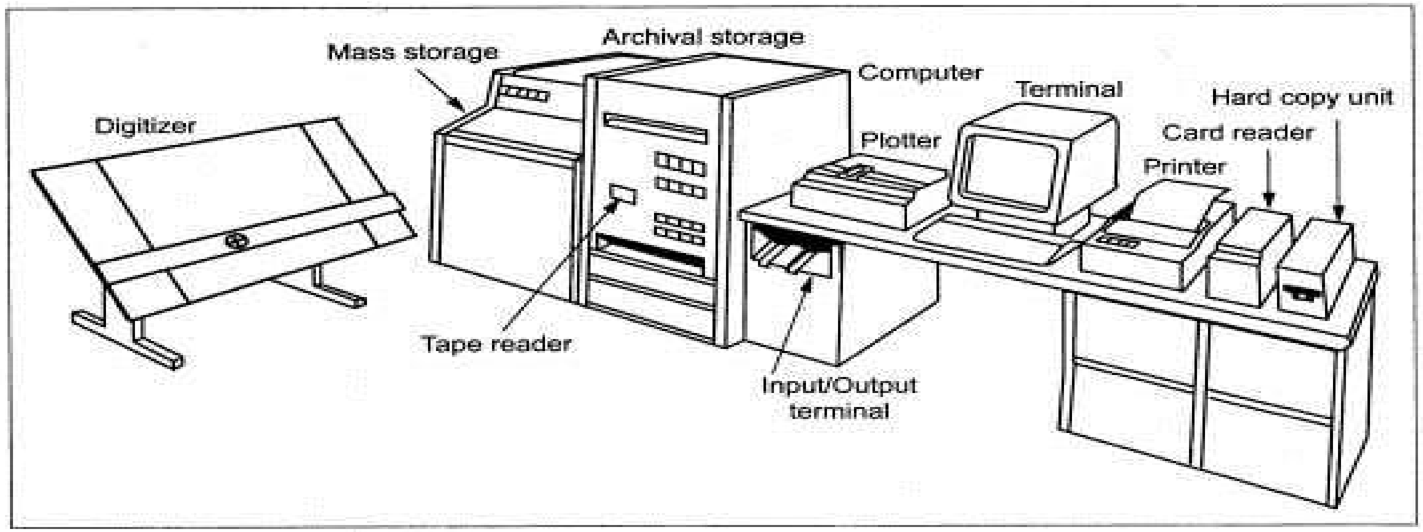
UNIT I
INTRODUCTION

CAD Hardware and Software

CAD hardware:

- Includes the computer, one or more graphical display terminals, keyboard and other peripheral equipment.
- In CAD, the drawing boards are replaced by electronic input and output devices, an electronic plotter, mass storage, an archival storage device, a tape reader, printer, card reader, and hard copy unit, as shown in Figure:



CAD Hardware and Software

CAD software:

- CAD software consists of

  (i) system software and

  (ii) application software.

(i) System software:

- It is used to perform/control the operation of the computer.
- Responsible for making the hardware components to work and interact with each others and the end user.
- Examples of system software are the operating systems, all kinds of hardware drivers, compilers and interpreters.

CAD Hardware and Software

(ii) Application software:

- It is also known as application programs,
- It is used for general or customised/specialized problems.
- Examples of application software are AutoCAD, Solid works, Pro-E, ANSYS, ADAMS, etc.

CAD Hardware and Software

Advantages of an Application Software

- Increased design productivity.
- Shorter lead time.
- Flexibility in design.
- Improved design analysis.
- Fewer design errors.
- Greater accuracy in design calculations
- Standardization of design, drafting and documentation procedures.
- Easier creation and correction of engineering drawings.
- Better visualization of drawings.
- Faster new products design.

CAD Hardware and Software

- The benefits of CAD in manufacturing can be realised in the following areas:

  (i)Tool and fixture design.

  (ii)Generation of NC (numerical control) part programming.

  (iii)CAPP (computer aided process planning).

  (iv)Models generated can be utilized for rapid prototyping.

  (v)Computer aided inspection.

  (vi)Preparation of assembly lists and bill of materials.

  (vii)Group technology (in coding and classification of parts).

  (viii)Robotics and materials handling equipment planning

  (ix) Assembly sequence planning.

Reasons for Implementing CAD

The four fundamental reasons for implementing a CAD system are as follows:

- **To increase the productivity of the designer.**

Using CAD, the designer can visualize quickly the product and its components, subassemblies and parts.

Reduces the time required for synthesis, analysis and documentation of the design.

Reduces product design time and cost.

- To improve the quality of design.

Design alterations can be done quickly without error.

Reasons for Implementing CAD

- **To improve communications.**

Provides better documentation of the design, fewer drawing errors with greater legibility.

- **To create a database for engineering.**

Design database consists of product geometries and dimensions, bill of materials, etc. which are essential input for manufacturing of the product.

Applications of CAD

Area	Application
Design	• Assembly layout • New-part design • Standard part library • Tolerance specification • Interface and clearance specification • Part relations in an assembly
Analysis	• Interference checking • Fit analysis • Weight and balance • Volume and area properties • Structural analysis • Kinematics analysis • Tolerance stacking

Applications of CAD

Area	Application
Documentation	• Drawing generation • Technical illustrations • Bill of materials • Image rending
Manufacturing	• Process planning • NC part program generation • NC part program verification • NC machine simulation • Inspection programming • Robot programming and verification • Factory layout

Applications of CAD

Area	Application
Management	• Review and release • Engineering changes • Project control and monitoring • Selection of standard parts and assemblies • Design standards

Design Process in a CAD System (Elements of CAD System)

The conventional design process has been accomplished on drawing boards with the design being documented in the form of detailed engineering drawing.

The conventional design process also known as Shigley model, consists of the following six steps/phases:

1. Recognition of need
2. Identification of problem
3. Synthesis
4. Analysis and optimization
5. Evaluation
6. Presentation

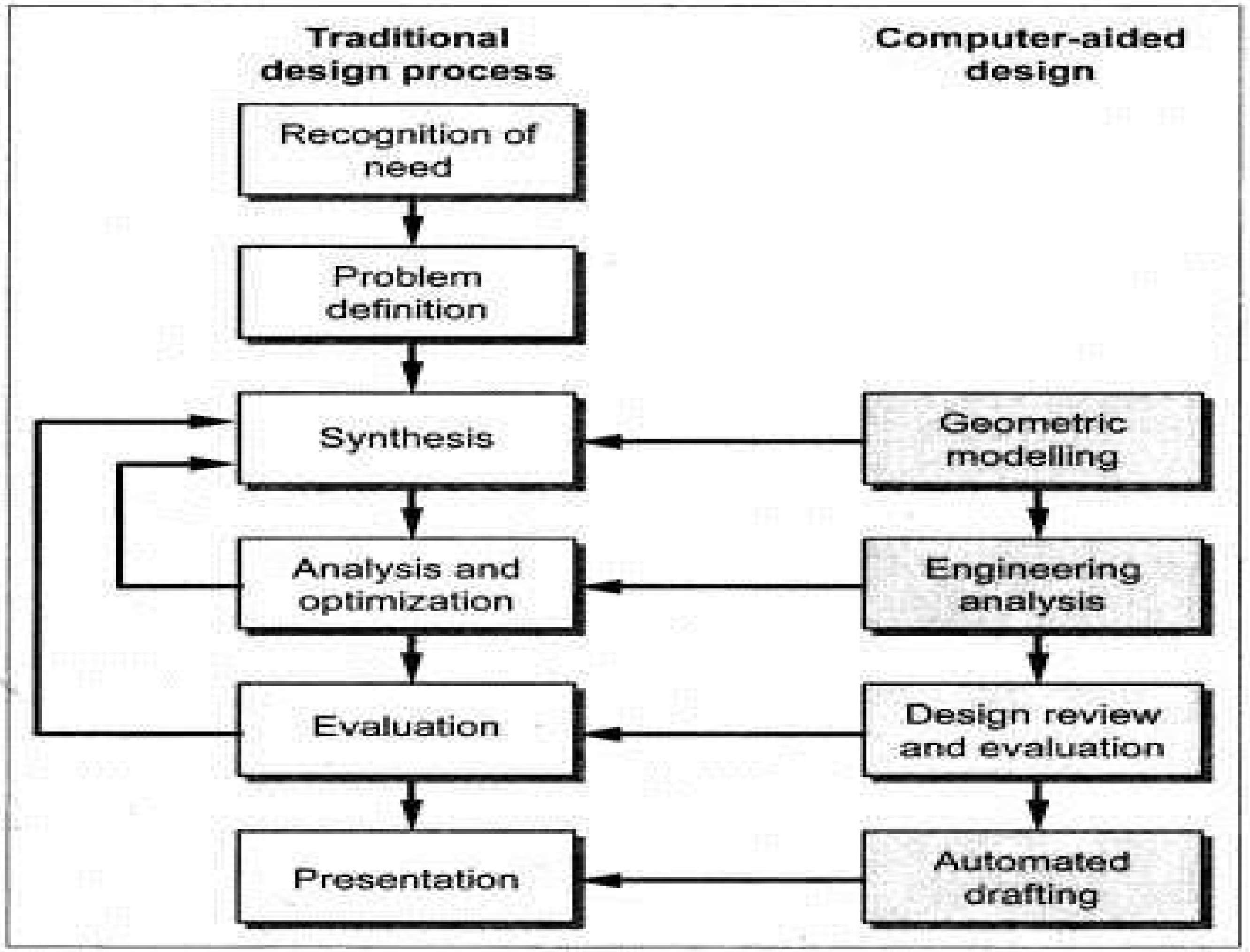
In CAD, the design related tasks are performed by a modern CAD system.

Four Stages of CAD Design Process

Four stages or functional areas of a CAD design process are:

1. Geometric modelling.
2. Design analysis and optimization.
3. Design review and evaluation.
4. Documentation and drafting.

Four Stages of CAD Design Process



Four Stages of CAD Design Process

- Geometric Modelling

Concerned with computer compatible mathematical description of geometry of an object.

The mathematic description of geometry should be such that:

(i) The image of the object can be displayed and manipulated in the computer terminals.

(ii) Modification of the geometry of the object can be done easily.

(iii) It can be stored in the computer memory.

(iv) It can be retrieved back on the computer screen for review, analysis or alteration.

Four Stages of CAD Design Process

- In geometric modelling, three types of commands are used. They are:

(i) Commands used to generate basic geometric entities like points, lines, circles, etc.

(ii) Commands used to do manipulation work like scaling, translation, rotation, etc.

- The models can be represented in three different ways:

(i)Wire-frame

(ii)Surface

(iii)Solid modelling

Four Stages of CAD Design Process

- Design Analysis and Optimization

Once the graphic model is created, the design is subjected to engineering analysis.

  - This phase consist of analysing stresses, strains, deflections and other parameters.
  - The analysis can be done either by using a specific program generated for it or by using general purpose software commercially available in the market.
  - Nowadays sophisticated packages (such as ANSYS, Pro-E, CATIA) having capabilities are available to compute the various performance parameters accurately.
  - Because of the relative ease with which such analysis can be made, designers are increasingly willing to thoroughly analyse a design before it moves into production.
  - Experiments and field measurements may be necessary to determine the effects of loads, temperature and other variables.

Four Stages of CAD Design Process

- Design Review and Evaluation
  - The phase is to review and evaluate to check for any interference between various components in order to avoid difficulties during assembly or use of the part and whether the moving members such as linkages are going to operate as intended.
  - Using the layering procedure, every stage of production can be checked; by using animation, the working of the mechanism can be checked.

- Documentation and Drafting
  - After analysis and review, the design is reproduced by automated drafting machines for documentation and reference.
  - In this phase, detailed and working drawing are developed and printed.
  - Important features of automated drafting are automated dimensioning, scaling of the drawing, development of generating sectional views, enlargement of minute part details and ability to generate different views of the object (like orthographic, oblique, isometric and perspective views).

Computer Aided Manufacturing (CAM)

- Defined as an effective use of computers and computer technology in the planning management and control of the manufacturing function.

- The use of computers to assist in all the phases of manufacturing a product, including process and production planning, machining, scheduling, management and quality control.

Applications of CAM

- The applications of CAM can be divided into two broad categories:

  1.Manufacturing planning.

  2.Manufacturing control.

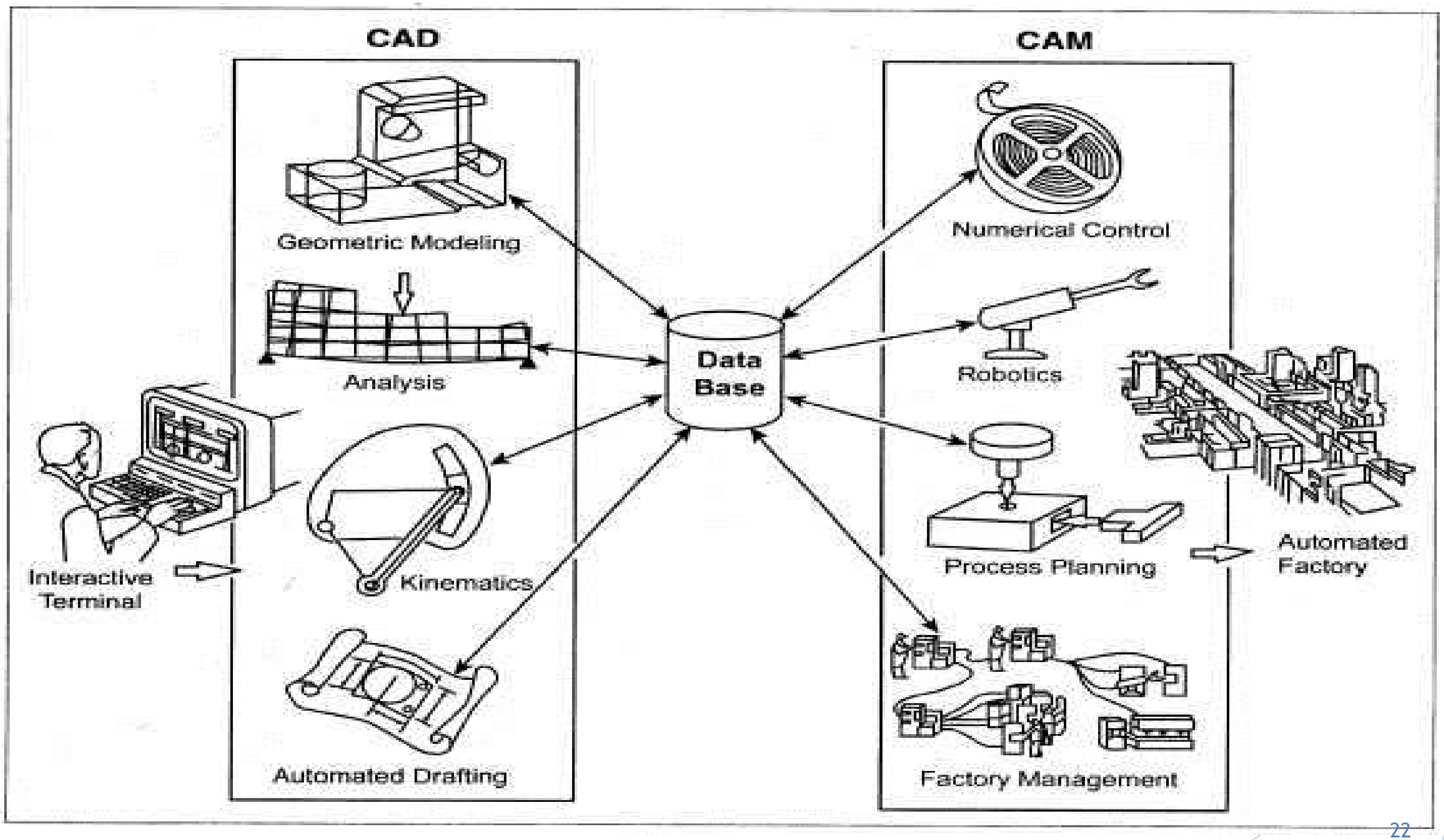
CAD/CAM Interface

- Computer-aided design and computer-aided manufacturing are often combined into CAD/CAM systems because of the benefits.

- By interfacing CAD/CAM technology, it is possible to establish a direct link between product design and manufacturing engineering.

- The user can interact with computer through a graphics terminal to accomplish all the design and manufacturing activities

CAD/CAM Interface

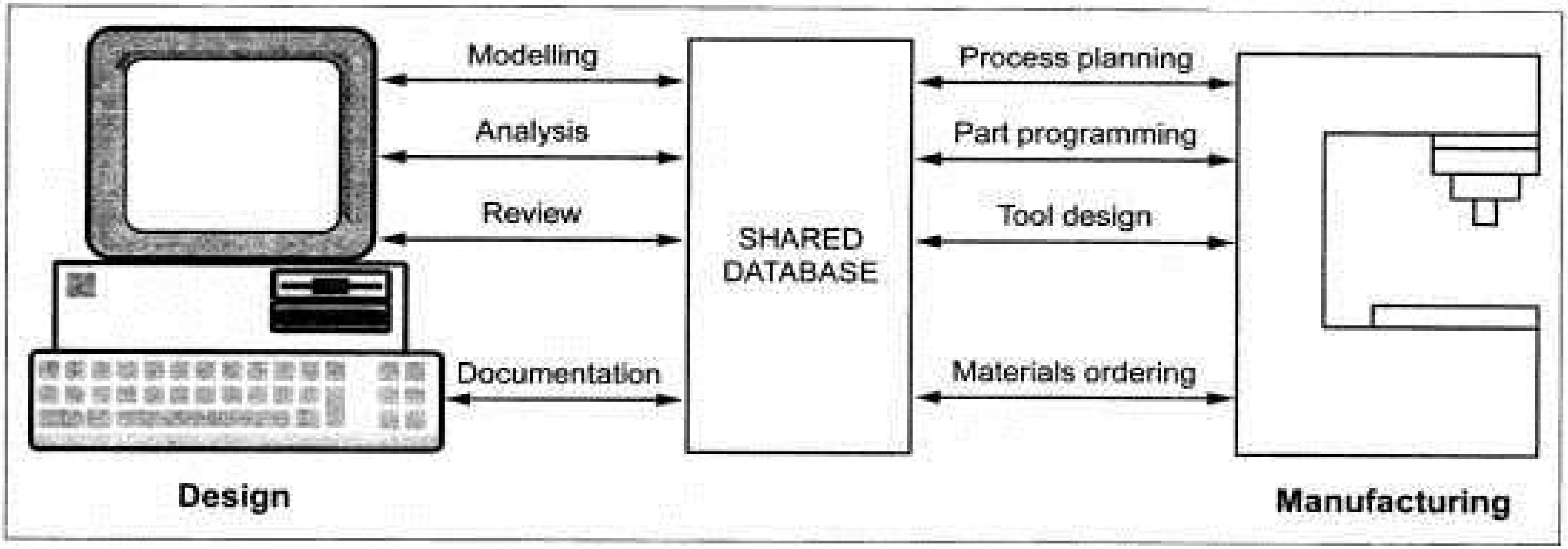


Elements of CAD/CAM interface

- CAD/CAM combination allows the transfer of information from the design stage into the stage of planning for the manufacture of a product without the need to re-enter the data on part geometry manually.

- Database developed during CAD is stored.

- It is processed further by CAM into the necessary data and instructions for operating and controlling production machinery, material-handling equipment and automated testing and inspection for product quality.



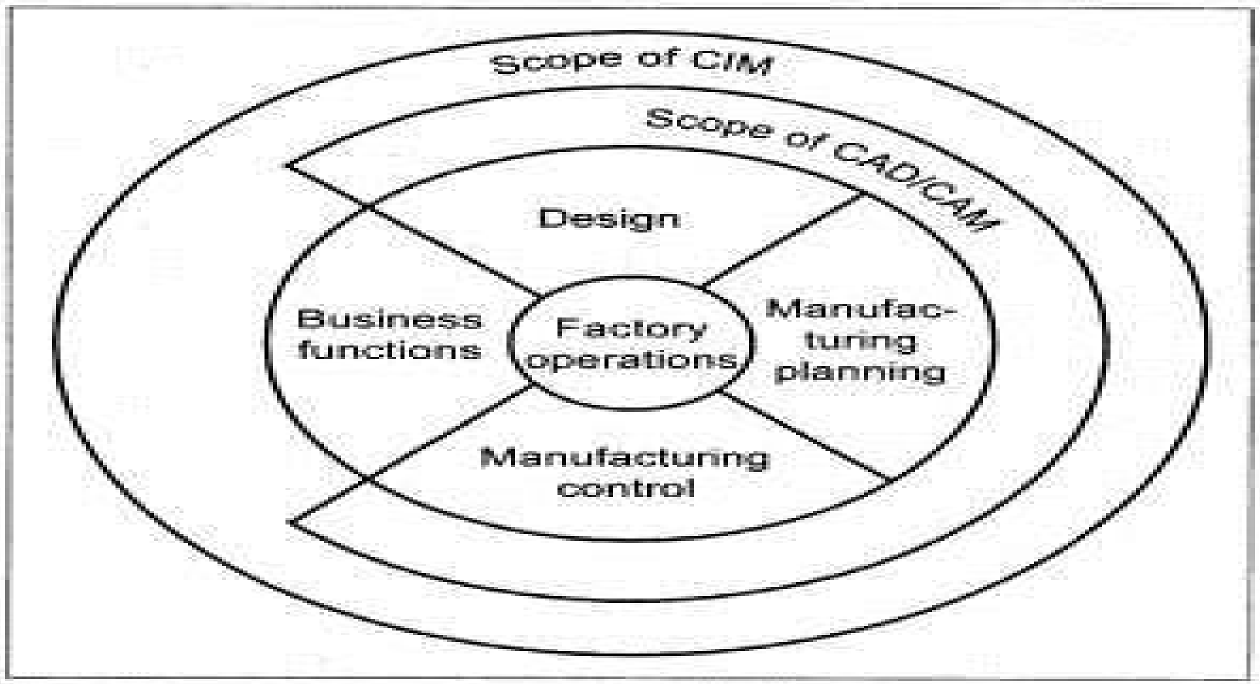
CAD/CAM Vs CIM

- The scope of CAD/CAM includes design, manufacturing planning and manufacturing control.
- Typical applications of CAD/CAM includes:

  - Programming for NC, CNC and industrial robots
  - Design of dies and moulds for casting
  - Dies for metal working operations
  - Design of tools
  - Quality control and inspection
  - Process planning and scheduling
  - Plant layout

CAD/CAM Vs CIM

- CIM
  - Computer Integrated Manufacturing (CIM) includes all of the engineering functions of CAD/CAM and the firm's business functions that are related to manufacturing.
  - CIM = CAD/CAM functions + Business functions
  - Figure below illustrates the scope of CAD/CAM and CIM presented by Groover.



Computer-Aided Drafting

- The process of preparing drawings with the aid of computer is known as computer-aided drafting or computer graphics.
- The computer graphics includes the methods of making plane and geometrical drawings . Plotting of points, drawing of lines, squares, circles, etc. and building up of simple blocks form the computer graphics activities in two dimensions.
- Pictorial views of a machine component, as viewed from different directions can be obtained by using computer graphics.
- In present days the availability of sophisticated computer hardware and computer programmes have enabled solid modelling, which is a 3D representation of a product.
- The entire computer graphics activities integrate the analysis, design, manufacturing and management aspects into one system that may be called computer-aided engineering (CAE).

Major function performed by a computer-aided drafting system

- Basic set-up of a drawing.
- Drawing the objects.
- Changing the object properties.
- Translating the objects.
- Scaling the objects.
- Clipping the object to fit the image to the screen.
- Creating symbol libraries for frequently used objects.
- Text insertion.
- Dimensioning.

Advantages of computer-aided drafting

- It is a fast and convenient method.
- Drawing can be stored in database.
- Changes in drawings can be done easily and quickly.
- Neat and clean drawings of good quality can be prepared.
- Accuracy can be maintained.

Features of CAD systems

- Modelling and drafting:
  - Majority of systems provide 2D and 3D modelling capabilities. Some low cost CAD systems are dedicated to 2D drafting only.
- Ease of use:
  - Users find CAD Systems very easy to learn and use.
- Flexibility:
  - Popular CAD systems provide greater flexibility when configuring the available hardware. Hundreds of computers, display devices, expansion boards, input and output devices are compatible and configurable with popular software.
- Modularity:
  - Standard input and output devices are attached to standard connectors thereby making the system modular in nature.
- Low maintenance cost:
  - Little maintenance is needed to keep the system functional.
  - Software Packages for Modelling (Popular CAD Packages).

