The facilities of the production system consists of the factory, the equipment in the factory and the way the equipment is organized.

The manufacturing support system is the set of procedures used by the company to manage production and to solve the technical & logistics problems encountered in the process.

Production System Facilities:

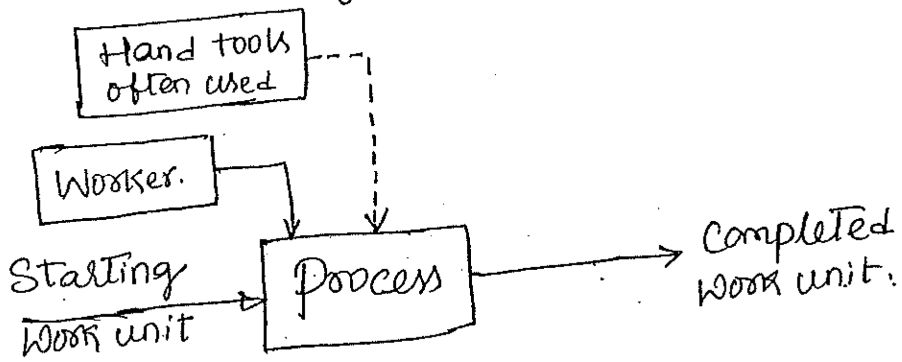
The facilities in the production system are the factory, production machines and tooling, material handling equipment, inspection equipment and computer systems that control the manufacturing operations. Facilities also include the plant Layout, which refers to the way the equipment is physically arranged in the factory.

The equipment is usually organized into logical groupings and these equipment arrangements and the workers who operate them are referred as Manufacturing Systems in the factory. The manufacturing systems come in direct physical contact with the parts. They 'touch the product'.

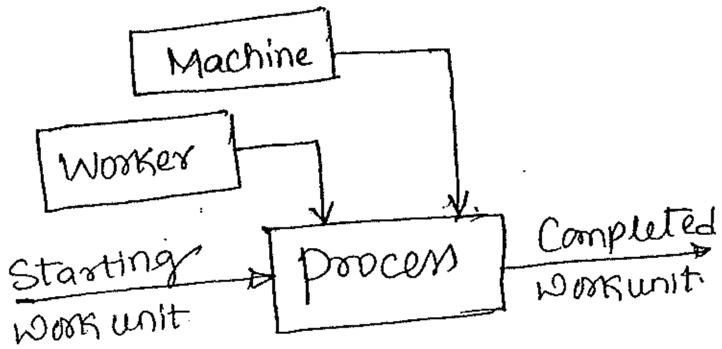
In Terms of the human participation in the processes performed by the manufacturing systems, three basic categories can be distinguished:

i) Manual Work Systems.
ii) Worker - Machine Systems.
iii) Automated Systems.

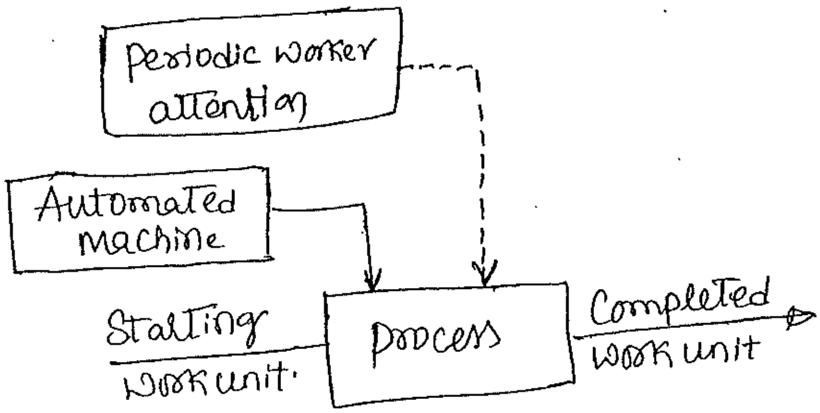
] Classification Based on the Human participation in the facility.



i) Manual work system.



ii) Worker - Machine system



iii) Automated System.

A manual work system consists of one or more workers performing one or more tasks without the aid of powered tools. Material handling is performed manually. production Tasks require the use of hand tools.

Examples include

* A machinist using a file to round the edges of rectangular part.
* A quality control inspector using a micrometer for measurement purposes.
* A material handling worker moving the parts.
* A team of workers doing the assembly.

In a worker-machine system, a human worker operates powered equipment like machine tools. This is the commonly used manufacturing systems. worker-machine systems include combinations of one or more workers and one or more equipments.

Examples include:

* A Machinist operating a Lathe.
* A fitter and robot working together in a work-cell.
* A crew of members operating the machines.

An automated ~~machine~~ 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. Power is required to drive the process and to operate the program and to control the system. Here, there will be a 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 human worker attends to the machine for the remainder of the cycle for loading/unloading operations. A fully automated machine has the capacity to operate for extended periods of time with no human attention.

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②

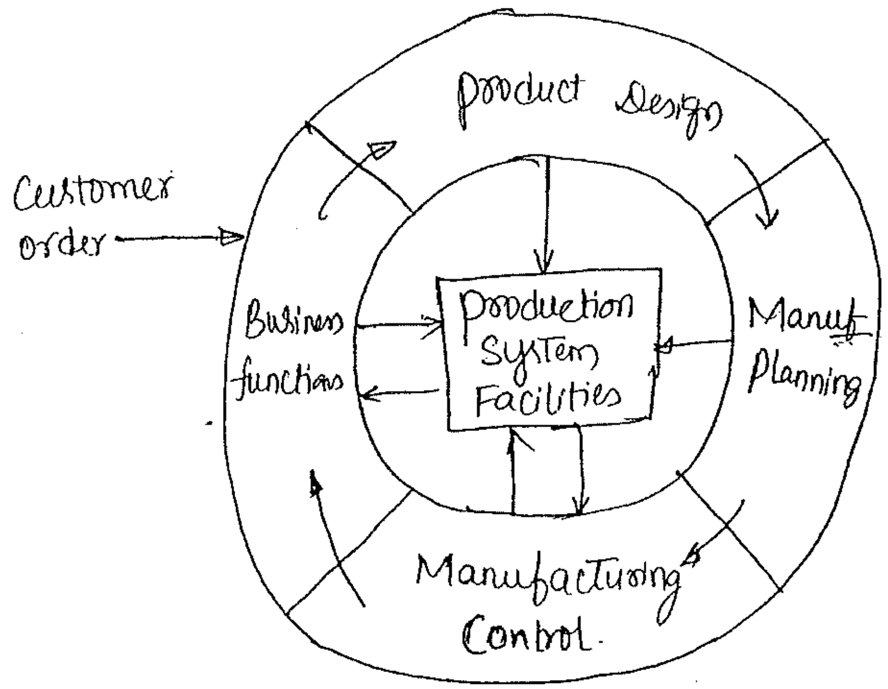
PTO →

Manufacturing Support Systems: This is the set of procedures used by the company to manage production and to solve the technical & logistics problems encountered. This system mainly involves design of process and equipment, plan & control the prodn orders and satisfying product quality requirement. These functions are accomplished by manufacturing support systems. These support systems do not directly contact the product, but they plan & control its progress through the factory.

This involves a cycle of information processing activities. They include;

i) Business Functions   iii) Manufacturing planning

ii) Product Design   iv) Manufacturing control.



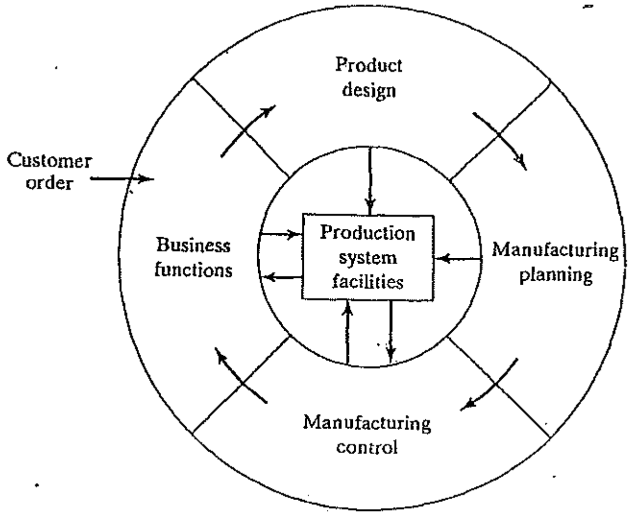


Figure 1.3 The information-processing cycle in a typical manufacturing firm.

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, as illustrated in Figure 1.3. The production system facilities described in Section 1.1.1 are pictured in the center of the figure. The information-processing cycle can be described as 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: (1) 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. 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.

If the product is proprietary, the manufacturing firm is responsible for its development and design. The cycle of events that initiates a new product design often originates in the sales and marketing department; the information flow is indicated in Figure 1.3. The departments of the firm that are organized to accomplish product design might include research and development, design engineering, and perhaps a prototype shop.

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, the dates on which they are to be delivered, and the quantities of each. Months are traditionally used to specify deliveries in the master schedule. Based on this schedule, the individual components and subassemblies 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 as indicated in Figure 1.3. 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 risk 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.

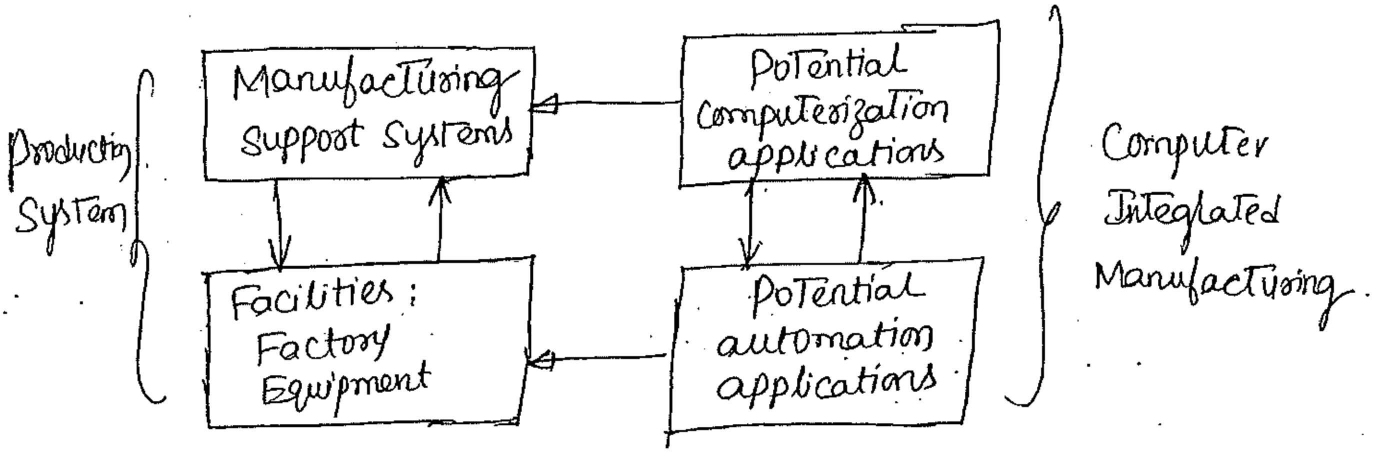
The function of *quality control* is to ensure that the quality of the product and its components meet the standards specified by the product designer. To accomplish its mission, quality control depends on inspection activities performed in the factory at various times during the manufacture of the product. Also, raw materials and component parts from outside sources are sometimes inspected when they are received, and final inspection and testing of the finished product is performed to ensure functional quality and appearance. Quality control also includes data collection and problem-solving approaches to address process problems related to quality. Examples of these approaches are statistical process control (SPC) and Six Sigma.

