material Handling and automated storage and retrieval systems, automatic data capture, identification methods, bar code and other technologies.

Module III **(12 hours)**

Introduction to manufacturing systems: Group Technology and cellular manufacturing, Part families, Part classification and coding, Production flow analysis, Machine cell design, Applications and Benefits of Group Technology.

Flexible Manufacturing system: Basics of FMS, components of FMS, FMS planning and implementation, flexibility, quantitative analysis of flexibility, application and benefits of FMS.

Computer Aided Quality Control: objectives of CAQC, QC and CIM, CMM and Flexible Inspection systems.

Text Books:

1. Automation, Production Systems and Computer Integrated Manufacturing: M.P. Groover, Pearson Publication.
2. Automation, Production systems & Computer Integrated Manufacturing, M.P Groover, PHI.
3. CAD/CAM/CIM, P.Radhakrishnan, S.Subramanyam and V.Raju, New Age International
4. Flexible Manufacturing Systems in Practice, J Talavage and R.G. Hannam, Marcell Decker

Reference Books:

1. CAD/CAM Theory and Practice, Zeid and Subramanian, TMH Publication
2. CAD/CAM Theory and Concepts, K. Sareen and C. Grewal, S Chand publication
3. Computer Aided Design and Manufacturing, L. Narayan, M. Rao and S. Sarkar, PHI.
4. Principles of Computer Integrated Manufacturing, S.K.Vajpayee, PHI
5. Computer Integrated Manufacturing, J.A.Rehg and H.W.Kraebber, Prentice Hall

Module-1

1. Introduction to CIM

Initially, machine tool automation started with the development of numerical control in 1950s. In less than 50 years, it is amazing that today's manufacturing plants are completely automated. However, establishment of these plants gave relatively a few varieties of product. At first we define what do we mean by a manufacturing plant? Here, we are considering a several categories of manufacturing (or production) for the various manufacturing plants. Manufacturing can be considered in three broad areas:

(i) Continuous process production,

(ii) Mass production, and

(iii) job-shop production.

Among these three, mass production and job-shop production can be categorized as discrete- item production.

Continuous Process Production

Such type of product flows continuously in the manufacturing system, e.g. petroleum, cement, steel rolling, petrochemical and paper production etc. Equipment used here are only applicable for small group of similar products.

Mass Production

It includes the production of discrete unit at very high rate of speed. Discrete item production is used for goods such as automobiles, refrigerators, televisions, electronic component and so on. Mass production contains the character of continuous process production for discrete products. That's why mass production has realized enormous benefits from automation and mechanization.

Job Shop Production

A manufacturing facility that produces a large number of different discrete items and requires different sequences among the production equipments is called job shop. Scheduling and routine problems are the essential features of job shop. As a result automation has at best been restricted to individual component of job shop. But there have been few attempts in the field of total automation. Physical components of an automated manufacturing system do not include continuous flow process as it only consists of a small percentage of manufacturing system. Mass production of discrete items is included in this category, where segments of production line are largely automated but not the entire line. Job shop facilities have used automated machines, but transfer of work among these machines is a difficult task. Apart from some physical equipment needed, a major component of the automated information that needs to be made available to the manufacturing operation must come from product design. This allows a plant to be automated and integrated. However, manufacturing is more concerned with process design rather than product design.

The characteristic of present world market include higher competition, short product life cycle, greater product diversity, fragmented market, variety and complexity, and smaller batch sizes to satisfy a variety of customer profile. Furthermore, non price factors such as quality of product design innovation and delivery services are the preliminary determinant for the success of product. In today's global arena, to achieve these requirements manufacturing company needs to be flexible, adaptable and responsive to changes and be able to produce a variety of products in short time and at lower cost. These issues attract manufacturing industries to search for some advanced technology, which can overcome these difficulties. Computer integrated manufacturing (CIM), which emerged in 1970, was the outcome of this protracted search.

A CIM System consists of the following basic components:

I. Machine tools and related equipment

II. Material Handling System (MHS)

III. Computer Control System

IV. Human factor/labor

CIM refers to a production system that consists of:

1. A group of NC machines connected together by

2. An automated materials handling system

3. And operating under computer control

In Production Systems CIM is appropriate for batch production as shown in Fig. 1.

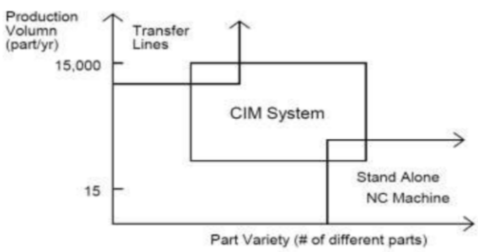


Fig. 1 Application of CIM in Production systems

Transfer Lines: is very efficient when producing "identical" parts in large volumes at high product rates.

Stand Alone: NC machine: are ideally suited for variations in work part configuration.