CAD packages available for modelling

- Auto CAD
- Pro-E
- IDEAS
- Uni-graphics
- CATIA
- Solid Works
- Solid Edge

Characteristics of a CAD Package

- According to Newman and Sproull, any graphic package should have the following six basic characteristics.

  - Simplicity
  - Consistency
  - Completeness
  - Robustness
  - Performance
  - Economic

Manufacturing Planning

- Important manufacturing planning applications include:

  - Computer-aided process planning (CAPP)
  - Computer-assisted NC part programming
  - Computerised machinability data systems
  - Development of work standards
  - Cost estimation
  - Production and inventory planning
  - Computer-aided line balancing

Manufacturing control

- The manufacturing control applications of CAM are concerned with developing computer systems for implementing the manufacturing control function.
- Is concerned with managing and controlling the physical operations in the factory.

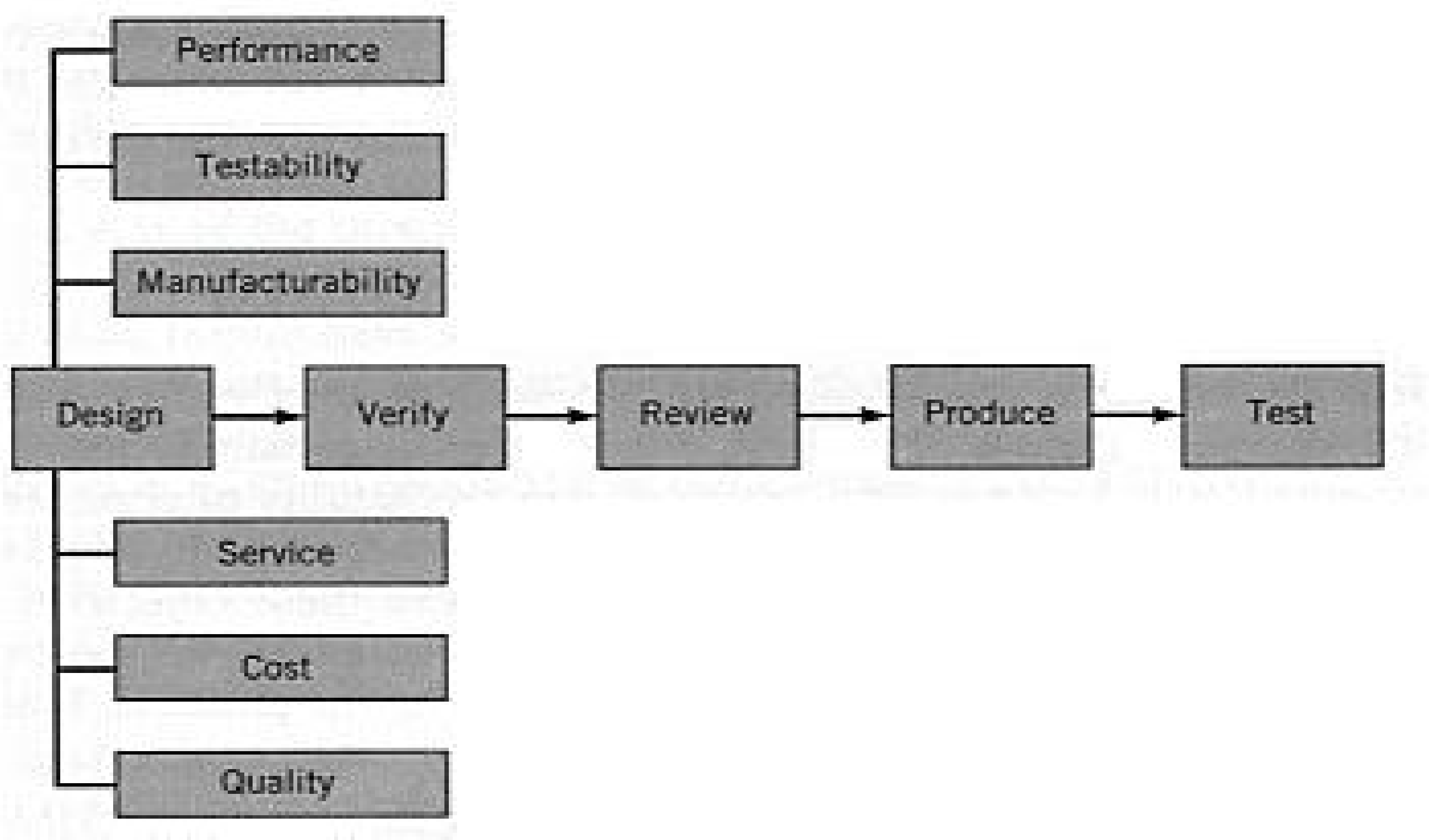
  - Some of the manufacturing control applications include:
    - Process monitoring and control
    - Quality control
    - Shop floor control
    - Inventory control
    - Just-in-time production systems

Concurrent Engineering

- A systematic approach to the integrated, concurrent design of products and their related processes including manufacture and support.

- It is intended to cause the developers from the outset, to consider all elements of the product life cycle from conception to disposal, including quality, cost, schedule and user requirements.

Concurrent Engineering



Concurrent Engineering Element

- Cross-functional teams
  - It Include members from various disciplines involved in the process including manufacturing, hardware and software design, marketing and so forth.
- Concurrent product realization
  - Process activities are at the heart of concurrent engineering.
  - Designing various subsystems simultaneously is critical to reduce design time.
- Incremental information sharing
  - As soon as new information becomes available, it is shared and integrated into the design.
  - It cross functional teams are important to the effective sharing of information in a timely fashion.
- Integrated project management
  - It ensures that someone is responsible for the entire project and that responsibility is not abdicated once one aspect of the work is done.

Applications of Concurrent Engineering

- The applications of concurrent engineering are as follows,
  - Development and production lead times
  - Measurable quality improvements
  - Engineering process improvements
  - Cost reduction

Applications of Concurrent Engineering

1. Development and production lead times

- Product development time is reduced up to 60%.
- Production spans are reduced 10%.
    - AT&T reduced the total process time for the ESS programmed digital switch by 46% in 3 years.
    - ITT reduced the design cycle for an electronic countermeasures system by33% and its transition-to-production time by 22%.

Applications of Concurrent Engineering

2. Measurable quality improvements

- Field failure rates reduced up to 83%.
  - AT&T achieved a fourfold reduction in variability in a poly silicon deposition process for very large scale integrated circuits and achieved nearly two orders of magnitude reduction in surface defects.
  - AT&T reduced defects in the ESS programmed digital switch up to 87% through a coordinated quality improvement program that included product and process design.
  - Degree reduced the number of inspectors by two-thirds through emphasis on process control and linking the design and manufacturing processes.

Applications of Concurrent Engineering

3. Engineering process improvements

- Engineering changes per drawing reduced up to 15 times.
- Early production engineering changes reduced by 15%.
- Inventory items stocked reduced up to 60%.
- Engineering prototype builds reduced up to three times.
- Scrap and rework reduced up to 87%.

Applications of Concurrent Engineering

4. Cost reduction

- McDonnell Douglas had a 60% reduction in life-cycle cost and 40% reduction in production cost on a short-range missile proposal.
- Boeing reduced a bid on a mobile missile launcher and realized costs 30 to 40% below the bid.
- IBM reduced direct costs in system assembly by 50%.
- ITT saved 25% in ferrite core bonding production costs .

CIM concepts

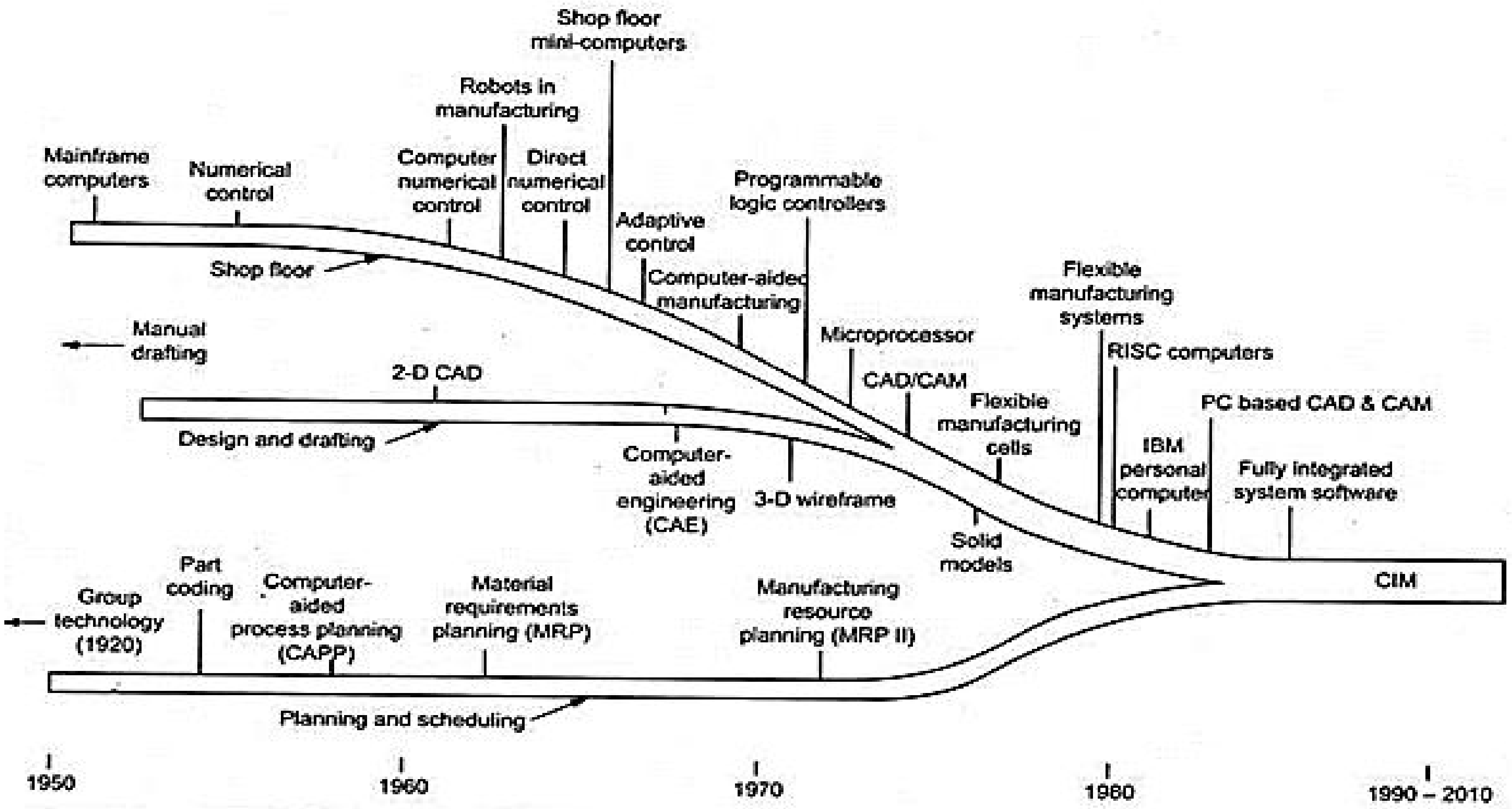
- It is a concept, an environment, an objective, a strategy.
- Modem technology is needed to implement/achieve the CIM environment.
- Thus CIM is also a technology.

Importance of CIM

Following factors have led to the development of the CIM concept and associated technologies:

1. Development of NC, CNC and DNC.
2. The advent and cost-effectiveness of computers.
3. Manufacturing challenges, such as
    - Global competition
    - High labour cost
    - Demand For quality products
    - Flexibility To meet the orders
    - Lower product cost
4. The capability-to-cost attractiveness of microcomputers.

Timeline of CIM



Activities of CIM

1. Evaluating and developing different product strategies.

2. Analysing markets and generating forecasts.

3. Analysing product/market characteristics and generating concepts of possible manufacturing system (i.e. FMS cells and FMS systems).

4. Designing and analysing components for machining, inspection, assembly and all other processes relating to the nature of the component and/or product.

Activities of CIM

5 . Evaluating and/or determining batch sizes, manufacturing capacity, scheduling and control strategies relating to the design and fabrication processes involved in the particular product.

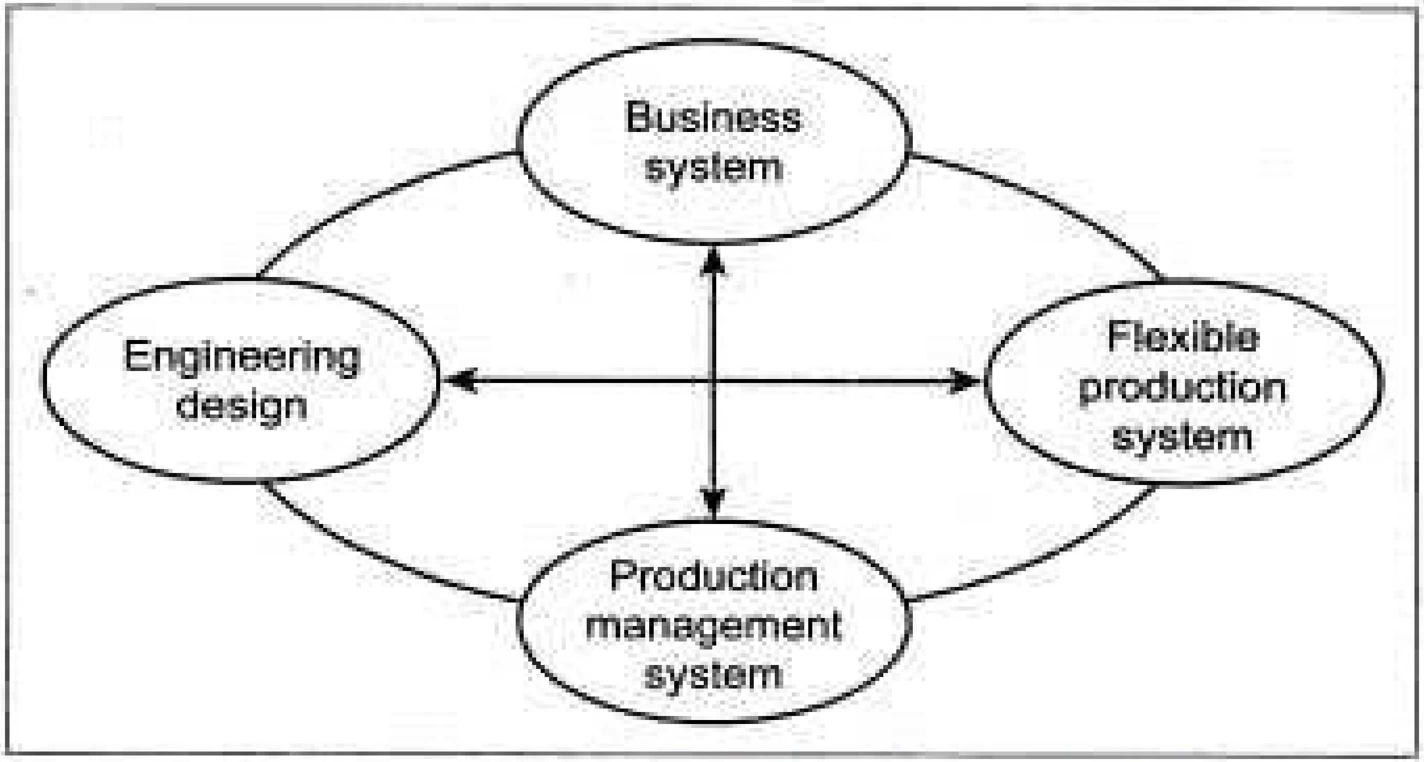
6. Analysis and feedback of certain selected parameters relating to the manufacturing processes, evaluation of status reports from the DNC system.

7. Analysing system disturbances and economic factors of the total system.

Elements of CIM System (Various Activities of CIM)

- CIM is a methodology and a goal rather than an assemblage of component and computers.
- The ideal CIM system applies computer technology to all of the operational functions and information processing functions in manufacturing from order receipt, through design and production to product delivery.

Elements of CIM System (Various Activities of CIM)



Elements of CIM System (Various Activities of CIM)

- At the broader level, CIM can be viewed as an integration of
  - Product and process design.
  - Production planning and control.
  - Production process.

Elements of CIM System (Various Activities of CIM)

- Computer integrated manufacturing is the automated version of the manufacturing process .

- Three major manufacturing functions are product and process design, production planning and control and production process—are replaced by the automated technologies CAD/CAM, CAPP and automated material handling systems , Automated guided vehicles (AGVs) and computerised business systems like order entry, payroll and billing.

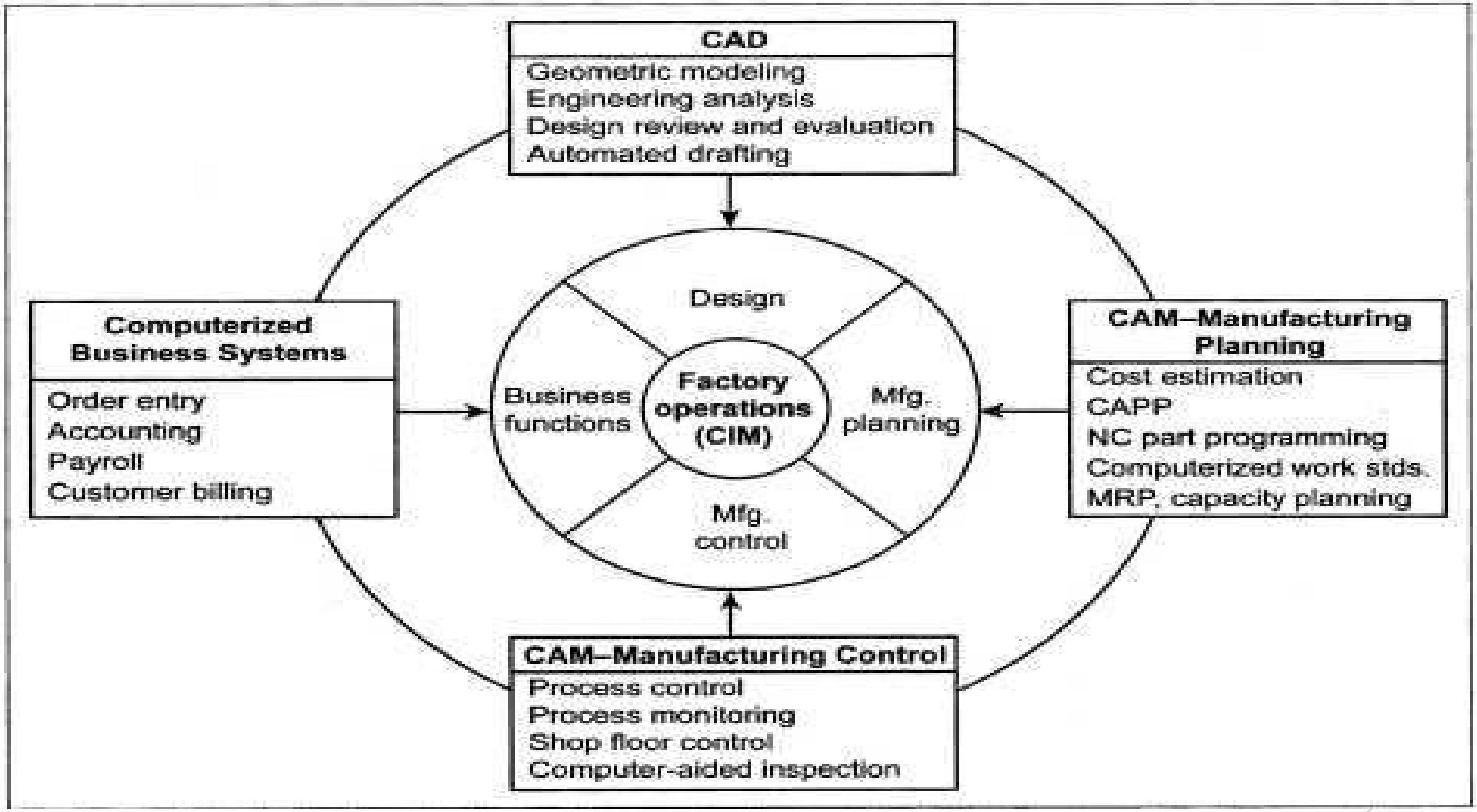
Elements of CIM System (Various Activities of CIM)

- CIM is also referred as completely automated factory with no human interference and factory of the future.

- CIM calls for the coordinated participation in all phases of manufacturing enterprises for the purpose of integration and supervision.

- Thus CIM includes:
  - Design of parts and components
  - Computer controlled flow of materials

Computerized elements of a CIM system



Subsystems of CIM

- CIM consists of subsystems that are integrated into a whole.

- These subsystems/elements consist of the following:

  (i) Product design

  (ii) Manufacturing planning

  (iii) Manufacturing control

  (iv) Business planning and support

Subsystems of CIM

- Subsystems are designed, developed and applied in such a manner that the output of one subsystem serves as the input of another system.

- These subsystems are usually divided into two functions as below:

  - Business planning functions

  - Business execution function

Subsystems of CIM

- 1. Business planning functions:

It Includes activities such as forecasting, scheduling, material-requirements planning, invoicing and accounting.

- 2. Business execution function:

It Includes production and process control, material handling, testing and inspection.

- Effectiveness of CIM depends greatly on the presence of a large-scale, integrated communications system involving computers, machines and their controls.

Islands of Automation

- The term 'islands of automation ’ represents the various technologies that facilitate manufacturing automation in isolation without having integrated with other manufacturing technologies.

- CIM represents the logical revolution of the islands of automation concept.

- As the ‘islands’ are not capable by themselves to bring out a ‘big picture’ of the entire manufacturing activities the evolution of CIM has become a natural evolution by the integration of these ‘islands of automation’.

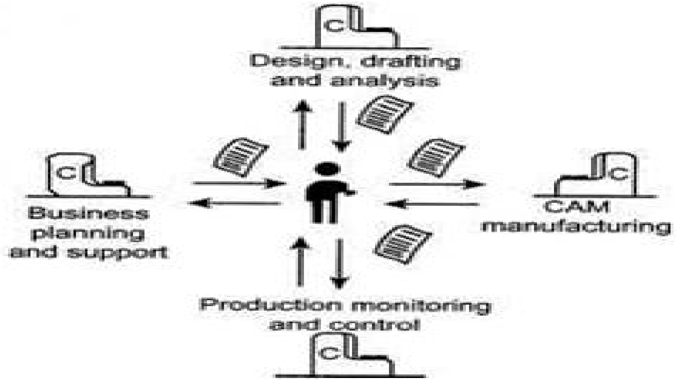
Islands of Automation

- The various ‘islands of automation which by integration forms computer integrated manufacturing, include:

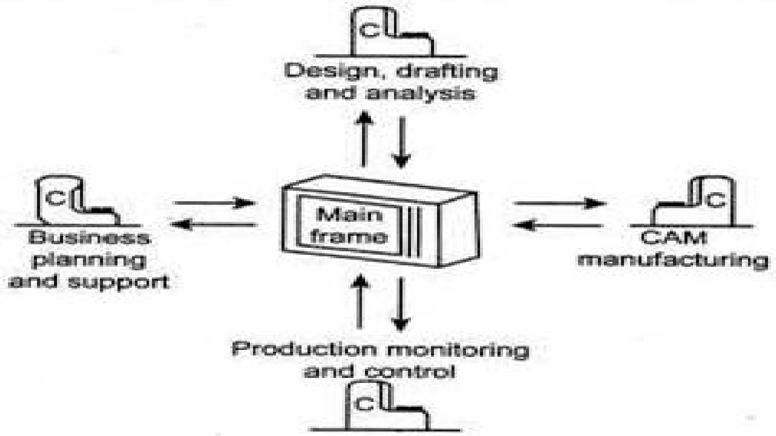
1. Computer-aided design (CAD)
2. Computer-aided manufacture (CAM)
3. Computer numerically controlled (CNC) machines
4. Flexible manufacturing systems (FMS)
5. Robotics
6. Automated material handling systems (AMHS)
7. Group technology (GT)
8. Computer aided process planning (CAPP)
9. Manufacturing resource planning (MRP II)
10. Computer control systems.

Islands of Automation

- CIM elements without mainframe computer and resulting islands of automation.