Automation in Production systems:

The Automated elements of the production system can be seperated into two categories:

i) Automation of the manufacturing systems in the factory
ii) Computerization of the manufacturing support systems.

These two categories are shown as below:



The Term computer Integrated manufacturing is used to indicate the Extensive use of computers in production systems.

Automated Manufacturing Systems:

Automated manufacturing systems operate in the factory on the physical product. They perform operations such as processing, assembly, inspection and material handling. They are called automated because they perform their operations with a reduced level of human participation. Examples of automated manufacturing systems include:

* Automated machine tools that process parts.
* Automated Flow lines that perform series of operations.
* Automated assembly systems.
* Automatic Material handling and storage systems.
* Automatic inspection systems.

Automated manufacturing systems can be classified in to three basic types : [Types of Automation]

1) Fixed Automation
2) programmable Automation
3) Flexible 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. It is the integration and co-ordination of many such operations into one piece of equipment that makes the systems complex. Features of fixed automation includes:

* High initial investment for custom engineered equipments
* High production rates.
* Relative inflexibility of the equipment to accomodate product variety.

The economic justification for fixed automation is found in products that are produced in very large quantities and high production rates. Examples includes Transferlines 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. New programs can be prepared and entered in to the equipment to produce new products.

Some of the features are:

* High investment in general purpose equipment
* Lower production rates than fixed automation
* Flexibility to deal with variations and changes in product configuration
* High suitability for batch production.

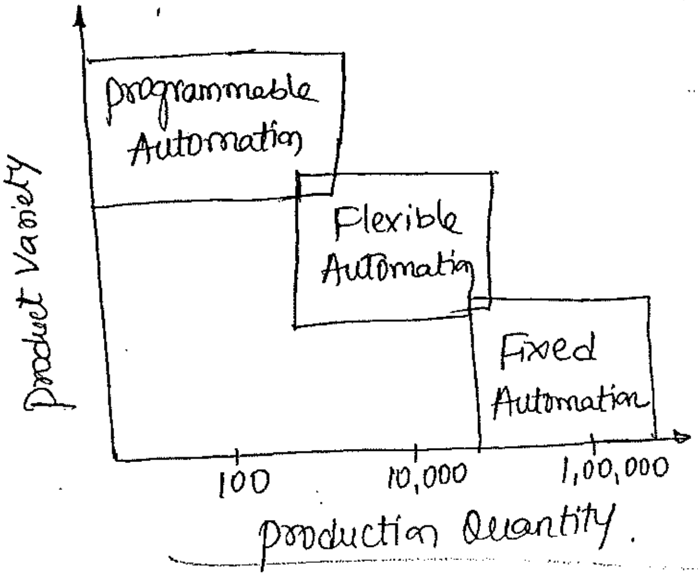
programmable automation system are used in low and medium volume production. The parts or products are typically made in batches. To produce each new batch of a different product, the system must be reprogrammed with the set of machine instructions that corresponds to the new product. The physical setup, tools, fixtures and settings must be changed. This changeover procedure takes time. Examples include NC machine tools, industrial robots and PLC's.

Flexible Automation: Flexible Automation is an extension of programmable automation. A flexible automated system is capable of producing a variety of parts with virtually no time lost for changeovers from one part style to the next. There is no lost production time while reprogramming the system and altering the physical setup. Hence the system can produce various mixes of products. The features include

* High investment
* Continuous prodn. of variable mixtures of products.
* medium prodn rates
* Flexibility to deal with product design variations.

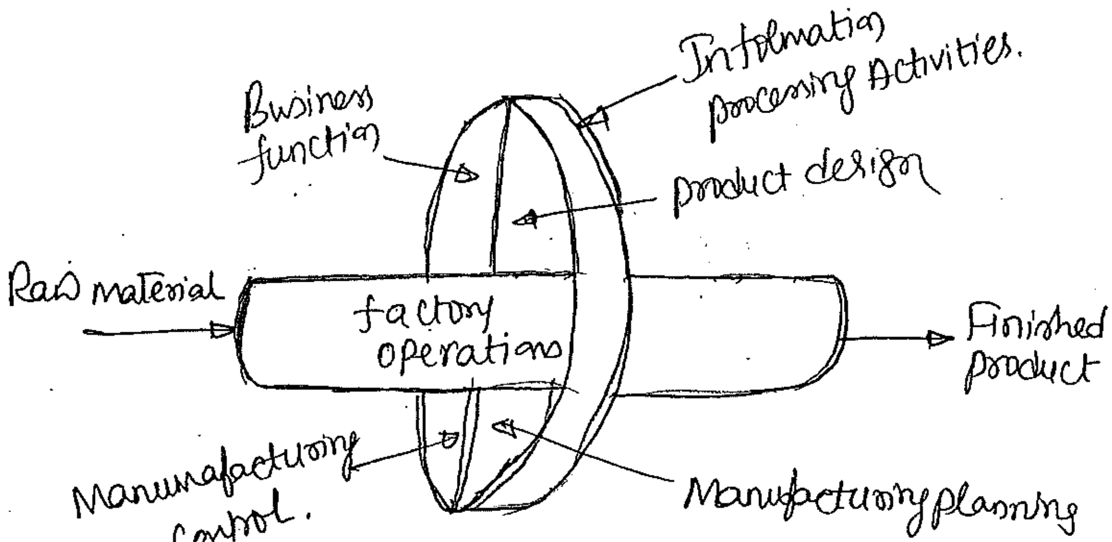
Ex: Flexible manufacturing systems.

The relative positions of three types of automation for different production quantity & product variety is shown below:



Computerized Manufacturing Support Systems:

Automation of the manufacturing support systems is aimed at reducing the amount of manual and clerical effort in product design, manufacturing planning & control and the business functions of the firm. All modern manufacturing support systems are implemented using computers. Computer Technology is used to implement automation of the manufacturing systems. The Term Computer Integrated Manufacturing (CIM) denotes the pervasive use of computer system to design the products, plan the production, control the operations and perform the various information processing functions. True CIM involves ~~the computer~~ integrating all of these functions in one system that operates throught the enterprise. Others Terms are used to identify the specific elements of the CIM system. This includes CAD, CAM, CAE, CAQC, CAPP etc. The Computer Integrated manufacturing involves the information processing activities that provide the data & knowledge required to successfully produce the product. The Automation & CIM models are shown below:



Reasons for Automation: The various reasons used to justify automation are:

* To increase labor productivity
* To reduce labor cost
* To mitigate the Effects of labor shortages.
* To reduce or eleminate the routine manual & Clerical Tasks.
* To improve worker safety
* To improve product quality

* TO reduce Manufacturing Lead Time.
* TO accomplish processes that Cannot be done manually.
* TO avoid the high cost of not automation.
* TO have intangible benefits like Improved quality, better labor relations, Improved Company image, Job Satisfaction.

Computer Integrated 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.

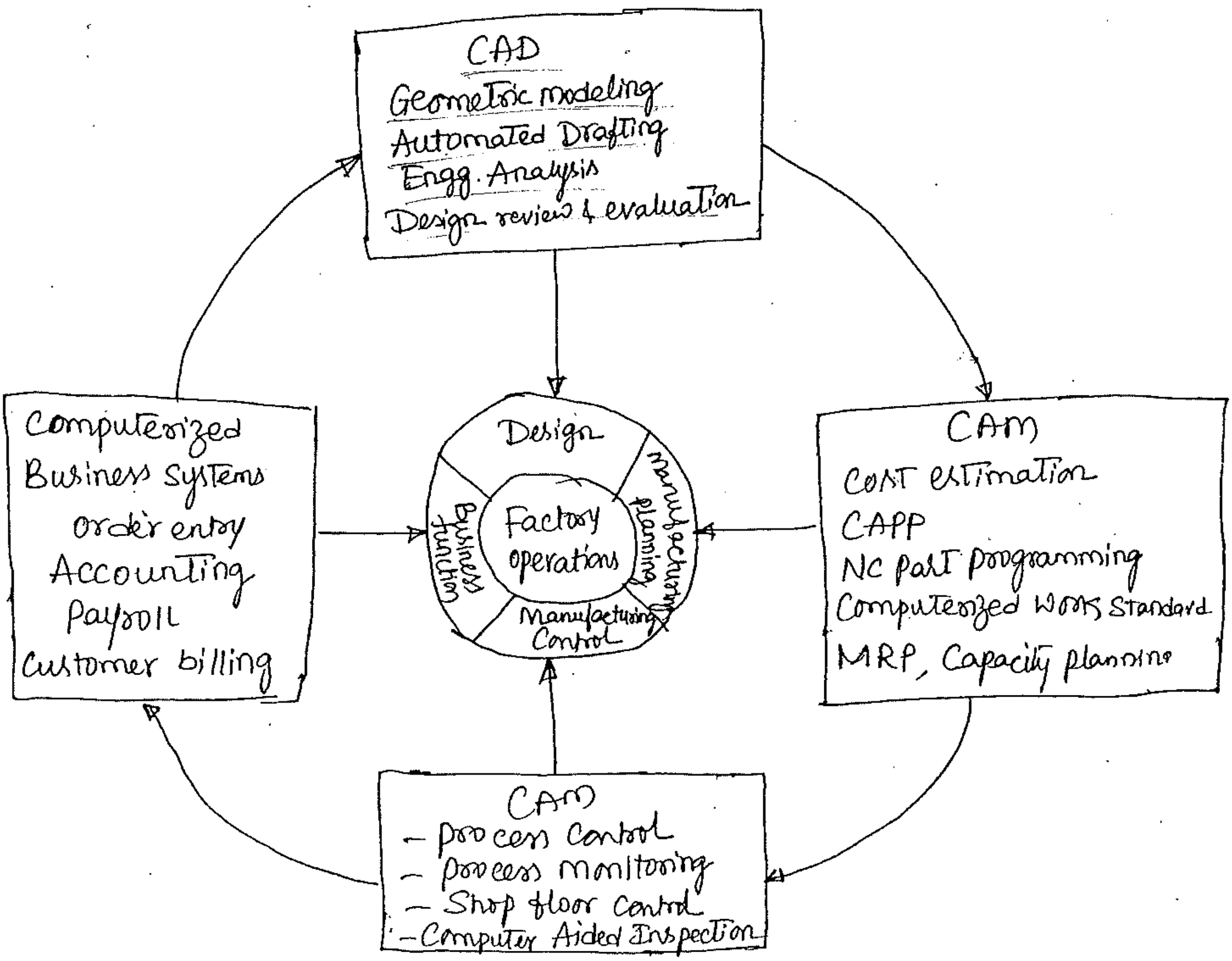
CIM is considered a natural evolution of the Technology of CAD/CAM which by itself evolved by the integration of CAD and CAM.

CIM is generally considered as a management and manufacturing strategy. It is nothing but use of Computer Technology to integrate or combine Together the product design, production, marketing and delivery of a product into a totally integrated System.

As per CASA/SME ('Computer and Automation Systems Association' division of 'Society of Manufacturing Engineers', CIM is defind as:

"CIM is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organizational and personnel efficiency".

Computerized Elements of CIM System:



Computerized elements of CIM is as shown in fig. The Elements consists of the various computerized function of manufacturing support systems. The functions of manufacturing support systems ie Business function, product Design, Manufacturing planning & Manufacturing control activities will be undertaken with the help of computer systems. Mainly the computerized Elements of CIM involves Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM), Computer Aided Process Planning (CAPP), Computer Aided Production Planning & Control (CAPP&C), Enterprise Resource Planning (ERP), Computer Aided Quality Control (CAQC) to name a few.