CIM involves a fundamental strategy of integrating manufacturing facilities and systems in an enterprise through the computer and it's peripheral. CIM can be defined in different ways depending upon its application. CIM involves integration of advanced technologies in various functional units of an enterprise, in an effective manner to achieve the success of the manufacturing industries. A deep knowledge and understanding of all the technology is required for an effective integration. At first integration of advanced manufacturing technology (AMT) is required to get success in the application of CIM. Computers act as a subordinate to the technologies. Computers help, organize, and restore information in order to achieve high accuracy and speed. Their basic aim is to achieve the goals of the objectives within limited available capital. Traditionally, all the efforts were focused on achieving single goal to improve the effectiveness and competitiveness of the organization. But they failed because they didn't satisfy the overall objectives of the manufacturing companies. Hence, a multiple goal selection or mult- criteria optimization is proposed to make the CIM an effective tool to improve the economy of the company. The new approach should be developed for improving the existing multi-criteria optimization mechanism, so that CIM can be realized globally. In addition, global integration approach should be applied to make globally distributed company as a single entity. This concept is applied to make virtual CIM more effective and hence helps in meeting the present global economic circumstances using intelligent manufacturing. Therefore, manufacturing technology should be blended with intelligence. This will help manufacturing enterprise to produce better quality. It will also facilitate the manufacturing equipments to solve problems posed during normal course of the operations. Computer technology is the necessary input to implement automation in manufacturing system. The term CIM denotes the widespread use of computer systems to design the product, to plan the production, control the operation, and perform the business related functions required in the manufacturing firm. True CIM includes integration of these functions in the system that operates throughout the enterprise. Other words are used to identify specific element of the CIM system. For example, computer aided design (CAD) denotes the use of computer system to support the product design system.

Computer aided manufacturing (CAM) denotes the use of computer system to perform the functions related to manufacturing engineering, such as process planning and numerically controlled (NC) part programming. Some computer system performs the CAD and CAM, and so the term CAD/CAM is used to indicate the integration of the two systems into one. In addition to CAD/CAM, CIM also includes the firm business function that is related to manufacturing.

Computer Integrated Manufacturing (CIM) encompasses the entire range of product development and manufacturing activities with all the functions being carried out with the help of dedicated software packages. The data required for various functions are passed from one application software to another in a seamless manner. For example, the product data is created during design. This data has to be transferred from the modeling software to manufacturing software without any loss of data. CIM uses a common database wherever feasible and communication technologies to integrate design, manufacturing and associated business functions that combine the automated segments of a factory or a manufacturing facility. CIM reduces the human component of manufacturing and thereby relieves the process of its slow, expensive and error-prone component. CIM stands for a holistic and methodological approach to the activities of the manufacturing enterprise in order to achieve vast improvement in its performance. This methodological approach is applied to all activities from the design of the product to customer support in an integrated way, using various m ethods, means and techniques in order to achieve production improvement, cost reduction, fulfillment of scheduled delivery dates, quality improvement and total flexibility in the manufacturing system. CIM requires all those associated with a company to involve totally in the process of product development and manufacture. In such a holistic approach, economic, social and human aspects have the same importance as technical aspects. CIM also encompasses the whole lot of enabling technologies including total quality management, business process reengineering, concurrent engineering, workflow automation, enterprise resource planning and flexible manufacturing. The challenge before the manufacturing engineers is illustrated in Fig. 2

Fig 2 Challenges in manufacturing

Manufacturing engineers are required to achieve the following objectives to be competitive in a global context.

• Reduction in inventory

• Lower the cost of the product

• Reduce waste

• Improve quality

• Increase flexibility in manufacturing to achieve imm ediate and rapid response to:

- o Product changes
- o Production changes
- o Process change
- o Equipment change
- o Change of personnel

CIM technology is an enabling technology to meet the above challenges to the manufacturing.

2. Production System:

The production system is the collection of people, equipment, and procedures organized to accomplish the manufacturing operations of a company (or other organization). Production systems can be divided into two categories or levels as indicated in Figure 3

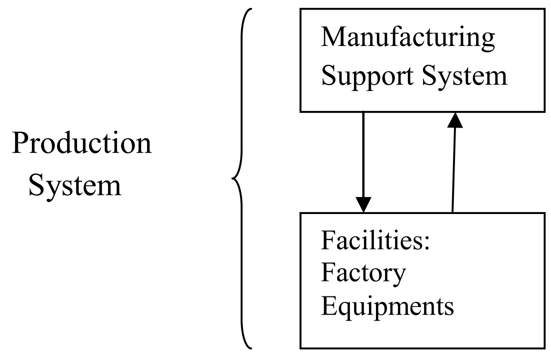


Fig:3 Production System Consisting of Manufacturing Support System and Facilities

1 **. Facilities**. The facilities of the production system consist of the factory, the equipment in the factory, and the way the equipment is organized.

2. **Manufacturing support systems**·. This is the set of procedures used by the company to manage production and to solve the technical and logistics problems encountered in ordering materials, moving work through the factory and ensuring that products meet quality standards. Product design and certain business functions are included among the manufacturing support systems.

In modern manufacturing operations, portions of the production system are automated and/or computerized. However, production systems include people. People make these systems work. In general, direct labor people (blue collar workers) are responsible for operating the facilities, and professional staff people (white collar workers) are responsible for the manufacturing support systems.

Facilities:

The facilities in the production system are the factory, production machines and tooling, material handling equipment, inspection equipment, and the computer systems that control the manufacturing operations. Facilities also include the plant layout, which is the way the equipment is physically arranged in the factory. The equipment is usually organized into logical groupings, and we refer to these equipment arrangements and the workers who operate them as the manufacturing systems in the factory. Manufacturing systems can be individual work cells, consisting of a single production machine and worker assigned to that machine. We more commonly think of manufacturing systems as groups of machines and workers, for example, a production line. The manufacturing systems come in direct physical contact with the parts and/or assemblies being made.

In terms of human participation in the processes performed by the manufacturing system, three basic categories can be distinguished (a) Manual work systems, (b) worker-machine systems and (c) automated systems.