- Computer Integrated Manufacturing (CIM) through mainframe computer.



Types of Production

- Production activity is classified according to the quantity of product made.
- In this classification there are three types of production:
  - Job shop production.
  - Batch production.
  - Mass production.

Job Shop Production

- Job shop production is commonly used to meet specific customer orders and there is a great variety in the type of work the plant must do.
- Production equipment must be flexible and general purpose to allow for this variety of work.
- Skill level of job shop workers must be relatively high so that they can perform a range of different work assignments.
- Examples of products manufactured in a job shop include space vehicles, aircraft, machine tools, special tools and equipment and prototypes of future products.
- Construction work and shipbuilding are not normally identified with the job shop category.
- Though these two activities involve the transformation of raw materials into finished products, the work is not performed in a factory.

Batch Production

- It involves the manufacture of medium-sized lots of the same item or product.
- Lots may be produced only once, or they may be produced at regular intervals.
- Purpose of batch production is often to satisfy continuous customer demand for an item.
- Examples of items made in batch-type shops include industrial equipment, furniture, textbooks and component parts for many assembled consumer products (household appliances, lawn mowers, etc.).
- Batch production plants include machine shops, casting foundries, plastic moulding factories and press working shops.

Mass Production

- It involves continuous specialized manufacture of identical products.
- Characterized by very high production rates, equipment that is completely dedicated to the manufacture of a particular product and very high demand rates for the product.
- Equipment is not only dedicated to one product, but the entire plant is often designed for the exclusive purpose of producing the particular product.
- Equipment is special purpose rather than general-purpose.
- Investment in machines and specialized tooling is high.
- Production skill has been transferred from the operator to the machine.
- The skill level of labour in a mass production plant tends to be lower than in a batch plant or job shop.

Manufacturing Models and Metrics

- Production Concepts and Mathematical Models

Production rate, Rp

Production capacity, PC

Utilization, U

Availability, A

Manufacturing lead time, MLT

Work-in-progress, WIP

Manufacturing Models and Metrics

- Operation Cycle Time
- Typical cycle time for a production operation:

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

where, Tc = cycle time

To = processing time for the operation.

Th = handling time (e.g. loading and unloading the production machine).

Tth = tool handling time (e.g. time to change tools).

Manufacturing Models and Metrics

- Production Rate
- Batch production:

  batch time $T_b = T_{su} + QT_c$

  Average production time per work unit $T_p = T_b / Q$

  Production rate, $R_p = 60/ T_p$ (pieces/hr)

- Job shop production:

  For $Q = 1$, $T_p = T_{su} + T_c$

- For quantity high production:

  $R_p \rightarrow R_c = 60/ T_c$ since $T_{su}/ Q \rightarrow 0$

- For flow line production

  $T_c = T_r + \text{Max } T_o$ and $R_c = 60/ T_c$

Manufacturing Models and Metrics

- Production Capacity

Plant capacity for facility in which parts are made in one operation (no=1):
PC w = n S w Hs Rp

Where, PC w = Weekly plant capacity, units/wk

Plant capacity for facility in which parts require multiple operations (n o >1):

$$PC_w = \frac{nS_wH_sR_p}{n_o}$$

where n o = Number of operations in the routing.

Manufacturing Models and Metrics

- Utilization and Availability

Utilization: $$U = \frac{Q}{PC}$$

where Q = Quantity actually produced and PC = plant capacity

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

Where, MTBF = Mean time between failures and

MTTR = mean time to repair

Availability - MTBF and MTTR Defined

Manufacturing Models and Metrics

- Manufacturing Lead Time

$$MLT = n_o (T_{su} + QT_c + T_{no})$$

Where, MLT = Manufacturing lead time

n_o = Number of operations

T_{su} = Setup time

Q = batch quantity, T_c cycle time per part

T_{no} = Non-operation time

Manufacturing Models and Metrics

- Work-In-Process

$$WIP = \frac{AU(PC)(MLT)}{S_w H_{sh}}$$

Where, WIP = work-in-process, pc

A = Availability, U = utilization,

PC = plant capacity, pc/wk

MLT = Manufacturing lead time, hr

S w = shifts per week,

Hsh = hours per shift,hr/shift

Manufacturing Models and Metrics

- Costs of Manufacturing Operations
- Two major categories of manufacturing costs:

  1. Fixed costs - remain constant for any output level

  2. Variable costs - vary in proportion to production output level

Adding fixed and variable costs

$$TC = FC + VC (Q)$$

Where, TC = Total costs

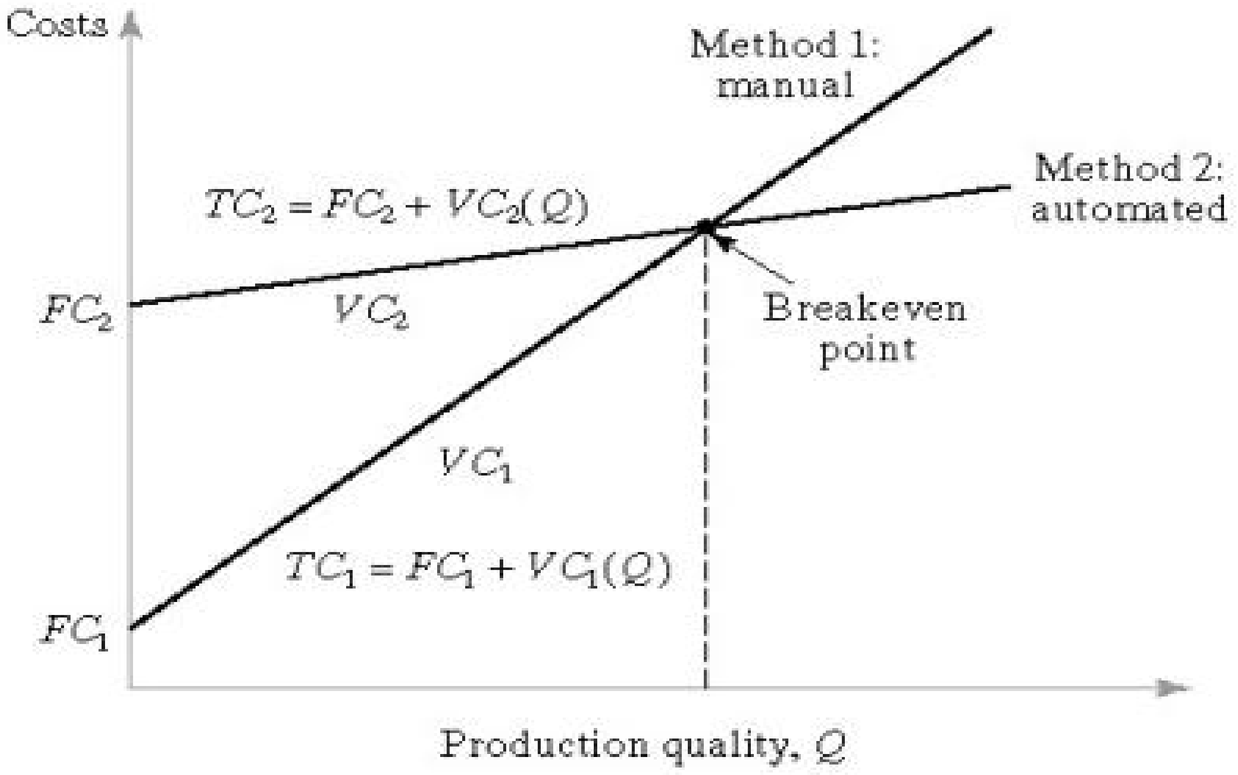
FC = Fixed costs (e.g. building, equipment, taxes)

VC = Variable costs (e.g. labor, materials, utilities)

Q = output level.

Manufacturing Models and Metrics

- Fixed and Variable Costs



Manufacturing Models and Metrics

- Manufacturing Costs
- Alternative classification of manufacturing costs:

  Direct labour -Wages and benefits paid to workers.

  Materials - Costs of raw materials.

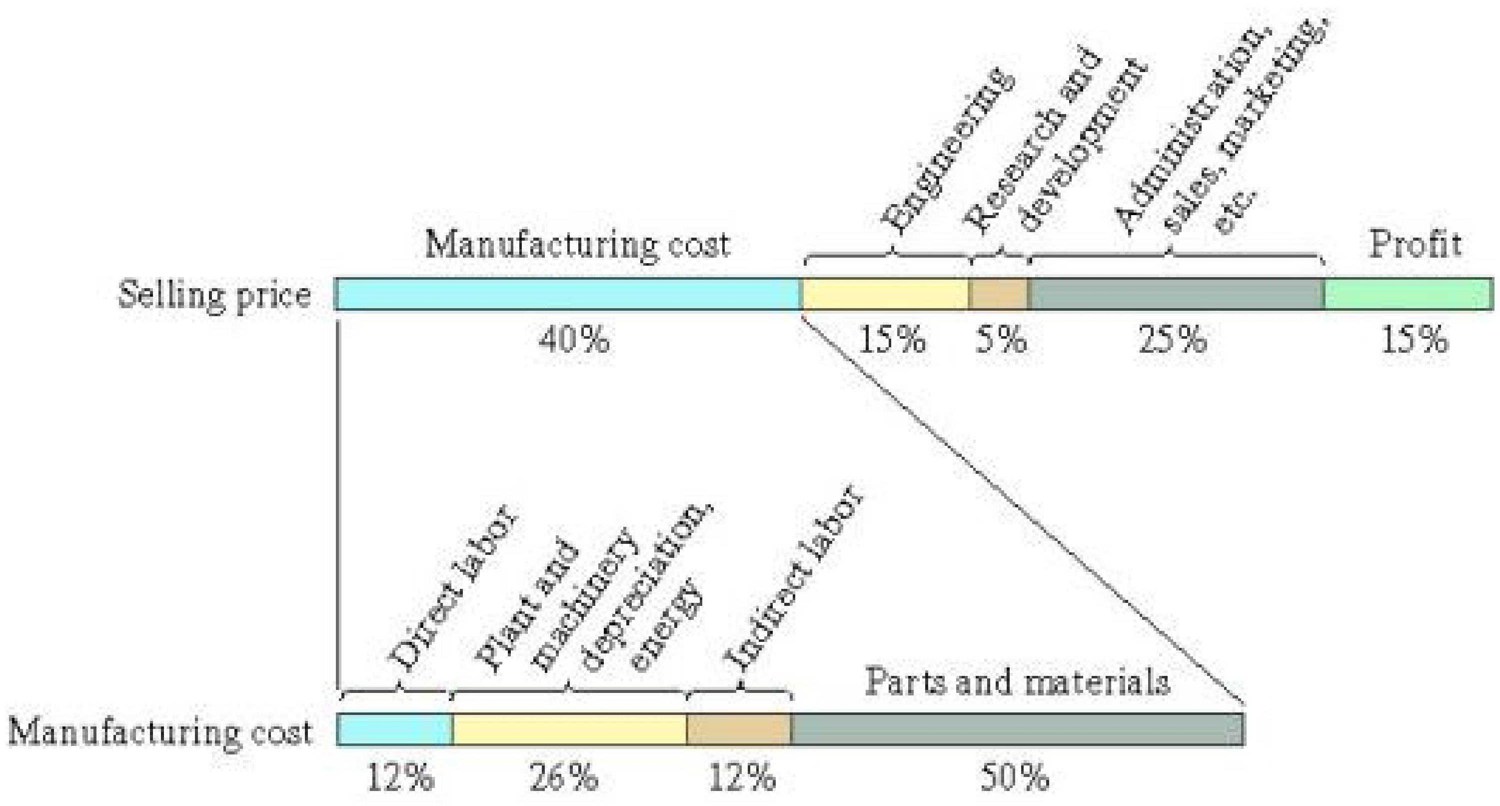
- Overhead - All of the other expenses associated with running the manufacturing firm.

  Factory overhead

  Corporate overhead

Manufacturing Models and Metrics

- Typical Manufacturing Costs



Manufacturing Models and Metrics

- Overhead Rates

- Factory overhead rate:

$$FOHR = \frac{FOHC}{DLC}$$

- Corporate overhead rate:

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

Where, DLC = Direct labour costs

Manufacturing Models and Metrics

- Cost of Equipment Usage
- Hourly cost of worker-machine system:

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

Where, C_o = hourly rate, S/hr.

C_L = labour rate, S/hr.

$FOHR_L$ = labour factory overhead rate,

C_m = machine rate, S/hr

$FOHR_m$ = machine factory overhead rate.

Manufacturing Planning & Control System

It includes the following functionalities:

- Restate business objectives in operations management terms.
- Ensure feasibility of plans.
- Identify gaps in current resources.
- Help formulate connective action-Suppliers.
- Prioritize activities - scheduling ,Facilitate feedback.

Production Plan

- It is the First step in the planning process.
- It is one of three high level plans namely Business Plan, Sales Plan and Production Plan.
- Difference between sales plan and production plan is the inventory plan.

Master Production Schedule

- A Document that defines the specific goods that specific shops will produce in definite quantities at definite times over a short-term horizon in accordance with the aggregate plan.

- The MPS represents an agreement between marketing and manufacturing.

Master Production Schedule

- A detailed aggregation of production plan tends to be:
  - Short time horizon
  - More detailed product information
  - More concern over capacity
  - Corporate plan
  - Quasi-contract
  - Updated regularly

Master Production Schedule

- MPS Problems:
  - Overloaded
  - Front end Loaded
  - Unstable
  - Incomplete
  - Short Horizon

Material Requirements Planning

- MRP Elements:

  - Gross Requirements
  - On-Hand Inventory
  - Allocations
  - Scheduled Receipts
  - Net Requirements
  - Planned and Order Releases
  - Time-phasing
  - Parent/Component

Material Requirements Planning

- Advantages of MRP
  - •Forward looking when planning (visibility). Useful simulator.
  - •Provides valid, credible priorities.
  - •Priorities reflect actual needs, not implied needs.
  - •Provides mangers with control over the execution system.

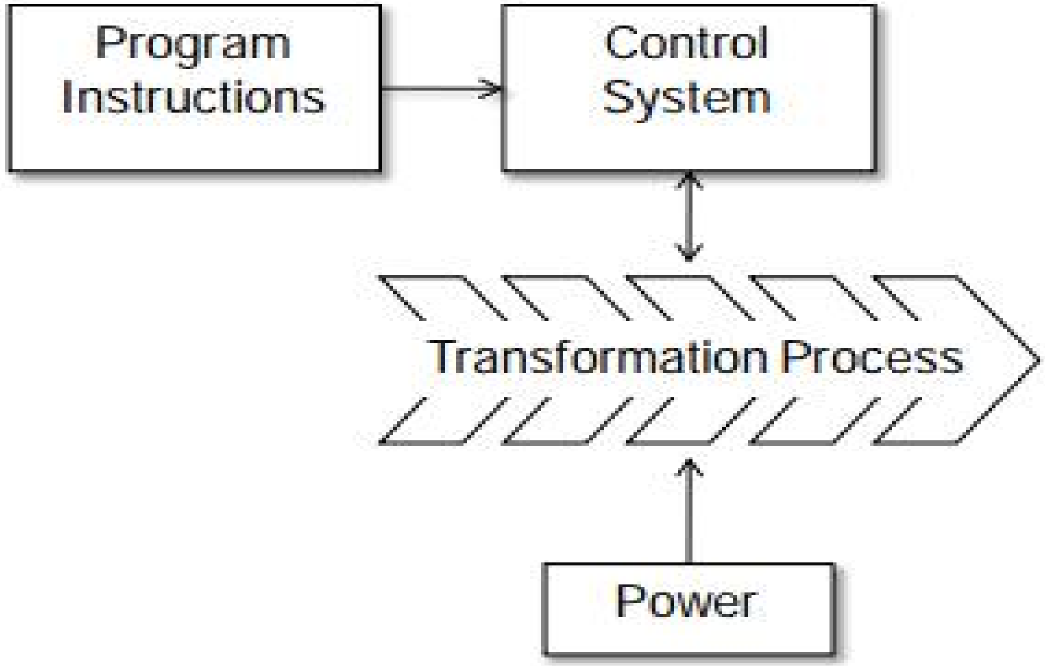
Material Requirements Planning

- Limitations of MRP
  - Looks at materials, ignores capacity, shop floor conditions.
  - Requires user discipline.
  - Requires accurate information/data.
  - Requires valid MPS.
  - High volume production.

Basic Elements of an Automated System

- Automation consists of three basic elements when applied to a particular transformation process:
  - Power to achieve the process and operate the system.
  - Programme of instructions to direct the process.
  - Control system to actuate the instructions.

Basic Elements of an Automated System



Basic Elements of an Automated System

- The programme of instructions used by the automated system is the series of controlled actions that are carried-out in the manufacturing or assembly process.

- Parts or products are usually processed as part of a work cycle and it is within this work cycle structure that programme steps may be defined, hence the term work cycle programmes.

- In numerical control work cycle programmes are called part programmes. The program of instructions can also be called software program.

- In complicated systems the work cycle consists of a number of work steps that are repeated with no deviation from one cycle to the next.

Basic Elements of an Automated System

- An example of this work cycle can be drawn from discrete-part manufacturing operation systems and consists of the following steps:

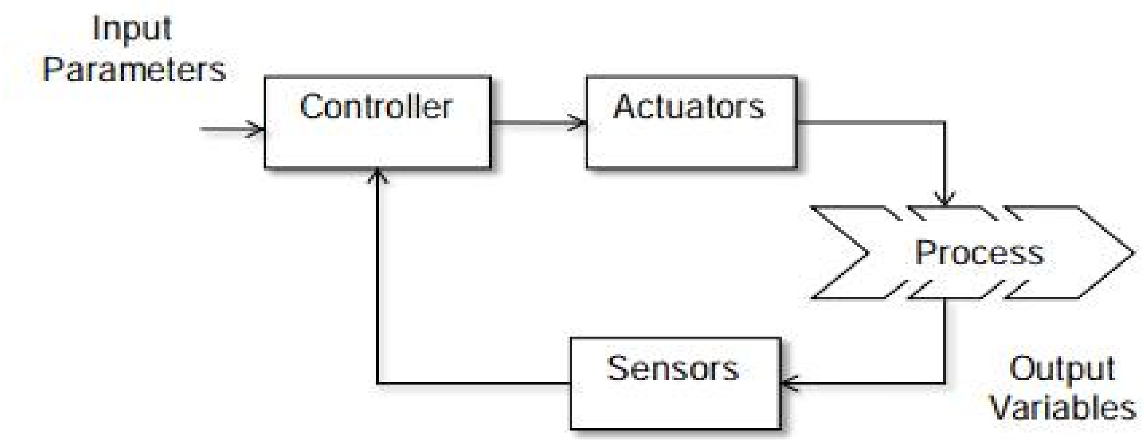
NUMLIST

- Load part into production machine.
- Perform process.
- Unload part from production machine.

Basic Elements of an Automated System

ENDLIST

- At each & every step, process parameters are being changed. A process parameters are inputs to the process, such as the initial process settings.
- Process parameters can be distinguished from process variables which are outputs from the process—these include actual process settings as the process is being performed.
- Different process parameters may be changed in each step.



Levels of Automation

- There are various levels at which automation can be applied in the context of the enterprise.

- A temperature sensor that feedback information to a regular in a shower is a reasonably low level of automation.

- On the other hand a high level automation system is required to run a train system in a city.

Levels of Automation

Five Level and Description:

- Device level:

The lowest level, it includes hardware components that comprise the machine level, such as actuators and sensors. Control loop devices are predominant here.

- Machine level :

Hardware at the device level is assembled into individual machines. Control functions at this level include performing the sequence of steps in the programme of instructions.

Levels of Automation

Cell or system level :

This operates under instructions from the plant level. Consists of a group of machines or workstations connected and supported by a material handling system, computers and other appropriate equipment, including production lines.

Plant level:

Factory or production systems level, it receives instruction from the corporate information system and translates them into operational plans for production.

Enterprise level :

The highest level, it consists of the corporate information system and is concerned with all the functions that are necessary to manage and coordinate the entire company.

Lean Production

- **It is also known as lean manufacturing. Also called as the Toyota Production System (TPS), as the concept was originated at Toyota motors.**

- It is Defined as an adoption of mass production in which workers and work cells are made more flexible and efficient by adopting methods that reduce waste in all forms.

Objectives of Lean Production

- The main benefits of lean production are lower production costs, increased output and shorter production lead times.

Some of the objectives of lean production are as follows.

- To reduce defects and unnecessary physical wastage, including excess use of raw material inputs, preventable defects, costs associated with reprocessing defective items.

- To reduce manufacturing lead times and production cycle times by reducing waiting times between processing stages.

Objectives of Lean Production

- To minimize inventory levels at all stages of production, particularly works-in-progress between production stages.

- To improve labour productivity both by reducing the idle time of workers and ensuring that when workers are working they are using their effort as productively as possible.

- To use equipment and manufacturing space more efficiently by eliminating bottlenecks and maximizing the rate of production through existing equipment, while minimizing machine downtime.

Objectives of Lean Production

- To have the ability to produce a more flexible range of products with minimum changeover costs and change over time.

- Due to reduced cycle times, increased labour productivity and elimination of bottlenecks and machine downtime, companies can significantly increase the output from their existing facilities.

Key Principles of Lean Manufacturing

Key principles behind lean manufacturing can be summarized as follows:

- Recognition of waste:

The first step is to recognize what does not create value from the customers perspective. Any material process or feature which is not required for creating value from the customers perspective is waste and should be eliminated.

- Standard processes:

Lean requires the implementation of very detailed production guidelines called standard work, which clearly state the content, sequence, timing and outcome of all actions by workers. This eliminates variation in the way that workers perform their tasks.

Key Principles of Lean Manufacturing

- Continuous flow:

Lean usually aims for the implementation of a continuous production flow free of bottlenecks, interruption, detours, back flows or waiting.

- Pull-production:

Also called Just-In-Time (JIT), pull-production aims to produce only what is needed, when it is needed. Production is pulled by the downstream workstation so that each workstation should only produce what is requested by the next workstation.

Key Principles of Lean Manufacturing

- Quality at the source:

Lean aims for defects to be eliminated at the source and for quality inspection to be done by the workers as part of the in-line production process.

- Continuous improvement:

Lean requires striving for perfection by continually removing layers of waste as they are uncovered. This in turn requires a high level of worker involvement in the continuous improvement process.

Just-In-Time Production Systems

- **It is a management philosophy that strives to eliminate sources of manufacturing waste by producing the right part in the right place at the right time.**

- **It is also known as stockless production.** Improves profits and return on investment by:

  - Reducing inventory levels.
  - Reducing variability.
  - Improving product quality.
  - Reducing production and delivery lead times.
  - Reducing others costs such as machine setup cost and equipment breakdown cost.

Objectives of JIT

- The JIT is applied to achieve the following goals:

1) Zero defects
2) Zero setup time
3) Zero inventories
4) Zero handling
5) Zero breakdowns
6) Zero lead time
7) Lot size of one.

Elements of JIT

Some of he key elements of the JIT philosophy are:

- The Reduce or eliminate Setup times
- The Reduce manufacturing and purchasing lot sizes
- The Reduce production and delivery lead times
- The Preventive maintenance
- The Stabilize and level the production schedule with uniform plant loading
- The Flexible workforce
- The Require supplier quality assurance and implement a zero defects quality program
- The Small unit (single unit) conveyance

Kanban Production Control System

- Kanban means ‘sign’ or ‘instruction card’ in Japanese.
- Kanban is a card that is attached to a storage and transport container.
- Identifies the part number and container capacity, along with other information.

Kanban Production Control System

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Two Main Types of Kanban

- 1.Production Kanban (P-Kanban): Signals the need to produce more parts.
- 2.Transport or Conveyance Kanban (T-Kanban): Signals the need to deliver more parts to the next work centre. T-Kanban is also called as ‘more Kanban’ or ‘withdrawal Kanban'.

Pull Vs Push Systems

- A Kanban system is a pull system, in which the Kanban is used to pull parts to the next production stage when they are needed. Here product is made-to-order.

- A MRP system (or any schedule based system) is a push system in which a detailed production schedule for each part is used to push parts to the next production stage when scheduled. In a push system the product is made-to-stock.

- A weakness of a push system over a pull system is excess inventory, longer load time and more room for error.

