SRINIX COLLEGE OF ENGINEERING, BALASORE

DEPARTMENT OF MECHANICAL ENGINEERING

NAME OF THE SUBJECT-

COMPUTER INTRGRATED MANUFACTURING/FLEXIBLE MANUFACTURING SYSTEM

BRANCH-**MECHANICAL ENGINEERING**

SEMESTER-**6TH**

UNIVERSITY-**BPUT, ODISHA**

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COURSE OUTLINES OF MODULE-I

1. Introduction of Manufacturing.
2. Production System.
3. Automation.
4. Automation in Production Systems.
5. Elements of Automation System.
6. Advanced Automation Functions.
7. Levels of automation.
8. Automation Principles and Strategies.
9. Manufacturing Industries.
10. Types of Production Function.
11. Product/Production Relationships.
12. Availability.
13. Production Capacity.
14. Utilization.
15. Cost-Benefit Analysis.
16. Product Design.
17. CAD/CAM/CIM/CAPP.
18. Concurrent Engineering.

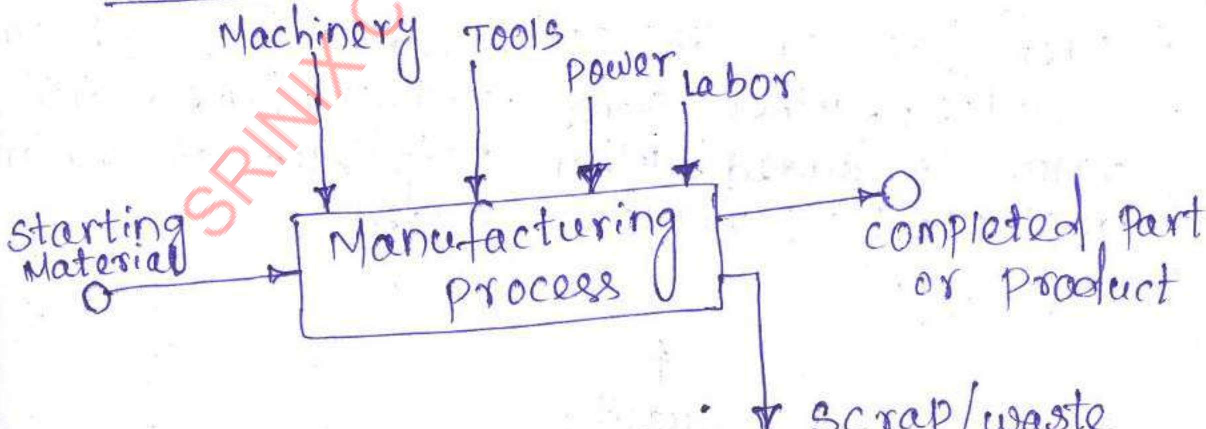
References-

1. **Automation, Production Systems and Computer Integrated Manufacturing: M.P.Groover, Pearson Publication.**

Introduction of Manufacturing

- The word manufacturing derives from two Latin words, manus (hand) and factus (make), so that the combination means made by hand.
- Manufacturing can be defined as the application of physical and chemical processes to alter the geometry, properties and appearance of a given starting material to make parts or products.
- Manufacturing also includes the joining of multiple parts to make assembled products.
- The processes that accomplish manufacturing involve a combination of machinery, tools, power and manual labor.
- Manufacturing is almost always carried out as a sequence of unit operations. A unit operation is a single step in the sequence of steps used to transform a starting material into a final part or product.

Alternative definitions of manufacturing



(Technological process)

Fig.(a)

Economic process

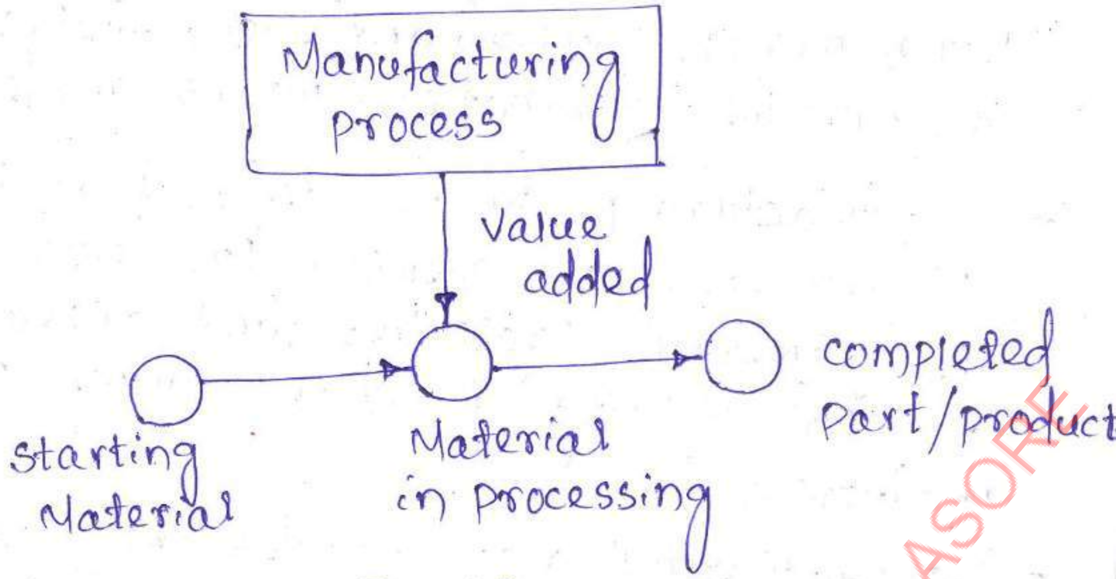
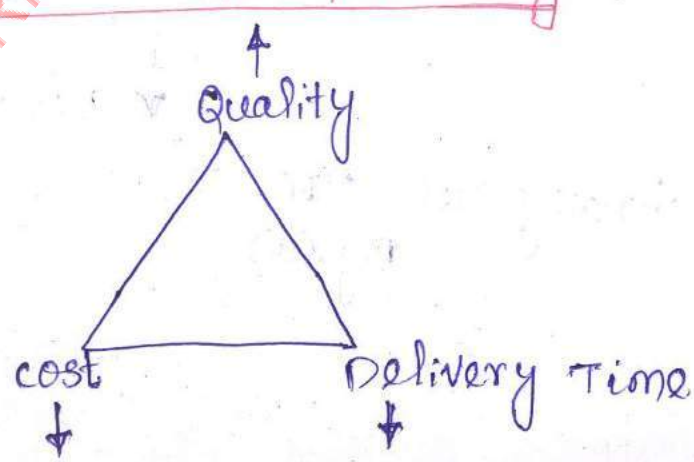


Fig. (b)

- From an economic viewpoint, manufacturing is concerned with the transformation of materials into items of greater value by means of one or more processing and assembly operations as shown in fig. (b).
- The key point is that manufacturing adds to the material by changing its shape or properties or by combining it with other materials that also have been altered.
- When iron ore is converted into steel, value is added. When sand is transformed into glass, value is added. When petroleum is refined into plastic, value is added.

Challenges in Manufacturing



- Manufacturing industries strive to reduce the cost of the product continuously to remain competitive in the face of global competition.
- In addition, there is the need to improve the quality and performance levels on a continuing basis.
- Another important requirement is on time delivery.
- In the content of global outsourcing and long supply chains cutting across several international borders, the task of continuously reducing delivery times is really a difficult task. CIM has several software tools to address the above needs.
- Manufacturing engineers are required to achieve the following objectives to be competitive in a global content.

  (1) Reduction in inventory.
  (2) Lower the cost of the product.
  (3) Reduce waste
  (4) Improve quality
  (5) Increase flexibility in manufacturing to achieve immediate and rapid response to:-
    (i) product changes
    (ii) production changes.
    (iii) process change
    (iv) Equipment change
    (v). change of personnel

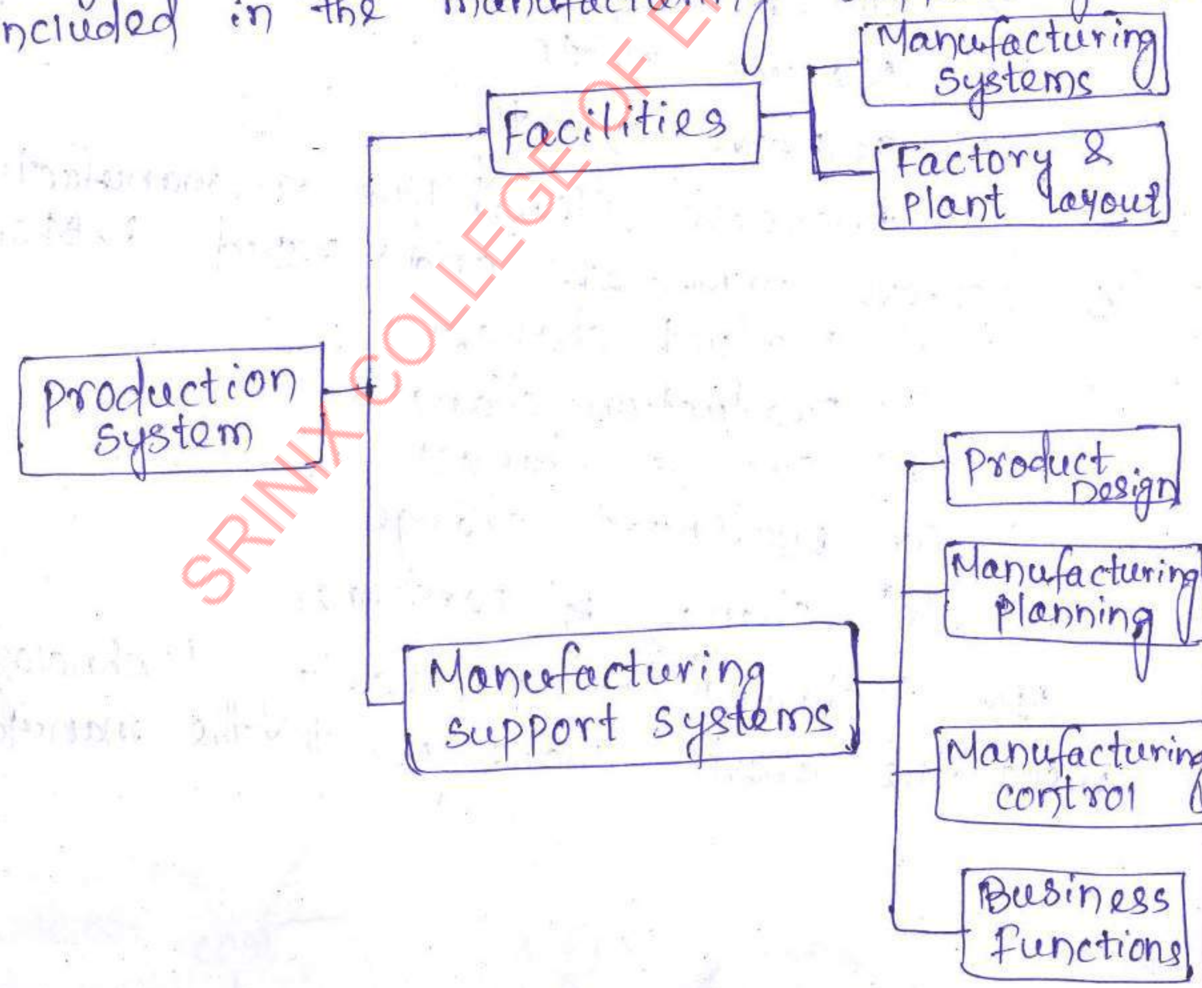
CIM technology is an enabling technology to meet the above challenges to the manufacturing

Production Systems

- A production system is a collection of people, equipment and procedures organized to perform the manufacturing operations of a company.
- It consists of two major components

① Facilities :- The physical facilities of the production system include the equipment, the way the equipment is laid out and the factory in which the equipment is located.