Advantages (or Benefits of CIM):

- Improves short run responsiveness.
- Reduces inventory
- Increases machine utilisation
- Higher profits
- Less direct labor involvement
- Reduced scrap & Reworks.
- Higher employee morale
- Safer working environment
- Improved customer image
- Increased job satisfaction
- Reduced MLT.

Production Concepts & Mathematical Models & Matrices:

A number of production concepts are quantitative & requires a quantitative approach to measure them. The various matrices are indicated below;

Manufacturing Lead Time: (MLT).

"Manufacturing Lead Time is the total time required to process a given part or product through the plant."

In the competitive business environment, the ability of a manufacturing firm to deliver a product to the customer in the shortest possible time wins the order. This time is referred to as Manufacturing Lead Time.

The components of MLT is as shown below:

We know that, production consists of a series of individual steps: processing & Assembly operations.

- Between the operations are material handling, storage, inspection & other non-productive activities.
- Therefore divide the activities in production in to two main categories; operations & Non-operations element.
- An operation on a product takes place when it is at the production machine.
- The non-operations elements are the handling, storage, inspection & other sources of delay.

Let T_o : Operation time at a given machine

T_{no} : Non-operation Time associated with the same m/c

n_m : No of machines (operations) through which the product must be routed inorder to be completely processed.

- Assuming a batch production situation, there are 'Q' units of the product in a batch.

- A setup procedure is generally required to prepare each machine for the particular product.

- This setup usually includes arranging the workplace & installing the tooling & fixturing required for the product. Let this setup time be denoted as T_{su}.

Given these terms, MLT is defined as the total time required to process a given product.

ie
$$MLT = \sum_{i=1}^{n_m} T_{su_i} + Q T_{o_i} + T_{no_i} \quad \text{—— (1)}$$

Where 'i' indicates the operations sequence in the processing ie $i = 1, 2, 3 \ldots n_m$.

Let us assume that all operations time, setup time & non-operations times are equal. ∴ The above Equation simplifies to

$$MLT = n_m(T_{su} + Q \cdot T_o + T_{no}) \quad \text{——— (2)}$$

This Equation can be adopted for jobshop production & mass production situation by adjusting the parameter values. For a job shop production, the batch size is 1 ie Q = 1, Hence above Equn becomes

$$MLT = n_m(T_{su} + T_o + T_{no})$$

For Mass production, the 'Q' term in Equn ② is very large & dominates the other terms.

In the Case of Quantity type mass production in which Large number of units are made on a single machine, the MLT becomes the operation time for the machine after the setup has been completed & production begins.

For flow-type mass prodn, the Entire production line is setup in advance. Also, the non-operation time between the processing steps consists only the time to transfer the product from one machine to the next machine.

If the workstations are integrated so that the parts are being processed simultaneously at each station, the station with the longest operation Time will determine the MLT value.

Hence $$MLT = n_m(\text{Transfer Time} + \text{Longest } T_o)$$

Here n_m represents the number of seperate workstations on the production line.

Production Rate: The prodn rate (R_p) for an individual process or assembly operations is usually Expressed as an hourly rate (eg: units of product per hour)

Let us consider T_o as the operations time & T_{su} as the setup Time at any given machine.

Considering for the Batch production;

The Total batch time for the machine.

$$\frac{\text{Batch time}}{\text{Machine}} = T_{su} + Q \cdot T_o$$

If the value 'Q' represents the desired quantity to be produced & if there is a scrap rate of an amount 'q' the quantity started through the process must be $\frac{Q}{1-q}$.

∴ The above Equn becomes,

$$\frac{\text{Batch time}}{\text{Machine}} = T_{su} + \frac{Q \cdot T_o}{(1-q)}$$

Dividing the batch time by the quantity in the batch yields "Average production time per unit of product" for the given machine ie

$$T_p = \frac{\text{Batch time / machine}}{Q}$$

∴ The average production rate for the machine is the reciprocal of the production time

ie $$R_p = \frac{1}{T_p}$$

For job shop production, Quantity $Q = 1$

∴ The production time per unit is $T_p = T_{su} + T_o$

∴ R_p for job shop production is $R_p = \frac{1}{T_p} = \frac{1}{T_{su} + T_o}$

For Quantity type mass production, the production rate Equals the cycle time of the machine ie the reciprocal of the operation time after the production has started and the Effects of setup are neglected. $R_p = \frac{1}{T_p} = \frac{1}{T_o}$

For flow line mass production, the production time approximates to the cycle time of the production line, neglecting the setup time. The problem in the production lines is the interdependence among workstations on the line. If one workstation breaks down, the entire line must often be stopped. The bottleneck station is sometimes used to refer to this workstation.

Therefore, cycle time of the production line is the sum of the longest operation time and the time to transfer the workunits between stations.

$$\therefore T_c = \text{Longest operation time} + \text{Transfer time}$$

$$\therefore \boxed{R_p = \frac{1}{T_c} = \frac{1}{\text{Longest } T_o + \text{Transfer Time}}}$$

Components of the Operation Time:

The operation time is the time an individual workpart spends on a machine but not all of this time is productive. Operation time for a given machining operation is composed of three elements:

i) The Actual machining time T_m

ii) The workpiece handling time T_h

iii) Tool handling time per workpiece T_{th}.

Hence, operation Time $T_0 = T_m + T_h + T_{th}$

The tool handling time represents

i) All the time spent in changing tools when they wearout

ii) Changing from one tool to the next for successive operations performed on a Turret lathe.

iii) Changing between the drill bit & Tap in a drill & Tap sequence performed at one drill press.

∴ T_{th} is the Average time per workpiece for any & all of these tool handling activities.

Capacity (or) Plant Capacity:

It is defined as the maximum rate of output that a plant is able to produce under a given set of assumed operating conditions. It is closely related to production rate. The assumed operating conditions refer to the following:

i) The number of Shifts per day (one, two or three)

ii) The number of days in the week (or Months) that the plant operates.

iii) Employment Level

iv) Whether or not overtime is included.

Capacity for a production plant is usually measured interms of the types of output produced by the plant.

Eg: Tons of steel for a steel plant.

Number of Cars produced for an Automobile industry.

Barrels of oil for an oil refinery.

Let PC = plant capacity of a given workcenter (or) group of workcenters.

Capacity will be measured as the number of good units produced per week.

W = Number of workcenters. A workcenter in a production system in the plant typically consists of one worker & one machine.

R_p = Average production rate produced by 'W' work-centers in units/hr

H = Total number of hrs/shift each workcenter operates.

Sw = Number of shifts/week

The above parameters can be used to calculate the production capacity as follows:

$$PC = W\,S_w\,H\,R_p$$

No. of Workcenter	No. of Shifts per week	Hours per shift	units per Hour

The unit of PC is units/week.

If each workunit is routed through n_o operations with each operation requiring a new setup on either a same or other machine, then the plant capacity equation becomes

$$PC = \frac{W\,S_w\,H\,R_p}{n_o}$$

where n_o = Number of distinct operations (Machines) through which the workunits are routed.

The above eqn indicates the operating parameters that affect plant capacity. The plant capacity can be appropriately adjusted as per the plans below:

Short Term plans to increase or decrease plant Capacity are:

i) Change the number of Shifts per week (S_w) : Make Saturday shifts authorized to Temporarily increase the capacity.

ii) Change the number of hours worked per shift (H) : OverTime on Each regular shift might be authorized to increase the capacity.

Intermediate or Long Term plans

i) Increase the number of workcenters 'W' in the shop: This might be done by using equipment that was formerly not in use & hiring new workers. Over the long Term new machines may be acquired.

ii) Increase the production rate R_p by making Improve-ments in methods (or) process methodology.

iii) Reduce the number of operations (n_o) required per workunit by using combined operations (or) Simulta-neous operations.

Utilization & Availability:

Utilization refers to the amount of output of a production facility relative to its Capacity. Let 'U' represents utilization. We have,

$$U = \frac{\text{output}}{\text{Capacity}}$$

This Term can be applied to an Entire plant, A Single machine or any other productive resources.

It is also defined as the proportion of Time that the facility is operating relative to the time available under the definition of Capacity. It is usually Expressed as percentage.

Availability: The Term availability is used as a measure of reliability of Equipment. Availability is defined using two reliability Terms, Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR). Here MTBF indicates the average length of time between breakdowns of the Equipment. MTTR indicates the average Time required to service the Equipment & place it back into operation when a breakdown occurs.

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

It is also Expressed as a percentage.

Work - In - Process (WIP):

Work in process is the amount of product currently located in the factory that is either being processed or is between processing operations.

WIP is an inventory that is in the state of being Transformed from rawmaterial to finished product. A measure of WIP is given by:

$$\boxed{WIP = \frac{PC \cdot U}{SW \cdot H} \cdot MLT}$$

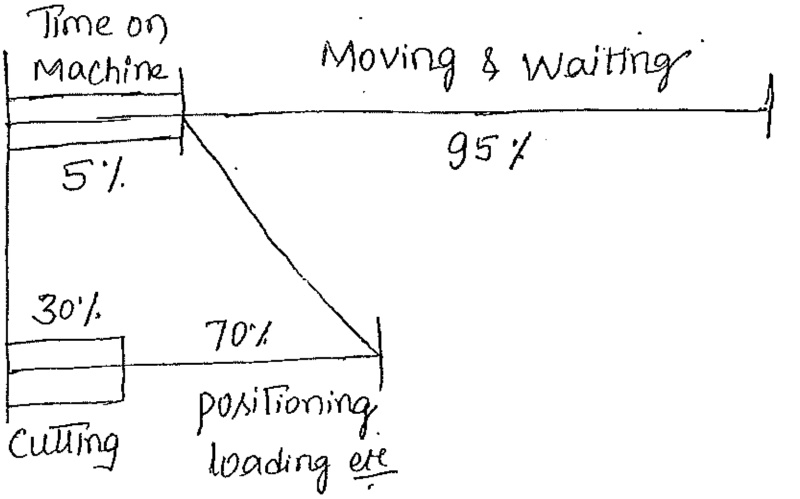
$\frac{\text{units/wk}}{\text{Shifts/wk} * \text{Hrs/shift}} * \text{Hr} = \text{units/hr} * \text{hr}.$

WIP represents the number of units in the process.

The above Equation states that the level of WIP will be Equal to the rate at which parts flows through the factory multiplied by the length of Time the parts spent in the factory.

WIP represents an investment by the firm, but that cannot be Turned into profit untill the processing is completed. Many manufacturing companies sustain major costs because work remains in-process in the factory too long. The units for $\frac{PC \cdot U}{SwH}$ (eg: parts per hr) must be consistent with the units of MLT (eg: hr).

Eugene Merchant, an advocate & spokesman for the manufacturing industry observed that materials in the factory spend more time waiting or being moved than in processing. His observation is illustrated as shown:



About 95% of the time of a workpart is spent either moving or waiting. Only 5% of the time is spent on the machine tool. Of this 5%, less than 30% of the time at the machine (1.5% of the total time of the part) is time during which actual cutting is taking place. The remaining 70% (ie 3.5% of the total time of the part) is required for loading, unloading, positioning & other causes of non processing time.

Two measures that can be used to assess the magnitude of the WIP are WIP ratio & TIP ratio.

<u>WIP Ratio:</u> The WIP ratio provides an indication of the amount of inventory in process relative to the work actually being processed.

It is the total quantity of a given part in the plant divided by the quantity of the same part that is being processed.

WIP ratio can be obtained by dividing the WIP level by the number of machines currently engaged in processing parts.

The divisor ie the number of machines processing can be calculated as:

$$\text{Number of machines processing} = W\,U\,\frac{Q\,T_o}{T_{su} + Q\,T_o}$$

Where W = Number of available workcenters.