Benefits of JIT

- JIT implementation leads to the following benefits:

    - Lower inventory cost.
    - Lower scrap and waste costs.
    - Improved quality and zero defect products.
    - Improved worker involvement.
    - Higher motivation and morale.
    - Increased productivity.
    - Reduced manufacturing lead time.
    - Improved product design and increased product flexibility.
    - Adherence to delivery time.

UNIT II

PRODUCTION PLANNING AND CONTROL AND COMPUTERISED PROCESS PLANNING

Process Planning

- Product design for each product has been developed in the design department.
- To convert the product design into a product, a manufacturing plan is required. Activity of developing such a plan is called process planning.
- Process planning consists of preparing sets of instructions that describe how to manufacture the product and its parts.

Process Planning

- The task of process planning consists of determining the manufacturing operations required to transform a part from a rough (raw material) to the finished state specified on the engineering drawing.
- Also known as operations planning.
- It is the systematic determination of the engineering processes and systems to manufacture a product competitively and economically.
- It is a detailed specification which lists the operations, tools and facilities.
- It is usually accomplished in manufacturing department.

Process Planning Definition

- It Can be defined as "an act of preparing a detailed processing documentation for the manufacture of a piece part or assembly." According to the American Society of Tool and Manufacturing Engineers.

- Process planning is the systematic determination of the methods by which a product is to be manufactured economically and competitively.

- It Consists of devising, selecting and specifying processes, machine tools and other equipment, transform the raw material into finished product as per the specifications called for by the drawings.

Process Planning Vs Product Planning

Process planning

- It is Concerned with the engineering and technological issues of how to make the product and its parts.
- It specifies types of equipment and tooling required to fabricate the parts and assemble the product.

Production planning

- It is concerned with the logistics issues of making the product.
- It is concerned with ordering the materials and obtaining the resources required to make the product in sufficient quantities to satisfy demand for it.
- Production is done only after the process planning.

Importance of Process Planning

- Process planning establishes the link between engineering design and shop floor manufacturing.
- It Determines how a part/product will be manufactured, the important determinant of production costs and profitability.
- Production process plans should be based on in-depth knowledge of process and equipment capabilities, tooling availability, material processing characteristics, related costs and shop practices.
- Economic future of the industry demands that process plans that are developed should be feasible low cost and consistent with plans for similar parts.
- Process planning facilitates the feedback from the shop floor to design engineering regarding the manufacturing ability of alternative.

Details of a Process Plan

- Detailed process plan usually contains the route, processes, process parameters and machine and tool selections.

- To prepare a process plan (also called as route. sheet), we require the following information:

1. Assembly and component drawings and bill of materials (part list):

- This detail give the information regarding the general description of part to be manufactured, raw material specification, dimensions and tolerances required, the surface finish and treatment required.

Details of a Process Plan

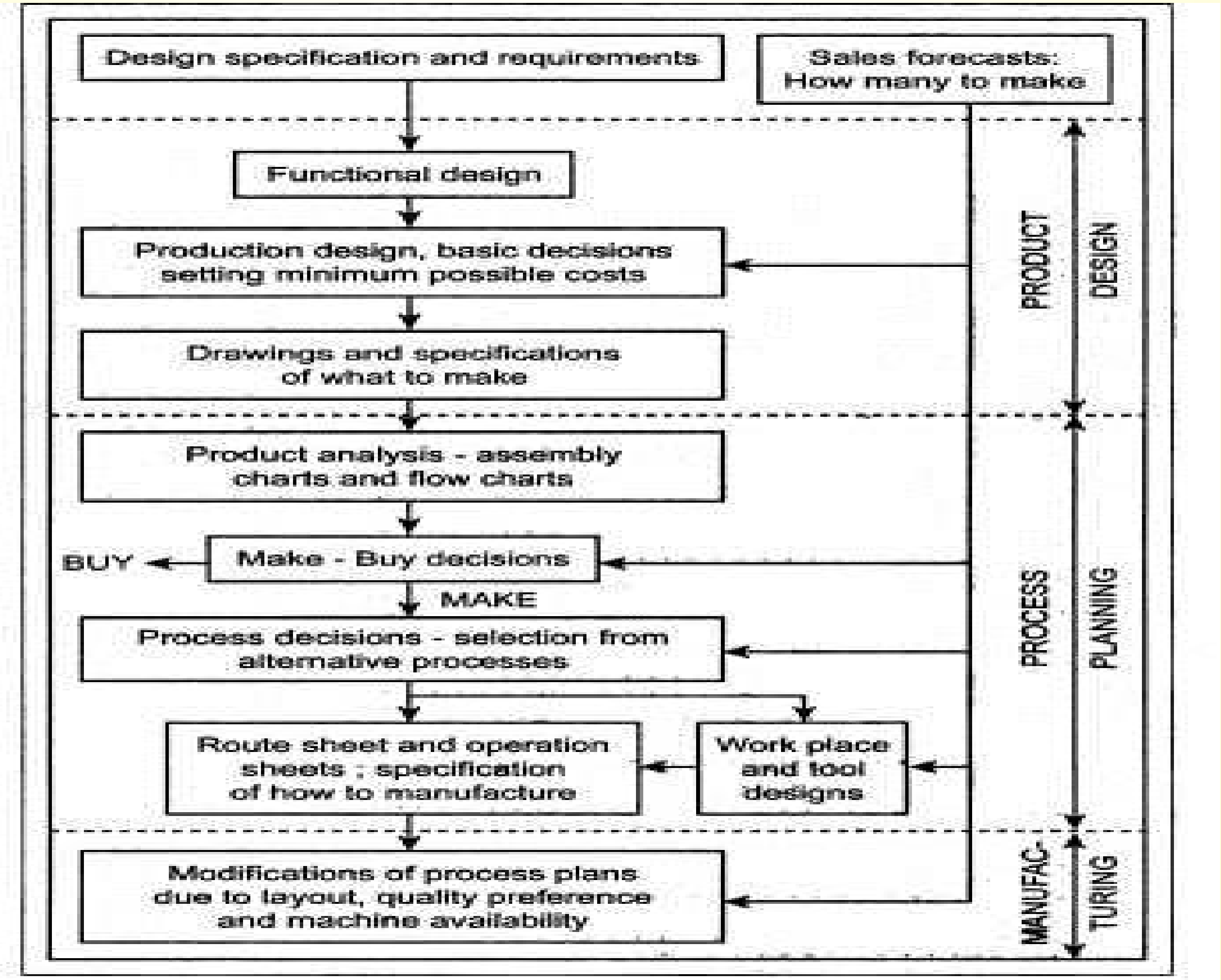
2.Machine and equipment details:

- (i)The various possible operations that can be performed.
- (ii) The maximum and minimum dimensions that can be machined on the machines.
- (iii) The accuracy of the dimensions that can be obtained.
- (iv)Available feeds and speeds on the machine.

3.Standard time for each operation and details of setup time for each job.

Details of a Process Plan

4.Availability of machines, equipment and tools.



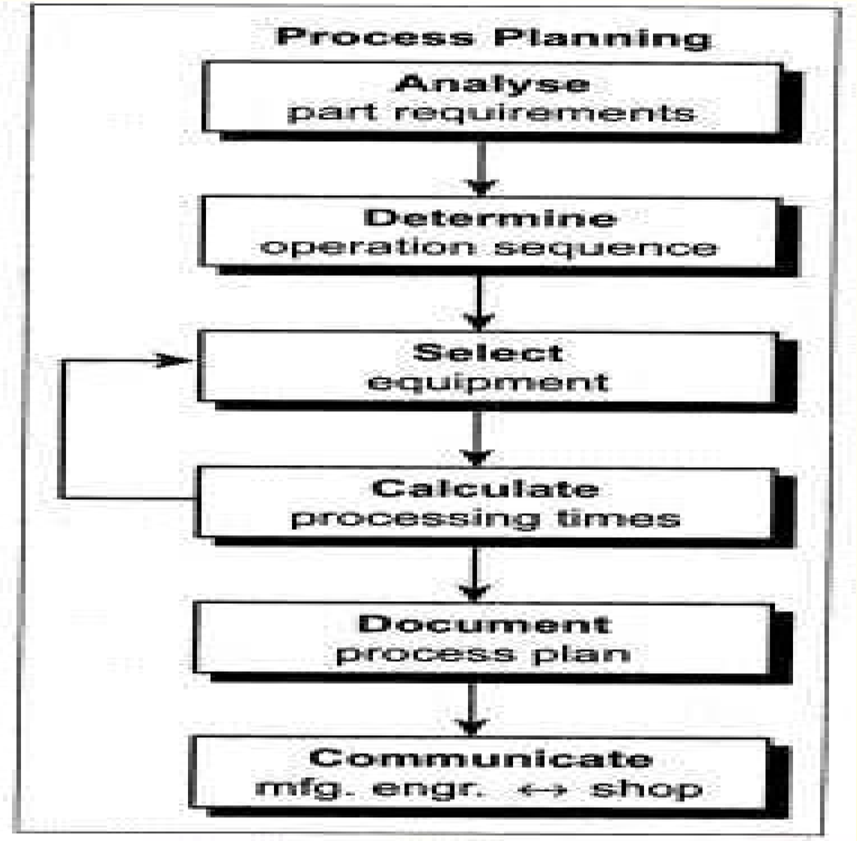
Process Planning Activities

The different steps or specific activities involved in process planning are:

- Analysis of the finished part requirements as specified in the engineering design.
- Determining the sequence of operations required.
- Selecting the proper equipment to accomplish the required operations.
- Calculating the specific operation setup times and cycle times on each machine.
- Documenting the established process plans.
- Communicating the manufacturing knowledge to the shop floor.

Process Planning Activities

- The above process planning activities are diagrammatically presented in figure.



Process Planning Activities

1) Analyse Finished Part Requirements

- First step in the process planning is to analyse the finished part requirements as specified in the engineering design.
- Engineering design may be shown either on an engineering drawing or in a CAD model format.
- Component drawing should be analysed in detail to identify its features, dimensions and tolerance specifications.
- Part's requirement defined by its feature, dimensions and tolerance specifications determines the corresponding processing requirements (such as operations encompassing part shape generation, inspections, testing, heat treatment, surface coating, packaging, etc.)

Process Planning Activities

2) Determine Operating Sequence

- Second step is to determine the sequence of operations required to transform the features, dimensions and tolerances on the part from a rough (initial) to a finished state.
- Basic aim of this step is to determine the type of processing operation that has the capability to generate the various types of features, given the tolerance requirements.

Process Planning Activities

3) Select "Machines"

- Once the appropriate type of manufacturing process has been determined, the next step in process planning is to select appropriate machines equipment and tools to accomplish the required operations.
- There are many factors which influence the selection of machines.

Process Planning Activities

The following considerations are to be made while selecting a machine:

(i) Economic considerations: Due analysis should be made with respect to the initial cost, maintenance and running cost. An alternative which results in lower total cost should be selected.

(ii) Production rate and unit cost of production.

(iii) Durability and dependability.

(iv) Lower process rejection.

(v) Minimum set up and put away times.

(vi) Longer productive life of machines or equipment.

(vii) Functional versatility i.e. ability to perform more than one functions.

Process Planning Activities

4) Material Selection Parameters

- Selection of a sound, economic material is an another important aspect of process planning.

Primary parameters affecting the choice of a material are given below:

- **Function :** Many of the parameters developed for material selection are related to the functions the product must perform in terms of mechanical, physical, electrical and thermal properties of materials.

- **Appearance:** The aesthetic value of the material must be considered while selecting the material.

Process Planning Activities

- **Reliability :** Important criterion for material selection because of increasing consumer demands for trouble free products.
- **Service life:** The length of service life over which the material maintains its desirable characteristics is a very important consideration in material selection.
- **Environment:** The environment to which the material is exposed during the product life is a very important consideration, depending on whether the environment is beneficial or harmful.

Process Planning Activities

5) Calculate Processing Times

- After an appropriate set of required machines is selected, next step is to calculate the specific operation setup times and cycle times on each machine.

- Determination of setup times requires knowledge of available tooling and the sequence of steps necessary to prepare the machine for processing the given work piece.

- For establishing accurate setup times, detailed knowledge of equipment capability, tooling and shop practice is required.

Process Planning Activities

6) Document Process Planning

- Having selected the best processing alternatives and associated machines, the next step in process planning is to document clearly all the information in detail.
- Resulting process plan is generally documented as a job routing or operation sheet.
- Operation sheet is also called “route sheet”, “instruction sheet”, “traveller” or “planner”.
- Route sheet lists the production operations and associated machine tools for each component and sub assembly of the product.

Manual Process Planning

- In traditional process planning systems the process plan is prepared manually.
- It involves examining and interpreting engineering drawings, making decisions on machining processes selection, equipment selection, operations sequence and shop practices.
- The manual process plan is very much dependent on the skill, judgement and experience of the process planner.
- If different planners were asked to develop a process plan for the same part, they would probably come up with different plans.

Advantages of Manual Process Planning

- Manual process planning is very much suitable for small scale companies with few process plans to generate.
- Highly flexible.
- Requires low investment costs.

Computer Aided Process Planning (CAPP)

- To overcome the drawbacks of manual process planning, the computer- aided process planning (CAPP) is used. With the use of computers in the process planning, one can reduce the routine clerical work of manufacturing engineers.

- It provides the opportunity to generate, rational consistent and optimal plans. In addition CAPP provides the interface between CAD and CAM.

Benefits of CAPP

The benefits of implementing CAPP include the following:

- **Process rationalization and standardization:** CAPP leads to more logical and consistent process plans than manual process planning.
- **Productivity improvement:** As a result of standard process plan, the productivity is improved.
- **Product cost reduction:** Standard plans tend to result in lower manufacturing costs and higher product quality.
- Elimination of human error.
- **Reduction in time:** As a result of computerised work, a job that used to take several days, is now done in a few minutes.

Benefits of CAPP

- Reduced clerical effort and paper work
- **Improved legibility:** Computer-prepared route sheets are neater and easier to read than manually prepared route sheets.
- **Faster response to engineering changes:** Since the logic is stored in the memory of the computer, CAPP becomes more responsive to any changes in the production parameters than the manual method of process planning.
- **Incorporation of other application programs**: The CAPP program can be interfaced with other application programs, such as cost estimating and work standards.

Approaches of CAPP

The two basic approaches or types of CAPP system are:

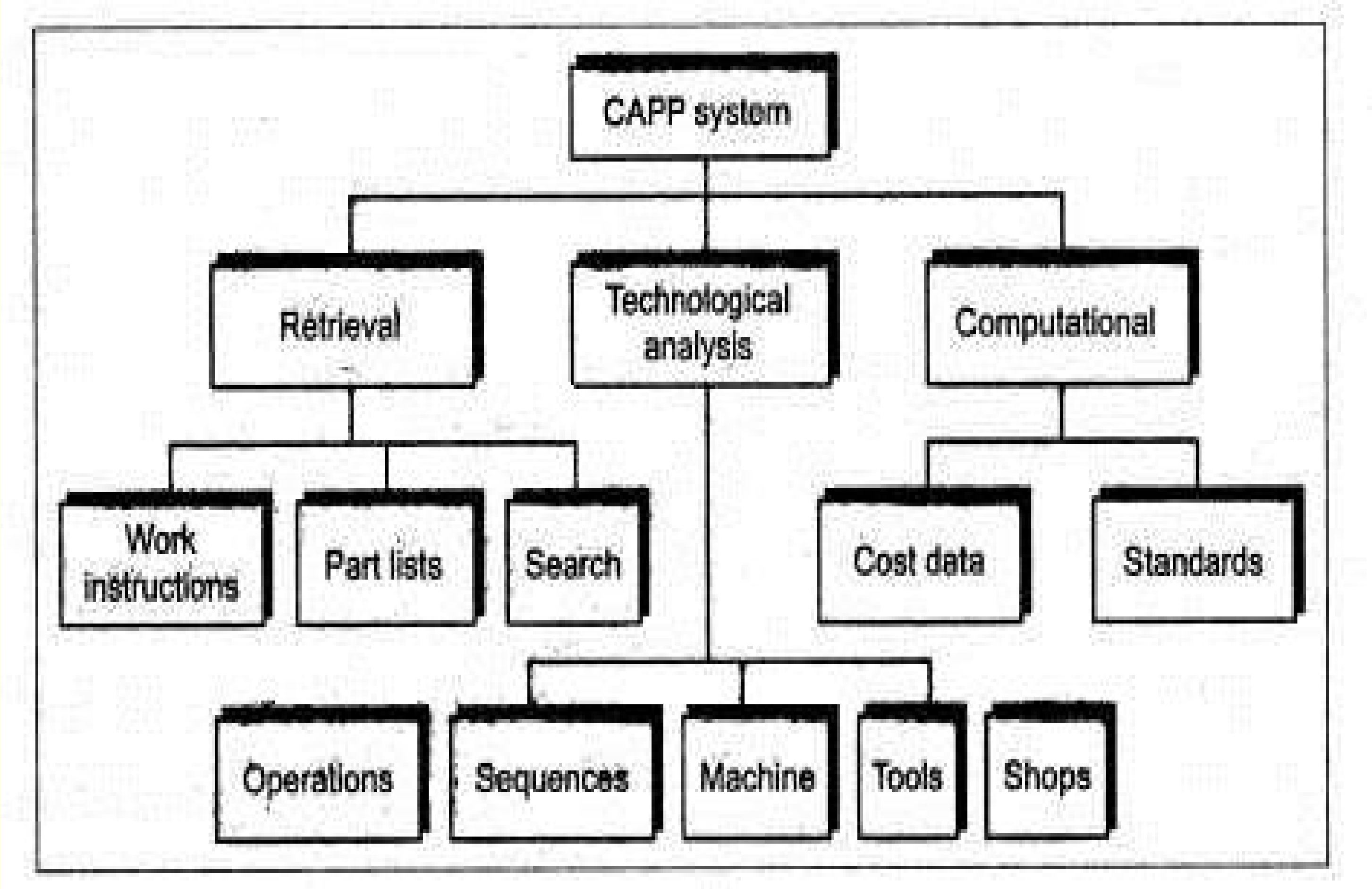
1. Retrieval (or variant) CAPP system.

2. Generative CAPP system.

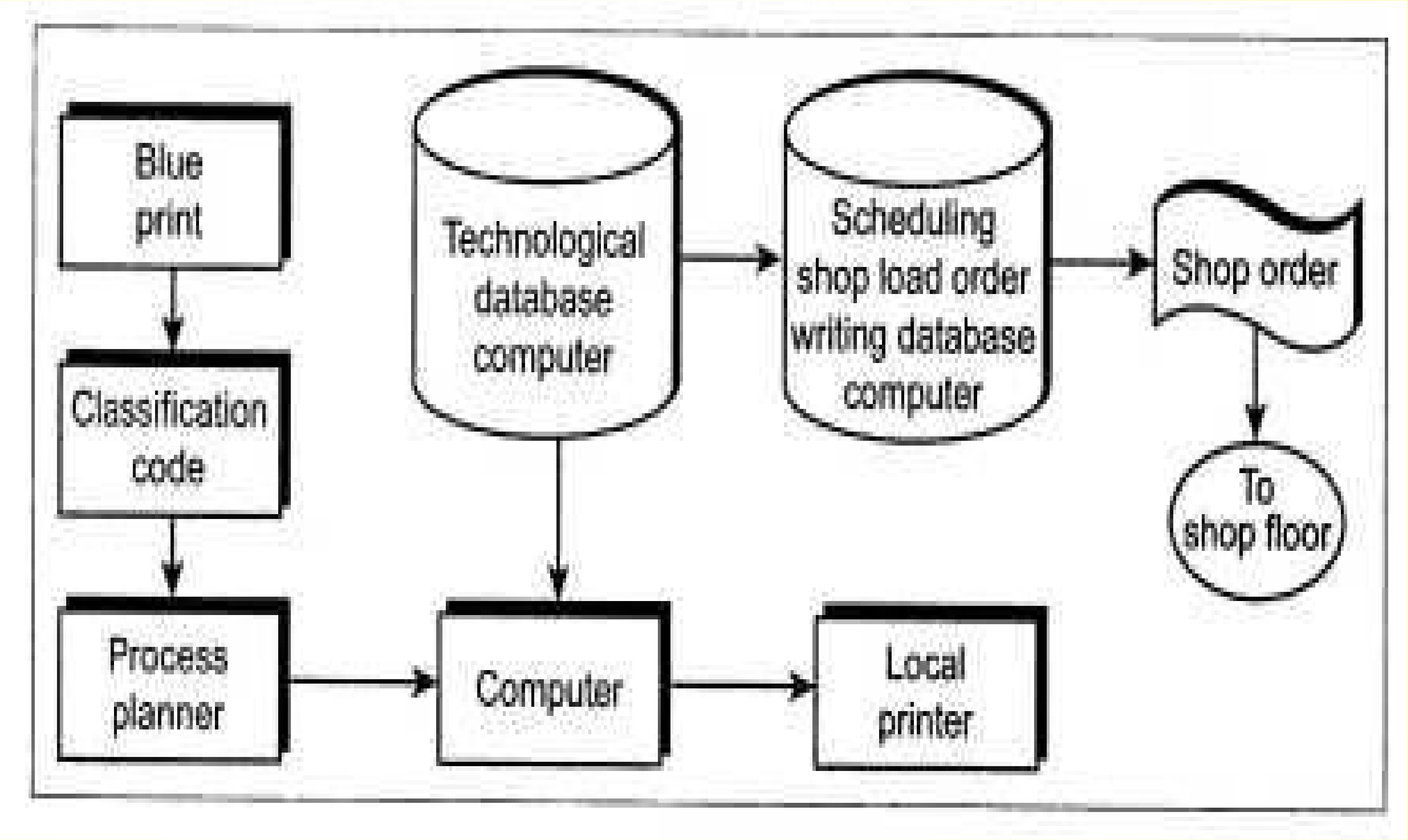
- A CAPP tool can be represented as having three separate functions:

  (i) Retrieval
  (ii) Technological analysis
  (iii) Computational

Approaches of CAPP



CAPP System for Engineering Data



Retrieval (or Variant) CAPP System

- It is also called a variant CAPP system and has been widely used in machining applications.
- Basic idea behind the retrieval CAPP is that similar parts will have similar process plans.
- A process plan for a new part is created by recalling, identifying and retrieving an existing plan for a similar part and making the necessary modifications for the new part.
- Variant CAPP is a computer-assisted extension of the manual approach.

Advantages of Retrieval CAPP System

- Once a standard plan has been written, a variety of parts can be planned.
- Comparatively simple programming and installation (compared with generative CAPP systems) is required to implement a planning system.
- Efficient processing and evaluation of complicated activities and decisions, thus reducing the time and labour requirements.
- Standardized procedures by structuring manufacturing knowledge of the process planners to company's needs.
- Lower development and hardware costs.
- Shorter development times.
- The system is understandable and the planner has control of the final plan.
- It is easy to learn and easy to use.