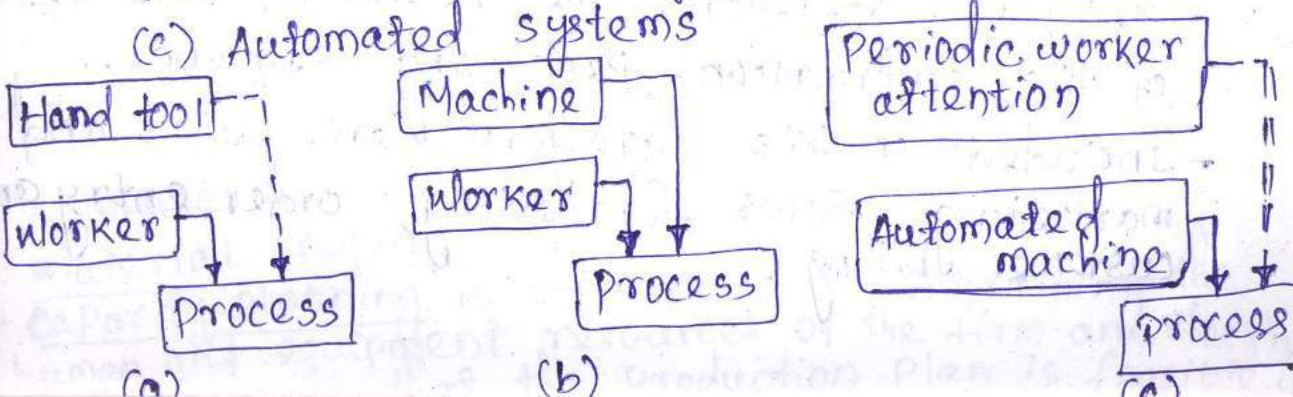
② Manufacturing support systems :- These are the procedures used by the company to manage production and to solve the technical and logistics problems encountered in ordering materials, moving the work through the factory and ensuring that products meet quality standards. product design and certain business functions are included in the manufacturing support systems.



- In modern manufacturing operations, portions of the production system are automated and computerized.
- In addition, 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 consist of the factory, production machines and tooling, material handling equipment, inspection equipment and 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 manufacturing systems which are the logical groupings of equipment and workers that accomplish the processing and assembly operations on parts and products made by the factory.
- In terms of human participation in the processes performed by the manufacturing systems, three basic categories can be distinguished
  - (a) Manual work systems
  - (b) Worker-machine systems
  - (c) Automated systems



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 requirements. These functions are accomplished by manufacturing support systems.

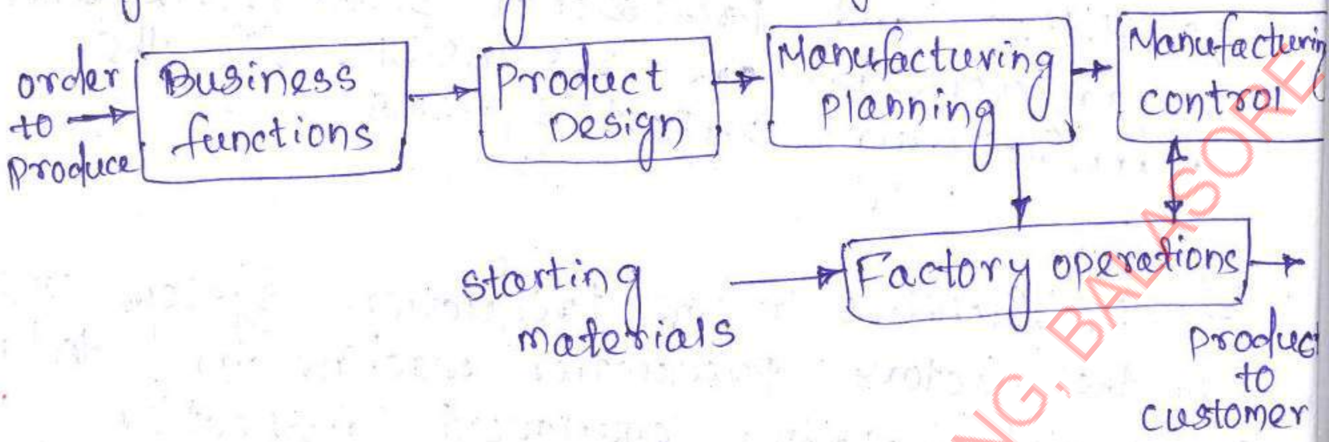


Fig. - Sequence of information-processing activities in a typical manufacturing firm.

- Manufacturing support involves a sequence of activities as shown in fig. The activities consist of four functions that include much information flow and data processing
(1) business functions (2) product design
(3) Manufacturing planning (4) Manufacturing control

Business Functions

- The business functions are the principal means by which the company communicates with the customer.
- They are, therefore, the beginning and the end of the information-processing sequence.
- Included in this category are sales and marketing, sales forecasting, order entry and customer billing.

Product Design

- If the product is manufactured to customer design, the design has been provided by the customer and the manufacturer's product design department is not involved.
- If 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, material requirement planning and capacity planning.
- Process planning consists of determining the sequence of individual processing and assembly operations needed to produce the part.
- Master production schedule, which is a listing of the products to be made, the dates on which they are to be delivered and the quantities of each. Based on this master schedule, the individual components and subassemblies that make up each product must be scheduled.
- Raw materials must be purchased or requistioned from storage, parts must be ordered from suppliers and all of these items must be planned so they are available when needed. The computations for this planning are made by material requirements planning.
- Capacity planning is concerned with determining the human and equipment resources of the firm and checking ... sure that the production plan is feasible.

Manufacturing Control

- Manufacturing control is concerned with managing and controlling the physical operations in the factory to implement the manufacturing plans.
- 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.
- Inventory control attempts to strike a proper balance between the risk of too little inventory 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 function 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.
- Quality control also includes data collection & problem-solving approaches to address process problems related to quality such as statistical process control (SPC) & Six Sigma.

Automation

- Automation describes a wide range of technologies which reduce human intervention in processes. Human intervention is reduced by pre-determining decision criteria subprocess relationships and related actions and embodying those predeterminations in machines.
- Automation defines as the creation and application of technology to monitor and control the production and delivery of products and services.
- Automation is a technology concerned with the operation of mechanical, electronic and computer based systems to operate and control production.

This technology includes

(1) Automatic machine tools to process parts
(2) Automatic assembly machines
(3) Industrial robots
(4) Automatic material handling and storage systems.
(5) Automatic inspection systems & quality control.
(6) Feedback control and computer process control.
(7) computer system for planning data collection and decision making to support manufacturing activities.

Mechanization
+
control Technology
↓
Automation

Reasons for Automation.

① Increase labor productivity :- This means greater output per hour of labor input.

② Reduce labor cost :- Machines are increasingly being substituted for human labor to reduce unit product cost.

③ Mitigate the effects of labor shortages :- There is a general shortage of labor in many advanced nations and this has stimulated the development of automated operations as a substitute for labor.

④ Reduce or eliminate routine manual and clerical tasks.

⑤ Improve worker safety

⑥ Improve product quality.

⑦ Reduce manufacturing lead time :- Automation helps reduce the elapsed time between customer order and product delivery, providing a competitive advantages to the manufacturer for future orders. By reducing manufacturing lead time, the manufacture also reduces work-in-process inventory.

⑧ Accomplish processes that cannot be done manually

Advantages of automation

(1) Increased predictability.
(2) Improved robustness (consistency).
(3) Increased consistency of output.
(4) Reduced direct human labor costs & expenses.
(5) Reduced cycle time.
(6) Increased accuracy.
(7) Relieving humans of monotonously repetitive work.

(8) Required work in development, deployment, maintenance and operation of automated processes.

(9) Increased human freedom to do other things.

(10) Relieving humans of dangerous work stresses and occupational injuries (fewer strained backs from lifting heavy objects)

(11) Removing humans from dangerous environments (fire, volcanoes, nuclear facilities)

Disadvantages of automation

(1) High initial cost.

(2) Faster production without human intervention can mean faster unchecked production of defects where automated processes are defective.

(3) Scaled-up capacities can mean scaled-up problems when systems fail - releasing dangerous toxins, forces, energies etc at scaled-up rates

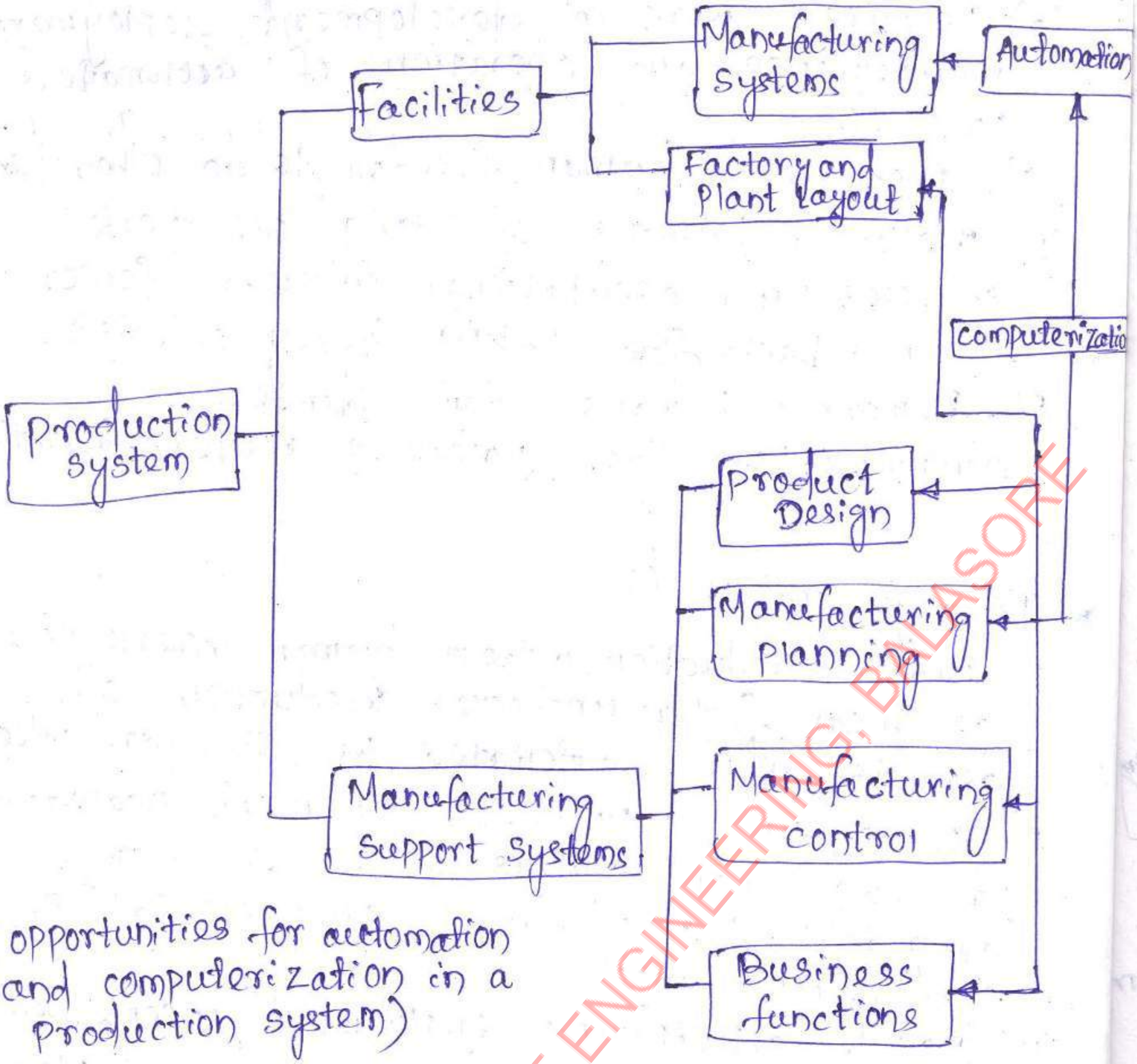
(4) People anticipating employment income may be seriously disrupted by others deploying automation where no similar income is readily available.

Automation in Production systems

The automated elements of the production system can be separated into two categories

(1) Automation of the manufacturing systems in the factory.

(2) Computerization of the manufacturing support systems.