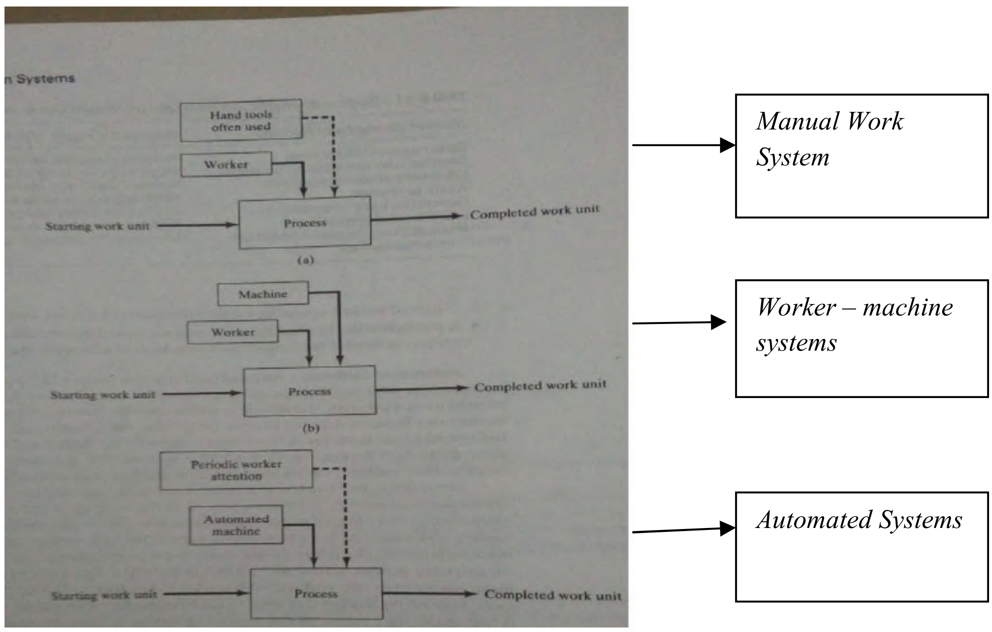
Manual work systems: A manual work system consist of one or more workers performing one or more tasks without the aid of powered tools. Manual material handling tasks are more common activities in manual work systems. Production tasks commonly require the use of hand tools. A hand tool is a small tool that is manually operated by the strength and skill of the human user. Examples are:

- A machinist using a file to round the edges of a rectangular part that has just been milled.
- A material handling worker using a dolly to move cartons in a warehouse.

Worker – machine systems: In a worker machine system , a human worker operates powered equipments such as machines tool or other production machines. This is one of the most widely used manufacturing systems. Worker-machine systems include combination of one or more workers and one or more pieces of equipment. The worker and machines are combined to take advantage of their relative strengths and attributes. Examples are:

- A machinist operating an engine lathe in a tool room to fabricate a part for a customer designed products.
- A fitter and an industrial robot working together in an arc welding work cell.

Automated Systems: An automated system is one in which a process is performed by a machine without the direct participation of a human worker. Automation is implemented using a program of instructions combined with a control system that executes the instructions. There are mainly two levels of automation: Semi-automated and fully automated. A semi automated machine performs a portion of the work cycle under some form of program control and a human worker tends to the machine for the remainder of the cycle by loading and unloading it or performing some other task each cycle. A fully automated machine is distinguished from semi automated counterpart by the capacity to operate for the extended periods of times with no human attention.



Manufacturing Support Systems:

To operate the production facilities efficiently, a company must organize itself to design the processes and equipment, plan and control the production orders, and satisfy product quality requirement. These functions are accomplished by manufacturing support systems- people and procedures by which a company manages its production operations. Most of these support systems do not directly contact the product, but they plan and control its progress through the factory.

Manufacturing support involves a cycle of information-processing activities. The information-processing cycle consisting of four functions: (1) business functions, (2) product design, (3) manufacturing planning. and (4) manufacturing control.

Business Functions*:* The business functions are the principal means of communicating with the customer. They are therefore, the beginning and the end of the information-processing cycle. Included in this category are sales and marketing, sales forecasting, order entry, cost accounting, and customer billing.

The order to produce a product typically originates from the customer and proceeds into the company through the sales and marketing department of the firm. The production order will be in one of the following forms: (l) an order to manufacture an item to the customer's specifications, (2) a customer order to buy one or more of the manufacturer's proprietary products, or (3) an internal company order based on a forecast of future demand for a proprietary product.

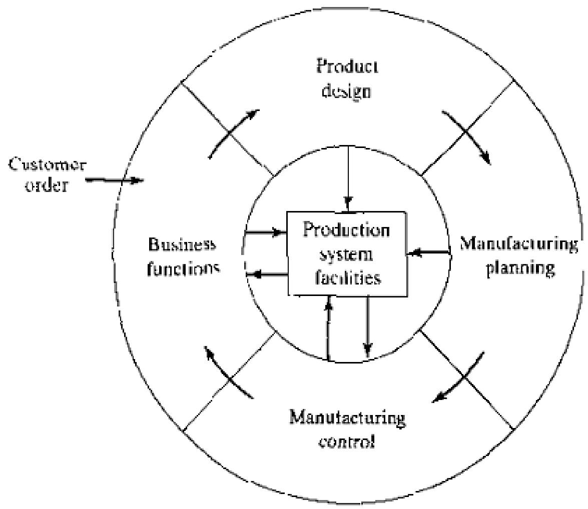
Product Design: If the product is to be manufactured to customer design, the design will have been provided by the customer. The manufacturer's product design department will not be involved. lf the product is to be produced to customer specifications, the manufacturer's product design department may be contracted to do the design work for the product as well as to manufacture it.