Disadvantages of Retrieval CAPP System

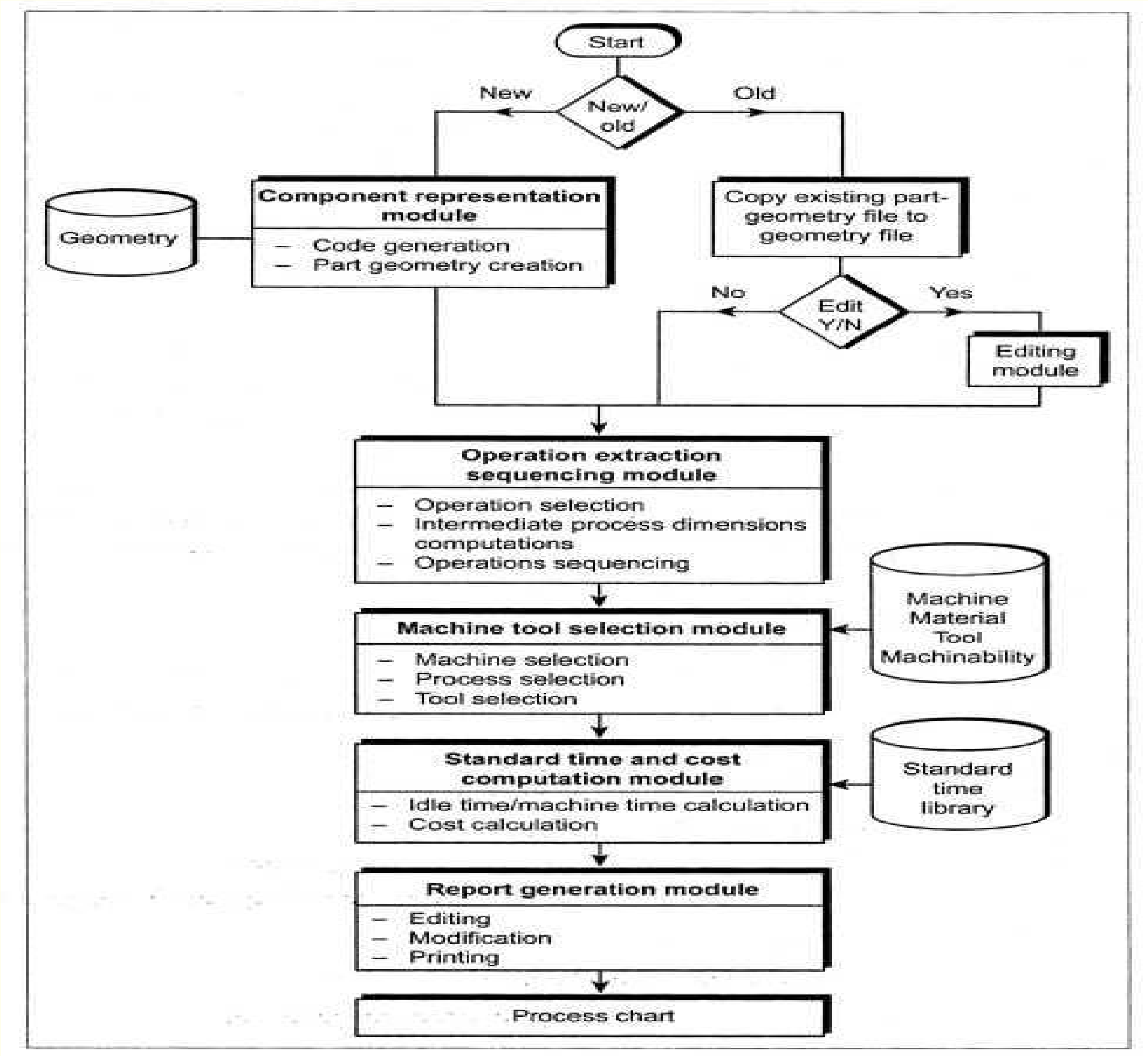
- The components to be planned are limited to similar components previously planned.
- Maintaining consistency in editing is difficult.
- Experienced process planners are still required to modify the standard plan for the specific component.

Components of a Generative CAPP System

The various components of a generative system are:

- A part description, which identifies a series of component characteristics, including geometric features, dimensions, tolerances and surface condition.
- A subsystem to define the machining parameters, for example using look-up tables and analytical results for cutting parameters.
- A database of available machines and tooling.
- A report generator which prepares the process plan report.

Structure of a Generative CAPP System



Advantages of Generative CAPP System

The generative CAPP has the following advantages:

- It can generate consistent process plans rapidly.
- New components can be planned as easily as existing components.
- It has potential for integrating with an automated manufacturing facility to provide detailed control information.

Drawbacks of Generative CAPP System

- The generative approach is complex.
- It is very difficult to develop.

CMPP Process Planning Functions

The CMPP system can perform the following four process planning functions:

- CMPP generates a sequence of operations in a summary format.
- The summary format contains for each operation an operation, number and description, type of machine orientation of the work piece on the machine, surfaces cut and heat treatment.
- CMPP determines the dimensioning reference surfaces for each cut in each operation. CMPP selects the clamping and locating surfaces.
- CMPP determines machining dimensions, tolerances and stock removals for each surface cut in each operation.

CMPP Process Planning Functions

CMPP produces three process plan documents:

(i) A printed summary of operations.

(ii) A printed tolerance analysis

(iii) Dimensional work piece sketches for each machining operation.

CMPP Process Planning Functions

Even though the CMPP system has received limited use in the industrial environment, the CMPP system is considered very significant because of the following three reasons:

(i) CMPP represent one of the most successful attempts at developing a generative system.

(ii) CMPP achieves a higher degree of automated process planning.

(iii) CMPP is being used as a basis for further search into automated process planning.

Selection of a CAPP System

- Evaluation and selection of the best process planning system for a particular firm involves numerous engineering management decisions.

- Process involves identifying, weighing and comparing various interrelated factors.

Logical Steps in Computer Aided Process Planning

Step 1: Define the coding scheme

- Adopt existing coding or classification schemes to label parts for the purpose of classification. In some extreme cases, a new coding scheme may be developed.

Step 2: Group the parts into part families

- Group the part families using the coding scheme defined in Step 1 based on some common part features. A standard process plan is attached to each part family (see: Step 3).
- Often, a number of part types are associated with a family, thereby reducing the total number of standard process plans.

Logical Steps in Computer Aided Process Planning

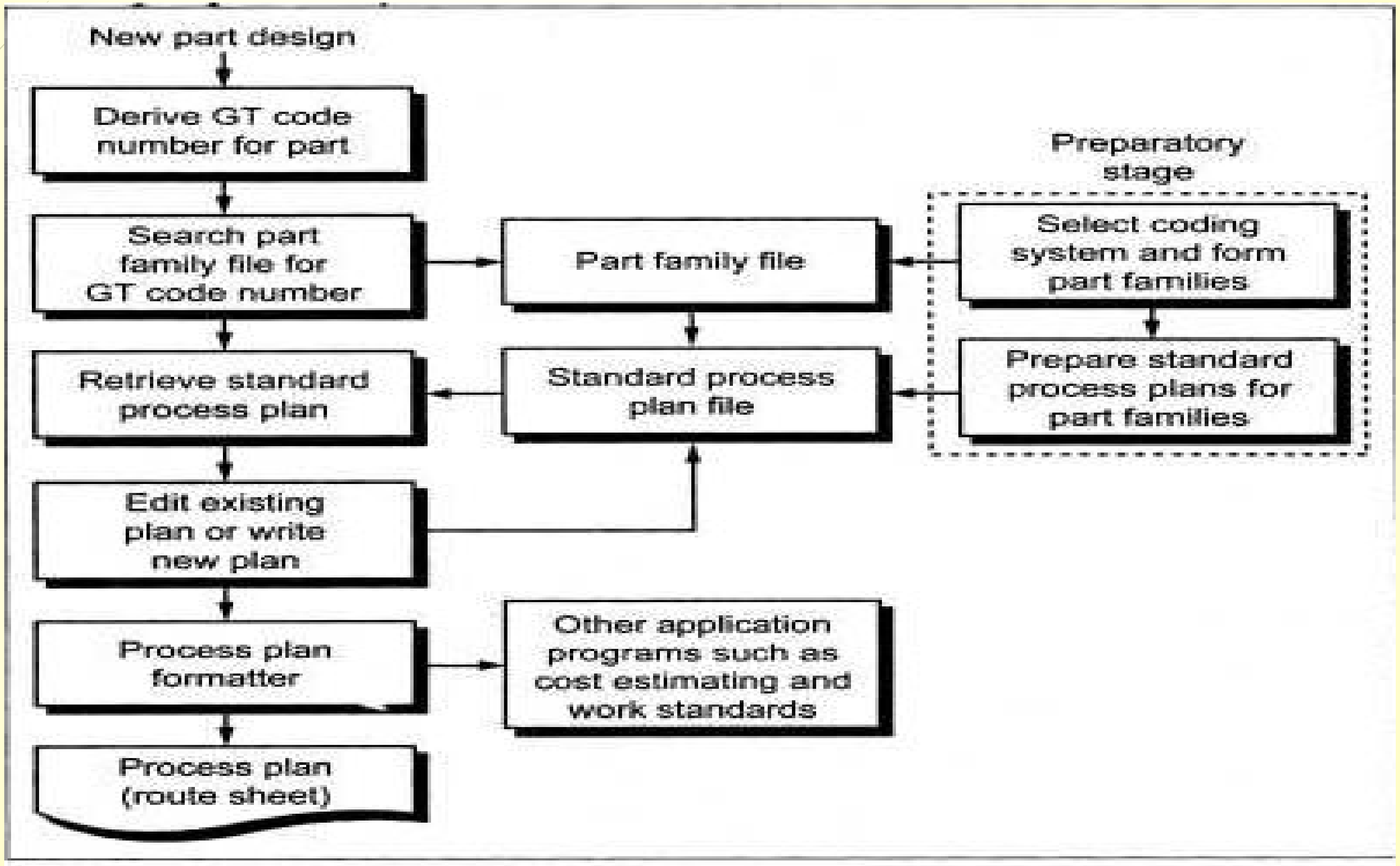
Step 3: Develop a standard process plan

- Develop a standard process plan for each part family based on the common features of the part types.
- This process plan can be used for every part type within the family with suitable modifications.

Step 4: Retrieve and modify the standard plan

- When a new part enters the system, it is assigned to a part family based on the coding and classification scheme.
- Then the corresponding standard process plan is retrieved and modified to accommodate the unique features of the new part.

Retrieval CAPP System Procedure



Aggregate Production Planning and the Master Production Schedule

Aggregate Production Planning

- Aggregate planning is concerned with determining the quantity and timing of production for the intermediate future (often 3 to 8 months) ahead, setting employment, inventory and subcontracting.
- Aggregate plans should be coordinated among various functions in the firm, including product design, production, marketing and sales.

Aggregate Production Planning and the Master Production Schedule

Aggregate Production Planning

- The aggregate production planning strategy provides the data to plan the variable resources, which include full and temporary employment levels, total labour hours per period and number of subcontractors.

- In addition, the aggregate production plan, along with forecasted customer demand, provides the aggregate information from which the disaggregate master production schedule (MPS) is produced.

Aggregate Production Planning

	Month				
	Jan.	Feb.	Mar.	Apr.	May
Planned output (Number of units of product)	1400	1750	1700	2250	2750
Product line models	Month				
	Jan.	Feb.	Mar.	Apr.	May
Model M1	475	500	500	600	625
Model M2	150	400	425	450	650
Model M3	450	500	475	600	675
Model M4	175	150	125	275	425
Model M5	150	200	175	250	300

Aggregate Production Planning and the Master Production Schedule

Master Production Schedule

- The aggregate production plan must be converted into master production schedule (MPS).
- Master production schedule is a listing of the products to be manufactured, when they are to be delivered and in what quantities.
- Aggregate plan lists the production quantities of the major product lines, whereas MPS provides a very specific schedule of individual products.
- Usually MPS is developed from customer orders and forecasts of future demand.

Basic Characteristics of MRP

- Two basic characteristics of MRP are:

1. Drives demand for components, sub assemblies, materials, etc. from demand for and production schedules of parent items.

2. Offsets replenishment orders (purchase orders or production schedules) relative to the date when replenishment is needed.

Information Needed for MRP

The following information are needed for MRP:

- Demand for all products.
- Lead times for all finished goods, components, parts and raw materials.
- Lot sizing policies for all parts.
- Opening inventory levels.
- Safety stock requirements.
- Any orders previously placed but which haven’t arrived yet.

Inputs to MRP

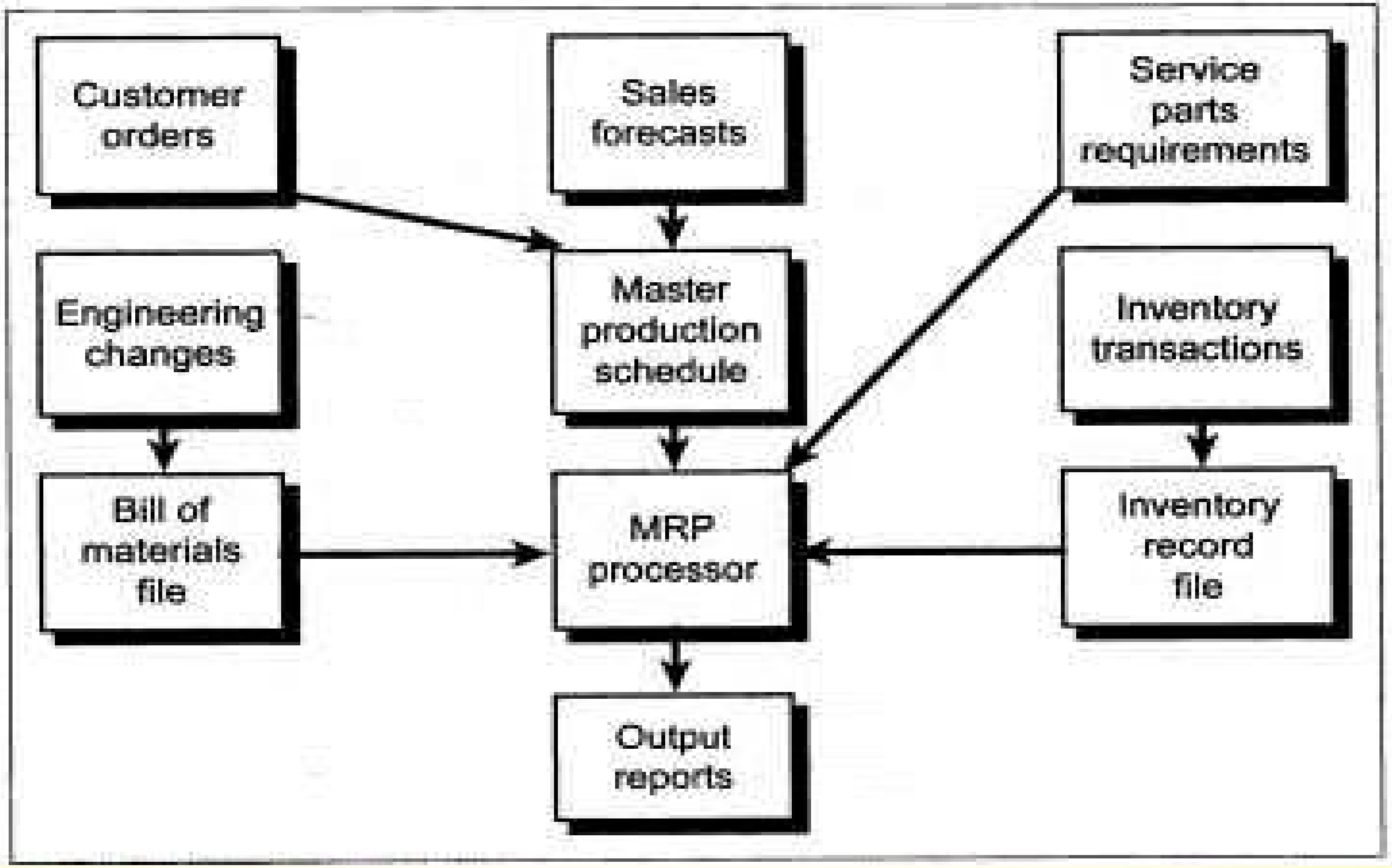
The three important inputs to MRP are:

1.Master production schedule,

2.Bill of materials file and

3.Inventory record file.

Inputs to MRP



Master Production Schedule (MPS)

- It is a detailed plan that states how many end items (i.e. the final product to be sold to the customer) will be available for sale or distribution during specific periods.

Purpose of the master production schedule:

(i) To set due dates for the availability of end items.

(ii) To provide information regarding resources and materials required to support the aggregate plan.

(iii) Input to MRP will set specific production schedules for parts and components used in end items.

Master Production Schedule (MPS)

- **Inputs to MPS:**

The MPS inputs are:

1. Market requirements.
2. Production plan from aggregate planning
3. Resources available.

- **MRP Output:**

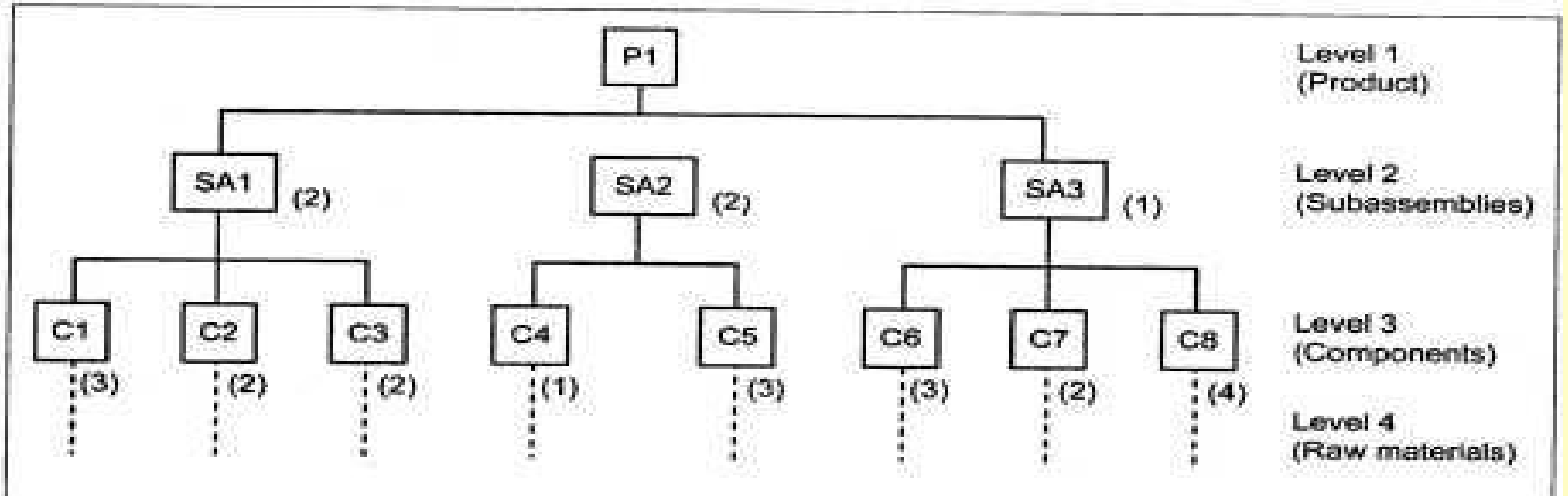
- It is the list of end items available every period that is feasible with respect to demand and capacity.

Bill of Materials File

- Designates what items and how many of each are used to make up a specified final product.
- Used to compute the raw material and component requirements for end products listed in the master schedule.
- It Provides information on the product structure by listing the component parts and subassemblies that make up each product.

Product structure

- Structure of an assembled product, in the form of a pyramid, can be depicted as shown in Fig.
- It can be seen from Figure. that the product P1 is the parent of sub assemblies SA1, SA2, and SA3. similarly SA1 is the parent of components C1, C2 and C3, and so on.



Note: The number in parenthesis below each block represents the number of each items required.

Inventory Record File

- All the data related to the inventory are recorded in the inventory record file.

- The inventory record file contains the following three segment.

  (i) Item Master Data Segment
  (ii) Inventory Status Segment
  (iii) Subsidiary Data Segment

Working of MRP

- MPS provides a period-by-period list of final products required.

- BOM defines what materials and components are needed for each product.

- Inventory record file contains information on the current and future inventory status of each component. using these three inputs, the MRP processor computes the number of each component and raw material required for the given final product.

MRP Output Reports

Types of reports	Purpose
II. Secondary Output Reports	
1. Performance reports of various types	To indicate costs, item usage, etc
2. Exception reports	To show deviations from schedule, orders that are overdue, scrap and so on
3. Inventory forecasts	To indicate the projected level in future periods
4. Cancellation notices	To indicate the cancellation of open orders because of changes in the master schedule
5. Reports on inventory status	To indicate the current status of the inventory

Benefits of MRP

The various benefits of implementing MRP system are:

- Reduced inventory levels.
- Better production scheduling.
- Reduced production lead time.
- Reduced setup cost.
- Reduced product changeover cost.
- Better machine utilization.
- Improved product quality.
- Quicker response to changes in demand.

Capacity Planning

- It is a major business problem Dependent on the type of company and the state of business;
- Much easier if the work load is declining.
- Simplified if the factory has been laid out, after careful simulation, for a planned production level.
- It takes place in three phases, which need to be reviewed within CIM systems.
- Finite capacity calculations are often optimistic, because they do not show the effect of future work, i.e. work not yet released to the factory.

Logic Required In Capacity Planning Under CIM

- The logic for detailed finite capacity planning (i.e. calculations based on actual capacity) must include the ability to summarize the various priority factors such as lateness on due date, important customer, accumulated cost, into a single numeric value so that queues can be sequenced.

Logic Required In Capacity Planning Under CIM

In addition, a number of other process routines that are as follows:

- Reduction of standard inter-operation (or move) time for urgent jobs.
- Overlapping of jobs across different work centres, e.g. the first items in a batch being heat treated while the last items are still being machined.
- Splitting of batches across identical machines,
- Use of alternative routing data, i.e. there may be different ways of making a product that could be chosen, depending on the load at the time on different work centres.

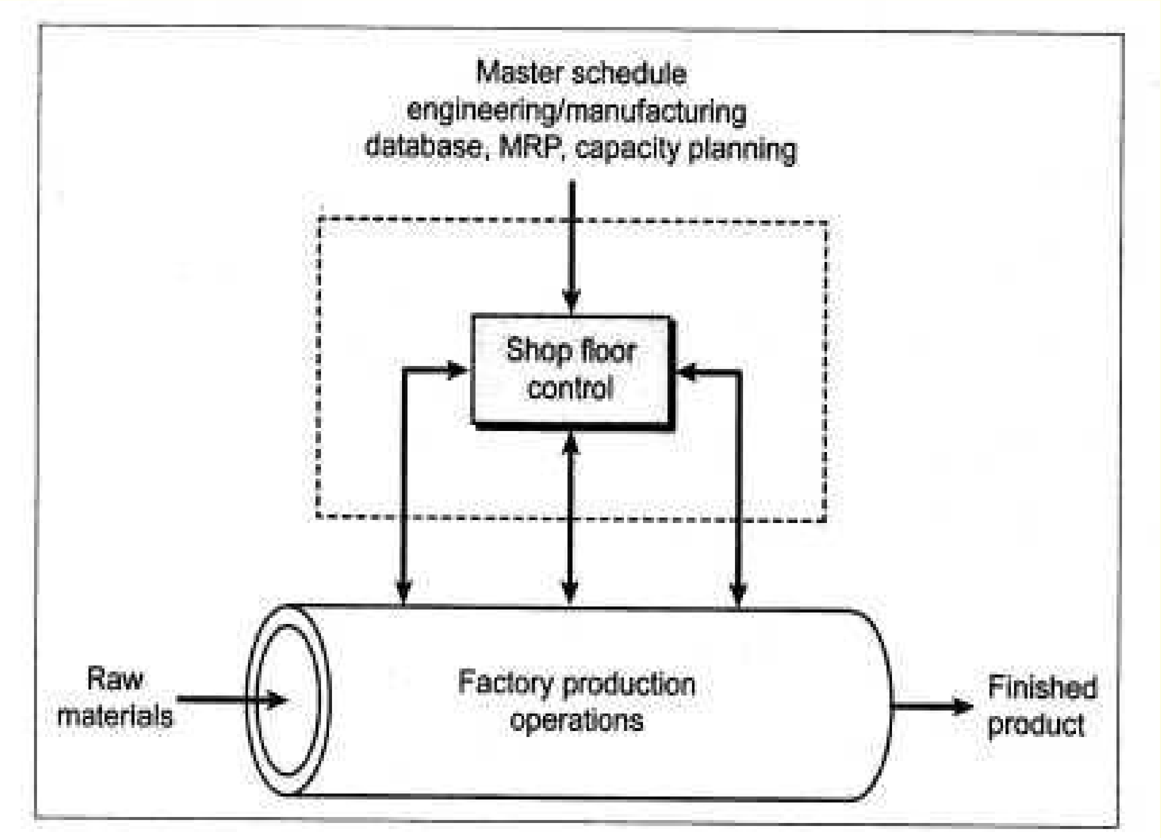
Control Systems

Shop Floor Control

- This control Manages the detailed flow of materials inside the production facility.
- It Encompasses the principles, approaches and techniques needed to schedule, control, measure and evaluate the effectiveness of production operations.
- Is an activity of production control one of the activity of process planning and control (PPC).
- To understand the significance of the shop floor control, it is essential to have the basic knowledge of various activities of PPC and their relations to shop floor control.
- It is defined as a system for utilizing data from the shop floor as well as data processing files to maintain and communicate status information on shop orders and work centre.

Shop Floor Control

Shop Floor Control



Shop Floor Control

Shop floor control (SFC) is concerned with:

(i) The release of production orders to the factory.

(ii) Monitoring and controlling the progress of the orders through the various work centres.

(iii) Acquiring information on the status of the orders.

(iv) Shop floor control deals with managing the work-in-process.