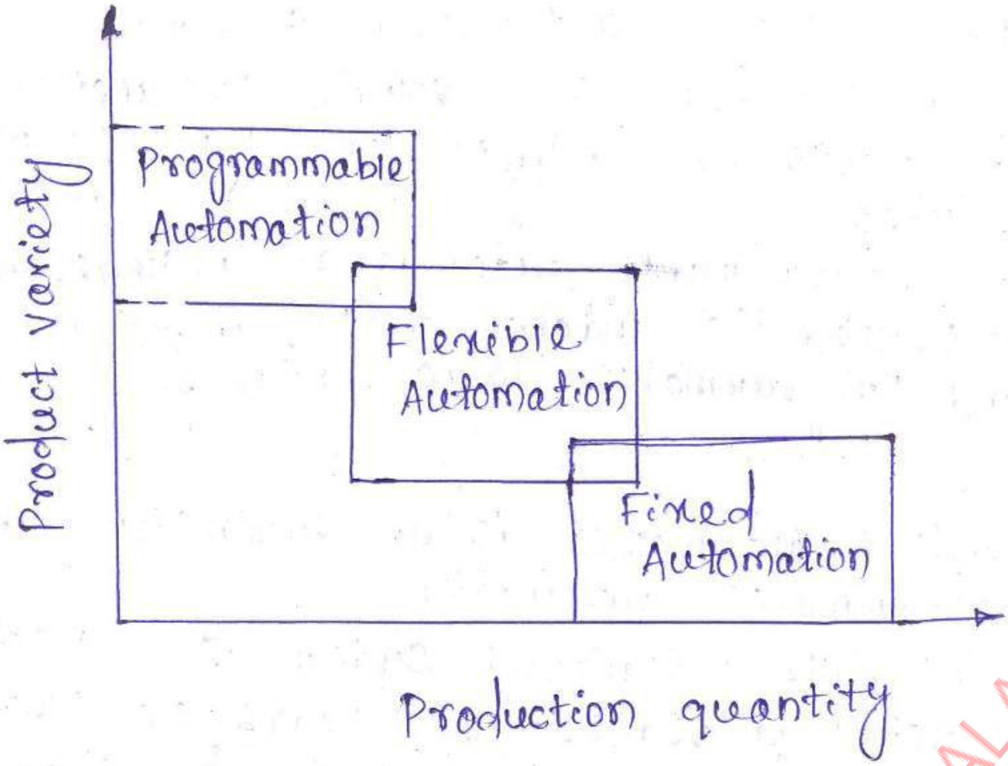


(opportunities for automation and computerization in a production system)

- Automated manufacturing systems can be classified into three basic types.
  (1) Fixed Automation (Hard Automation)
  (2) programmable Automation (Soft Automation)
  (3) Flexible Automation (Soft Automation)

Fixed Automation

- Fixed automation is a system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration.
- Each operation in the sequence is usually simple.
- Typical features of fixed automation are
  (1) high initial investment for custom-engineered equipment.
  (2) high production rates



(3) inflexibility of the equipment to accommodate product variety.

Ex:- Machining transfer lines and automated assembly machines.

Programmable Automation

- In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accomodate different product configurations. The operation sequence is controlled by a program, which is a set of instructions coded so that they can be read and interpreted by the system.
- New programs can be prepared and entered into the equipment to produce new products.
- Some of the features that characterize programmable automation include

(1) high investment in general-purpose equipment.
(2) lower production rates than fixed automation
(3) Flexibility to deal with variations and changes in product configuration.
(4) high suitability for batch production.

- Programmable automated systems are used in low and medium volume production.
- The parts or products are typically made in batches.

Ex:- programmable automation include numerically controlled (NC) machine tools, industrial robots and programmable logic controllers.

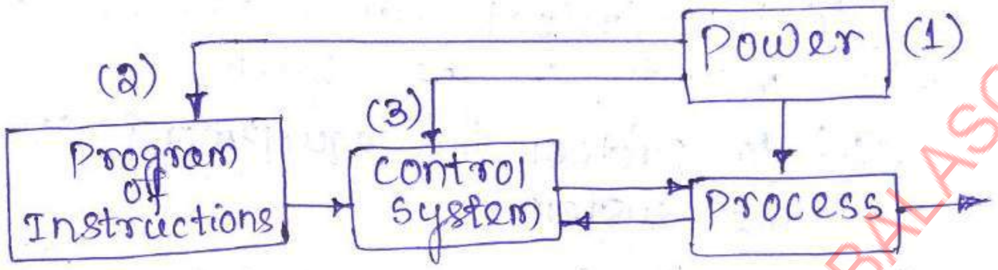
Flexible Automation

- Flexible Automation is an extension of programmable automation.
- A flexible automated system is capable of producing a variety of parts or products with virtually no time lost for changeovers from one design to the next.
- There is no lost production time while reprogramming the system and altering the physical setup (tooling, fixtures, machine settings)
- Features of flexible automation include
  (1) high investment for a custom-engineered system
  (2) continuous production of variable mixtures of parts or products
  (3) Medium production rates
  (4) Flexibility to deal with product design variations.

Ex:- Flexible manufacturing systems that perform machining processes.

Basic Elements of an Automated System

- An automated system consists of three basic elements
  (1) power to accomplish the process and operate the system
  (2) a program of instructions to direct the process
  (3) a control system to actuate the instructions.

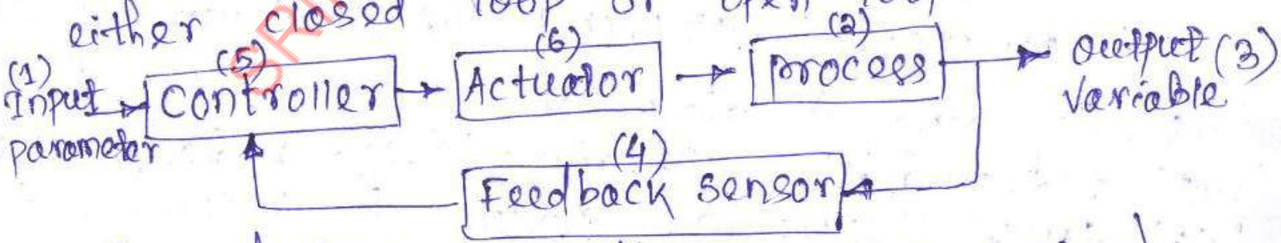


<u>Power for the process</u> :- In production the term process refers to the manufacturing operation that is performed on a work unit.

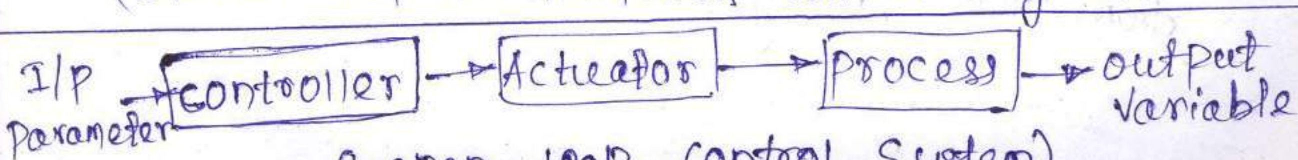
<u>Program of Instructions</u> :- The actions performed by an automated process are defined by a program of instructions.

<u>Control system</u> :- The control element of the automated system executes the program of instructions. The control system causes the process to accomplish its defined function which is to perform some manufacturing operation.

- The controls in an automated system can be either closed loop or open loop.



(Closed loop or Feedback control system)



(open-loop control system)

Advanced Automation Functions

Advanced automation functions include the following (1) safety monitoring (2) Maintenance and repair diagnostics (3) error detection and recovery.

Safety Monitoring :- There are two reasons for providing an automated system with a safety monitoring capability.

(1) to protect human workers in the vicinity of the system.

(2) to protect the equipment comprising the system.

- safety monitoring means more than the conventional safety measures taken in a manufacturing operation, such as protective shields around the operation or the kinds of manual devices that might be utilized by human workers, such as emergency stop buttons.
- safety monitoring in an automated system involves the use of sensors to track the system's operation and identify conditions and events that are unsafe or potentially unsafe.
- The safety monitoring system is programmed to respond to unsafe conditions in some way.
- possible responses to various hazards include one or more of the following
  (1) completely stopping the automated system.
  (2) sounding an alarm
  (3) reducing the operating speed of the process
  (4) taking corrective actions to recover from the safety violation.

Maintenance and Repair Diagnostics

- Modern automated production systems are becoming increasingly complex and sophisticated, complicating the problem of maintaining and repairing them.
- Maintenance and repair diagnostics refers to the capabilities of an automated system to assist in identifying the source of potential or actual malfunctions and failures of the system.
- Three modes of operation are typical of a modern maintenance and repair diagnostics subsystem :

(1) Status monitoring :- In the status monitoring mode the diagnostic subsystem monitors and records the status of key sensors and parameters of the system during normal operation.

(2) Failure diagnostics :- The failure diagnostics mode is invoked when a malfunction or failure occurs.

(3) Recommendation of repair procedure :- In the third mode of operation, the subsystem recommends to the repair crew the steps that should be taken to effect repairs.

Error Detection and Recovery

- The error detection step uses the automated system's available sensors to determine when a deviation or malfunction has occurred, interpret the sensor signals and classify the error.
- In analyzing a given production operation, the possible errors can be classified into one of three general categories
(1) random errors (2) Systematic errors
(3) aberrations.

The ~~two~~ main design problems in error detection are (1) anticipating all of the possible errors that can occur in a given process
(2) specifying the appropriate sensor systems and associated interpretive software so that the system is capable of recognizing each error.

* Possible Errors in the Automated Machining cell

Category	Possible Errors
1- Machine & process	– Loss of power, power overload, thermal deflection, no coolant, chip fouling, defective part.
2- Cutting tools	– Tool breakage, tool wear-out, Vibration, wrong tool.
3- Workholding fixture	– Part not in fixture, clamps not actuated, part deflection during machining, chips causing location problems.
4- Part storage unit	– Oversized or undersized work part
5- Load/unload robot	– Improper grasping of work part, dropping of work part, no part present at pickup.

- Error recovery is concerned with applying the necessary corrective action to overcome the error and bring the system back to normal operation.
- Generally a specific recovery strategy and procedure must be designed for each different error. The types of strategies can be classified as follows :-

(1) Make adjustments at the end of the current work cycle.
(2) Make adjustments during the current cycle.
(3) Stop the process to invoke corrective action.
(4) Stop the process & call for help.

* Error recovery in an automated Machining cell

Error detected	Possible corrective Action to Recover
1- Part dimensions deviating due to thermal deflection of machine tool	- Adjust coordinates in part program to compensate.
2- Chatter (tool vibration)	- Increase or decrease cutting speed to change harmonic frequency.
3- Cutting tool failed	- Replace cutting tool with another sharp tool.
4- Starting work part is oversized	- Adjust part program to take a preliminary machining pass across the work surface.

Levels of Automation

- Automated systems can be applied to various levels of factory operations. Five levels of automation can be given below

① Device level :- This is the lowest level in the automation hierarchy. It includes the actuators, sensors and other hardware components that comprise the machine level. The devices are combined into the individual control loops of the machine, for ex- the feedback control loop for one axis of a CNC machine or one joint of an industrial robot.

Level		Description/ Example
5	Enterprise level	corporate information system
4	Plant level	production system
3	Cell or system level	Manufacturing system - groups of machines
2	Machine level	Individual machines
1	Device level	Sensors, actuators, other hardware elements

Flow of data

(Five levels of automation & control in manufacturing)

② **Machine level** :- Hardware at the device level is assembled into individual machines. Ex- include CNC machine tools and similar production equipment, industrial robots, powered conveyors and automated guided vehicles. control functions at this level include performing the sequence of steps in the program of instructions in the correct order and making sure that each step is properly executed.

③ **Cell or system level** :- This is the manufacturing cell or system level, which operates under instructions from the plant level. A manufacturing cell or system is a group of machines or workstations connected and supported by a material handling system, computer and other equipment appropriate to the manufacturing process. production lines are included in this level. Functions include part dispatching and machine loading, coordination among machines and material handling system and collecting and evaluating inspection data.

(4) Plant level :- This is the factory or production systems level. It receives instructions from the corporate information system and translates them into operational plans for production. Likely functions include order processing, process planning, inventory control, purchasing, material requirements planning, shop floor control and quality control.