Manufacturing Planning: The information and documentation that constitute the product design flows into the manufacturing planning function. The information-processing activities in manufacturing planning include process planning, master scheduling, requirements planning, and capacity planning. Process planning consists of determining the sequence of individual processing and assembly operations needed to produce the part. The manufacturing engineering and industrial engineering departments are responsible for planning the processes and related technical details. Manufacturing planning includes logistics issues, commonly known as production planning. The authorization to produce the product must be translated into the master production schedule. The master production schedule is a listing of the products to be made, when they are to be delivered. and in what quantities. Months are traditionally used to specify deliveries in the master schedule. Based on this schedule, the individual components and sub assemblies that make up each product must be planned. Raw materials must be purchased or requisitioned from storage. Purchased parts must be ordered from suppliers, and all of these items must be planned so that they are available when needed. This entire task is called material requirements planning. In addition, the master schedule must not list more quantities of products than the factory is capable of producing each month with its given number of machines and manpower. A function called capacity planning is concerned with planning the manpower and machine resources of the firm.

Manufacturing Control: Manufacturing control is concerned with managing and controlling the physical operations in the factory to implement the manufacturing plans. The flow of information is from planning to control. Information also flows back and forth between manufacturing control and the factory operations. Included in the manufacturing control function are shop floor control, inventory control, and quality control.

Shop floor control deals with the problem of monitoring the progress of the product as it is being processed, assembled, moved and inspected in the factory. Shop floor control is concerned with inventory in the sense that the materials being processed in the factory are work-in-process inventory. Thus shop floor control and inventory control overlap to some extent. Inventory control attempts to strike a proper balance between the danger of too little inventory (with possible stock-outs of materials) and the carrying cost of too much inventory. It deals with such issues as deciding the right quantities of materials to order and when to reorder a given item when stock is low.

The mission of quality control is to ensure that the quality of the product and its components meet the standards specified by the product designer. To accomplish its mission, quality control depends on inspection activities performed in the factory at various times during the manufacture of the product. Also, raw materials and component parts from outside sources arc sometimes inspected when they are received and final inspection and testing of the finished product is performed to ensure functional quality and appearance.



Reasons for Automation of system:

1. *To increase labour productivity.* Automating a manufacturing operation usually increase production rate and labour productivity This means greater output per hour of labour input.
2. *To reduce labour cost.* Ever-increasing tabor cost has been and continues to be the trend in the world's industrialized societies. Consequently, higher investment in automation has become economically justifiable to replace manual operations. Machines are increasingly being substituted for human labour to reduce unit product cost.
3. *To minimise the effect of labour shortage.* There is a general shortage of labor in many advanced nations and this has stimulated the development of automated operations as a substitute for labour.
4. *To reduce or eliminate routine manual and clerical tasks.* An argument can be put forth that there is social value in automating operations that are routine, boring, fatiguing. Automating such tasks serves a purpose of improving the general level of working condition.
5. *To improve worker safety.* By automating a given operation and transferring the worker from active participation in the process to a supervisory role, the work is made safer.
6. *To improve product quality.* Automation not only results in higher production rates than manual operations; it also performs the manufacturing process with greater unifermity and conformity to quality specifications. Reduction of fraction defect rate is one of the chief benefits of automation.

Automation Principles and Strategies:

1. **USA Principle:**

   The USA Principle is a common sense approach to automation projects. Similar procedures have been suggested in the manufacturing and automation trade literature, but none has a more captivating title than this one. USA stands for

   a. Understand the existing process
   b. Simplify the process
   c. Automate the process

   Understand the Existing Process. The obvious purpose of the first step in the USA approach is to comprehend the current process in all of its details. What arc the inputs? What are the outputs? What exactly happens to the work unit between input and output? What is the function of the process? How does it add value to the product? What are the upstream and downstream operations in the production sequence, and can they be combined with the process under consideration?

   Simplify the Process. Once the existing process is understood, then the search can begin for ways to simplify. This often involves a checklist of questions about the existing process. What is the purpose of this step or this transport? Is this step necessary? Can this step be eliminated? Is the most appropriate technology being used in this step? How can this step be simplified? Are there unnecessary steps in the process that might be eliminated without detracting from function?

Automate the Process. Once the process has been reduced to its simplest form, then automation can be considered. The possible forms of automation include those listed in the ten strategies. An automation migration strategy might be implemented for a new product that has not yet proven itself.

2. Ten Strategies for Automation and Production Systems:

a. **Specialisation of operations**; The first strategy involves the use of special-purpose equipment designed to perform one operation with the greatest possible efficiency. This is analogous to the concept of labor specialization, which is employed to improve labor productivity.

b. **Combined operations**. Production occurs as a sequence of operations. Complex parts may require dozens, or even hundreds, of processing steps. The strategy of combined operations involves .reducing the number of distinct production machines or workstations through which the part must be routed. This is accomplished by performing more than one operation at a given machine, thereby reducing the number of separate machines needed. Since each machine typically involves a setup, setup time can usually be saved as a consequence of this strategy. Material handling effort and non operation time are also reduced. Manufacturing lead time is reduced for better customer service.

c. **Simultaneous operations**. A logical extension of the combined operations strategy is to simultaneously perform the operations that are combined at one workstation. In effect, two or more processing (or assembly) operations are being performed simultaneously on the same workpart, thus reducing total processing time.