U = Plant utilization

Q = Batch Quantity

T_o = Operation time

T_{su} = Setup time.

$$\therefore \text{WIP ratio} = \frac{\text{WIP}}{\text{Number of machines processing}}$$

The ideal WIP ratio is 1 : 1 which implies that all parts in the plant are being processed.

TIP Ratio: The TIP ratio measures the time that the product spends in the plant relative to its actual processing Time. It is determined as the Total Manufacturing Lead Time for a part divided by the sum of the individual operations times for the part.

$$\text{TIP ratio} = \frac{MLT}{n_m T_o}$$

The ideal TIP ratio is 1 : 1

Comments on the Production Concepts:

Manufacturing Lead time determines how long it will Take to deliver a product to the customer. Here the ability of the firm to deliver the product to the customer in the shortest possible Time is important.

High production rates are important objective in automation. These objective can be achieved by reducing workpiece handling time (T_h), processing Time (T_m), Tool handling time (T_{th}) & Setup Time (T_{su}).

Another objective of automation is to increase the plant capacity without the need for drastic change in employment levels.

Utilization provides a measure of how well the production resources are being used given that they are available. If the utilization is low, the facility is not being operated nearly to its capacity. If the utilization is higher, it may mean that the facility is being used fully.

Availability gives an indication of how well the maintenance personnel are servicing & maintaining the equipment in the plant. If it is 100% it means that the equipment is reliable & maintenance personnel are doing a good job.

WIP is an important issue in manufacturing. Many firms are attempting to reduce the high cost of WIP and one of the approaches that is being used is to automate the operation.

Finally, WIP ratio & TIP ratio should be kept as low as possible as the ideal ratio's being 1:1.

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AUTOMATED PRODUCTION LINES.

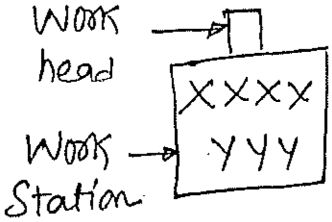
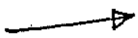
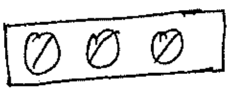
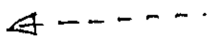
Dr. K.M. SATHISH
BMSIT&M.

Introduction: Some of the products have to be manufactured in large quantities as the demand is larger. Such large quantities of production may be Termed as High volume production. High volume production is same as mass production using various types of processes and operations. This system is used for products that requires multiple processing operations. Each processing operation is performed at a workstation, and the stations are physically integrated by means of mechanized transport system to form an Automated production Line. These lines are commonly referred as Automated Flow Line (or) Transfer Line (or) Transfer Machines.

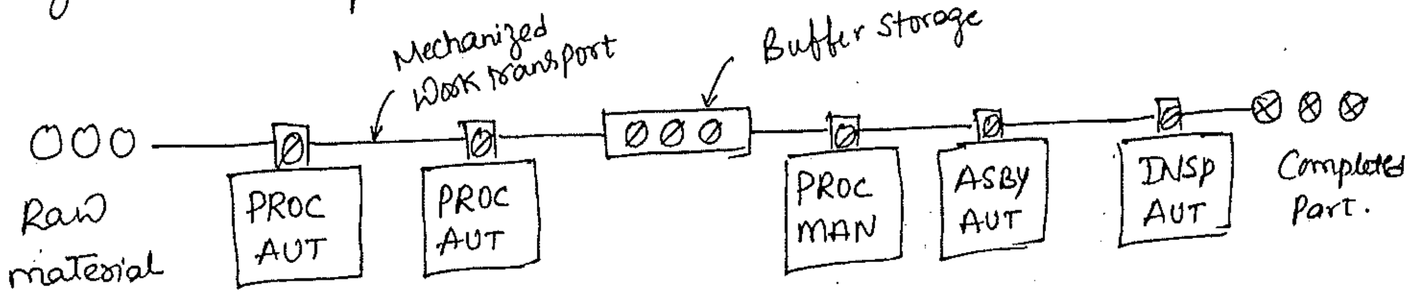
Automated Flow Line: An automated flow line consists of multiple workstations that are automated and linked together by a work handling system that transfers parts from one station to the next. A raw workpart enters one end of the line, and the processing steps are performed sequentially as the part progresses forward. The line may include inspection stations. Also, manual stations may also be located.

Each station performs a different operations, so all the operations are required to complete one work. Automated flow lines require a significant capital investment.

The following are the Symbols used to represent an Automated flow line:

Symbol	Description
	Workstation may be represented as XXXX and YYY. It indicates type of workstation. XXXX may be; PROC: Processing Station ASBY: Assembly Station INSP: Inspection Station WASH: Wash Station. YYY may be; AUT: Automated Station MAN: Manual Station
	Material Handling System
	Raw Material
	Semi finished part
	Finished Part
	Buffer Storage
	Information flow / Data flow (feedback).

General configuration of Automated flow line with the symbols is represented as below;



Objectives of Automated flow Lines: Are as follows;

- To reduce labor costs
- To increase production rate
- To reduce Work-In-Process.
- To minimize distance moved between the operations.
- To Achieve specialisation of operations.
- To achieve integration of operations.

Applications of Automated flow line (When to use?).

Automated flow line is recommended under the following conditions:

- Stable product design
- High rate of production
- High rate of demand for the product.
- Low amount of direct labor.
- When the products are generally heavy
- When Multiple operations needs to be performed.

System Configurations of Automated Flow Lines:

(Arrangements of Automated Flow Lines)

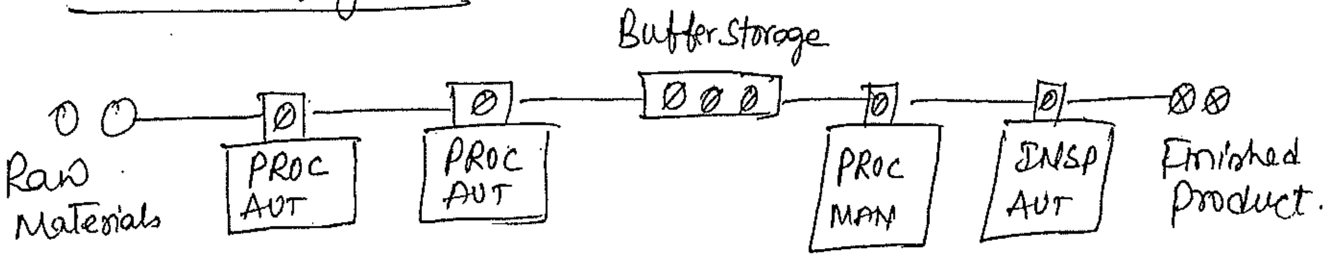
The various configuration of automated flow lines are categorized/classified into;

i) In-line configuration
ii) Segmented In-line configuration
iii) Rotary type configuration.

The above said configurations/Arrangements of automated flow lines are adopted depending on;

* Availability of space
* Number of workstations required.
* Number of operations to be performed.
* Rate of production
* Accomodation of Buffer storage.
* Size of the workparts.

In-line configuration:



In line configuration consists of sequence of stations in a straight line arrangement as shown in fig. All the workstations will be arranged in the straight line manner.

This is the most commonly used configuration. This is common for machining larger workpieces such as automotive engine blocks, engine heads etc. This is also recommended when larger number of operations is required to be processed on the workpart. In-line system can also accomodate storage buffer along the path. One of the major disadvantage is that it requires a larger space to accomodate many workstations along the line.

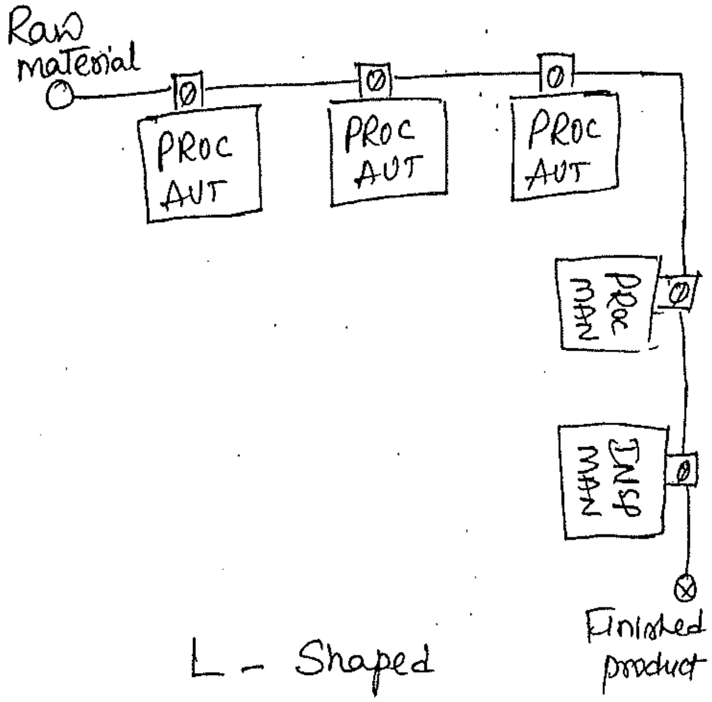
Segmented- In line Configuration:

The Segmented in-line configuration consists of two or more straight line transfer sections where the segments are usually perpendicular to each other. Fig below shows the the various types of the segmented In-line configulation like L-Shaped, U-Shaped and Rectangular type.

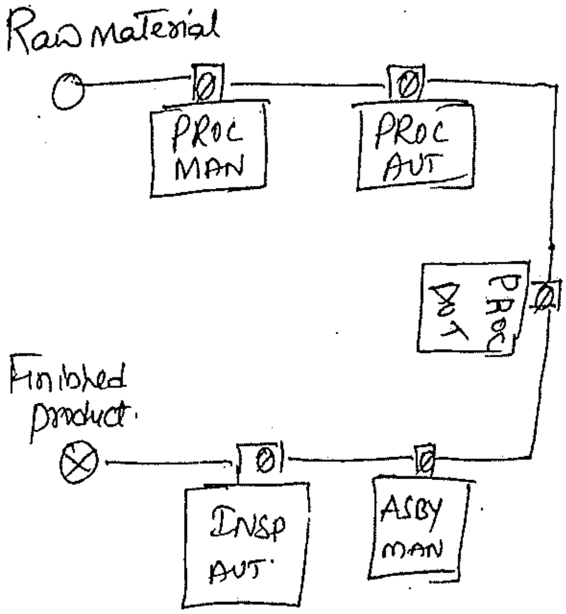
The reasons for Segmented In-line configulation is:

i) Available floor space may limit the length of the line

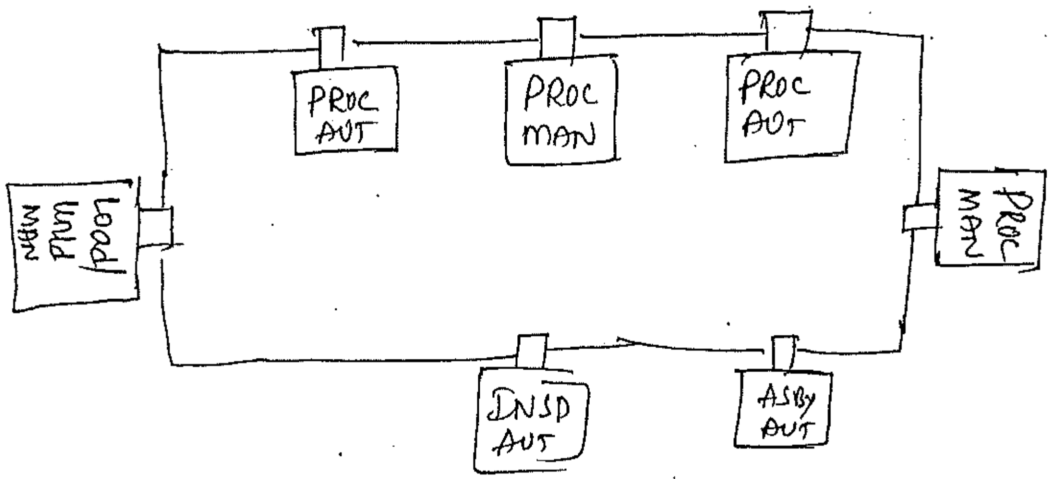
ii) A workpiece in a segmented in-line configuration may be reoriented to present different surfaces for machining.