(5) Enterprise level :- This is the highest level, consisting of the corporate information system. It is concerned with all of the functions necessary to manage the company, marketing & sales, accounting, design, research, aggregate planning and master production scheduling. The corporate information system is usually managed using Enterprise Resource Planning.

Automation principles and strategies

(1) The USA principle
(2) Ten strategies for Automation and Process Improvement.
(3) An automation Migration strategy.

* The USA principle :-

- the USA principle is a commonsense approach to automation and process improvement projects.
- USA stands for (1) understand the existing process
(2) Simplify the process
(3) automate the process

Understand the existing process

The first step in the USA approach is to comprehend the current process in all of its details.

(1) What are the inputs?

(2) What are the outputs ?
(3) What exactly happens to the work unit betn input and output ?
(4) What is the function of the process ?
(5) How does it add value to the product ?
(6) What are the upstream and downstream operations in the production sequence and can they be combined with the process under consideration ?

- Mathematical models of the process may also be useful to indicate relationships between input parameters and output variables.
(1) What are the important output variables ?
(2) How are these output variables affected by inputs to the process, such as raw material properties, process setting, operating parameters and environmental conditions ?

- This information may be valuable in identifying what output variables need to be measured for feedback purposes and in formulating algorithms for automatic process control.

Simplify the process

- Once the existing process is understood, then the search begins for ways to simplify.
(1) What is the purpose of this step or this transport ?
(2) Is the step necessary ?
(3) Can it be eliminated ?
(4) Does it use the most appropriate technology ?
(5) How can it be simplified ?
(6) 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.

* Ten strategies for Automation and Process Improvement :-

① Specialization 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 specialization of labor, which is employed to improve labor productivity.

② 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.

③ Simultaneous operations :- A logical extension of the combined operations strategy is to simultaneously perform the operations that are combined at one workstation.

④ Integration of operations :- This strategy involves linking several workstations together into a single integrated mechanism, using automated work handling devices to transfer parts betⁿ stations. In effect, this reduces the number of separate work centers through which the product must be scheduled.

⑤ Increased flexibility :- This strategy attempts to achieve maxᵐ utilization of equipment for job shop and medium-volume situations by using the same equipment for a variety of parts or products.

(6) Improved material handling & storage ÷ A great opportunity for reducing non-productive time exists in the use of automated material handling and storage systems. Typical benefits include reduced work-in-process, shorter manufacturing lead times and lower labor costs.

(7) On-line inspection ÷ Inspection for quality of work is traditionally performed after the process is completed. This reduces scrap and brings the overall quality of the product closer to the nominal specifications intended by the designer.

(8) 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 can be improved.

(9) Plant operations control ÷ It attempts to manage and coordinate the aggregate operations in the plant more efficiently. Its implementation involves a high level of computer networking within the factory.

(10) Computer-integrated manufacturing (CIM) ÷ CIM involves extensive use of computer systems, database and networks throughout the enterprise to integrate the factory operations and business functions.

Automation Migration Strategy

A typical automation migration strategy is the following :-

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 betn workstations manually.

Phase 3 : Automated integrated production using a multi-station automated system with serial operations and automated transfer of work units betn 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.

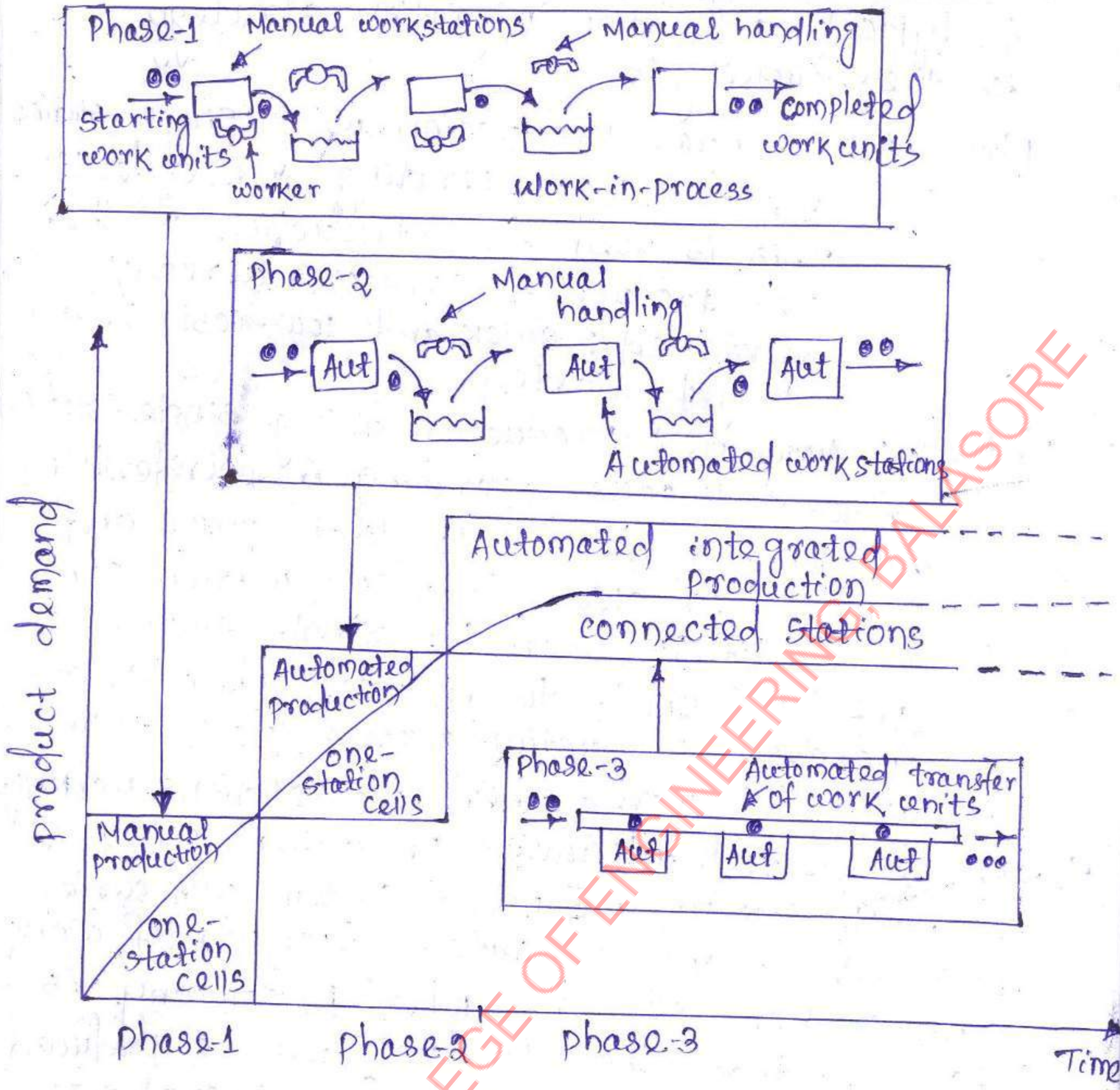


Fig :- A typical automation migration strategy.

Phase-1 → Manual production with single independent workstations

Phase-2 → Automated production stations with manual handling betn stations.

Phase-3 → Automated integrated production with automated handling betn stations

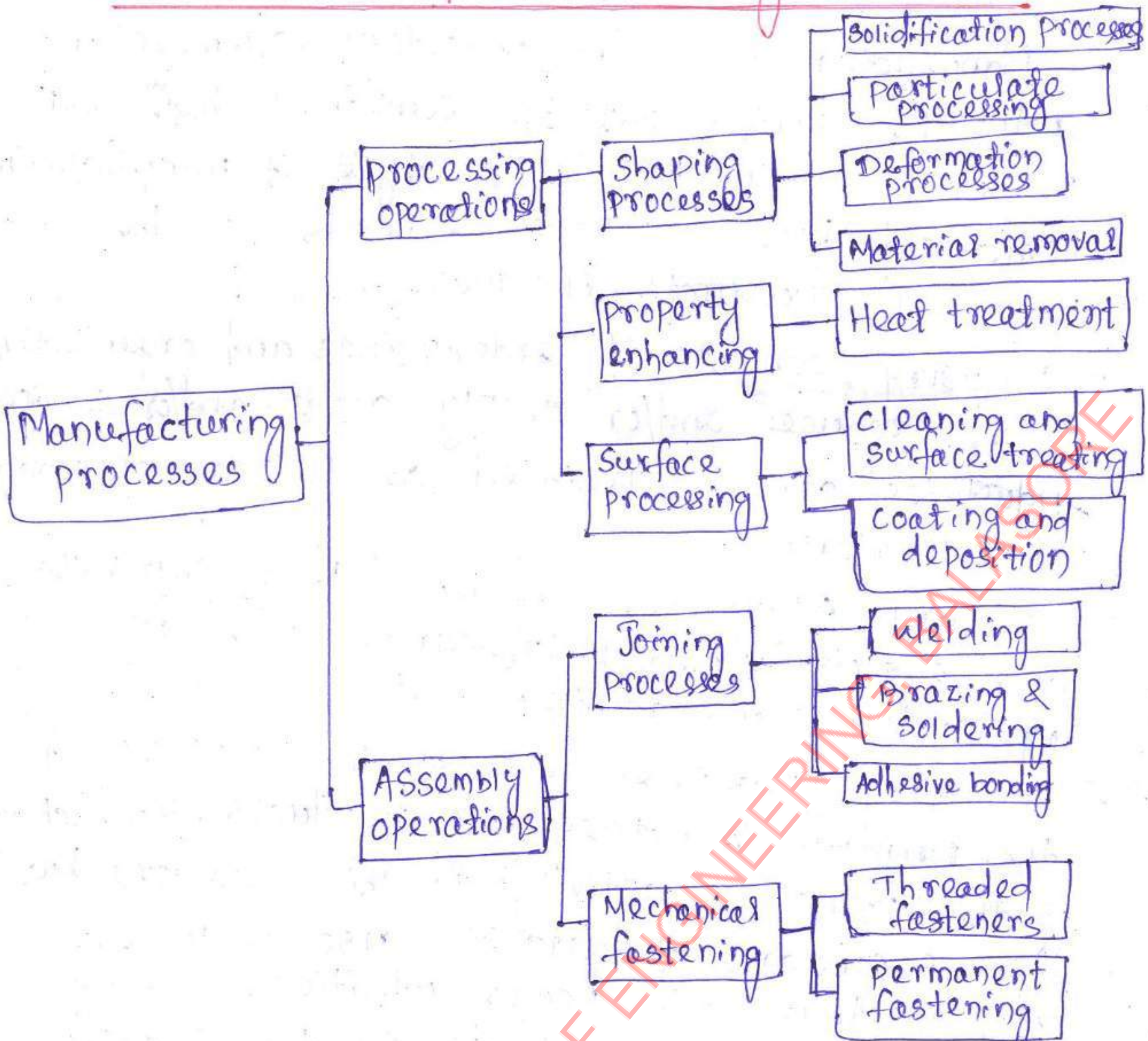
(Aut = Automated workstation)

Manufacturing Industries

- Manufacturing is an important commercial activity, carried out by companies that sell products to customers. The type of manufacturing performed by a company depends on the kinds of products it makes.
- Industry consists of enterprises and organizations that produce and/or supply goods and/or services.
- Industries can be classified as primary, secondary and tertiary.
- primary industries are those that cultivate and exploit natural resources such as agriculture and mining.
- secondary industries convert the outputs of the primary industries into products. Manufacturing is the principal activity in this category, but the secondary industries also include construction and power utilities.
- Tertiary industries constitute the service sector of the economy.

Primary	Secondary	Tertiary (service)
Agriculture	Aerospace	Banking
Forestry	Automotive	Communications
Fishing	Basic Metals	Education
Mining	Building Materials	Entertainment
petroleum	Electronics	Hotels
	Food processing	Health and medical services
	paper	Information
	petroleum refining	Insurance
	pharmaceuticals	Real estate
	power utilities	Tourism
	Textiles	wholesale trade
	Wood & furniture	Restaurants
	computers	Repair & Maintenance
		Legal Services

Classification of manufacturing Processes



Types of production function

- The functional relationship under given technology betn i/p and o/p per unit of time.

$$\text{Quantity of o/p } (Q) = f(L, K)$$

where K = Amount of capital
L = Amount of labor used.