d. **Integration of operations**. Another strategy is to link several workstations together into a single integrated mechanism, using automated work handling devices to transfer parts between stations. In effect, this reduces the number of separate machines through which the product must be scheduled. with more than one workstation. several parts can be processed simultaneously, thereby increasing the overall output of the system.

e. **Increased flexibility**. This strategy attempts to achieve maximum utilization of equipment for job shop and medium-volume situations by using the same equipment for a variety of parts or products, It involves the use of the flexible automation concepts . Prime objectives are to reduce setup time and programming time for the production machine. This normally translates into lower manufacturing lead time and less work-in-process.

f. **Improved material handling and storage**. A great opportunity for reducing non-productive lime exists in the use of automated material handling and storage systems. Typical benefits include reduced work-in-process and shorter manufacturing lead times.

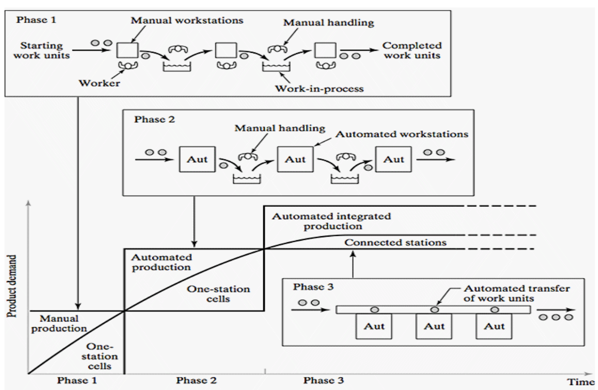
g. **On-line inspection**; Inspection for quality of work is traditionally performed after the process is completed. This means that any poor-quality product has already been produced by the time it is inspected. Incorporating inspection into the manufacturing process permits corrections to the process as the product is being made. This reduces scrap and brings the overall quality of the product closer to the nominal specifications intended by the designer.
h. **Process control and optimization**. This includes a wide range of control schemes intended to operate the individual processes and associated equipment more efficiently. By this strategy, the individual process times can be reduced and product quality improved.
i. **Plant operations control**. Whereas the previous strategy was concerned with the control of the individual manufacturing process, this strategy is concerned with control at the plant level. It attempts to manage and coordinate the aggregate operations in the plant more efficiently. Its implementation usually involves a high level of computer networking within the factory.
j. **Computer-integrated manufacturing (CIM).** Taking the previous strategy one level higher. we have the integration of factory operations with engineering design and the business functions of the firm, ClM involves extensive use of computer applications, computer data bases, and computer networking throughout the enterprise.

Automation Migration Strategy:

Phase 1: Manual production using single-station manned cells operating independently. This is used for introduction of the new product for reasons already mentioned: quick and low-cost tooling to get started.

Phase 2: Automated production using single-station automated cells operating independently. As demand for the product grows, and it becomes clear that automation can be justified, then the single stations are automated to reduce labor and increase production rate. Work units are still moved between workstations manually.

Phase 3: Automated integrated production using a multi station automated system with serial operations and automated transfer of work units between stations. When the company is certain that the product will be produced in mass quantities and for several years, then integration of the single-station automated cells is warranted to further reduce labor and increase production rate.



PLANT LAYOUT :

In addition to the organizational structure, a firm engaged in manufacturing-must also be concerned with its physical facilities. The term plant layout refers to the arrangement of these physical facilities in a production plant. A layout suited to flow-type mass production is not appropriate for job shop production, and vice versa. There are three principal types of plant layout associated with traditional production shops:

1. Fixed-position layout
2. Process layout
3. Product-flow layout

1. Fixed-position layout

In this type of layout, the term "fixed-position" refers to the product. Because of its size and weight, the product remains in one location and the equipment used in its fabrication is brought to it. Large aircraft assembly and shipbuilding are examples of operations in which fixed-position layout is utilized. As product is large, the construction equipment and workers must be moved to the product. This type of arrangement is often associated with job shops in which complex products are fabricated in very low quantities.

2. Process layout

In a process layout, the production machines are arranged into groups according to general type of manufacturing process. The advantage of this type of layout is its flexibility. Different parts, each requiring its own unique sequence of operations, can be routed through the respective departments in the proper order.

3. Product-Flow Layout

Productions machines are arranged according to sequence of operations. If a plant specializes in the production of one product or one class of product in large volumes, the plant facilities should be arranged to produce the product as efficiently as possible with this type of layout, the processing and assembly facilities are placed along the line of flow of the product. As the name implies, this type of layout is appropriate for flow-type mass production. The arrangement of facilities within the plant is relatively inflexible and is warranted only when the production quantities are large enough to justify the investment.

PRODUCTION CONCEPTS AND MATHEMATICAL MODELS

A number of production concepts are quantitative, or require a quantitative approach to measure them.

Manufacturing lead time

Our description of production is that it consists of a series of individual steps: processing and assembly operations. Between the operations are material handling, storage, inspections, and other non productive activities. Let us therefore divide the activities in production into two main categories, operations and non operation elements. An operation on a product (or work part) takes place when it is at the production machine. The non operation elements are the handling, storage, inspections, and other sources of delay. Let us use T_0 to denote the time per operation at a given machine or workstation, and T_{no} to represent the non operation time associated with the same machine. Further, let us suppose that there are n_m separate machines or operations through which the product must be routed in order to be completely processed. If we assume a batch production situation, there are Q units of the product in the batch, A setup procedure is generally required to prepare each production machine for the particular product. The setup typically includes arranging the workplace and installing the tooling and fixturing required for the product. Let this setup time be denoted as T_m.