L - Shaped



U - Shaped.



Rectangular shaped.

L - Shaped configuration has the advantage of orientation for a product in the process and also the length of space required is comparatively less when compared to In-line configuration.

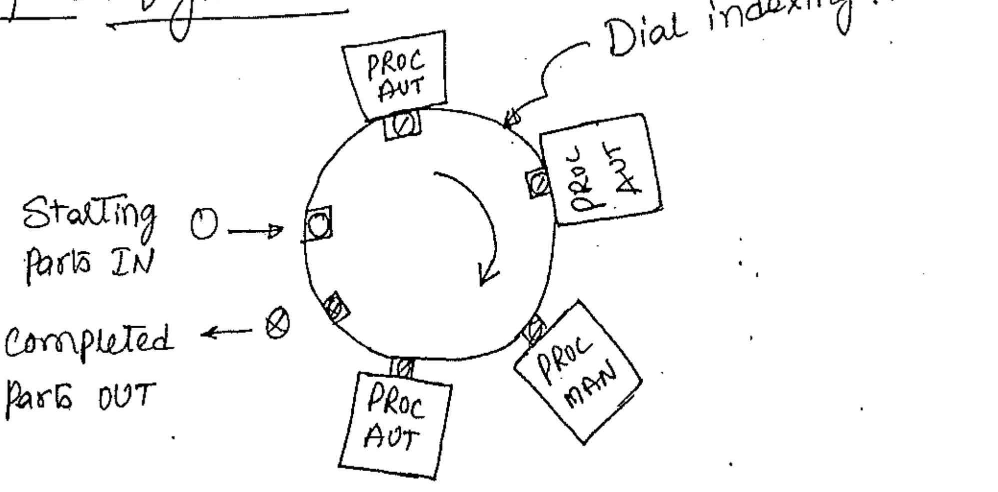
U - Shaped configuration is characterized by two orientation when compared to in-line and the total space to accomodate the entire process is also comparative lesser for the same product.

Rectangular configuration is an improvement on U-shaped configuration. Also, the space required is much less when compared to In-line, L and U configurations. Notable advantage is that only one operator is necessary for loading & unloading resulting in reduction of labor.

NOTE: In line | Segmented In-line configuration is adopted when,
* The no of operations on the product is more.
* Size of the product is Large
* Availability of large space.
* Availability of buffer storage.

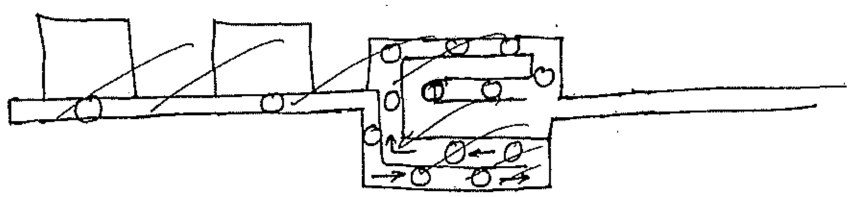
Rotary configuration in ~~contract~~ Contrast to the above, used when,
* The number of operations required on the product is less.
* Smaller size of the product.
* Limitation on the available space.
* Limitation of the buffer storage.

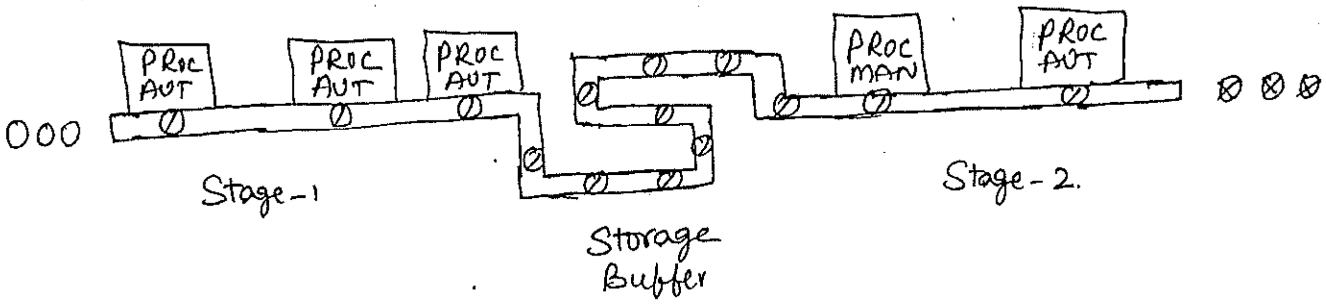
Rotary Configuration:



In the rotary configuration, the workparts are attached to fixtures around the periphery of a circular worktable and the table is indexed to present the parts to workstations for processing. The worktable is often referred to as a dial and the equipment is called a dial indexing machine (or) Indexing machine.

Buffer Storage:





A Buffer storage is a location in the production line where parts can be collected and temporarily stored before proceeding to subsequent workstations. The storage buffers can be manually operated or automated. When it is automated, a storage buffer consists of a mechanism to accept parts from the upstream workstation, a place to store the parts, and a mechanism to supply parts to the downstream station. A key parameter of a storage buffer is its storage capacity, that is the number of workparts it is capable of holding.

The principal reasons for the use of buffer storage is to reduce the effect of individual breakdowns in the line. When a breakdown occurs at the individual stations, production must be stopped.

The following are the common reasons for line stoppages;

- Tool failures or tool adjustments at individual stations
- Scheduled tool changes.
- Defective workparts or components at assembly stations.
- Any electrical malfunction.
- Mechanical failure of transfer mechanism systems.

When a breakdown occurs on an automated ~~flow~~ line, the purpose of buffer storage is to allow a portion of the line to continue operating. The remaining portion of the line is stopped for repair.

A buffer storage divides the line into two stages. If the breakdown of any workstation cause first stage of the line to stop, then the second stage will continue to operate as long as the supply of parts in the buffer zone lasts. Similarly, If the second stage has to be shut down, the first stage will continue to operate as long as there is a place in the buffer storage to store the parts.

Reasons for use of Buffer Storage in flow Lines;

i) TO reduce the Effect of station breakdown - Storage buffers permit one stage to operate continuously.

ii) TO provide a bank of parts to supply the line - Parts can be collected into a storage unit and can be automatically fed to a downstream stations.

iii) TO allow for curing time or other required delay - A curing or setting Time is required for some processes like painting or adhesive applications. The storage buffer is designed to provide sufficient time for curing.

iv) TO smooth out cycle Time variations :- If any of manual stations are present in a line, this point is relevant as the cycle time will vary from one operator to another on the manual stations.

The Disadvantages of the buffer storage are Increased floor space, Higher work-in-process inventory, more material handling equipment and greater complexity of the line.

Control of the Production Line: Controlling an automated production line is a complex process because of the number of sequential and simultaneous activities that occur during the operations.

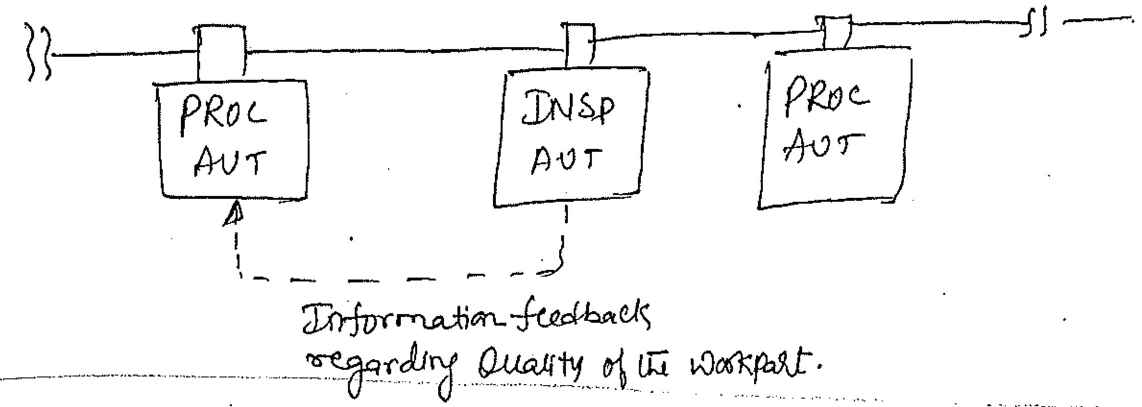
Following are the basic control functions that can be considered to control the operations of production line:

i) Sequence Control – Operational requirement
ii) Safety monitoring – Safety requirement.
iii) Quality Control – Quality requirement.

The purpose of sequence control is to co-ordinate the sequence of actions of the transfer system and workstations. The various activities of the production line must be carried out with split-second timing and accuracy. On a Transfer line, the parts must be released from their current workstations, transported, located and clamped into position at their respective next workstations. All these operations to be sequentially monitored.

The safety monitoring ensures that the production line does not operate in an unsafe manner. Safety applies to both the workers and the machines. Sensors may be incorporated to monitor the tool status, breake of the tool etc.

In Quality control functions, quality attributes of the workparts are monitored. The purpose is to detect and possibly reject defective workunits produced on the line. The inspection devices will be incorporated into the flow line. It is possible to Extend the quality monitoring to incorporate a control loop into the flow line as shown in fig below:



An inspection station will be used to monitor the quality characteristics of the part and to feed back information to the preceeding ~~~~~~~~ workstation so that adjustments in the process could be made.

Two additional alternative control strategies (or) Auxillary control functions present. They are

a) ~~Instantaneous control~~

a) Instantaneous control

b) Memory control.

Instantaneous control mode stops the line immediately when a defect or malfunction is detected. This is relatively simple, inexpensive, easiest to implement & reliable. Diagnostic features can be added to aid in identifying the location and cause of the problem so that repairs can be made instantly.

In contrast to ~~instaneous~~ instantaneous control, memory control is designed to keep the line running. If the problem is associated with a particular work unit ie a defective part is detected, memory control prevents subsequent stations from processing the particular unit as it moves towards the end of the line. When the part reaches the last station, it is seperated from the rest of the good parts produced.

Fundamentals of Automated Assembly Systems:

The Term automated assembly refers to the use of mechanized and automated devices to perform the various assembly Tasks in an assembly line. Most automated assembly systems are designed to perform a fixed sequence of assembly steps on a specific product. Automated assembly Technology should be considered when the following conditions Exist:

* High product demand.
* Stable product design.
* A limited number of components in the assembly
* product designed for automated assembly.

An automated assembly system performs a sequence of automated assembly operations to combine multiple components into a single entity. The single entity can be a final product or a sub assembly in a larger product. A typical automated assembly system consists of the following subsystems:

i) one or more Workstations at which the assembly is done.
ii) Parts feeding devices that deliver the individual components to the Workstations.
iii) A Workhandling System.

Configurations (or Classifications or Types) of Automated Assembly Systems:

Automated assembly systems can be classified according to physical configuration. They are

i) In-line assembly machine.

ii) Dial type assembly machine.

iii) Carousel assembly system

iv) Single station assembly machine.