- There are two types of production function
  1. Short-run production functions
  2. Long-run production functions

* Short-run production functions :- At what rate the o/p of a good changes when only one I/p is varied and other I/ps used in production of that good are kept fixed. The resulting behaviour of output is termed as returns to a factor.

* Long-run production functions :- At whole rate of output of a good changes when all the inputs used in production of that good are changes simultaneously and in the same proportion. The resulting behaviour of output is termed as returns to scale.

Product/ production Relationships

- It is instructive to recognize that there are certain product parameters that are influential in determining how the products are manufactured. consider the following parameters
(1) production quantity (2) product variety
(3) product complexity (of assembled products)
(4) part complexity.

* Production quantity and product variety :-

Q = Production quantity
P = product variety

Let each part or product style be identified using the subscript j, so that

Q_j = annual quantity of style j.

Q_f = total quantity of all parts or products made in the factory.

$$Q_f = \sum_{j=1}^{P} Q_j$$

where P = total number of different part or product styles and j is a subscript to identify products.

- P refers to the different product designs or types that are produced in a plant.
- Hard product variety is when the products differ substantially. Soft product variety is when there are only small differences betn products.
- The parameter 'p' can be divided into two levels as in a tree structure. P_1 & P_2. P_1 refers to the number of distinct product lines produced by the factory and P_2 refers to the number of models in a product line. P_1 represent hard product variety and P_2 soft variety. The total number of product models is given by

$$P = \sum_{j=1}^{P_1} P_{2j}$$

where the subscript j identifies the product line, $j = 1, 2, \cdots P_1$.

(EX-1) (Product lines and product Models)

A company specializes in home entertainment products. It produces only TVs and audio systems. In its TV line it offers 15 different models and in its audio line it offer 5 models. Calculate the total number of product models.

Ans:- Given data

$P_1 = 2$, $P_2 = 15$ (for TVs) & $P_2 = 5$ (for audio systems)

$$P = \sum_{j=1}^{P_1} P_{2j} = \sum_{j=1}^{2} 15 + 5 = 20$$

* Product and part complexity

- How complex is each product made in the plant? Product complexity is a complicated issue. It has both qualitative and quantitative aspects.
- For a manufactured component, a possible measure of part complexity is the number of processing steps required to produce it.

Typical Number of separate components in various assembled products

Product	Approx. number of components
1- Ball Bearing (Modern)	20
2- Rifle (1800)	50
3- Sewing Machine (1875)	150
4- Bicycle chain	300
5- Bicycle (Modern)	750
6- Automobile (Modern)	10,000
7- Commercial Airplane (1930)	100,000
8- Commercial Airplane (Modern)	4,000,000

Typical No. of processing operations required to fabricate various parts

Part	No. of processing operations	Typical processing operations used
1- Plastic Molded part	01	Injection molding
2- Washer (stainless steel)	01	Stamping
3- Washer (Plated steel)	02	stamping, electroplating
4- pump shaft	10	Machining (from bar stock)
5- pump housing	20	casting, machining
6- V-6 engine block	50	casting, machining
7- Integrated circuit chip	100	photolithography, various thermal & chemical processes

- complexity of an assembled product can be defined as the number of distinct components.

Let n_p = the number of parts per product

- processing complexity of each part can be defined as the number of operations required to make it,

Let n_0 = the number of operations or processing steps to make a part.

The total number of manufacturing operations performed by the factory is given by

$$\boxed{n_{of} = PQ\, n_p n_0}$$

*(EX-2) (A Production system problem)

Suppose a company has designed a new product line and is planning to build a new plant to manufacture this product line. The new line consists of 100 different product types and for each product type the company wants to produce 10,000 units annually. The products avg. 1,000 components each and the avg. number of processing steps required for each component is 10. All parts will be made in the factory. Each processing step takes an avg. of 1 min. Determine (a) how many products (b) how many parts (c) how many production operations will be required each year (d) how many workers will be needed in the plant if each worker works 8 hr per shift for 250 days/yr. (2000 hr/yr)?

Ans ÷ (a) The total number of units to be produced by the factory annually is given by $Q = PQ$

$= 100 \times 10,000 = 1,000,000$ products

(b) The total number of part, produced annually is

$n_{pf} = PQn_p = 1,000,000 \times 1,000$

$= 1,000,000,000$ parts

(c) The number of distinct production operation is

$n_{of} = PQn_p n_o = 1,000,000,000 \times 10$

$= 10,000,000,000$ operations

(d) Total Time (TT) to perform these operations if each operation takes 1 min ($\frac{1}{60}$ hr).

$TT = 10,000,000,000 \times \left(\frac{1}{60}\right)$

$$\boxed{TT = 166,666,667 \text{ hr}}$$

If each worker works 2000 hr/yr. then the total number of workers required is

$$w = \frac{166,666,667}{2000} = 83,333 \text{ workers}$$

Production Performance Metrics

① **Cycle Time Analysis** ÷ For a unit operation, the cycle time (T_c) is the time that one work unit spends being processed or assembled. It is the time interval between when one work unit begins processing and when the next unit begins. T_c is the time an individual part spends at the machine but not all of this is processing time.

→ T_c consists of

(i) actual processing time
(ii) work part handling time
(iii) tool handling time per workpiece.

$$T_c = T_0 + T_h + T_t$$

where T_c = cycle time, min/pc
T_0 = time of the actual processing or assembly operation min/pc
T_h = handling time, min/pc
T_i = Avg. tool handling time, min/pc.

② **Production Rate** ÷ The production rate for a unit production operation is usually expressed as an hourly rate i.e work units completed per hour (pc/hr).

$$R_p = \frac{60}{T_p}$$

where
T_p = avg. production time min/pc
R_p = hourly production rate pc/hr

$$R_p \rightarrow R_c = \frac{60}{T_c}$$

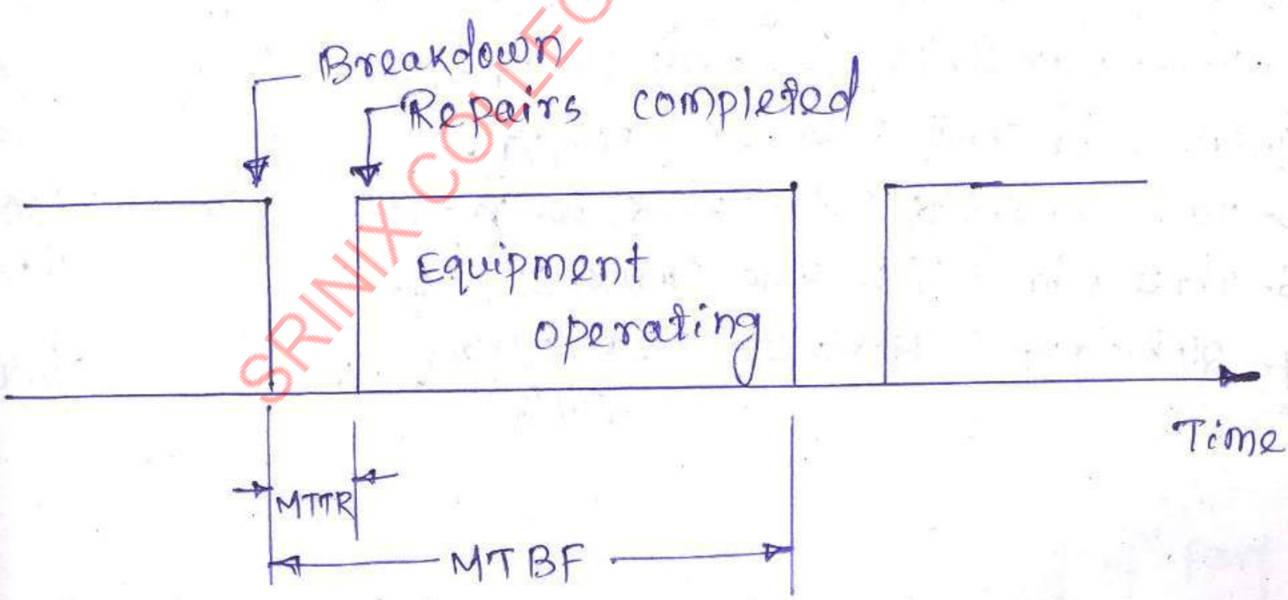
where R_c = operation cycle rate of the machine pc/hr.

Equipment Reliability - Availability

- The most useful measure of reliability is availability, defined as the uptime proportion of the equipment i.e, the proportion of time that the equipment is capable of operating relative to the scheduled hours of production.
- The measure is especially appropriate for automated production equipment.
- Availability can also be defined using two other reliability terms, mean time between failures (MTBF) and mean time to repair (MTTR). MTBF is the average length of time the piece of equipment runs betn breakdowns and MTTR is the average time required to service the equipment and put it back into operation when a breakdown occurs.

$$A = \frac{MTBF - MTTR}{MTBF} \quad (A = \text{Availability})$$

- Availability is expressed as a percentage.



(Time scale showing MTBF and MTTR used to define availability A)

Production capacity

- It is defined as the maximum rate of output that a production facility (Production line or group of machines) is able to produce under a given set of assumed operating conditions.
- The production facility usually refers to a plant or factory and so the term Plant capacity is often used for this measure.

$$PC = n H_{pc} R_p$$

where PC = Production capacity pc/period
n = number of machines
H_{pc} = the number of hours in the period being used to measure production capacity (plant capacity).

Number of Hours of Plant operation for various periods and operating conditions

Operating conditions	Week	Month	Year
1- one 8-hr shift, 5 days/week, 50w/yr	40	167	2000
2- Two 8-hr shifts, 5 days/week, 50w/yr	80	333	4000
3- Three 8-hr shifts, 5days/week, 50w/yr	120	500	6000
4- one 8-hr shift, 7 days/week, 50w/yr	56	233	2800
5- Two 8-hr shifts, 7 days/week, 50w/yr	112	467	5600
6- Three 8-hr shifts, 7 days/week, 50w/yr	168	700	8400
7- 24 hr/day, 7 days/week, 52 weeks/year (24/7)	168	728	8736

* (EX-3) - (Production capacity)

The automatic lathe department has 5 machines, all devoted to the production of the same product. The machines operate two 8-hr shifts, 5 days/week, 50 weeks/year. production rate of each machine is 15 unit/hr. Determine the weekly production capacity of the automatic lathe department.

Ans ÷

$$PC = n H_{PC} R_P$$

$$= 5 \times 80 \times 15$$

$$PC = 6{,}000 \text{ pc/week}$$

Utilization

- Utilization is the proportion of time that a productive resource (production machine) is used relative to the time available under the definition of plant capacity.

$$U_i = \sum_j f_{ij}$$

where U_i = utilization of machine i

f_{ij} = the fraction of time during the available hours that machine i is processing part style j.

- Workload is defined as the total hours required to produce a given number of units during a given week or other period of interest.

$$WL = \sum_i \sum_j Q_{ij} T_{pij}$$

where WL = workload, hr

Q_{ij} = number of work units produced of part style j on machine i during the period of interest

T_{pij} = avg. production time of part style j on machine i.

Manufacturing Lead Time and Work-In-Process

- In the competitive environment of global commerce, the ability of a manufacturing firm to deliver a product to the customer in the shortest possible time often wins the order. This section examines this performance measure called manufacturing lead time (MLT)
- closely correlated with MLT is the amount of inventory located in the plant as partially completed product, called work-in-process (WIP).
- when there is too much work-in-process, manufacturing lead time tends to be long.

Manufacturing Costs

- Decisions on automation and production systems are usually based on the relative costs of alternatives.
- Manufacturing costs can be classified into two major categories (1) Fixed costs (2) Variable costs.
- A fixed cost is one that remains constant for any level of production output.
  Ex- cost of the factory building and production equipment, insurance and property taxes.
- A variable cost is one that varies in proportion to production output. As output increases, variable cost increases.
  Ex:- Direct labor, raw materials and electric power to operate the production equipment.

$$\boxed{TC = C_f + C_v Q}$$

where TC = Total annual cost, C_f = fixed annual cost
C_v = variable cost, Q = annual quantity produced pc/yr.