Shop Floor Control

Functions of Shop Floor Control

- The major functions of shop floor control are:

1. Assigning priority of each shop order (Scheduling).

2. Maintaining work-in-process quantity information (Dispatching).

3. Conveying shop-order status information to the office (Follow up).

4. Providing actual output data for capacity control purposes.

5. Providing quantity by location by shop order for work-in-process inventory and accounting purposes.

6. Providing measurement of efficiency, utilisation and productivity of manpower and machines.

Shop Floor Control

- The functions of SFC are:

1. Scheduling
2. Dispatching and
3. Follow-up or Expediting.

Shop Floor Control

Phases of SFC

The three important phases of SFC are:

1.Order release

2.Order scheduling and

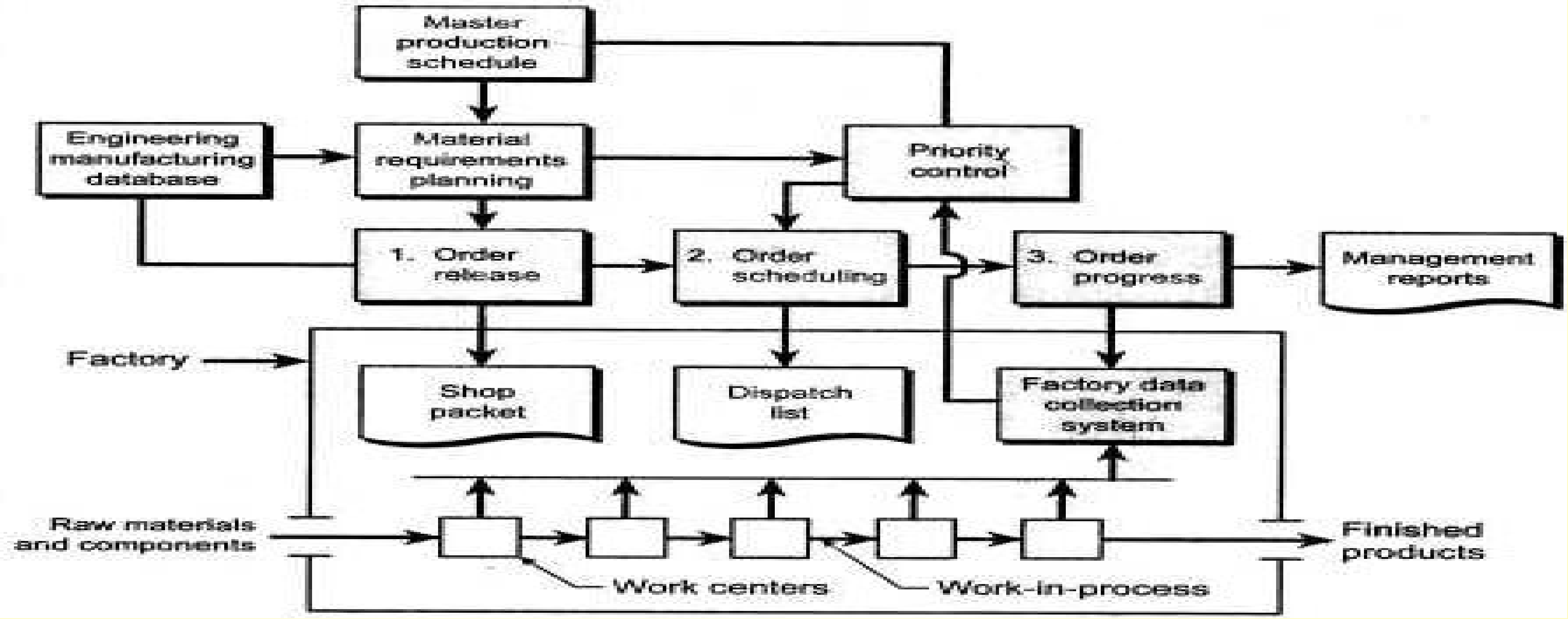
3.Order progress.

It Depicts the three phases and their relationship to other functions in the production management system.

In a computer integrated manufacturing system these phases are managed by computer software.

Shop Floor Control

- In a typical factory which works on manual processing of data, the above documents move with the production order and are used to track the progress through the shop.
- In a CIM factory, more automated methods are used to track the progress of the production orders.



Shop Floor Control

i) The first input is the authorization to produce (that derives from master schedule). This authorisation proceeds through MRP which generates work orders with scheduling information.

(ii) The second input is the engineering and manufacturing database.

- This database contains engineering data (such as the product design, component material specifications, bills of materials, process plans, etc.) required to make the components and assemble the products.

- Database input provides the product structure and process planning information needed to prepare the various documents that accompany the order through the shop.

Shop Floor Control

2) Order Scheduling

- The two inputs required to the order scheduling are:

  (i) The order release and

  (ii) The priority control information

- It Priority control is used in production planning and control to denote the function that maintains the appropriate levels for the various production orders in the shop.

Shop Floor Control

The order scheduling module is used to solve the following two problems in production controls:

- **Machine loading:** Allocating orders to work centres is known as machine loading.
- The term shop loading is used when loading of all machines in the plant are done.
- **Job sequencing:** Determining the priority in which the jobs should be processed is termed as job sequencing.
- Each work centre will have a queue of orders waiting to be processed. Queue problem can be solved by job sequencing.
- Priority sequencing rules, also known as dispatching rules, have been developed to establish priorities for production orders in the plant.

Shop Floor Control

Some of the commonly used priority sequencing rules are presented below.

- **SOT (shortest operating time**): Run the job with the shortest completion time first, next shortest second and so on.
- **Earliest due date:** Run the job with the earliest due date first.
- **STR (slack time remaining):** This is calculated as the difference between the time remaining before the due date minus the processing time remaining. Orders with the STR are run first.
- **STR/OP (slack time per operation):** Orders with shortest STR/OP are run first. STR/OP is calculated as follows:

$$\text{STR/OP} = \frac{\begin{Bmatrix}\text{Time remaining}\\ \text{before due date}\end{Bmatrix} - \begin{Bmatrix}\text{Remaining}\\ \text{processing time}\end{Bmatrix}}{\text{Number of remaining operations}}$$

- **CR (critical ratio):** This is calculated as the difference between the due date and the current date divided by the number of work days remaining. Orders with the smallest CR are run first.

Shop Floor Control

Some of the commonly used priority sequencing rules are presented below.

- **QR (queue ratio):** This is calculated as the slack time remaining in the schedule divided by the planned remaining queue time. Orders with the smallest QR are run first.

- **FCFS (first-come, first-served):** Orders are run in the order they arrive in the department.

- **LCFS (last-come, first-served):** As orders arrive, they are placed on the top of the stock and are run first.

Shop Floor Control

3) Order Progress

- The third and final phase of SFC is order progress phase.
- The order progress phase monitors the status of the various orders in the plant, work-in-progress (WIP)
- Order progress collects data from shop floor and generates reports to assist production management.
- Function of order progress module is to provide information that is useful in managing the factory based on data collected from the factory.

Shop Floor Control

- **Progress reports:** These reports indicate the performance of the shop during a certain time period (say, week or month in the master schedule).

- Typical information listed in these reports include how many orders were completed during the period, how many orders that should have been completed during the period were not completed.

- **Exception reports:** These reports indicate the deviations from the production schedule (e.g. overdue jobs), and similar exception information.

Shop Floor Control

The three forms of order progress reports that are presented to production management are;

- **Work order status reports :** These reports indicate the current status o each shop through the shop.
- It provides information on the current work centre where each order is located, processing hours remaining before completion of each order, whether the job is on-time or behind schedule and priority level.

Control Systems

Inventory Control

- **Inventory Management:**

It is defined as the scientific method of determining what to order, when to order and how much to order and how much to stock so that costs associated with buying and storing are optimal without interrupting production and sales.

- **Inventory decisions:**

There are two basic decisions to be made for every item in the inventory. They are:

(i) How much of an item to order when the inventory of that item is to be replenished? (i.e. order quantity) and

(ii) When to replenish the inventory of that item?

The use of inventory models answer the above two questions.

Inventory Control

- **Objective of Inventory Control**

The main objectives of inventory control are:

(i) To ensure continuous supply of materials so that production should not suffer at any time.

(ii) To maintain the overall investment in inventory at the lowest level, consistent with operating requirements.

(iii) To minimize holding, replacement and shortage cost of inventories and maximize the efficiency in production and distribution.

(iv) To keep inactive, waste, surplus, scrap and obsolete items at the minimum level.

Inventory Control

- **Objective of Inventory Control**

(v) To supply the product, raw material, WIP, etc., to its users as per their requirements at right time and at right price.

(vi) To ensure timely action for replenishment.

(vii) To maintain timely record of inventories of all the items and to maintain the stock within the desired limits.

(viii) To avoid both over-stocking and under-stocking of inventory.

Inventory Control

- Costs Associated with Inventory (What are Inventory Costs?)

The major costs associated with procuring and holding inventories are:

1. Ordering costs
2. Carrying (or holding) costs
3. Shortage (or stock out) costs and
4. Purchase costs.

Inventory Control

1) Ordering costs

There are costs associated with the placement of an order for the acquisition of inventories.

- It is Refer to the managerial and clerical costs to prepare the purchase or production order.
- It is also known by the names procurement costs, replenishment costs and acquisition costs.

These costs include:

(i) Costs of staff of purchase department,

(ii) Costs of stationery consumed for ordering, postage, telephone bills, etc.

(iii) Depreciation costs and expenses for maintaining equipment required for ordering, receiving and inspecting incoming items.

(iv) Inspection costs of incoming materials.

Inventory Control

2) Holding (or inventory carrying) costs

- Inventory carrying costs are the costs associated with holding a given level of inventory on hand.
- It varies in direct proportion to the amount of holding and period of holding the stock in stores. This cost will not occur if inventory is not carried out.

The holding costs include:

(i) Costs for storage facilities.

(ii) Handling costs.

(iii) Depreciation, taxes and insurance.

(iv) Costs on record keeping.

(v) Losses due to pilferage, spoilage, deterioration and obsolescence.

(vi)Opportunity cost of capital.

Inventory Control

3) Shortage (or stock-out) costs

When the stock of an item is depleted and there is a demand for it, then the shortage cost will occur.

Shortage cost is the cost associated with stock-out.

The shortage costs include:

(i) Back order costs.

(ii) Loss of future sales.

(iii) Loss of customer goodwill.

(iv) Loss of profit contribution by lost sales revenue.

(iv) Extra cost associated with urgent, small quantity ordering costs.

Inventory Control

4) Purchase (or production) costs

- These are the costs incurred to purchase/or produce the item. This Costs include the price paid or the labour, material and overhead charges necessary to produce the item.

Manufacturing Resource Planning (MRP-II)

- It Represents the natural evolution of closed-loop MRP (materials requirements planning).

- It is an integrated information system that synchronize all aspects of the business.

- It is Coordinates sales, purchasing, manufacturing, finance and engineering by adopting a focal production plan and by using one unified database to plan and update the activities in all the systems.

- MRP II consists of virtually all the functions in the PPC system (presented in Figure) plus additional business functions that are related to production.

Manufacturing Resource Planning (MRP-II)

- Important MRP II system functions include:

1.**Management planning** — business strategy, aggregate production planning, master production scheduling, rough-cut capacity planning and budget planning.

2.**Customer services** — sales forecasting, order entry, sales analysis and finished goods inventory.

3.**Operations planning** — purchase order and work order release.

4.**Operations execution** — purchasing, product scheduling and control, work-in - process inventory control, shop floor control and labour hour tracking.

5. **Financial functions** — cost accounting, accounts receivable, accounts payable, general ledger and payroll.

Manufacturing Resource Planning (MRP-II)

Now-a-days many commercial software are available incorporating MRP II functions with more features.

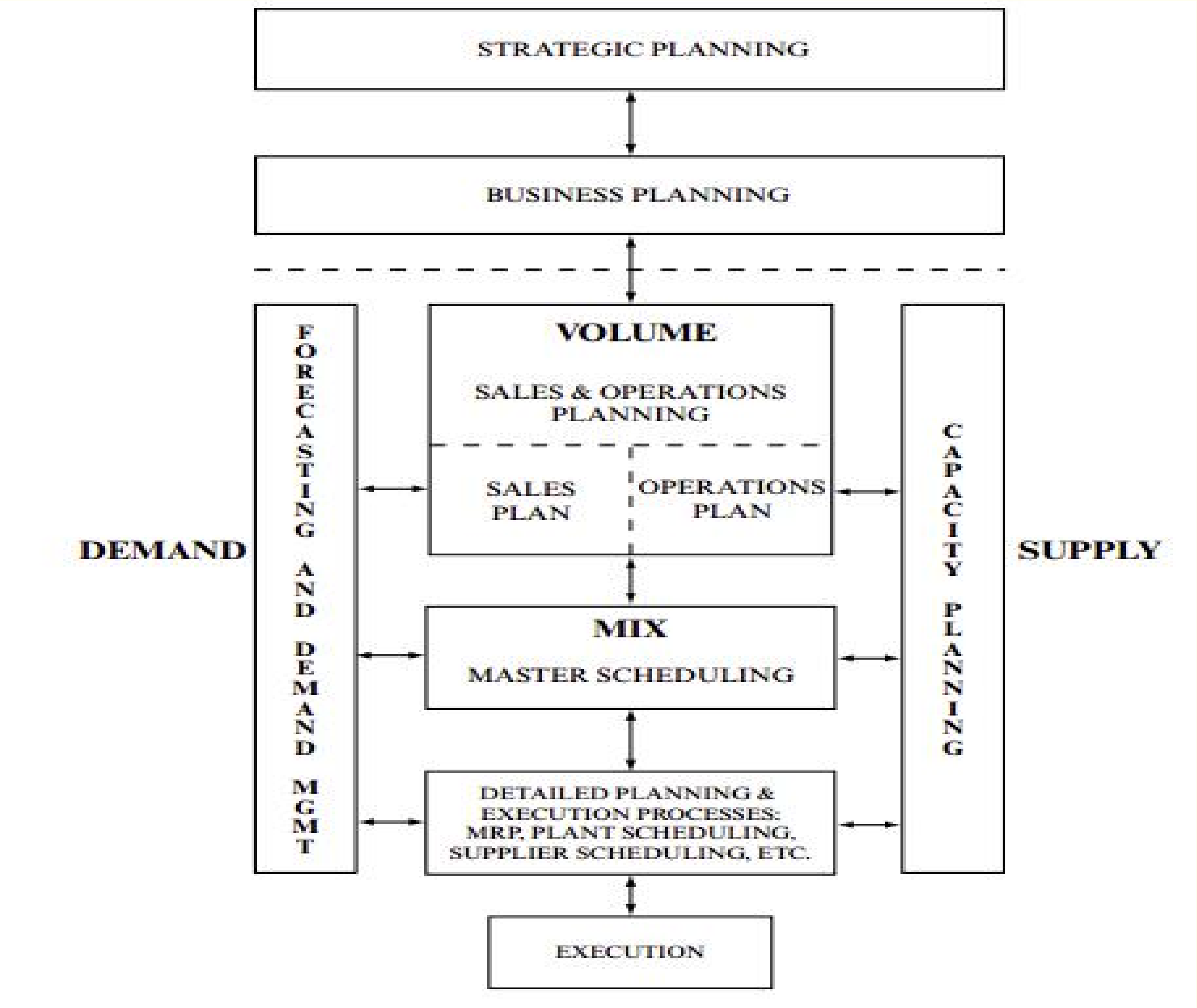
Some of them include:

- Enterprise Resource Planning (ERP)
- Customer-Oriented Manufacturing Management Systems (COMMS)
- Manufacturing Execution Systems (MES)
- Customer-Oriented Management Systems (COMS).

Enterprise Resource Planning (ERP)

- It latest step in this evolution is Enterprise Resource Planning (ERP).
- Fundamentals of ERP are the same as with MRP II.
- Predicts and balances demand and supply.
- It is an enterprise-wide set of forecasting, planning and scheduling tools.
- Links customers and suppliers into a complete supply chain, Employs proven processes for decision-making and Coordinates sales, marketing, operations, logistics, purchasing, finance, product development and human resources.
- Goals include high levels of customer service, productivity, cost reduction and inventory turnover and it provides the foundation for effective supply chain management and e-commerce.

Enterprise Resource Planning (ERP)



Enterprise Resource Planning (ERP)

- Enterprise Resource Planning is a direct outgrowth and extension of Manufacturing Resource Planning and as such includes all of MRP II's capabilities.

a) Applies a single set of resource planning tools across the entire enterprise,

b) Provides real-time integration of sales, operating and financial data and

c) Connects resource planning approaches to the extended supply chain of customers and suppliers.

- Primary purpose of implementing Enterprise Resource Planning is to run the business, in a rapidly changing and highly competitive environment, far better than before.

Enterprise Resource Planning (ERP)

- **The Applicability of ERP**

ERP and its predecessor, MRP II, have been successfully implemented in companies with the following characteristics:

- Make-to-stock
- Design-to-order
- Simple product
- Single plant
- Manufacturers with distribution networks
- Make-to-order
- Complex product
- Multiple plants
- Contract manufacturers
- Sell direct to end users

Enterprise Resource Planning (ERP)

ERP problems fall into these four types:

- The system itself is bad.
- The system is good, but it's set up incorrectly.
- The system is good, but it's not being used.
- The system is good, but it's being used ineffectively.

UNIT III

CELLULAR MANUFACTURING

Group Technology (GT)

- Group technology (GT) is a manufacturing philosophy to increase production efficiency by grouping a variety of parts having similarities of shape, dimension and/or process route.
- GT may be defined as a manufacturing philosophy that justifies batch production by capitalizing on design and/or manufacturing similarities among component parts. In batch production, the products are made in small batches and in large variety.
- Every batch contains identical items but every batch is different from the others.
- For example, a plant producing many parts (say 5000 different parts) may be grouped into several distinct families (say 20 to 25 part families). Each family possesses similar design and manufacturing characteristics.
- This grouping philosophy results in increased manufacturing efficiencies.

Group Technology (GT)

- Efficiencies are due to reduced setup times, lower in-process inventories, better scheduling, streamlined material flow, improved quality, improved tool control and the use of standardized process plans.

- In many plants where GT has been implemented, the production equipment is arranged into ‘machine groups’ (also known as ‘cells’) to facilitate work flow and parts handling.GT is felt advantageous in the product design stage also. GT is a prerequisite for computer integrated manufacturing.

- GT is not an automation strategy associated with either the design or the production engineering area, Implementation of GT is a critical first step for computer-aided process planning (CAPP) and many of the production engineering activities.

Group Technology (GT)

BENEFITS OF GT

- Group technology, when successfully implemented, offers many benefits to industries.
- GT benefits can be realised in a manufacturing organisation in the following areas;

1. Product design
2. Tooling and setups
3. Materials handling
4. Production and inventory control
5. Process planning
6. Management and employees.

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Group Technology (GT)

1.Product design

- Importance of GT for product design come in cost and time savings.
- Design engineers can quickly and easily search the database for parts that either presently exist or can be used with slight modifications, rather than issuing new part numbers.
- Similar cost savings can be realised in the elimination of two or more identical parts with different part numbers.
- Advantage is the standardisation of designs.
- Design features such as comer radii, tolerances, counter bores, and surface finishes can be standardized with GT.

Group Technology (GT)

2) Tooling and Setups

- In the area of tooling, group jigs and fixtures are designed to accommodate every member of a part family.
- Also work holding devices are designed to use special adapters in such a way that this general fixture can accept each part family member.
- Since setup times are very short between different parts in a family, a group layout can also result in dramatic reductions in setup times.

3) Materials Handling

- GT facilitates a group layout of the shop.
- Since machines are arranged as cells, in a group layout, the materials handling cost can be reduced by reducing travel and facilitating increased automation.

Group Technology (GT)

4) Production and Inventory Control

- GT simplifies production and planning control.
- Complexity of the problem has been reduced from a large portion of the shop to smaller groups of machines.
- Production scheduling is simplified to a small number of parts through the machines in that cell.
- In addition, reduced setup times and effective materials handling result in shorter manufacturing lead times and smaller work-in-process inventories.

Group Technology (GT)

5) Process Planning

- Concept of group technology parts, classification and coding lead to an automated process planning system.
- Grouping parts allows an examination of the various planning/route sheets for all members of a particular family.
- Once this has been accomplished, the same basic plans can be applied to other members, there by optimizing the shop flow for the group.

Advantages of Group Technology (GT)

- GT facilitates (a) efficient retrieval of similar parts, (b) development of a database containing effective product design data and (c) avoidance of design duplication.
- GT encourages standardization of designs, tooling, fixing and setups.
- GT facilitates (a) development of a computer-aided process planning (CAPP) system, (b) retrieval of process plans for part families and (c) development of standard routings for part families.
- Times and costs for material handling and waiting between stages are reduced.
- Production planning and control is simplified.
- Setup time and setup cost for each job are reduced, because several jobs are grouped and processed in sequence.
- Machining cells can reduce work-in-process inventory, resulting in shorter queues and shorter manufacturing throughput times.
- Part and product quality are improved.
- GT facilitates better employee involvement and increases workers satisfaction.

Limitations of Group Technology (GT)

- Implementing GT is expensive.
- Large costs may be incurred in rearranging the plant into machine cells or groups.
- Installing a coding and classification system is very time-consuming.
- As there is no common implementation approach, the implementation of GT is often difficult.

Part Families

- Part family is a collection of parts which are similar either because of geometric shape and size or because similar processing steps are required in their manufacture.

- Parts which are similar in their design characteristics (i.e. shape and geometry) are grouped in a family referred to as a design part family.

- Parts which are similar in their manufacturing characteristics are grouped in a family referred to as a manufacturing part family.

- Characteristics used in classifying parts are referred to as "attributes".

Part Families

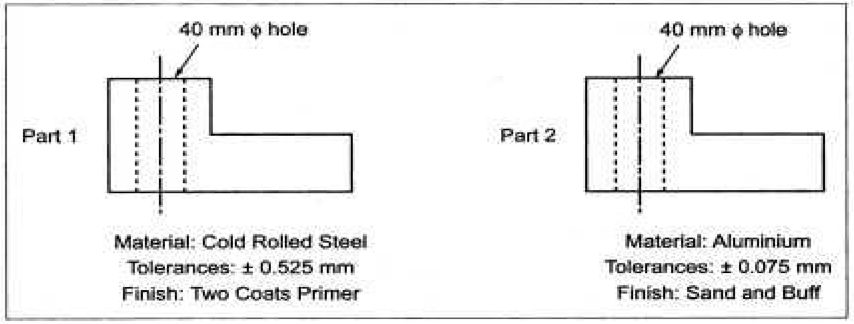
- The two parts are placed in the same family based on design characteristics.

- They have exactly the same shape and size.

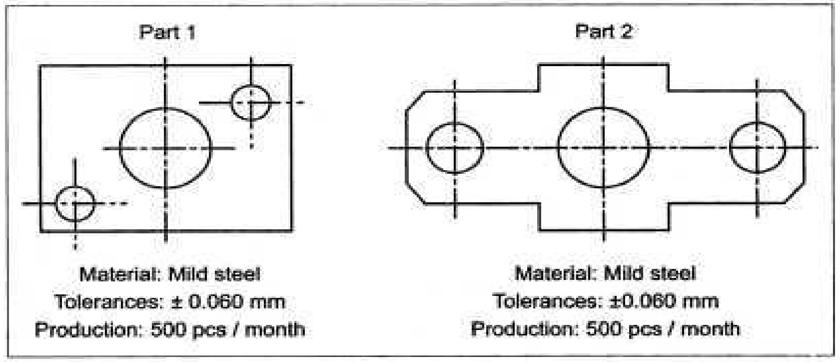
- They differ in terms of manufacturing requirements such as tolerances, production quantities and material.

Part Families

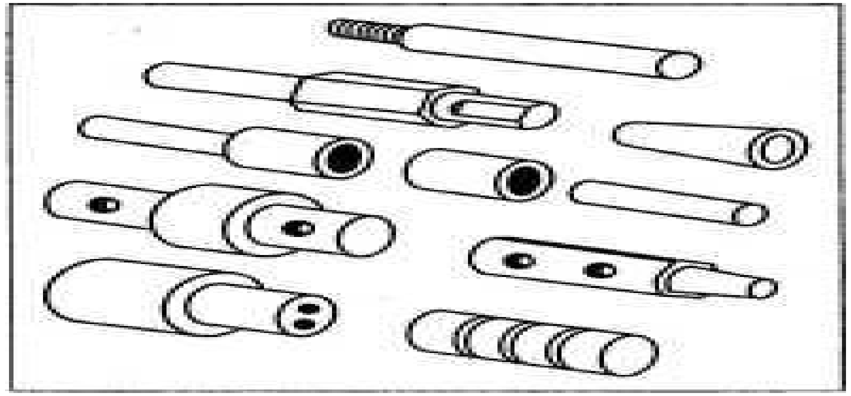
- Design part family



- Manufacturing part family



- A family of parts with similar manufacturing process requirements but different design attributes.