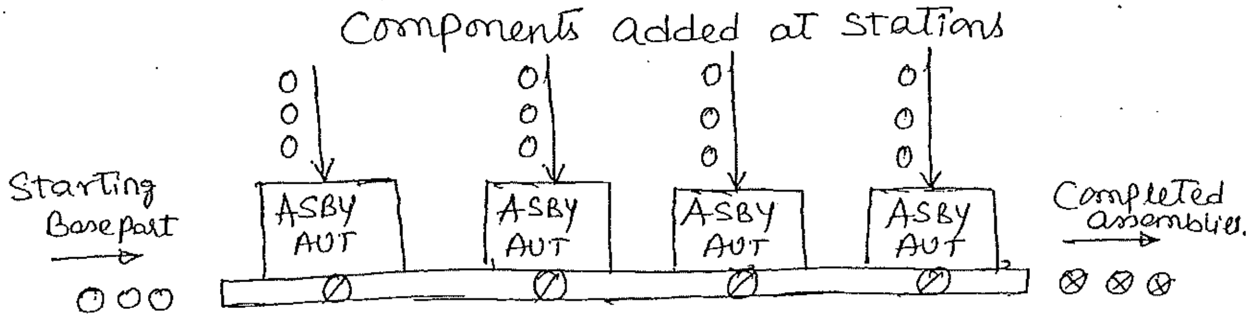


Fig: In-line Type

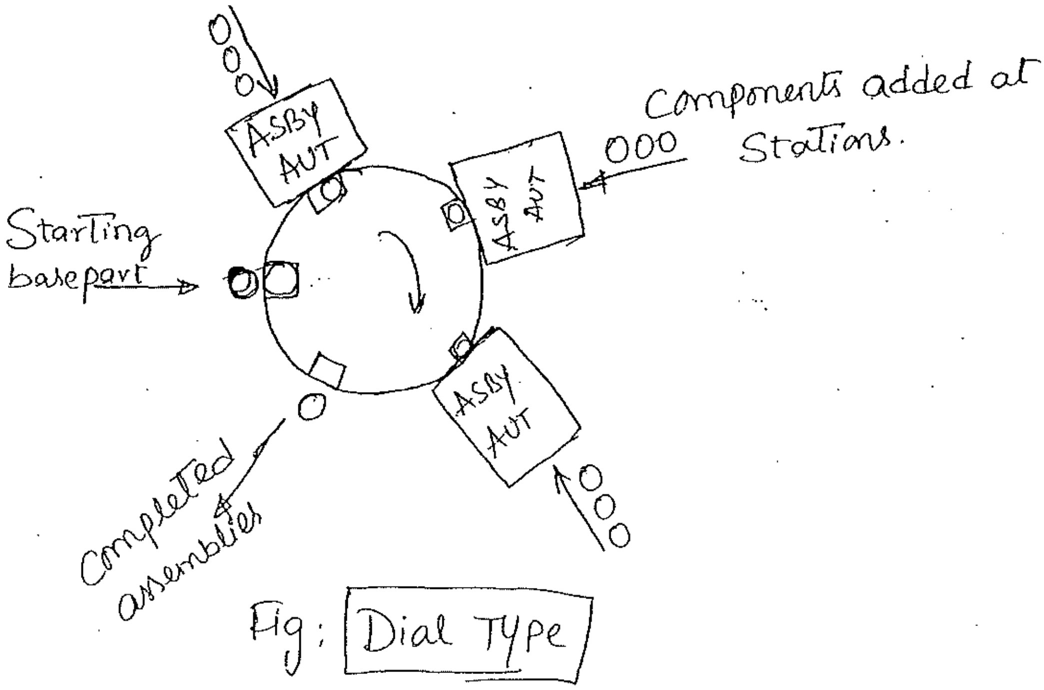


Fig: Dial Type

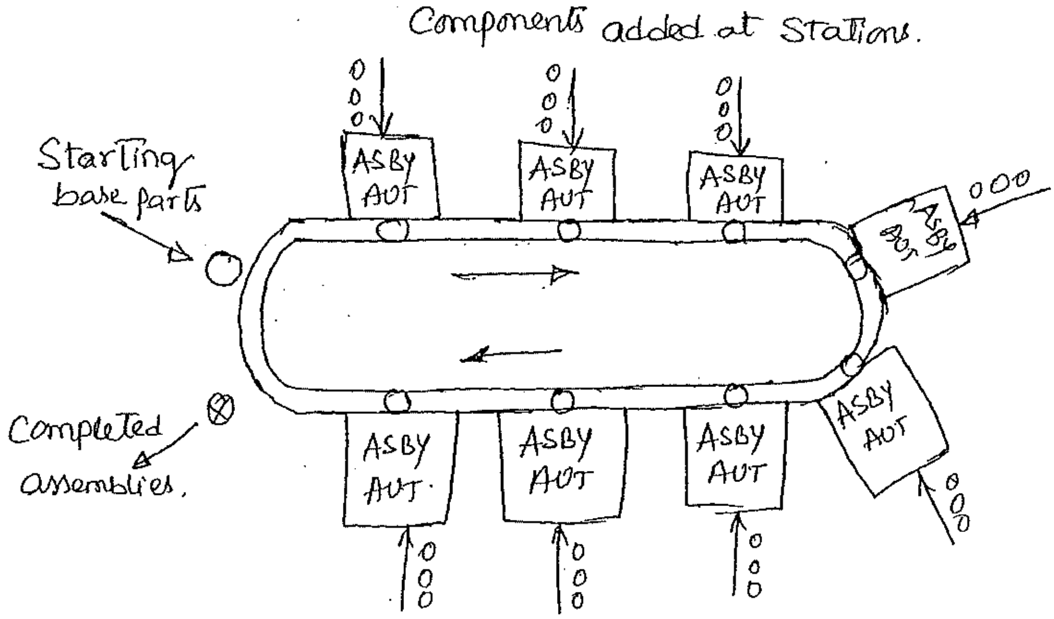


Fig: Carousel Type

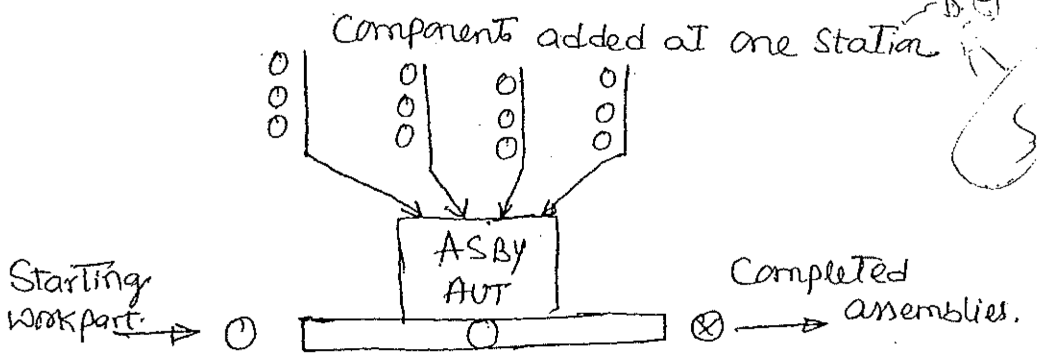


Fig: Single Station Type

The in-line assembly machine is a series of automatic workstations located along an in-line transfer system. Here the base part is launched on to the first workstation. In Each workstations, the components will get added up to make the final assembly.

In Dial-Type machine, base parts are loaded on to fixtures attached to the circular dial. Components are added to the base part at the various workstations located around the periphery of the dial. This is common in beverage bottling & canning plants.

The Carousel assembly system represents a hybrid between the circular work flow of the dial type assembly machine and the straight work flow of the in-line system.

In the single-station assembly machine, assembly operations are performed on a base part at a single location. The operating cycle involves the placement of base part, the addition of components and finally the removal of the completed assembly from the station.

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Unit - 6

Computerized Manufacturing Planning System

CONTENTS : Computerized Manufacturing Planning System : Introduction, Computer Aided Process Planning, Retrieval types of process planning, Generative type of process planning, Material requirement planning, Fundamental concepts of MRP Inputs to MRP, Capacity planning.

6.1 INTRODUCTION

The product design is the plan for the product, and its components and subassemblies. To convert the product design into a physical entity, a manufacturing plan is needed. The activity of developing such a plan is called **PROCESS PLANNING**. It is the link between product design and manufacturing.

Process planning involves determination of the sequence of processing and assembly operations that must be performed to develop the product. Process planning is concerned with the engineering and technological issues of how to make the product and its parts. The scope and variety of processes that can be planned are generally limited by the available processing equipment and the technological capability of the plant.

Process planning is usually accomplished by manufacturing engineers. The process planner must be familiar with all the manufacturing processes available in the plant and be able to interpret engineering drawings. The logical steps and decisions incorporated during process planning stage are as follows :

(1) **Interpretation of design drawings :** The part or product design must be analyzed (i.e., materials, dimensions, tolerances, surface finish etc) at the start of the process planning.

(2) **Processes and sequence :** The process planner must select which processes are required and their sequences. A brief description of the processing steps must be prepared.

(3) **Equipment selection :** In general, process planners must develop plans that utilize existing equipment in the plant.

(4) **Tools, dies, jigs and fixtures :** The process planner must decide what tooling is required for each processing step, which includes dies, jigs and fixtures in addition to cutting tool.

(5) **Work standards :** Work measurement techniques are used to set time standards for each operation.

(6) **Cutting tools and cutting conditions :** These must be specified for each machining operation very clearly.

Process planning for parts : For individual parts, the processing sequence is documented on a form called **"Route sheet"** (operation sheet). A typical route sheet format and the general contents includes the following information.

(1) All operations to be performed on the workpart listed in the order in which they should be performed.

(2) A brief description of each operation indicating the processing steps to be performed.

(3) The specific machines on which the work is to be done.

(4) Any special tooling, jigs and fixtures required.

(5) Setup time and standard time required to complete the operation.

It is called as a route sheet because the processing sequence defines the route that the part must follow in the factory so as to finish the product manufacturing.

Routing :

Routing is a series of actions to be performed to achieve a particular goal. In a manufacturing or production unit routing defines the exact process by which a product is to be manufactured or a service is to be delivered. That is routing will spell the most efficient and economical way to perform a function. In manufacturing sector routings are prepared keeping in mind, the number of employees' available, type/s of machinery/equipment available, their capacity and run time etc.

Route sheet :

Route sheet is a hardcopy document which has the information and data inputs and a step wise listing of all processes and transaction performed in minute detail. It is a form containing the details of manufacturing processes of a part. It provides the exact location of the various processes of the part. In addition to this it also provides the sequence or order of involvement of various departments in the production of that part. It also contains details such as date and time log in/out, point of contact remarks etc..A typical route sheet format is as shown in Table 6.1.

Table 6.1 : A typical Route Sheet Format

Sl.No.	Symbols	Task Number	Description of the task	Time taken for the task	Machinery/ Equipment Required

6.2 COMPUTER AIDED PROCESS PLANNING (CAPP)

Computer Aided Process Planning is a means of implementing process planning function by computer. The CAPP represents the link between design and manufacturing. There is a much interest by a manufacturing firm in automating the task of process planning. The subsequent result in Computer Aided Process Planning. The shop-trained people who are familiar with the details of machining and other processes are gradually retiring and these people will be unavailable in the future to do process planning. An alternative way of accomplishing this function is needed and CAPP systems are providing this alternative.

Computer Aided Process Planning systems are designed around two approaches.

(1) Retrieval CAPP system.

(2) Generative CAPP system.

6.3 RETRIEVAL CAPP SYSTEM

Retrieval type CAPP system also called variant CAPP systems. It is based on the principles of group technology and parts classification & coding. In this approach, similar parts are identified and grouped together to take advantage of their similarities in manufacturing and design. Similar parts are arranged in to a part family. Parts classification and coding results in a code number that uniquely identifies the part's characteristics.