*(EX-4) (Manual Vs Automated Production)

Two production methods are being compared, one manual and the other automated. The manual method produces 10 Pc/hr and requires one worker at Rs 15.00/hr. Fixed cost of the manual method is Rs 5,000/yr. The automated method produces 25 Pc/hr, has a fixed cost of Rs 55,000/yr and a variable cost of Rs 4.50/hr. Determine the break-even point for the two methods, determine the annual production quantity at which the two methods have the same annual cost. Ignore the costs of materials used in the two methods.

Ans :- The variable cost of the manual method is $C_v = \frac{15}{10} = 1.50/PC$

Annual cost of the manual method is

$$TC_m = C_f + C_v Q = 5000 + 1.50Q \quad -(1)$$

The variable cost of the automated method is

$$C_v = \frac{4.50}{25} = 0.18/Pc$$

Annual cost of the automated method is

$$TC_a = C_f + C_v Q = 55000 + 0.18Q \quad -(2)$$

At the break-even point $(TC_m = TC_a)$

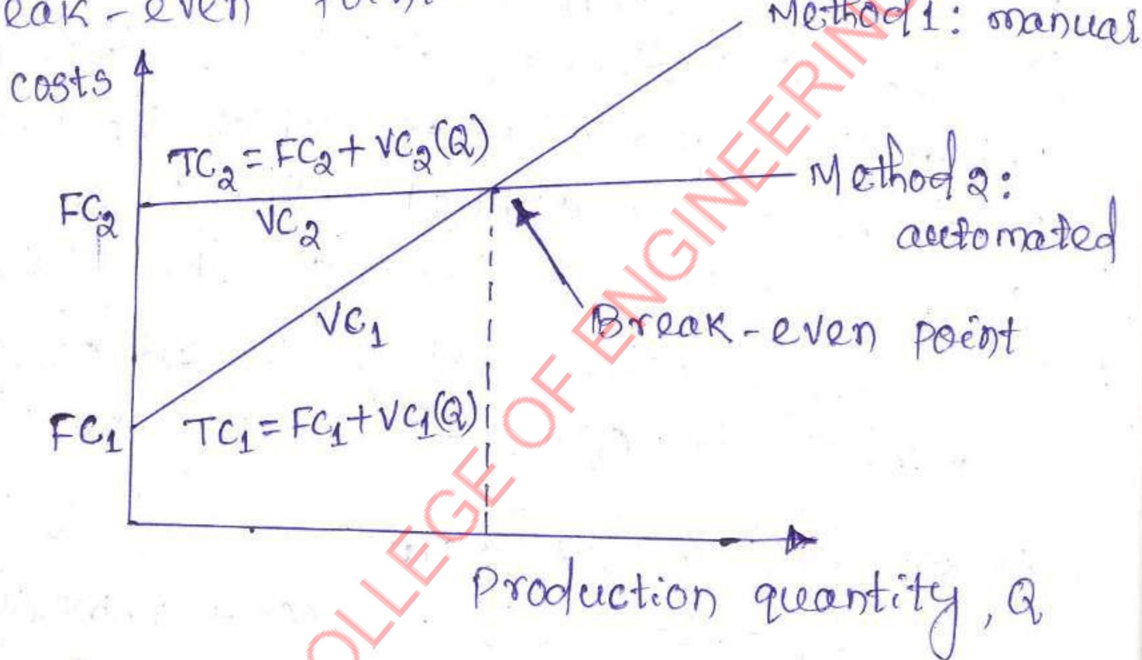
$$\Rightarrow 5000 + 1.5Q = 55000 + 0.18Q$$

$$\Rightarrow 1.5Q - 0.18Q = 55000 - 5000$$

$$\Rightarrow 1.32Q = 50000$$

$$\Rightarrow \boxed{Q = \frac{50000}{1.32} = 37,879 \text{ Pc}}$$

Comment:- It is of interest to note that the manual method operating one shift, 8 hr, 250 days per year would produce $8 \times 250 \times 10 = 20{,}000$ pc/yr which is less than the break-even quantity of 37,879 pc. On the other hand, the automated method operating under the same conditions, would produce $8 \times 250 \times 25 = 50{,}000$ pc, well above the break-even point.



(Fixed and variable costs as a function of production output for manual and automated production methods)

Product Design

- Product design describes the process of imagining, creating and iterating products that solve users problems or address specific needs in a given market.
- product design is a critical function in the production system.
- The quality of the product design is probably the single most important factor in determining the commercial succes and societal value of a product.
- If the product design is poor, no matter how well it is manufactured, the product is very likely doomed to contribute little to the wealth and well-being of the firm that produced it.
- If the product design is good, there is still the question of whether the product can be produced at sufficiently low cost to contribute to the company's profits and sucess.
- one of the facts of life about product design is that a very significant portion of the cost of the product is determined by its design.

* **Concepts of Product Design :-**

(1) Research and development

(2) Reverse Engineering

(3) CAD - CAM

* **Steps :-**

(1) synthesis
(2) sketching
(3) Analysis
(4) Selection
(5) Basic engineering
(6) Detail design
(7) prototype
(8) Manufacturing
(9) operation
(10) Product development

CAD

- computer-aided design (CAD) is defined as any design activity that involves the effective use of computer systems to create, modify, analyze, optimize and document an engineering design.
- CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system.
- CAD system can facilitate four of the design phases.
  (1) Geometric Modeling.
  (2) Engineering Analysis.
  (3) Design review and evaluation.
  (4) Automated drafting
- compared with manual design and drafting methods, CAD provide many advantages, including the following

(1) Increased design productivity:- The use of CAD herps the designer conceptualize the product and its components, which in turn helps reduce the time required by the designer to synthesize, analyze and document the design. The result is a shorter design cycle and lower product development costs.

(2) Increased available geometric forms in the design:- CAD permits the designer to select among a wider range of shapes such as mathematically defined contours, blended

angles and similar forms that would be difficult to create by manual drafting techniques.

(3) Improved quality of the design :- The use of a CAD system permits the designer to do a more complete engineering analysis and to consider a larger number and variety of design alternatives. The quality of the resulting design is thereby improved.

(4) Improved design documentation :- The graphical output of a CAD system results in better documentation of the design than what is practical with manual drafting.

(5) Creation of a manufacturing database :- In the process of creating the documentation for the product design much of the required database to manufacture the product is also created.

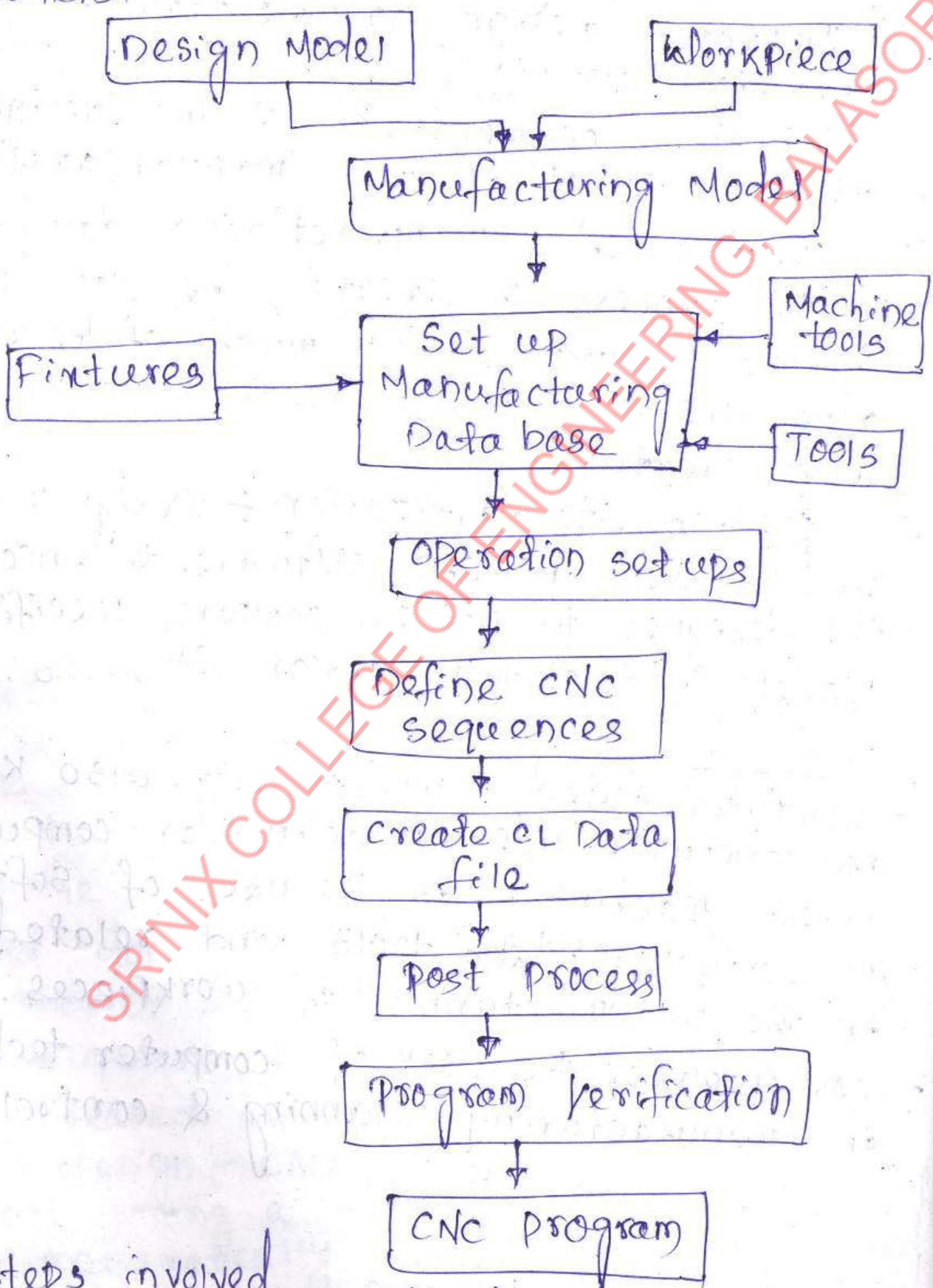
(6) Design standardization :- Design rules can be included in CAD software to encourage the designer to utilize company specified models for certain design features.

CAM

- Computer aided manufacturing also known as computer-aided modeling or computer-aided machining is the use of software to control machine tools and related ones in the manufacturing of workpieces.
- CAM involves the use of computer technology in manufacturing planning & control.

Technology of CAM

- The block diagram shown in fig. below illustrates the steps involved in creating a NC program using a CAM software package.
- The starting point of CAM is the CAD file.
- A common approach is the program creation carried out using solid models or surface models.
-



(Steps involved in NC program creation)

- Data for program creation can also be obtained from SAT (ACIS solids), IGES, VDA, DXF, CADL, STL and ASCII file using suitable translators.

(i) create a manufacturing model from the design model and the workpiece.

(ii) set up the tool database. Tools must be defined before an operation is performed. Tool Libraries can be created and retrieved for a manufacturing operation.

(iii) Select the set up for the machining operation. A component may require more than one set up to complete the machining operation.

(iv) Fixtures are necessary for each set up.

(v) create a machinability database. Parameters like spindle speed and feed rate can be selected from the machinability database.

(vi) create the manufacturing operations to generate the CL data.

(vii) If needed the CL data can be modified by modifying the operation parameters or by editing the CL data file.

(viii) create a manufacturing route sheet at the end of the manufacturing session.