Given these terms, we can define an important production concept, manufacturing lead time. The manufacturing lead lime (MLT) is the total time required to process a given product (or work part) through the plant. We can express it as follows:

$$MLT = \sum_{i=1}^{n_m} \left(T_{sui} + QT_{oi} + T_{noi} \right)$$

Where i indicates the operation sequence in the processing, i = 1,2, . .n The MLT equation does not include the time the raw work part spends in storage before its turn in the production schedule begins.

Let us assume that all operation times, setup times, and non operation times are equal, respectively then MLT is given by

$$MLT = n_m \left(T_{su} + QT_o + T_{no} \right)$$

For mass production, where a large number of units are made on a single machine, the MLT simply becomes the operation time for the machine after the setup has been completed and production begins. For flow-type mass production, the entire production line is set up in advance. Also, the non operation time between processing steps consists simply of the time to transfer the product (or pan) from one machine or workstation to the next. If the workstations are integrated so that parts are being processed simultaneously at each station, the station with the longest operation time will determine the MLT value. Hence,

$$MLT = n_m \left(Transfer\ time + \ Longst\ T_o \right)$$

In this case, n_m represents the number of separate workstations on the production line.

The values of setup time, operation time, and non operation time are different for the different production situations. Setting up a flow line for high production requires much more time than setting up a general-purpose machine in a job shop. However, the concept of how time is spent in the factory for the various situations is valid.

Problem .1

A certain part is produced in a batch size of 50 units and requires a sequence of eight operations in the plant. The average setup time is 3 h, and the average operation time per machine is 6 min. The average non operation time due to handling, delays, inspections, and so on, is 7 h. compute how many days it will take to produce a batch, assuming that the plant operates on a 7-h shift per day.

Solution:

The manufacturing lead time is computed from

$$MLT = n_m \left(T_{su} + QT_o + T_{no}\right)$$

$$MLT =_m 8\left(3 + 50 \times 0.1 + 7\right) = 120 \;\; Hr$$

Production Rate

The production rate for an individual manufacturing process or assembly operation is usually expressed as an hourly rate (e.g., units of product per hour). The rate will be symbolized as R_p

$$R_P = \frac{1}{T_P}$$

Where T_P is given by

$$T_P = \frac{Batch\ time\ \ per\ Machine}{Q}$$

$$T_P = \frac{\left(T_{su} + QT_o\right)}{Q}$$

If the value of Q represents the desired quantity to be produced, and there is a significant scrap rate, denoted by q, then T_P is given by

$$T_P = \frac{\left(T_{su} + \left(\frac{QT_o}{1-q}\right)\right)}{Q}$$

Components of the operation time

The components of the operation time $T_{o,}$ The operation time is the time an individual workpart spends on a machine, but not all of this time is productive. Let us try to relate the operation time to a specific process. To illustrate, we use a machining operation, as machining is common in discrete-parts manufacturing. Operation lime for a machining operation is composed of three elements: the actual machining time T_{m}, the workpiece handling time T_{h}, and any tool handling time per workpiece T_{h}. Hence,

$$T_o = T_m + T_h + T_{th}$$

The tool handling time represents all the time spent in changing tools when they wear out, changing from one tool to the next for successive operations performed on a turret lathe, changing between the drill bit and tap in a drill-and-tap sequence performed at one drill press, and so on. $T_{,h}$ is the average time per workpiece for any and all of these tool handling activities.

Each of the terms T_m, T_h, and $T_{,h}$ has its counterpart in many other types of discrete-item production operations. There is a portion of the operation cycle, when the material is actually being worked *(T_m)*, and there is a portion of the cycle when either the work part is being handled *(T_k)* or the tooling is being adjusted or changed *($T_{,h}$)*. We can therefore generalize on Eq. (2.8) to cover many other manufacturing processes in addition to machining.

Capacity

The term *capacity,* or *plant capacity,* is used to define the maximum rate of output that a plant is able to produce under a given set of assumed operating conditions. The assumed operating conditions refer to the number of shifts per day (one, two, or three), number of days in the week (or month) that the plant operates, employment levels, whether or not overtime is included, and so on. For continuous chemical production, the plant may be operated 24 h per day, 7 days per week.

Let *PC* be the production capacity (plant capacity) of a given work center or group of work centers under consideration. Capacity will be measured as the number of good units produced per week. Let *W* represent the number of work centers under consideration. A work center is a production system in the plant typically consisting of one worker and one machine. It might also be one automated machine with no worker, or several workers acting together on a production line. It is capable of producing at a rate R_p units per hour. Each work center operates for *H* hours per shift. *H* is an average that excludes time for machine breakdowns and repairs, maintenance, operator delays, and so on. Provision for setup time is also included.

Problem 2

The turret lathe section has six machines, all devoted to production of the same pad. The section operates 10 shifts per week. The number of hours per shift averages 6.4 because of operator delays and machine breakdowns. The average production rate is 17 units/h. Determine the production capacity of the turret lathe section.