In this type of a CAPP, a standard process plan is stored in computer files for each part code number. The standard route sheets are based on current part routings in use in the factory or an ideal plan that is prepared for each family.

The general procedure of a retrieval type CAPP system is as shown in the fig. 6.1.

The user begins by deriving the GT code number for the component for which the process plan is to be determined. With this code number, a search is made in the part family file to determine if a standard route sheet exists for the given part code. If the file contains a process plan for the part, it is retrieved and displayed for the user. The standard process plan is examined to determine whether any modifications are necessary. The user edit the standard plan accordingly. Because of this capability of alternation to the existing process plan, retrieval system is also called **"Variant System"**.

If an exact match cannot be found between the code number of the new part, the user may search the computer file for the presence of a similar or related code number for which a standard route sheet exist. Now either by editing an existing process plan or by starting from scratch, the user can write the route sheet for the new part. This route sheet becomes the standard process plan for the new part code number.

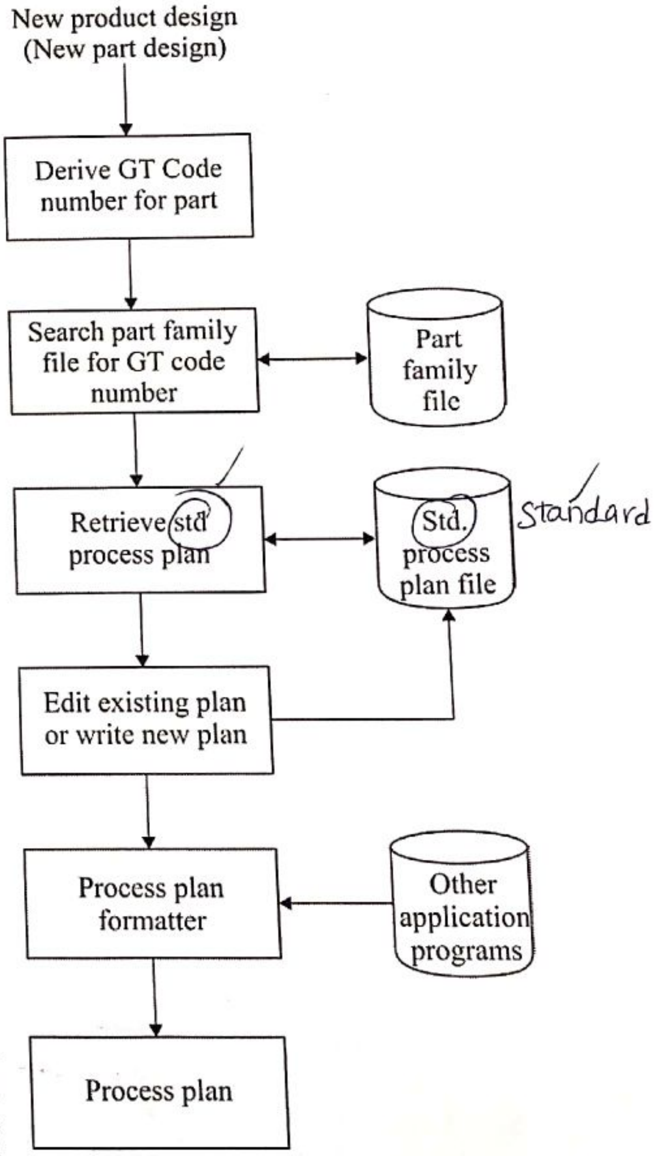

Fig. 6.1 : Retrieval type CAPP system

The process planning session concludes with the process plan formatter prints out the route sheet. The formatter may call other application programs like, To determine machining conditions for the various machine tools. To calculate the standard time for operations etc. One of the commercially available retrieval CAPP system is MultiCAPP from Organisation of Industrial Research.

6.4 GENERATIVE TYPE CAPP SYSTEM

Generative type CAPP involves the use of the computer to create an individual process plan from scratch automatically and without human assistance. Instead of retrieving and editing an existing plan contained in a computer database, a generative system creates the process plan based on logical procedures similar to the human process planner. In a fully generative CAPP system, the process sequence is planned without human assistance and without a set of predefined standard plans. The general procedure of Generative type CAPP system is shown in fig. 6.2.

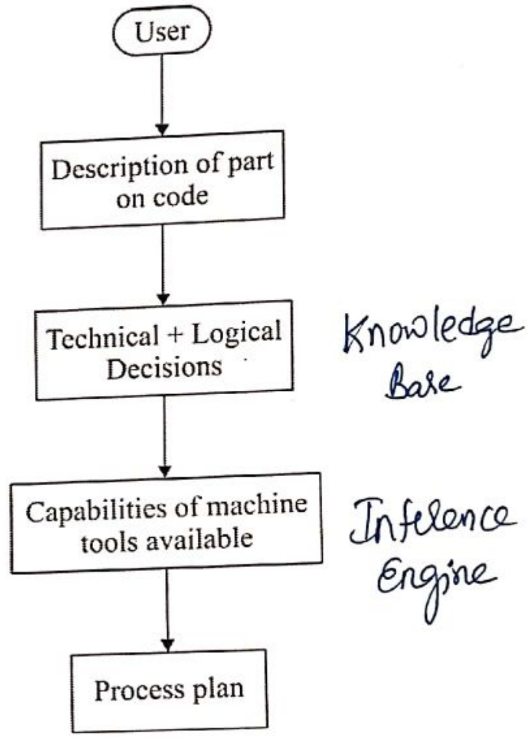

Fig. 6.2 : Generative type CAPP system

Designing a generative CAPP system is a part of the expert system and branch of artificial intelligence. An expert system is a computer program that is capable of solving complex problems that normally requires a human being with more experience and education.

There are several parameters required in a fully generative process planning system. The most important of them are :

The technical knowledge of manufacturing and the logic used by the successful process planners must be obtained and coded into a computer program. In an expert system applied to process planning, the knowledge and the logic of the human process planners is incorporated into a "Knowledge Base". The generative CAPP system will then use this knowledge base to solve a process planning problems.

The second parameter in the important list is a computer compatible description of the part to be produced. The description contains all of the pertinent data and informations needed to plan the process sequence. The possible ways of providing this information is given by :

(i) The geometric model of the part developed on a CADD system.

(ii) The GT code number of the part which defines the part features.

The third is the capability to apply the process knowledge and the logic contained in the knowledge base to a given part. The CAPP system uses its knowledge base to solve a specific problem of writing a process planning. This problem solving procedure is referred as "Inference Engine". By using the knowledge base and inference engine, a generative CAPP system synthesizes a new process plan from scratch for each new part.

Benefits of CAPP

(1) **Process rationalization and standardization :** Automated process planning leads to more logical and consistent process plans. Standard plans tend to result in lower manufacturing costs and higher product quality.

(2) **Increased productivity of process planners :** The systematic approach and the availability of standard process plans permit more work to be accomplished by the process planners.

(3) **Reduced lead time for process planning :** Process planners working with the CAPP system can provide route sheets in a shorter lead time compared to manual process planning operation.

(4) **Improved legibility :** Computer prepared route sheets are legible and easier to read and understand.-

(5) **Incorporation of other application programs :** The CAPP programs can be interfaced with other application programs like cost estimation, work standards, estimating machining conditions etc.

6.5 COMPUTER INTEGRATED PRODUCTION PLANNING SYSTEMS

The principle functions (or activities) involved in a production planning systems are given in fig. 6.5.

6.3

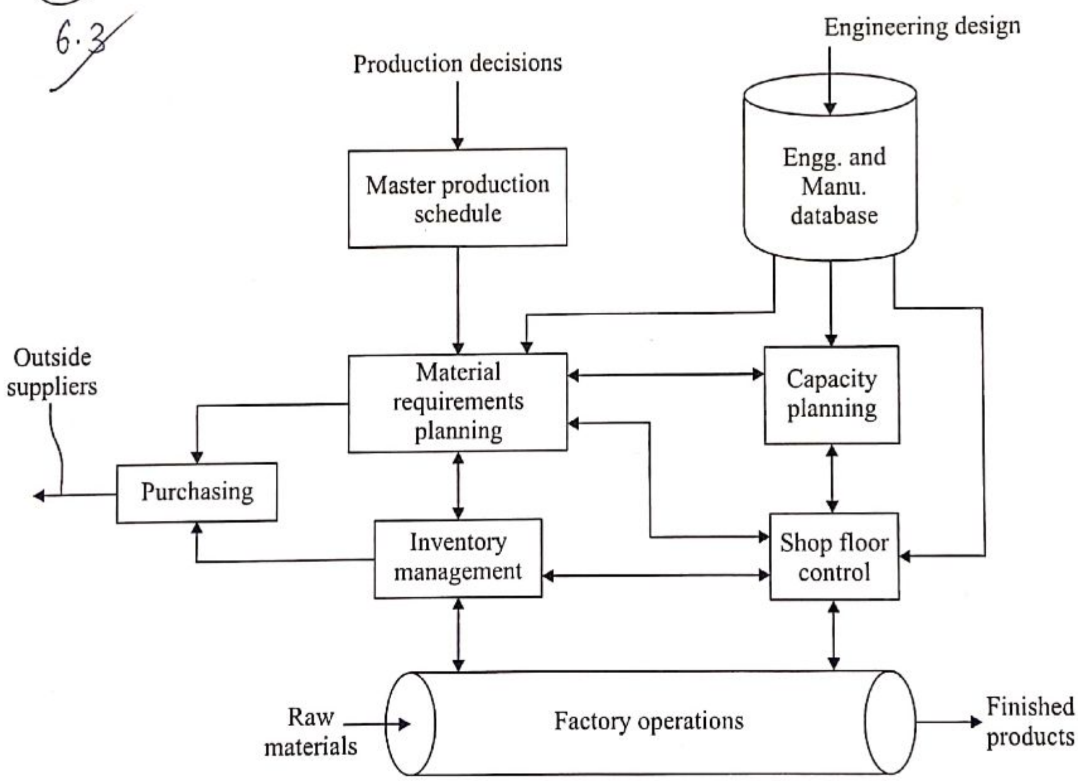

Fig. 6.3 : Activities in a production planning and control system

(1) **Master production schedule :** Master production schedule is a listing of the products to be manufactured, when they are to be delivered and in what quantities. It is developed from customer orders and forecasts of future demand. The master schedule represents the plan of the production for the firm which serves as an input to the material requirement planning function.

(2) **Material Requirement Planning (MRP) :** This is a procedure used for determining when to order raw materials and components for assembled products.

(3) **Capacity planning :** Capacity planning is concerned with the planning of production resources like labor and equipment needed to meet the master schedule.

In addition to the above functions, there are other functions which interface with the production planning functions. They are :

(i) **Engineering and Manufacturing database :** This database contains the engineering data required to make the components. The engineering data includes the product design, material specifications, bill of materials, process plan etc. This data base is utilized to perform the planning calculations for MRP and capacity planning.

(ii) **Inventory Management :** This is concerned with investment on raw materials, work-in-process, finished goods, factory supplies. This should be as low as possible without disrupting the production operations.

(iii) **Purchasing :** Purchasing department places the orders that are specified by the MRP and inventory management. Qualifying vendors are included to achieve this function.

(iv) **Shop floor control :** It is concerned with monitoring the progress of orders in the factory and reporting the status of each order to management so that effective control can be exercised.

6.6 MATERIAL REQUIREMENTS PLANNING

Material Requirement Planning (MRP) is a computational technique that converts the master schedule into a detailed schedule for the raw materials and components used in the end product. The detailed schedule identifies the quantities of each raw material and components required. It also indicates when each item must be ordered and delivered so as to meet the master schedule.