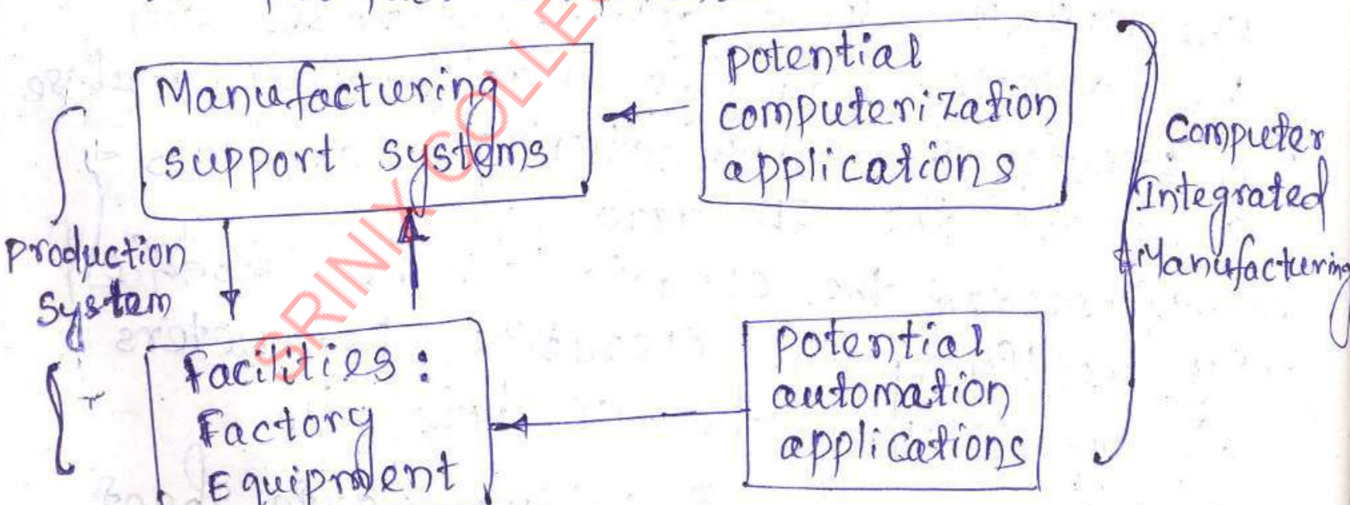
(ix) post-process the CL file to create the NC program.

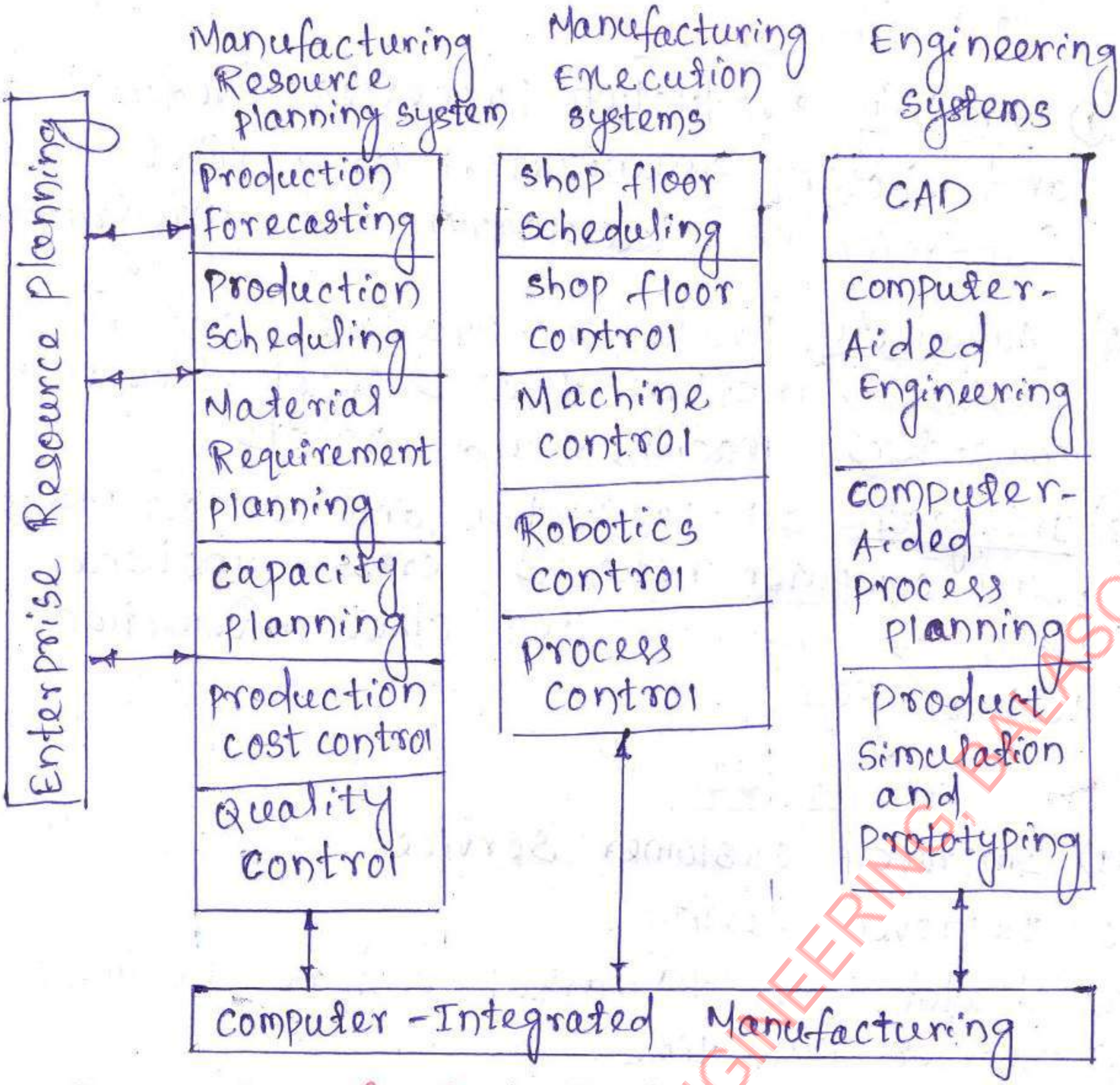
There are several popular CAM packages available.

(1) PRO/Manufacturing
(2) CVCNC
(3) I-DEAS generative Manufacturing
(4) UG- Manufacturing
(5) Master CAM
(6) Cimatron
(7) Prospector

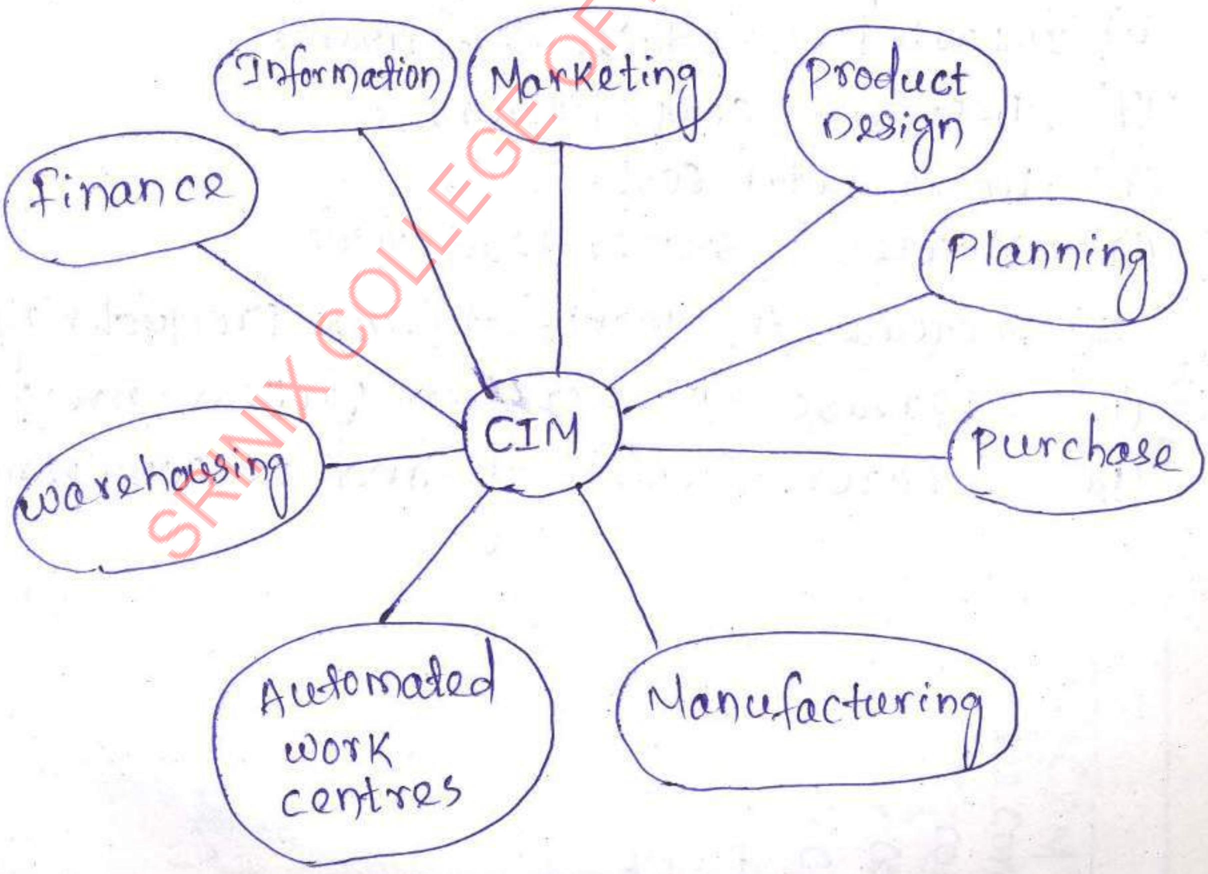
Computer Integrated Manufacturing (CIM)

- Computer integrated manufacturing is the manufacturing approach of using computers to control entire production process. This integration allows individual processes to exchange information with each part.
- CIM includes all of the engineering functions of CAD/CAM, but it also includes the firm's business functions that are related to manufacturing.
- The ideal CIM system applies computer and communications technology to all the operational functions and information processing functions in manufacturing from order receipt through design and production to product shipment.





Elements of CIM Systems



CIM Objectives

(1) Simplify production processes, product designs and factory organization as a vital foundation to automation and integration.

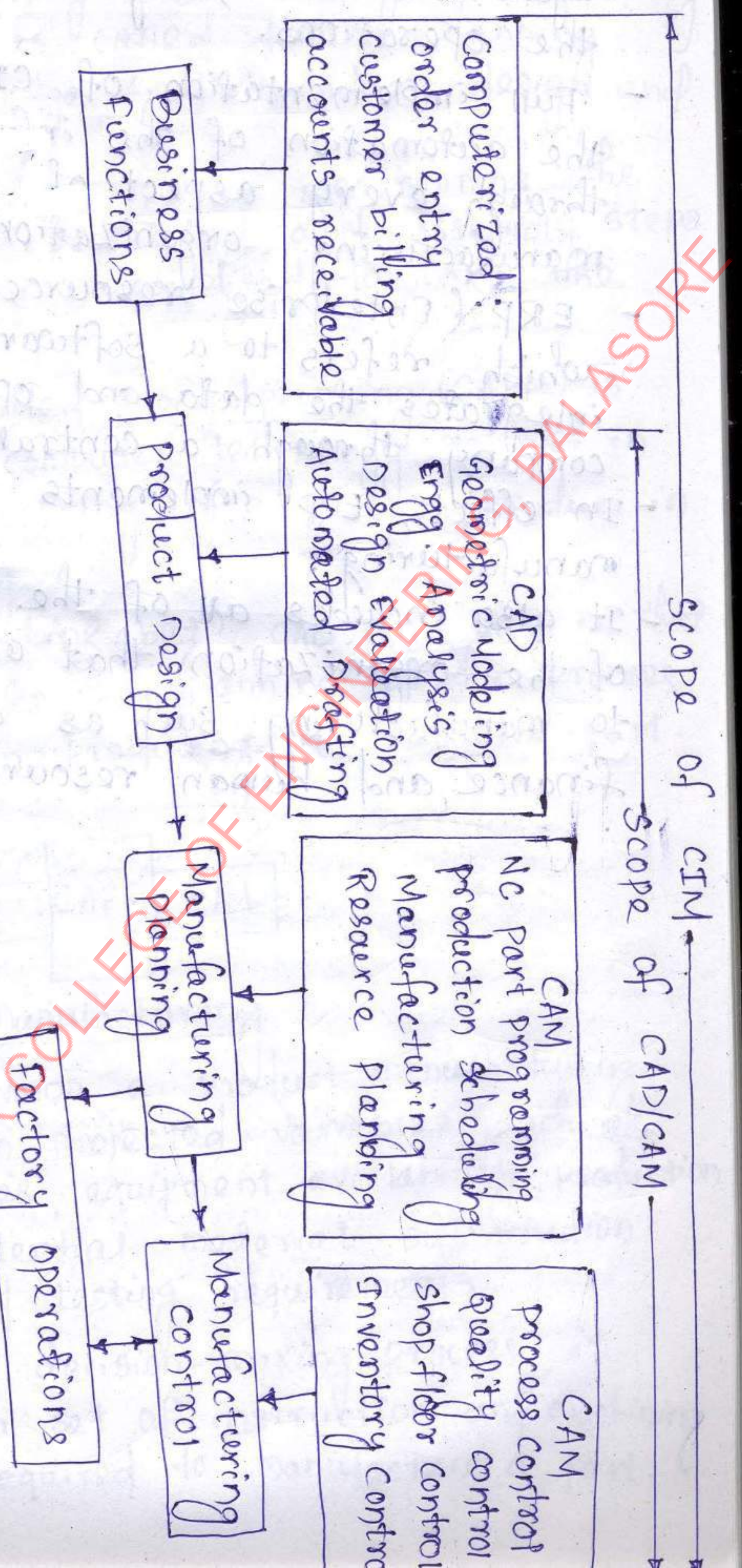
(2) Automate production processes and the business functions that support them with computers, machines and robots.