Part Families

Methods for Part Family Formation

- The three general methods for grouping parts into families are:

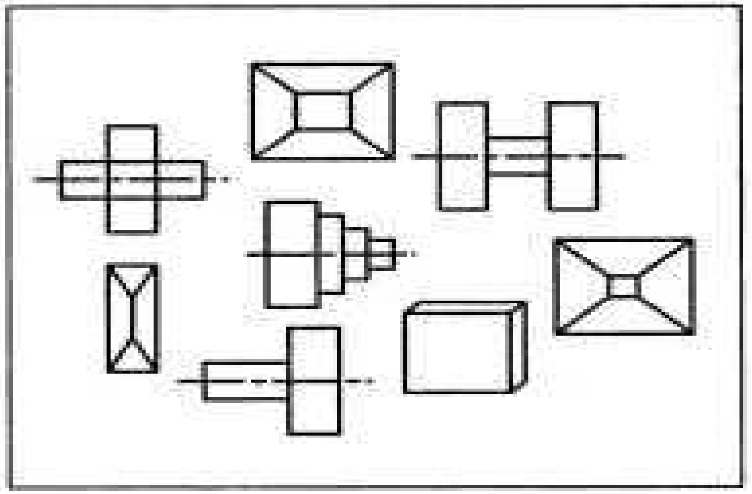
1. Visual inspection

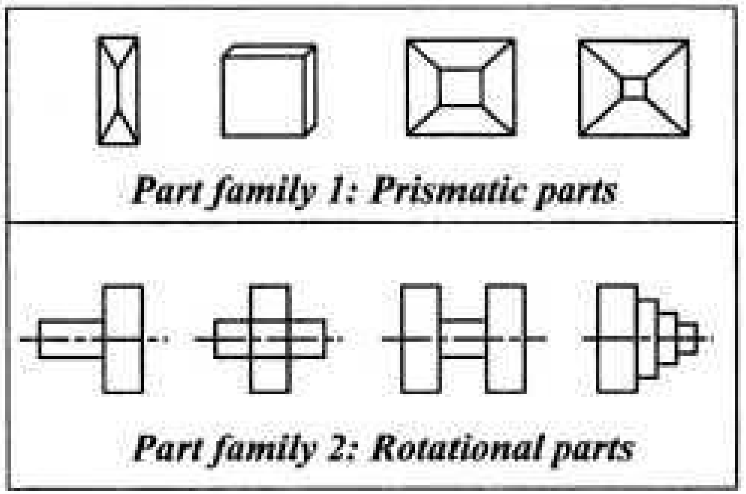
2. Parts classification and coding system

3. Production flow analysis.

Visual Inspection Method

- Visual inspection method is the simplest and least expensive method.
- It involves looking at parts, photos of parts or drawings of parts and arranging them into similar groups.





Parts Classification and Coding

- Coding is a systematic process of establishing an alphanumeric value for parts based on selected part features. Classification is the grouping of parts based on code values.

- It is the most sophisticated, most difficult, most time-consuming and widely used of the three methods.

- Here the various design and/or manufacturing attributes of a part are identified, listed and assigned a code number.

- Though several classification and coding systems have been developed, no system has been universally adopted. one of the reasons for this is that the information that is to be represented in the classification and coding system will vary from one company to another company.

Parts Classification and Coding

Design and Manufacturing Attributes

- Any parts classification systems fall into one of the following three categories:

1. Systems based on part design attributes.

2. Systems based on part manufacturing attributes.

3. Systems based on both design and manufacturing attributes.

Parts Classification and Coding

- Parts classified by design attributes can be coded from information on the engineering drawing. This first category systems are useful for design retrieval and to promote design standardization.

- In grouping of manufacturing attributes, in addition to drawing information, other information such as operation sequence, lot size, machines used, production processes, surface finish, etc. are also considered.

- Systems in the second category are used for computer-aided process planning, tool design and other production related functions.

- The third category represents an attempt to combine the functions and advantages of the other two systems into a single classification scheme..

Parts Classification and Coding

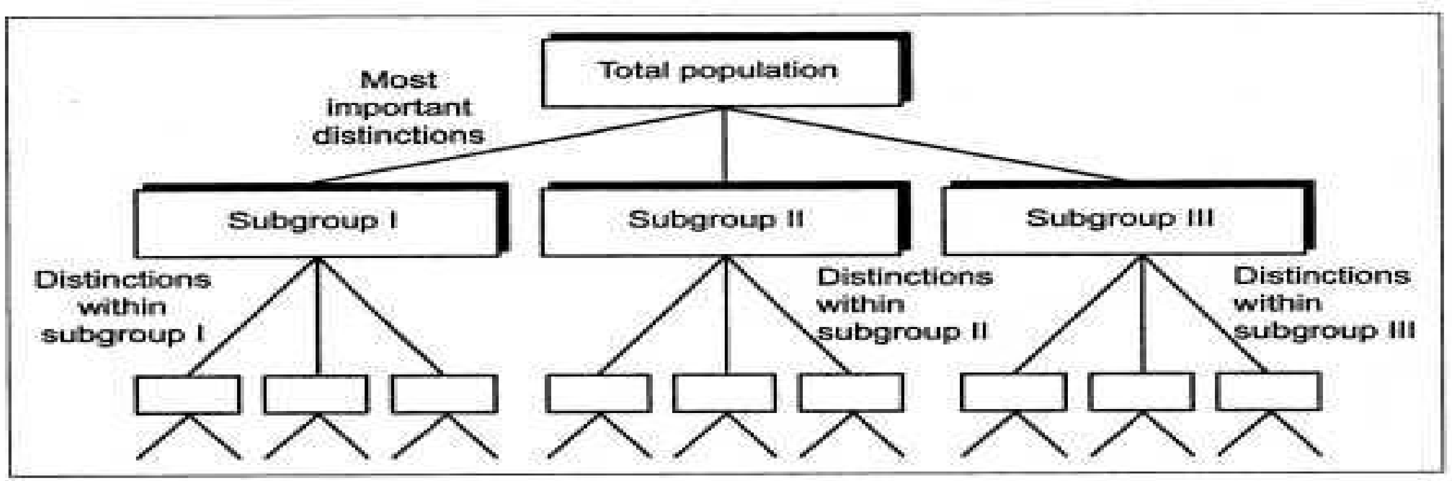
Coding System Structure

- A GT code is a string of characters capturing information about an item.
- A coding scheme is a vehicle for the efficient recording, sortingand retrieval of relevant information about objects.
- A part coding scheme consists of a sequence of symbols that identify the part's design and/or manufacturing attributes.
- The symbols in the code can be all numeric, all alphabetic or a combination of both types.

Parts Classification and Coding

1.Hierarchical Code (or Mono code)

- Interpretation of each successive symbol depends on the value of the preceding symbols.
- Each symbol amplifies the information contained in the preceding digit, so a digit in the code cannot be interpreted alone. Structure of these codes is like a tree in which each symbol amplifies the information provided in the previous digit.
- Hierarchical coding system can be depicted using a tree structure as shown in Figure.



Parts Classification and Coding

Merits and demerits of mono code system:

- Provides a large amount of information in a relatively small number of digits.
- This tree structure works well for designing an existing ordered structure but is more difficult to use in classifying things that have no apparent order.
- Defining the meanings for each digit in a hierarchical system (and hence the construction) is difficult.
- Frequently used in design departments for part retrieval.
- Their utility is limited in manufacturing departments, because it is difficult to retrieve and analyse process-related information when it is in a hierarchical structure.

Parts Classification and Coding

2) Attribute Code (or Poly code)

- In this structure, the interpretation of each symbol in the sequence does not depend on the value of preceding symbols.
- Each digit in this code represents information in its own right and does not directly qualify the information provided by the other digits.
- Attribute code is also known by other names ‘poly code’, ‘chain code’, ‘discrete code’ and ‘fixed-digit code’.

Parts Classification and Coding

- Illustration: shows an example for attribute code.
- For the spur gear shown in Figure. using code, we can obtain the poly code as "22213".

Digit	Class of feature	Possible value of digits			
		1	2	3	4
1	External shape	Cylindrical without deviations	Cylindrical with deviations	Boxlike	...
2	Internal shape	None	Center hole	Brind center hole	...
3	Number of holes	0	1-2	3-5	...
4	Type of holes	Axial	Cross	Axial cross	...
5	Gear teeth	Worm	Internal spur	External spur	...
⋮	⋮	⋮	⋮	⋮	⋮

Parts Classification and Coding

Merits and demerits of poly codes:

- The major advantages of poly codes are that they are compact and easy to use and develop.
- It is popular with manufacturing departments because it makes it easy to identify parts that have similar features that require similar processing.
- Because a poly code represents a class of items as a string of features, it is also particularly suitable for computer analysis.
- The primary disadvantage is that, for comparable code size, a poly code lacks the detail presence in a mono code structure. also poly codes tend to be longer than mono codes.

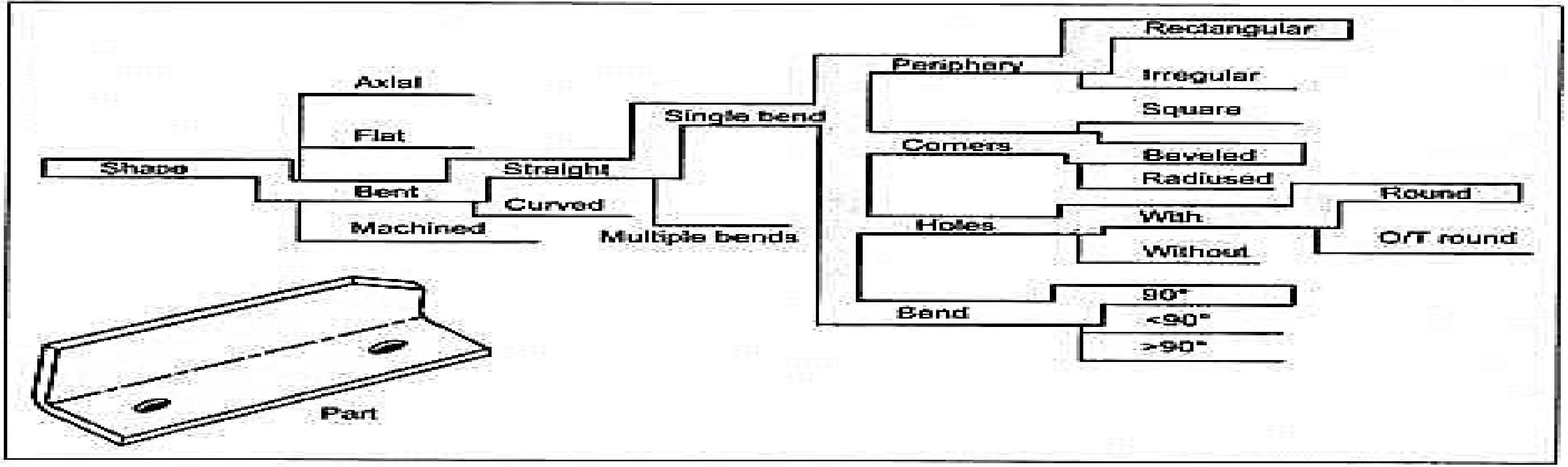
Parts Classification and Coding

3.Decision-Tree (or Hybrid) Code

- A hybrid code captures the best features of the hierarchical and poly code structures.
- This system is also known as decision-tree coding and it combines both design and manufacturing attributes.
- In practice, most coding systems use a hybrid construction to combine the best.
- To reduce the length of a strict poly code, the first digit of such a system may split the population into appropriate subgroups, as in a mono code structure. Then each subgroup can have its own poly code structure.
- For example, the first digit might be used to denote the type of part, such as gear.
- The next four positions might be reserved for a short attribute that would describe the attributes of the gear.

Parts Classification and Coding

features of monocodes and polycodes.



- The next digit position 6, might be used to designate another subgroup, such as material, followed by another attribute code that would describe the attributes. Thus, a hybrid code can be generated.
- Hybrid code is relatively more compact than a pure attribute code while retaining the ability to easily identify parts with specific characteristics.

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Production Flow Analysis

- Developed by Burbridge in 1971, Is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather on part drawings.
- Work parts with identical or similar routings are classified into part families.
- PFA neither uses a classification and coding system nor part drawings to identify families.
- It uses the information such as part number, operation sequence, lot size, etc., contained on the route sheet.
- This method is based on the route sheet information and sometimes referred as the route sheet inspection method.

Production Flow Analysis

Steps Involved in PFA

- The following four steps are followed to carryout PFA:

(i) Data collection

(ii) Sortation of process routings

(iii) Preparation of PFA chart

(iv) Cluster analysis.

Production Flow Analysis

Step 1: Data collection

- The step in the PFA procedure is to collect the necessary data.
- Route sheets of all the components to be manufactured in the shop are prepared.
- Route sheet should contain the part number and operation sequence.
- Other data that can be collected/obtained from route sheet/operation sheet include lot size, time standards and annual demand.

Step 2: Sortation of process routes

- The second step in the PFA is to arrange the parts into groups according to the similarity of their process routings.
- A typical card format is required for organizing the data such as the part number, sequence of code and lot size. A sortation procedure is used to arrange the parts into 'packs'.
- Pack is nothing but a group of parts with identical process routings. Some pack may even contain only one part number. A pack identification or letter is provided for each pack.

Production Flow Analysis

Step 3: PFA chart

- A PFA chart is a graphical representation of the process used for each pack.
- It is a tabulation of the process or machine code numbers for all of the part packs. Also known as 'part-machine incidence matrix' or 'component-machine incidence matrix'.
- The table below Illustrates a typical PFA chart having 7 machines (M1 to M7) and 9 parts (P1 to P9).

Machines	Parts								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
M1	1	1		1				1	
m2					1				1
m3			1		1				1
m4		1		1		1			
M5	1							1	
m6			1						1
m7		1				1	1		

Production Flow Analysis

- In this matrix, the entries have a value $x_{ij} = 1$ or 0:
- A value of $x_{ij} = 1$ indicates that the corresponding part i requires processing on machine j
- $x_{ij} = 0$ indicates that no processing of component i is accomplished on machine j
- However, in Table , the 0's are indicated as blank (entry) entries for better clarity of the matrix.

Machines	Parts								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
M1	1	1		1				1	
m2					1				1
m3			1		1				1
m4		1		1		1			
M5	1							1	
m6			1						1
m7		1				1	1		

Production Flow Analysis

Step 4: Cluster analysis

- From the PFA chart, related grouping are identified and rearranged into a new pattern that brings together packs with similar machine sequences.
- Table shows one possible rearrangement of the original PFA chart.
- It is clear that for the PFA chart considered we have three part families and three machine cells, as shown below.

Machines	Parts								
	P_1	P_8	P_2	P_4	P_6	P_7	P_9	P_3	P_5
M_1	1	1	1	1					
m_5	1	1							
m_4			1	1	1				
m_7			1		1	1			
m_3							1	1	1
m_6							1	1	
m_2							1		1

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Production Flow Analysis

Table : Rearranged PFA chart, indicating possible machine grouping

Part Families: Cell groups:

PF_1 ={P_1, P_8}C,= { M_1, M_5}

PF_2 ={P_2, P_4, P_6}C_2= {M_4, M_7}

PF_3 ={P_3, P_5, P_9}C_3={M_2, M_3, M_6}

Machines	Parts								
	P_1	P_8	P_2	P_4	P_6	P_7	P_9	P_3	P_5
M_1	1	1	1	1					
m_5	1	1							
m_4			1	1	1				
m_7			1		1	1			
m_3							1	1	1
m_6							1	1	
m_2							1		1

Production Flow Analysis

Advantages of PFA

- Parts classification and coding uses design data and the PFA uses manufacturing data (i.e., route sheet) to identify part families.
- Due to this fact, as pointed out by Groover, PFA can overcome two possible anomalies that can occur in parts classification and coding.
- First, parts whose basic geometries are quite different may nevertheless require similar or identical process routings.
- Second, parts whose geometries are similar may nevertheless require process routings that are quite different.
- Also PFA requires less time than a complete parts classification and coding procedure.

Production Flow Analysis

Disadvantages of PFA

- PFA does not provide any mechanism for rationalizing the manufacturing routings.
- No consideration being given to routing sheet whether the routings are optimal or consistent or logical.
- Process sequences from route sheets are prepared by different process planners, hence the routings may contain processing steps that are non- optimal, illogical and unnecessary.

Cellular Manufacturing

- It is an application of group technology in which dissimilar machines have been aggregated into cells, each of which is dedicated to the production of a part family.
- Primary advantage of CM implementation is that a large manufacturing system can be decomposed into smaller subsystems of machines called cells. Cells are dedicated to process part families based on similarities in manufacturing requirements. Parts having similar manufacturing requirements can be processed entirely in that cell.
- In addition, cells represent sociological units conducive to team work which lead to higher levels of motivation for process improvements.
- Benefits associated with the application of CM include improved market response, more reliable delivery promises, reduced tooling and fixtures and simplified scheduling.
- Literature surveys confirm substantial benefits from implementing cellular manufacturing in manufacturing industries.

Cellular Manufacturing

Rank	Reasons for implementing manufacturing cells	Average improvement
1	Reduce manufacturing lead time	61
2	Reduce work-in-process	48
3	Improve part and/or product quality	28
4	Reduce response time for customer orders	50
5	Reduce more distances/more times	61
6	Increase manufacturing flexibility	—
7	Reduce unit costs	16
8	Simplify production planning and control	—
9	Facilitate employee involvement	
10	Reduce set-up times	44
11	Reduce finished goods inventory	39

Cellular Manufacturing

- Design Considerations Guiding the Cell Formation
- We know that cell formation is the early activity in the cell design process where part families and associated machine groups are identified. Cell formation is influenced by a variety of objectives and concerns.
- Lists the important design considerations that should be taken into account during cell formation.

Rank	Design considerations
1	Parts/products to be fully completed in the cell
2	Higher operator utilization
3	Fewer operators than equipment
4	Balanced equipment utilization in the cell
5	The number of part/product assigned to the cell
6	Unidirectional (linear) material flows
7	The number of cell operators
8	High utilization on expensive equipment
9	The number of workstations/machines in the cell
10	High equipment flexibility to ease new product introduction over time
11	High flexibility in selecting alternative routes through the cell

Composite Part Concept

- Mitrofanov (1959) and Edwards (1970) have proposed composite part approach to implement the concept of cellular manufacturing.
- A composite part is formed by merging the primitives of all the parts of a part family.
- Composite is a single hypothetical part that can be completely processed in a manufacturing cell/group.
- If a new part is loaded in a machine group, the degree of dissimilarity of the part of its related part family or the hypothetical composite should have minimum deviation and desired to be zero.
- The manufacturing facility could be planned on the basis of composite part to facilitate economical production.

Composite Part Concept

- The primitives of three parts shown are merged into composite part by incorporating all the primitives of the three parts.

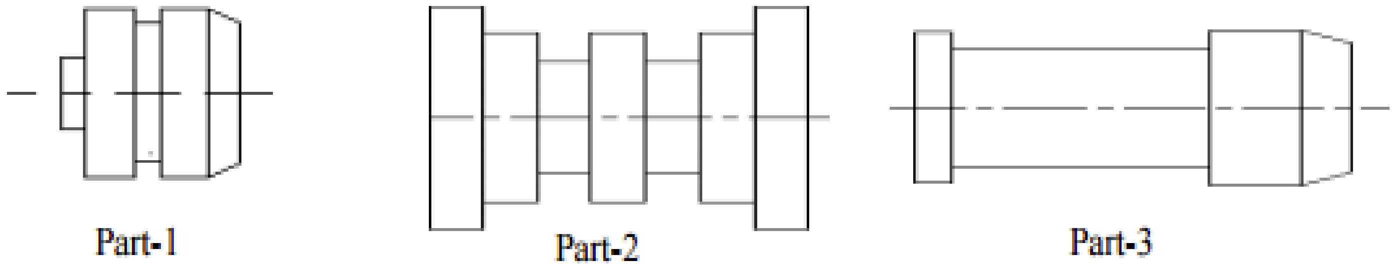
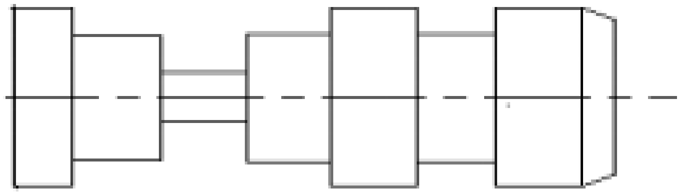


Figure 1: Individual parts



Composite Part Concept

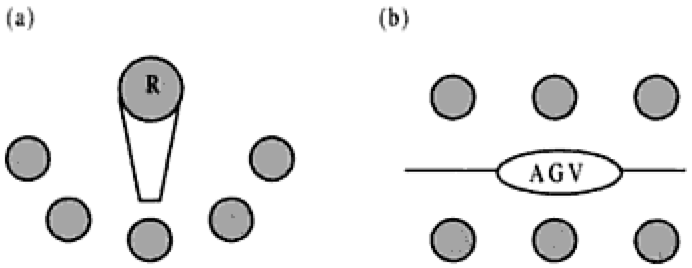
- It may not be judicious to merge all the primitives of parts due to various production considerations,
- In such situation the shop will converge back to a large job shop and all the benefits of CMS will be lost. Size of the manufacturing group depends on initial capital investment capacity, machines available and outsourcing facilities.
- Individual parts features (in terms of primitives) could be merged in the composite part based on their repetitions in the parts.
- Primitives having more repetitions will be more eligible candidates for merging in the composite part.
- Various techniques could be used for selection of optimum primitives for merging in composite parts.
- Genetic algorithm is proved to be one of the effective techniques.

Machine Cell Design and Layout

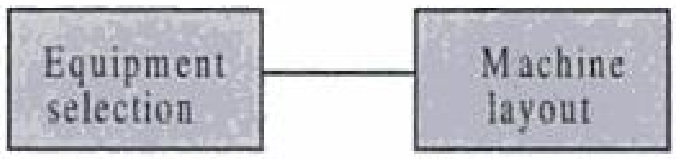
- Machine layout aims at determining the best arrangement of machines in each product cell.
- Minimization of material handling cost is an often used objective in determining the layout of machines in a cell.
- Constraints related to the availability of space, material handling system type and so on are considered.
- Type of operations and parts are not the only factors that impact the layout of machines.
- Type of material handling system to be used also needs to be considered;

Machine Cell Design and Layout

- Example, the articulated robot (R) in figure(a) implies a circular arrangement of machines.
- If an AGV had been selected to tend the same machines, it would have been necessary to use the layout in figure(b).



- Two step design of system



Machine Cell Design and Layout

- Goal of machine cell layout is to arrange the product or functional cells formed on the factory floor.
- Determining the layout of machine cells involves locating the cells in order to minimize the total material handling cost subject to some constraints (e.g. shape of the facility).
- If all cells were square in shape and of the same size, then the cell layout could be modelled as the quadratic assignment problem (QAP).
- Cell layout problem can be viewed as a machine layout problem, where each machine represents a cell.
- Though cellular manufacturing offers numerous benefits, it is not always implemented due to the following:

1. Parts and machines may not form mutually exclusive clusters.
2. The data required from the formation of cells might not be available.

Quantitative analysis in Cellular Manufacturing

Rank Order Clustering Method

- It also known as binary ordering algorithm (BOA), It is a simple algorithm used to form machine-part groups. it was Developed by J.R.King (1980).
- It considers two data:
- Number of components and Component sequences. Based on the component sequences, a machine-part incidence matrix is developed.
- Rows of the machine component incidence matrix represent the machines which are required to process the components. Columns of the matrix represent the component numbers.

Quantitative analysis in Cellular Manufacturing

Concept:

- Each row and each column of the matrix are considered as binary words.