Solution:

$$PC = 6(10)(6.4)(17) = 6528 \text{ units/week}$$

If we include the possibility that in a batch production plant, each product is routed through n_m machines, the plant capacity equation must be amended as follows:

$$PC = \frac{(WS_W HR_P)}{n_m}$$

Another way of using the production capacity equation is for determining how resources might be allocated to meet a certain weekly demand rate requirement. Let D_w be the demand rate for the week in terms of number of units required. Replacing PC and rearranging, we get

$$WS_W H = \frac{(D_W n_m)}{R_P}$$

Given a certain hourly production rate for the manufacturing process, indicates three possible ways of adjusting the capacity up or down to meet changing weekly demand requirements:

1. Change the number of work centers, *W,* in the shop. This might be done by using equipment that was formerly not in use and by hiring new workers. Over the long term, new machines might be acquired.
2. Change the number of shifts per week, 5_W. For example, Saturday shifts might be authorized.
3. Change the number of hours worked per shift, W. For example, overtime might be authorized.

In cases where production rates differ, the capacity equations can be revised, summing the requirements for the different products.

$$WS_W H = \sum \frac{(D_W n_m)}{R_P}$$

Problem 3

Three products are to be processed through a certain type of work center. Pertinent data are given in the following table.

Product	*Weekly demand*	*Production rale (units/hi*
1	600	10
2	1000	20
3	2200	40

Determine the number of work centers required to satisfy this demand, given that the plant works 10 shifts per week and there are 6.5 h available for production on each work center for each shift. The value of $n_m = 1$.

Solution:

Product	*Weekly demand*	*ProductionHrs*
1	600	600/10
2	1000	1000/20
3	2200	2200/40
Total production hours required		165

Since each work center can operate (10 shifts/week)(6.5 h) or 65 h/week, the total number of work centers is

$$W = 165/65 = 2.54 \text{ work centers} \approx 3$$

Utilization

Utilization refers to the amount of output of a production facility relative to its capacity. Letting *U* represent utilization, we have

$$U = \frac{Output}{Capacity}$$

Problem 4

A production machine is operated 65 h/week at full capacity. Its production rate is 20 units/hr. During a certain week, the machine produced 1000 good parts and was idle the remaining time.

(a) Determine the production capacity of the machine.

(b) What was the utilization of the machine during the week under consideration?

Solution:

(a) The capacity of the machine can be determined using the assumed 65-h week as follows:

$$PC = 65(20) = 1300 \text{ units/week}$$

(b) The utilization can be determined as the ratio of the number of parts made during productive use of the machine relative to its capacity.

$$U = \frac{Output}{Capacity} = \frac{1000}{1300} = 76.92\%$$

Availability

The availability is sometimes used as a measure of-reliability for equipment. It is especially germane for automated production equipment. Availability is defined using two other reliability terms, the *mean lime between failures* (MTBF) and the *mean time to repair* (MTTR). The MTBF indicates the average length of time between breakdowns of the piece of equipment. The MTTR indicates the average time required to service the equipment and place it back into operation when a breakdown does occur:

$$Availability = \frac{MTBF - MTTR}{MTBF}$$

Work-in-process

Work-in-process (WIP) is the amount of product currently located in the factory that is either being processed or is between processing operations. WIP is inventory that is in the state of being transformed from raw material to finished product. A rough measure of work-in-process can be obtained from the equation

$$WIP = \frac{PC\ U}{S_W H}(MLT)$$

Where WIP represents the number of units in-process.

Costs in Manufacturing: CIM (8)

Fixed and variable costs:

→ Manufacturing costs can be divided into two major categories (i) fixed costs (ii) variable costs.

→ The difference between the two is based on whether the expense varies in relation to the level of output.

→ A fixed cost is one that is constant for any level of production output. e.g cost of factory building, insurance, property taxes, cost of production equipment etc.

→ All of these costs can be expressed as annual costs. Those items that are capital investments (i.e factory building and production equipment) can be converted to their equivalent uniform costs using interest rate factors.

→ A variable cost is one that varies in proportion to the level of production output.

→ As the output increases, variable costs increases. e.g Direct labor costs, raw material, electrical Power to operate etc.

→ The variable cost is directly proportional to the output level.

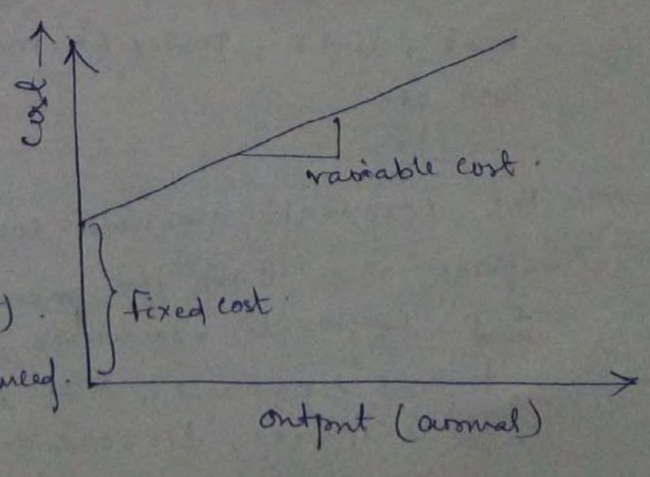
$TC = FC + VC(Q)$.

TC = Total cost (Rs/yr).

FC = Fixed Annual cost (Rs/yr)

VC = Variable cost (Rs/Pc).

Q = Annual Quantity produced. (Pc/yr).



overhead cost, Direct labor cost, Malerial costs: ming

→ classification of costs as either fixed or variable is not always convenient for accountants & finance people

→ An alternative classification separates costs into

(a) Direct labor cost
(b) Malerial cost
(c) overhead cost

→ Direct labor cost is the sum of the wages paid to the people who operate the production machines and perform the processing and assembly operations.