MRP is a method of inventory control. It is an effective tool for minimizing unnecessary inventory investment. MRP is also useful in production scheduling and purchasing of materials. The master schedule provides the overall production plan for the final products in terms of units to be produced. Each of the product may contain hundreds of individual components. These components are produced from raw materials, some of which are common among the components. The components are assembled into simple subassemblies and these subassemblies are put together into a main assembly. Each step in the manufacturing and assembly sequence takes time. All these factors must be considered during MRP calculations.

6.7 FUNDAMENTAL CONCEPTS OF MRP

MRP is based on the following concepts :

(1) Independent demand versus Dependent demand.

(2) Lead Times.

(3) Commonly used items.

Independent demand means that demand for a product is **not directly related** to demand for other items. End products and spare parts are examples of independent demand. **Independent demand patterns must usually be forecasted**. Dependent demand means that demand for the item is related directly to the demand for some other product. The components, raw materials and subassemblies are the items subjected to dependent demand.

The demand for the company's end product can be forecasted. But the raw materials and component parts should not be forecasted. Once the delivery schedule for end products is established, the requirements for components and raw materials can be calculated directly.

MRP is the appropriate technique for determining quantities of dependent demand items. These items constitute the inventory of manufacturing i.e., raw materials, work-in-process, component parts and subassemblies. Thus, MRP is a powerful technique in the planning and control of manufacturing inventories.

The lead time for a job is the time required to complete the job from start to finish. There are two types of lead times in MRP. **Ordering lead time** and **manufacturing lead time.**

An ordering lead time is the time required from the initiation of the purchase requisition to the receipt of the item from the vendor. If the item is a raw material that is stocked by the vendor, the ordering lead time is shorter. If the item is fabricated, the lead time may be larger. The manufacturing lead time is the total time required to complete the job considering operation time, Non-operation time and setup time.

Commonly used items are raw materials and components that are used on more than one product. MRP collects these common use items from different products to effect economies during ordering the raw materials.

6.8 INPUTS TO MRP SYSTEM

For the MRP to function properly, it must operate on data contained in several files. These files serve as inputs to the MRP system and they are

(1) Master production schedule file.

(2) Bill Of Materials (BOM) file.

(3) Inventory record file.

Fig. 6.4 illustrates the flow of data into the MRP system and its conversion into useful output reports.

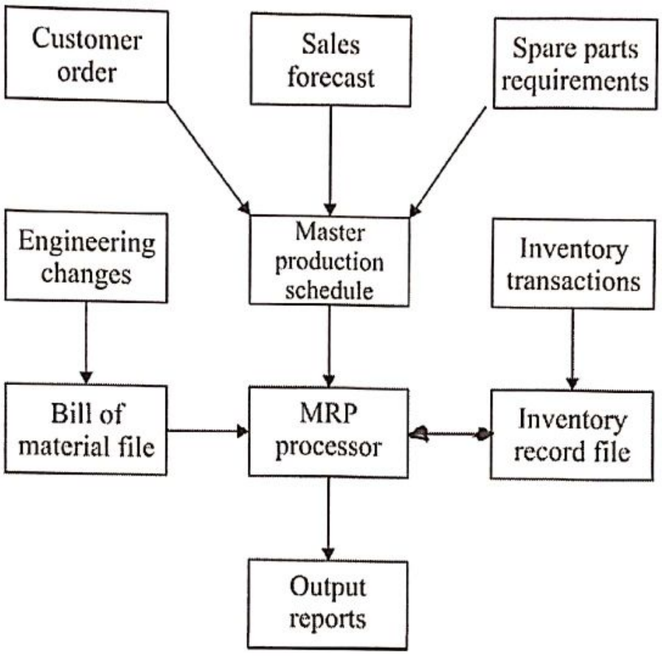

Fig. 6.4 : Structure of MRP system

The master production schedule is a listing of what end products are to be produced, how many of each product to be produced and when they are to be delivered. The master schedule must be based on an accurate estimation of demand and a realistic assessment of its production capacity.

Product demand that makes up the master schedule can be separated into three categories. The first consists of guaranteed customer orders for specific products. These orders usually includes a delivery date promised to the customer. The second category is forecasted demand. The forecast may constitute the major portion of the master schedule. The third category is the demand for individual component parts. These are spare parts and are stocked in the companys spare parts department.

The Bill Of Materials (BOM) file is used to compute the raw material and component requirements for end products listed in the master schedule. It provides information about the product structure by listing the component parts and subassemblies that make up each product. The structure of an assembled product can be pictured as shown in figure 6.5

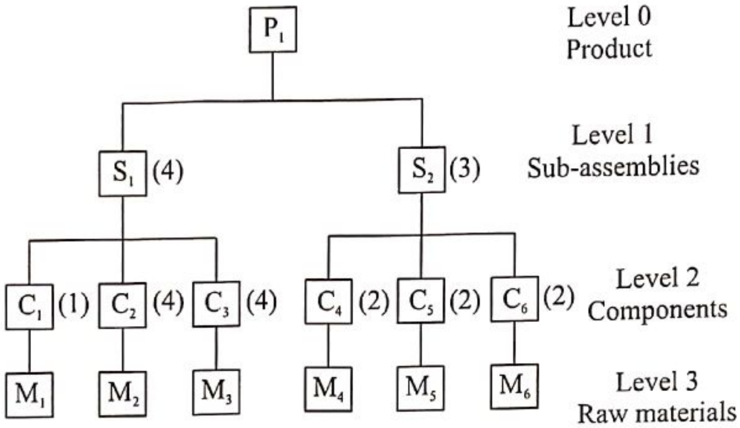

Fig. 6.5 : Bill of Material structure for a single product

This is relatively a simple product in which a group of individual components make up two subassemblies which inturn make up the product. The product structure is in the form of pyramid, with lower levels feeding into the levels above. The items at each successively higher level are called the parents of the items in the level directly below i.e., subassembly S_1 is the parent of component C_1, C_2 and C_3. The product structure also specifies how many of each item are included in its parent. This is shown in the paranthesis. Explanation of the above structure is provided below.

To produce one product P, 4 items of S_1 (hence [(S_1)4)] and 3 items of S_2 [i.e. (S_2)3] are required.

One item of S_1 requires one item of C_1, [C_1(1)], 4 items of C_2 and 4 items of C_3.

The raw materials required to produce one part C_1 is M_1, part C_2 is M_2 and part C_3 is M_3 respectively.

Similar explanation holds good for item $\mathbf{S_2}$.

The inventory record file is referred to as the **item master file** in a computerized inventory system. The data contained in the inventory record file are divided into three segments.

(a) Item Master Data : This provides the items identification (part number) and the other data about the part such as order quality and lead time.

(b) Inventory status : This gives a time phased record of inventory status. In MRP, it is important to know not only the current level of inventory but also the future changes that may occur against the inventory.

(c) Subsidiary data : It provides data such as purchase orders, scrap or rejects and engineering changes.

The MRP processor operates on the data contained in the Master Production Schedule (MPS), the Bill of Materials file and the inventory record file.

WORKING Of MRP:

The MPS provides a period-by-period list of final products required. The BOM defines what materials and components are needed for each product. The inventory record file contains information on the current and future inventory status of each component. The MRP processor computes how many of each component and raw material are needed each period by "exploding" the end product requirements into successively lower level in the product structure.

6.9 MRP OUTPUT REPORTS

The MRP program generates a variety of outputs which can be used in planning and managing plant operations. The output include

(i) Planned order releases which provide the authority to place orders as planned by MRP system.

(ii) Report of planned order releases in future periods.

(iii) Rescheduling notices, indicating changes in due dates.

(iv) Cancellation notices, indicating the reasons.

(v) Report on inventory status.

(vi) Performance reports of various types, costs, actual v/s planned lead times etc.

(vii) Exception reports showing deviations from the schedule.

(viii) Inventory forecasts indicating projected inventory levels.

6.10 MRP BENEFITS

The benefits from a well-designed MRP system is

(i) Reduction in inventory.

(ii) Quicker response to changes in demand.

(iii) Reduced setup and product changeover costs.

(iv) Better machine utilization.

(v) Improved capacity to respond to changes in the master schedule.

(vi) As an aid in developing the master schedule.

6.11 CAPACITY PLANNING

Capacity planning is concerned with determining what labor and equipment capacity is required to meet the master production schedule as well as long term future production needs of the company. Capacity planning also serves to identify the limitations of the production resources so that an unrealistic master schedule is not planned.

Capacity planning is typically accomplished in two stages. When MPS is established and when the MRP computations are done. Fig. 6.6 shows the concept of capacity planning.

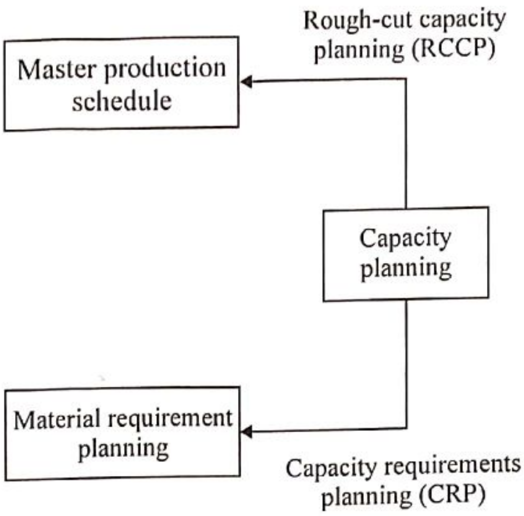

Fig. 6.6 Concept of Capacity Planning

In the MPS stage, a **Rough-Cut Capacity Planning (RCCP)** calculation is made to assess the feasibility of the master schedule. Such a calculation indicates whether there is a significant violation of production capacity in the MPS. A second capacity calculation is made at the time the MRP schedule is prepared called the **Capacity Requirements Planning (CRP)**. This determines whether there is sufficient production capacity in the individual department to complete the specific parts, that have been scheduled by MRP. If the schedule is not compatible with capacity, adjustments must be made either in plant capacity or in the MPS.

Capacity adjustments can be divided into short term and long term adjustments. Short term capacity adjustments include the following :

(i) Employment levels : Employment in the plant can be increased or decreased in response to changes in capacity requirements.

(ii) Temporary workers : Increase in employment level can also be made by using temporary workers.

(iii) Number of work shifts : The number of shifts worked per production period can be increased or decreased.

(iv) Labor hours : The number of labor hours per shift can be increased or decreased through the use of overtime or reduced hours.

(v) Inventory stockpiling : This might be used to maintain steady employment levels during slow demand periods.

(vi) Order backlogs : Deliveries of the product to the customer could be delayed during busy periods when production resources are insufficient to keep up with demand.

(vii) Subcontracting : This involves the letting of jobs to other shops during busy periods.

Capacity planning adjustments for the long term include possible changes in production capacity that generally require long lead times. These adjustments include

(i) **New equipment investments :** This involves investing in more machines to meet increased future production requirements or investing in new types of machines to match future changes in product design.

(ii) **New plant construction :** It represents a significant increase in production capacity for the firm.

(iii) Purchase of existing plants from other companies.

Exercise

1. Define Process planning. List and explain the logical steps involved in it.
2. Define CAPP. Discuss the benefits of CAPP.
3. With a neat diagram explain the Retrieval type CAPP system.
4. With a neat diagram explain the Generative type CAPP system.
5. With a block diagram explain the principal functions involved in a production planning system.
6. Explain the importance of MRP.
7. With a block diagram explain the fundamental concepts of MRP.
8. With a block diagram explain the inputs to the MRP system.
9. List the MRP output reports and benefits of MRP.
10. Define Capacity Planning. How capacity planning can be accomplished?
11. What are the short term and long term adjustments needed to meet the capacity. Explain.