(3) Integrate all production and support processes using computer networks cross-functional business software and other information technologies.

Benefits of CIM

(1) Improved customer service.
(2) Improved quality.
(3) shorter time to market with new products.
(4) Shorter flow time.
(5) Reduced inventory levels.
(6) Improved schedule performance.
(7) Improved competitiveness.
(8) Lower ~~total~~ cost.
(9) Shorter customer lead time.
(10) Increase in manufacturing productivity.
(11) Decrease in work-in process inventory.
(12) Greater flexibility and responsiveness.

Scope of CAD/CAM and CIM



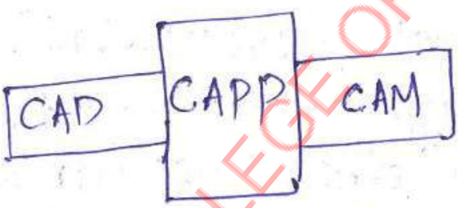
(The scope of CAD/CAM and CIM and the computerized elements of a CIM system)

- The CIM concept is that all of the firm's operations related to production are incorporated in an integrated computer system to assist, augment and automate the operations.
- Full implementation of CIM results in the automation of the information flow through every aspect of the company's manufacturing organization.
- ERP (Enterprise resource planning) which refers to a software system that integrates the data and operations of a company through a central database.
- In effect, ERP implements computer-integrated manufacturing.
- It also includes all of the business functions of the organization that are not related to manufacturing such as accounting, finance and human resources.

Computer-Aided Process Planning

Process Planning :- A manufacturing plan is needed to convert the product design into a physical entity. The activity of developing such a plan is called process planning.

- It is the bridge betn product design and manufacturing.
- process planning involves determining the sequence of processing and assembly steps that must be accomplised to make the product.
- computer-aided process planning (CAPP) is the use of computer technology to aid in the process planning of a part or product in manufacturing.
- CAPP is the link betn CAD and CAM in that it provides for the planning of the process to be used in producing a designed part.

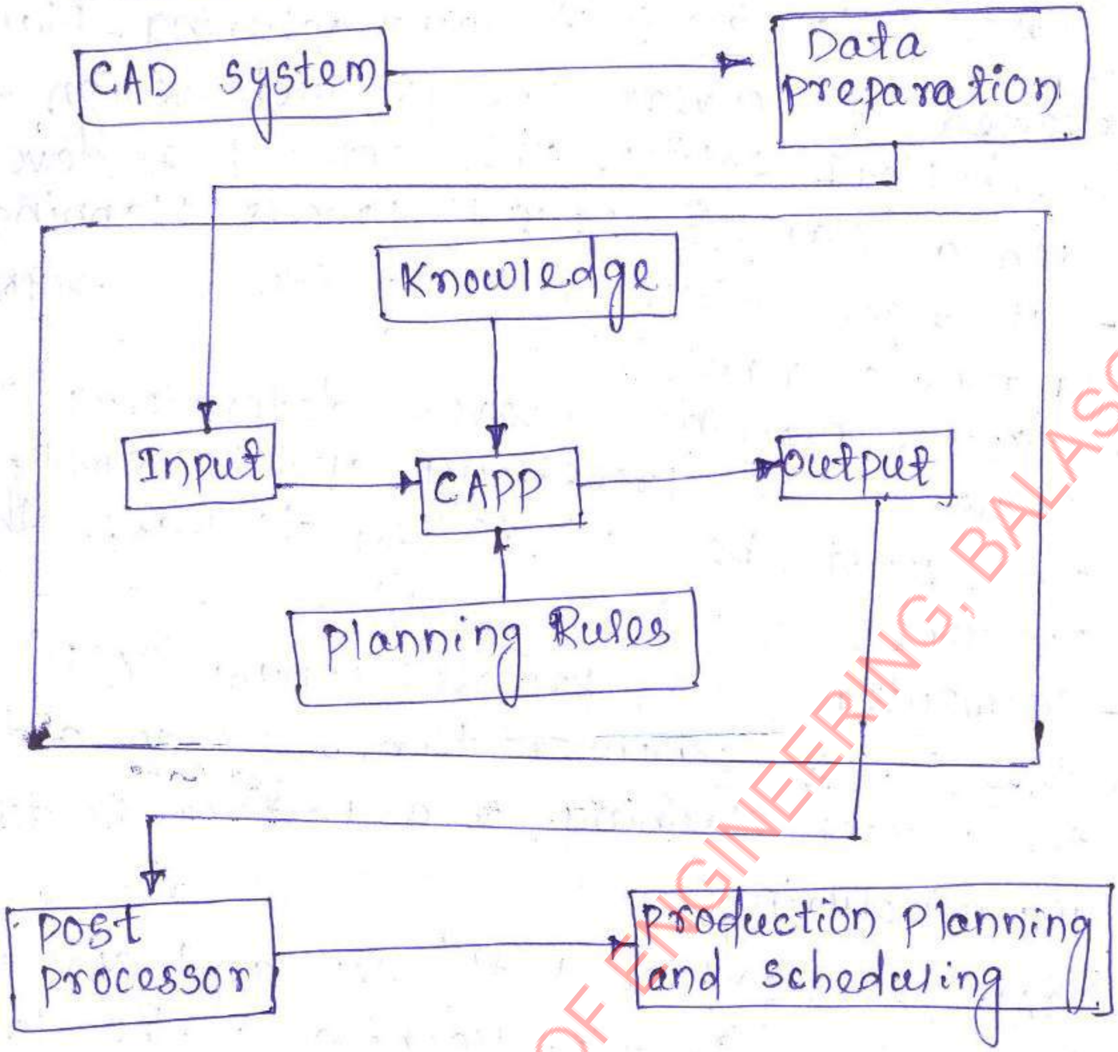


Roles in manufacturing

(1) used to develop a product manufacturing plan based on projected variables such as cost, lead times, equipment availability, production volumes, potential material substitution routings and testing requirements.

(2) CAPP is a decision-making process, it determines a set of instruction and machining parameters required to manufacture a part.

CAPP Model



Concurrent Engineering

Concurrent engineering is an approach used in product development in which the functions of design engineering, manufacturing engineering and other departments are integrated to reduce the elapsed time required to bring a new product to market.

- In the traditional approach to launching a new product, the two functions of design engineering and manufacturing engineering tend to be separated and sequential as shown in fig.(a).

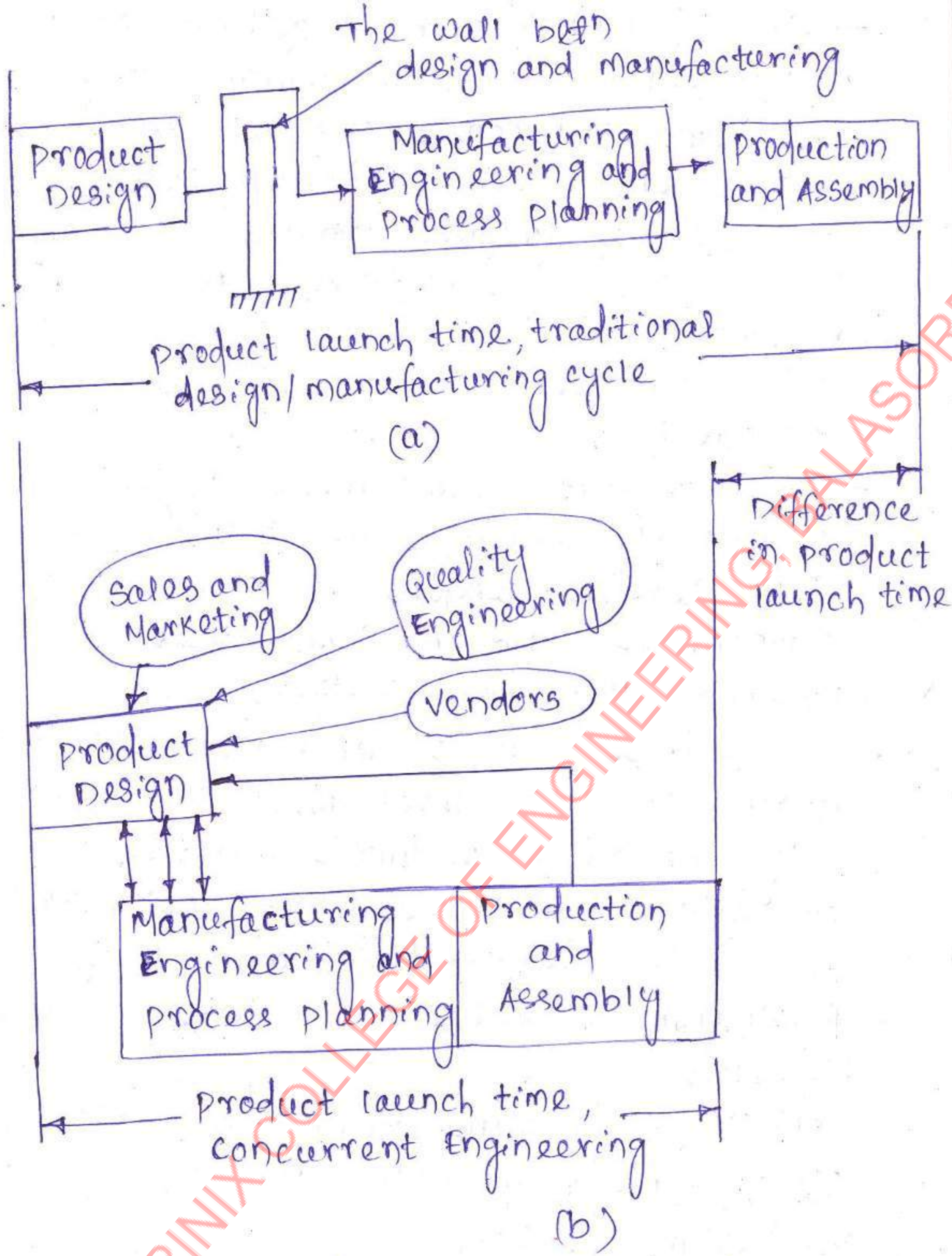


Fig. (a) Traditional product development cycle (b) product development using concurrent Engineering.

- In a company that practices concurrent engineering, the manufacturing engineering department becomes involved in the product development cycle early on, providing advice on how the product and its components can be designed to facilitate manufacture and assembly.
- This concurrent engineering approach is pictured in fig. (b).
- The product development cycle also involves quality engineering, the manufacturing department, field service, vendors supplying critical components and in some cases the customers who will use the product.
- All of these groups can make contributions during product development to improve not only the new product's function and performance but also its produceability, inspectability, testability, serviceability and maintainability.
- Concurrent engineering includes several elements
  (1) Design for manufacturing and assembly.
  (2) Design for quality.
  (3) Design for cost.
  (4) Design for life cycle.
- In addition, certain enabling technologies such as rapid prototyping, virtual prototyping and organizational changes are required to facilitate the concurrent engineering approach in a company.