→ The malerial cost is the cost of all the raw malerials that are used to produce the finished Product of the firm.

→ Overhead costs are all the other costs associated with running a manufacturing firm.

→ over head cost can be divided into two catagories
(i) factory overhead (factory expenses)
(ii) corporate overheads costs.

→ Factory over head costs includes the cost of operating the factory other than direct labor and malerials. e.g plant supervision, Line foreman, Mainte-nance crew, Custodial services, Security personnel, attendant, Malerial handling crew, taxes, Insurance, heat, light, power of machines, factory costs, Equipment cost etc.

→ The corporate overhead costs is the cost of running the company other than its manufacturing activities.
e.g Corporate executives, Sales Personnel, Accounting dept, finance department, R&D, Design & Engineering, cost of office spares, Air conditioning etc.

→ $$FOHR = \frac{FOHC}{DLC}.$$

FOHR = factory overhead rate.

FOHC = Annual factory overhead costs (Rs/year).

DLC = Annual direct labor costs (Rs/yr)

$$COHR = \frac{COHC}{DLC}.$$

COHR = corporate overhead rate.

COHC = Annual corporate overhead costs (Rs/yr).

DLC = Annual direct labor costs (Rs/yr).

Eg Suppose that all costs have been compiled for a certain manufacturing firm for last year. The summary is shown in the table below. The company operates two different manufacturing plants plus a corporate head quarters. Determine (a) the factory overhead rate for each plant & (b) the corporate overhead rate.

Expense category	Plant 1 (Rs)	Plant 2 (Rs)	Head Quarters (Rs)	Total Cost (Rs)
Direct labor	800,000	400,000		1,200,000
Material	2,500,000	1,500,000		4,000,000
factory expense	2,000,000	1,100,000		3,100,000
corporate expense			7,200,000	7,200,000
Totals.	5,300,000	3,000,000	7,200,000	15,500,000

Scanned by CamScanner

n in
neral
in

Solⁿ:

(a) $FOHR_1 = \frac{2,000,000}{800,000} = 2.5 = 250\%$.

$FOHR_2 = \frac{1,100,000}{400,000} = 2.75 = 275\%$.

(b) $COHR = \frac{7,200,000}{1,200,000} = 6.0 = 600\%$.

Prob :- A batch of 50 parts is to be processed through the factory for a particular customer. Raw materials and tooling are supplied by the customer. The total time for processing the parts (including setup and direct labor) is 100 hr. Direct labor cost is Rs 9.00 per hr. The factory overhead rate is 125% and the corporate overhead rate is 160%. Compute the cost of the job.

Solⁿ:

(1) The direct labor cost of the job

$= (100)(9.00/hr) = Rs\ 900/-$

(2) The allocated factory overhead charge, at 125% of direct labor

$= 900(1.25) = Rs\ 1125/-$

(3) The allocated corporate overhead charge at 160% of direct labor,

$= 900(1.60) = Rs\ 1440/-$

Total cost $= 900 + 1125 + 1440$

$= Rs\ 3465/-$

for 10% profit.

Total cost $= 1.1 \times 3465$

$= Rs\ 3811.50$.

(2) ... defined ... peripheral

→ Cost of equipment usage

$$UAC = IC\,(A/p,\ i,\ n)$$

UAC = equivalent uniform annual cost (Rs/yr)

IC = Initial cost of the machine (Rs).

$(A/p, i, n)$ = capital recovery factor that converts initial cost at year '0' into a series of equivalent uniform annual year-end values.

i = Annual interest rate.

n = no. of years in the service life of the equipment.

$$(A/p, i, n) = \frac{i(1+i)^n}{(1+i)^n - 1}$$

$$C_o = C_L(1 + FOHR_L) + C_m(1 + FOHR_m)$$

C_o = hourly rate to operate the work center (Rs/hr)

C_L = direct labor wage rate (Rs/hr).

$FOHR_L$ = factory overhead rate for labor.

C_m = machine hourly rate (Rs/hr).

$FOHR_m$ = factory overhead rate applicable to the machine.

e.g

The following data are given for a work center consisting of one worker and one machine:

direct labor rate = Rs 10.00/hr.

Applicable factory overhead rate of labor = 60%.

Capital investment in machine = Rs 100,000/-

Service life of the machine = 8 yrs.

rate of return = 20%.

Salvage value in 8 yr = 0

Applicable factory overhead rate on machine = 50%

The work center will be operated one 8 hr shift, 250 day/yr. Determine the appropriate hourly rate for the work center

Sol:

Labor cost / hr = $C_L(1 + FOHR_L) = 10(1 + 0.60)$

$= Rs\ 16.00/hr$.

Capital recovery factor:

$$(A/P, 20\%, 8) = \frac{0.20(1+0.20)^8}{(1+0.20)^8 - 1} = \frac{0.20(4.2998)}{4.2998 - 1}$$

$$= 0.2606.$$

$$UAC = 100,000(A/P, 20\%, 8)$$

$$= 100,000(0.2606)$$

$$= Rs\ 26,060.00/yr.$$

The number of hours per year = (8 hr/day)(250 day/yr)

$= 2000$ hr/yr.

$$C_m = \frac{26,060}{2000} = Rs\ 13.03/hr.$$

Total cost rate for the work center

$= C_o = 16.00 + C_m(1 + FOHR_m) = 16 + 19$

$= Rs\ 33.55/hr$