- Example, in a row if we have numbers (1 0 1 0 1), then the decimal equivalent is computed as follows:

- Row decimal equivalent $= (1\times 24) + (0\times 23) + (1 \times 22) + (0 \times 21) + (1 \times 20)$

  $= 16 + 0 + 4 + 0 + 1 = 21$

Quantitative analysis in Cellular Manufacturing

Concept:

- If a column has the following entries from top to bottom, the decimal equivalent is computed as explained below:
- Column entries = (11010)
- Column decimal equivalent = (1 × 24) + (1 × 23) + (0 × 22) + (1 × 21) + (0 × 20)

  = 16 + 8 + 0 + 2 + 0 = 26

- Row with the largest decimal equivalent is considered to have the highest rank 1 among the rows.
- Column with the largest decimal equivalent is considered to have the highest rank among the columns.
- Procedure to obtain final machine component incidence matrix is summarized below.

Quantitative analysis in Cellular Manufacturing

Steps in ROC Algorithm

The steps in ROC algorithm are given below:

Step 0: Input: Total number of components, component sequences.

Step 1: Form the machine-component incidence matrix using the component sequences.

Step 2: Compute binary equivalent of each row.

Step 3: Rearrange the rows of the matrix in rank wise (high to low from top to bottom).

Quantitative analysis in Cellular Manufacturing

Steps in ROC Algorithm

Step 4: Compute binary equivalent of each column and check whether the columns of the matrix are arranged in rank wise (high to low from left to right). If not, go to Step 7.

Step 5: Rearrange the columns of the matrix rank wise and compute the binary equivalent of each row.

Step 6: Check whether the rows of the matrix are arranged rank wise, If not, go to Step 3; otherwise, go to Step 7.

Step 7: Print the final machine-component incidence matrix.

Quantitative analysis in Cellular Manufacturing

Arranging Machines in a GT cell

There are three basic ways to arrange machines in a GT cell are :

1. Line (or product) layout.

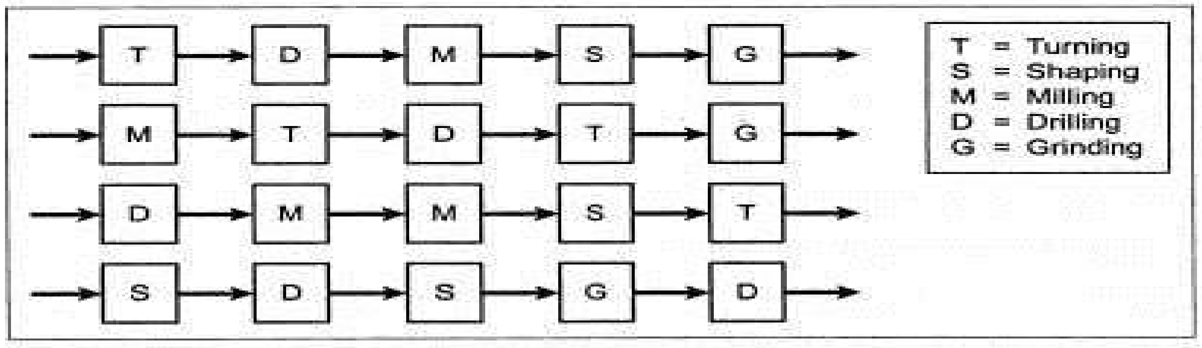
2. Functional (or process) layout.

3. Group (or combination) layout.

Quantitative analysis in Cellular Manufacturing

1) Line (or Product) Layout

- Here the machines are arranged in the sequence as required by the product.
- If volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit.



Suitability:

- Suitable for the continuous mass production of goods as it makes it possible for the raw material to be fed into the plant and take out finished product on the other end.

Quantitative analysis in Cellular Manufacturing

Advantages	Disadvantages
Smooth and continuous work flow. Less space requirements for the same production volume. Automatic materials handling possible.	Lack of flexibility. That is product changes require major changes in layout. Large capital investment.
Lesser work-in-process inventory. Reduced product movement and processing time. Simple production planning and control, better co-ordination. Less skilled workers can serve the purpose.	Dedicated or special purpose machines. Dependence of the whole activity on each part. breakdown of any one machine in the sequence may result in stoppage of production.

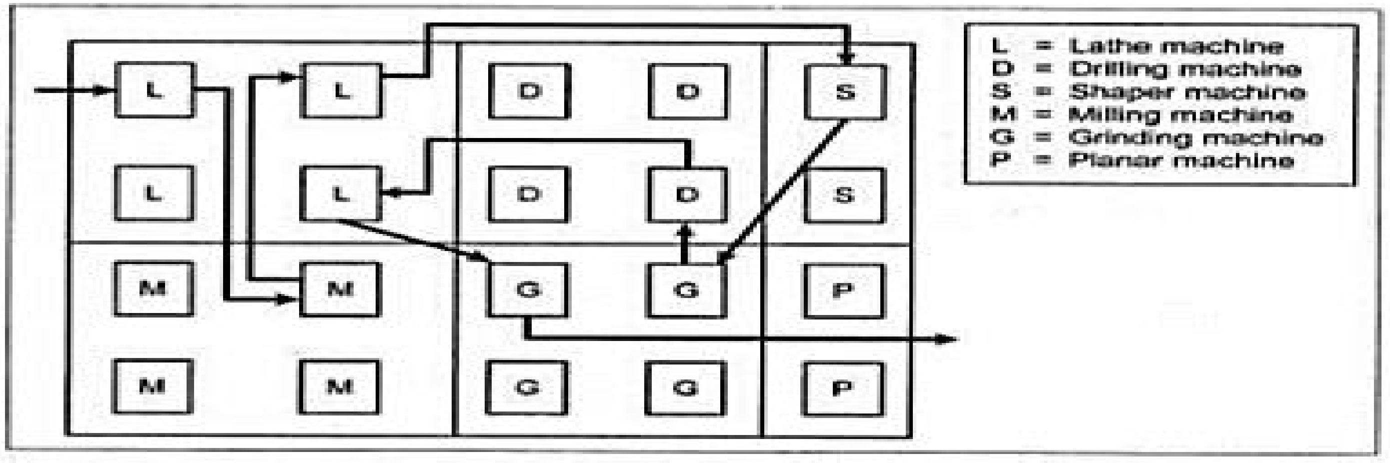
Table: Advantages and disadvantages of line layout

Quantitative analysis in Cellular Manufacturing

2) Functional (or Process) Layout

- Characterized by keeping similar machines, operations at one location, i.e. all lathes at one place, all milling machines at another place.
- In process layout, machines are arranged according to their functions.

Suitability: Suitable for job order/non-repetitive type production.



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Quantitative analysis in Cellular Manufacturing

Advantages	Disadvantages
Flexibility in assigning work to equipment and workers.	Automatic material handling is extremely difficult.
Better equipment utilisation.	Difficult production planning and control.
Comparatively less number of equipment needed.	More space is required.
Better product quality because of specialisation.	Large work-in-process inventory.
Variety of job makes the job challenging and interesting.	Higher grades of skill required.
	Lower productivity due to number of setups.

Table: Advantages and disadvantages of process layout

Quantitative analysis in Cellular Manufacturing

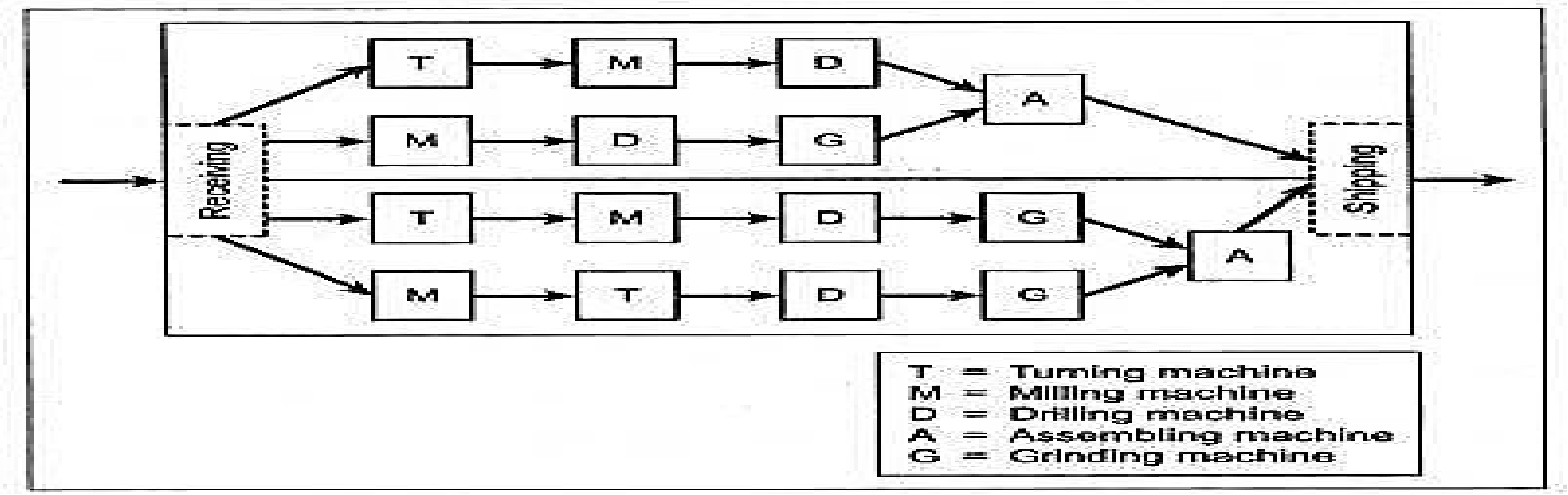
3) Group (or Combination) Layout

- It is a combination of the product layout and process layout.
- This layout Combines the advantages of both layout systems.
- Here machines are arranged into cells, each cell is capable of performing manufacturing operations on one or more families of part.
- If there are m machines and n components, in a group layout, the m-machines and n - components will be divided into distinct number of machines-component cells (groups) such that all the components assigned to a cell are almost processed within that cell itself.
- Objective is to minimize the inter-cell movements.

Suitability: Preferred for batch type production, where the products are n batches and in large variety.

Quantitative analysis in Cellular Manufacturing

3) Group (or Combination) Layout



- If there are m machines and n components, in a group layout, the m-machines and n -components will be divided into distinct number of machines-component cells (groups) such that all the components assigned to a cell are almost processed within that cell itself.
- Objective is to minimize the inter-cell movements.

Suitability: Preferred for batch type production, where the products are n batches and in large variety.

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Quantitative analysis in Cellular Manufacturing

Advantages	Disadvantages
Group technology layout can increase.	This type of layout may not be feasible for all situations. if the product mix is completely dissimilar, then we may not have meaningful cell formation.
Component standardization and rationalisation	
Reliability of estimates	Comparatively high investment in equipment is required.
Effective machine operation.	
Productivity	
Costing accuracy	Higher grades of skill are required.
Customer service	Groupings of machines may lead to poor utilization of some machines in the group.

Hollier Method-Simple Problems

Hollier Method 1:

- The first method uses the sums of flow "From" and "To" each machine in the cell. The method can be outlined as follows:

1. Develop the From—To chart from part routing data. The data contained in the chart indicates number of part moves between the machines for workstations)

2. Determine the "From" and "To" sums for each machine. This is accomplished by summing all of the "From" trips and "To" trips for each machine (or operation).The "From" sum for a machine is determined by adding the entries in the corresponding row and the "To" sum is found by adding the entries in the corresponding column.

3. Assign machines to the cell based on minimum "From" or To sums. The machine having the smallest sum is selected. If the minimum value is a "To" sum, then the machine is placed at the beginning of the sequence. If the minimum value is a “From” sum, then the machine is placed at the end of the sequence. Tie breaker rules:

Hollier Method-Simple Problems

Hollier Method 1:

(a) If a tie occurs between minimum. "To" sums or minimum "From" sums, then the machine with the minimum "From/To" ratio is selected.

(b) If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.

(c) If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and the end of the sequence respectively.

Hollier Method-Simple Problems

Hollier Method 1:

(a) If a tie occurs between minimum. "To" sums or minimum "From" sums, then the machine with the minimum “From/To” ratio is selected.

(b) If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.

(c) If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and the end of the sequence respectively.

- Reformat the From-To chart After each machine has been selected, restructure the From-To chart by eliminating the row and column corresponding to the selected machine and recalculate the "From" and "To" sums. Repeat steps 3 and 4 until all machines have been assigned.

Hollier Method-Simple Problems

Hollier Method 2:

- This approach is based on the use of From/To ratios formed by summing the total flow from and to each machine in the cell. The method can be reduced to three steps:

1. Develop the From—To chart. This is the same step as in Hollier Method 1.

2. Determine the From/To ratio for each machine. This is accomplished by summing up all of the "From" trips and "To" trips for each machine (or operation). The "From" sum for a machine is determined by adding the entries in the corresponding row and the "To" sum is determined by adding the entries in the corresponding column. For each machine, the From/To ratio is calculated by taking the "From" sum for each machine and dividing by the respective "To" sum.

Hollier Method-Simple Problems

Hollier Method 2:

- **3. Arrange machines in order of decreasing From/To ratio.** Machines with a high From/To ratio distribute work to many machines in the cell but receive work from few machines. Conversely machines with a low From/To ratio receive more work than they distribute. Therefore, machines are arranged in order of descending From/Ip ratio. That is, machines with high ratios are placed at the beginning of the work flow and machines with low ratios are placed at the end of the work flow. In case of a tie, the machine with the higher "From" value is placed ahead of the machine with a lower value.

Hollier Method-Simple Problems

Percentage of in-sequence moves

- Percentage of backtracking moves.
- The percentage of in sequence moves is computed by adding all the values representing in sequence moves and dividing by the total number of moves.
- The percentage of back tracking moves is determined by summing all of the values representing back tracking moves and dividing by the total number of moves.

UNIT IV

FLEXIBLE MANUFACTURING SYSTEM (FMS) AND AUTOMATED GUIDED VEHICLE SYSTEM (AGVS)

Types of Flexibility

- Many people are unaware of the fact that there are different types of flexibility. These different types of flexibility are grouped according to the various types of activities involved in athletic training.
- The ones which involve motion are called dynamic and the ones which do not are called static.
- The different types of flexibility are,

1. Dynamic flexibility
2. Static-active flexibility
3. Static-passive flexibility

Types of Flexibility

1. Dynamic flexibility

- Dynamic flexibility (also called kinetic flexibility) is the ability to perform dynamic (or kinetic) movements of the muscles to bring a limb through its full range of motion in the joints.

2. Static-active flexibility

- Static-active flexibility (also called active flexibility) is the ability to assume and maintain extended positions using only the tension of the agonists and synergists while the antagonists are being stretched.
- For example, lifting the leg and keeping it high without any external support (other than from your own leg muscles).

Types of Flexibility

3. Static-passive flexibility

- Static-passive flexibility (also called passive flexibility) is the ability to assume extended positions and then maintain them using only our weight, the support of our limbs, or some other apparatus (such as a chair or a barre).
- Note that the ability to maintain the position does not come solely from our muscles, as it does with static active flexibility.
- Being able to perform the splits is an example of static-passive flexibility.
- Research has shown that active flexibility is more closely related to the level of sports achievement than in passive flexibility.
- Active flexibility is harder to develop than passive flexibility (which is what most people think of as "flexibility"); not only does active flexibility require passive flexibility in order to assume an initial extended position, it also requires muscle strength to be able to hold and maintained.

FMS- Components

Components/Elements Of FMS:

- As pointed out in the definition a four basic components/elements of a FMS are:

(i) Workstations

(ii)Material handling and storage system

(iii)Computer control system

(iv)Human resources

FMS- Components

1) FMS Workstations

- The workstations/processing stations used in FMS depends upon the type of product manufactured by the system.
- In metal cutting/machining systems, the principle processing stations are usually CNC machine tools. In addition, a FMS requires other several machines for completing the manufacturing.
- The types of workstations that are usually found in a FMS are:

(i)Load/unload stations

(ii)Machining stations

(iii)Assembly workstations

(iv)Inspection stations

(v)Other processing stations

FMS- Components

2) Material Handling and Storage System:

- Material handling and storage system is the second main component of an FMS.
- Requirements set against the FMS material handling and storage system include part transportation, raw material and final product transportation and storage of work pieces, empty pallets, auxiliary materials, wastes, fixtures and tools.

FMS- Components

Functions of the material handling system

- **Random, independent movement of work parts between stations.** This means that the material handling system should be capable of moving work parts from one workstation to any other station. This provides various routing alternatives for the different parts.
- **Handle a variety of work part configurations.** The material handling system should be capable of handling any work part configurations, (prismatic or rotational parts).
- **Temporary storage.** The material handling should be capable of storing the work parts temporarily, so as to wait in a small queue at workstations. This helps to increase machine utilisation.

FMS- Components

Functions of the material handling system

- **Convenient access for loading and unloading work parts.** The material handling system should provide a means to load and unload parts from the FMS. This can be achieved by locating one or more loading and/or unloading stations in the system.

- **Compatible with computer control.** Last but not the least, the material handling system should be capable of being controlled by the computer to direct it to the various workstations, load/unload stations and storage areas.

Types of Material Handling Equipment

The material handling function in a FMS is shared between two systems:

(i)Primary handling system

(ii)Secondary handling system.

Types of Material Handling Equipment

(i)Primary Handling System

- It establishes the basic layout of the FMS and is responsible for moving work parts between workstations in the system.

- Table given below summarizes the type of material handling equipment typically used as the primary handling system for the five FMS layouts.

FMS Layout

Sl.NO	Layout configuration	Typical material handling system
1.	In-line layout	Conveyor system Shuttle system Rail guided vehicle system
2.	Loop layout	Conveyor system In-floor towline carts
3.	Ladder layout	Conveyor system Rail guided vehicle system Automated guided vehicle system
4.	Open-field layout	In-floor towline carts Automated guided vehicle system
5.	Robot-centered layout	Industrial robot

Types of Material Handling Equipment

(ii)Secondary Handling System

- It consists of transfer devices, automatic pallet changers, and similar mechanisms located at the workstations in the FMS.

The functions of the secondary handling systems are:

(i) To transfer work parts from the primary system to the machine tool or other processing station.

(ii) To position the work parts with sufficient accuracy and repeatability at the workstation for processing.

(iii) To provide buffer storage of work parts at each workstation, if required.

(iv) To reorient the work parts, if necessary, to present the surface that is to be processed.

Computer Control System

- The third major component of FMS is the computer control system.

- In flexible manufacturing systems, computers are required to control the automated and semi-automated equipment and to participate in the overall coordination and management of the manufacturing system.

- A typical FMS computer control system consists of a central computer and micro-computers controlling the individual machines and other components.

- The central computer coordinates the activities of the components to achieve smooth overall operation of the system.

Human Resources

- The fourth and final component in the FMS is human labour.
- Like in any other manufacturing approaches, the operations of the FMS are also managed by human labours.
- In FMS, human labours are needed to perform the following functions:

  (i)To load raw work parts into the system.

  (ii)To unload finished work parts from the system.

  (iii)For tool changing and tool setting.

  (iv)For equipment maintenance and repair.

  (v)To furnish NC part programming in a machining system.

  (vi)To program and operate the computer system.

  (vii)To accomplish overall management of the system.


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Flexible Manufacturing System Labortary
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FMS Application

- The applications of FMS are realized in the following areas:

(i)Machining

(ii)Assembly

(iii)Sheet-metal press working

(iv)Forging

(v)Plastic injection moulding

(vi)Welding

(vii)Textile machinery manufacture

(viii)Semiconductor component manufacture

Economics of FMS

(i)5–20% reduction in personnel.

(ii)15–30% reduction in engineering design cost.

(iii)30–60% reduction in overall lead time.

(iv)30–60% reduction in work-in-process.

(v)40–70% gain in overall production.

(vi)200–300% gain in capital equipment operating time.

(vii)200–500% gain in product quality.

(viii)300–500% gain in engineering productivity.

Advantages of FMS

- Successfully implemented FMS offer several advantages. Some of them are given below:

1. **Increased machine utilization -** Several features of FMS (such as automatic tool/pallet changing, dynamic scheduling of production and so on).

2. **Reduced inventory -** Following the GT concept, FMS processes different parts together. This tends to reduce the work-in-process inventory significantly.

3. **Reduced manufacturing lead time -** Because of reduced setups and more efficient materials handling, manufacturing lead times are reduced.

4. **Greater flexibility in production scheduling -** A FMS has a greater responsiveness to change. It means, FMS has the capability to make adjustments in the production schedule on day-to-day basis to respond to immediate orders and special customer requests.

Advantages of FMS

5.Reduced direct labour cost - Reduced (manual) material handling and automation control of machines make it possible to operate an FMS with less direct labour in many instances. Thus the direct labour cost is reduced considerably.

6.Increased labour productivity - Due to higher production rates and reduced direct labour cost, FMS achieves greater productivity per labour hour.

7.Shorter response time - Setup time is relatively low with FMS as majority of the work is done automatically. The lead time of production is hence very low and the response time will be shorter.

8.Consistent quality - Human error is minimised, as there is maximum automation. In the absence of human interface, the quality is consistent.

Advantages of FMS

9.Other FMS benefits include:

(i) Reduced factory floor space.

(ii) Reduced number of tools and machines required.

(iii) Improved product quality.

(iv) Easy expandability for additional processes or added capacity.

Disadvantages of FMS

- The major limitations of implementing a FMS are given below:

(i)Very high capital investment is required to implement a FMS.

(ii)Acquiring, training and maintaining the knowledgeable labour pool requires heavy investment.

(iii)Fixtures can sometimes cost much more with FMS and software development costs could be as much as 12 –20% of the total expense.

(iv)Tool performance and condition monitoring can also be expensive since tool variety could undermine efficiency.

(v)Complex design estimating methodology requires optimizing the degree of flexibility and finding a trade-off between flexibility and specialization.

FMS Planning and Control

FMS Planning

- The planning level (that is to say, the generation of day lists) determines to a high degree the conditions at the scheduling level. We mention two possible types of day lists which make a good schedule difficult, they are:

1) Day lists for which the capacity of at least one of the machines is underutilized. This will result in idle time at the scheduling level.

2) Day lists where the machining activities use a large number of tools. This may induce high change over times on the turret lathe. In addition, many tool loading and unloading activities may be necessary. By this the utilization of operators, that perform these activities, may become temporarily so high, that delays and machine idle times is the result.

FMS Planning and Control

- Generally , we expect at the planning level to be able to form day list without significant under utilization of the machines, regardless of the solution method used.
- So we concentrate on the prevention of the second type of day lists.
- This will hopefully be realized by introducing the following objective:
- Minimize the total number of tools needed for the day lists over the planning horizon.
- This objective is used in addition to the primary objective:
- Minimize the total number of late orders within the planning horizon.

FMS Planning and Control

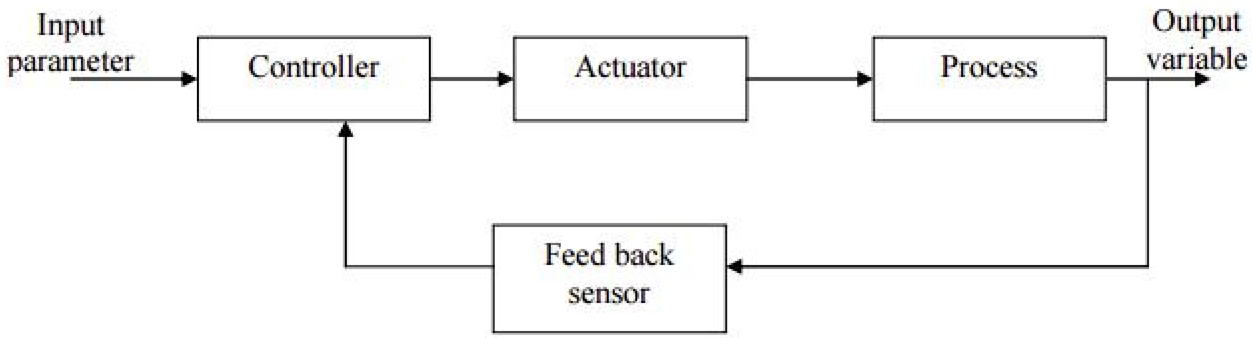
Control of FMS system

- The FMS includes a distributed computer system that is linked to the work stations, material handling system and other hardware components.
- A typical FMS computer system consists of a central computer and micro computers controlling the individual machines and other components.
- The control system in FMS causes the process to accomplish its defined function. The control can be either closed loop or open loop.

FMS Planning and Control

Control of FMS system

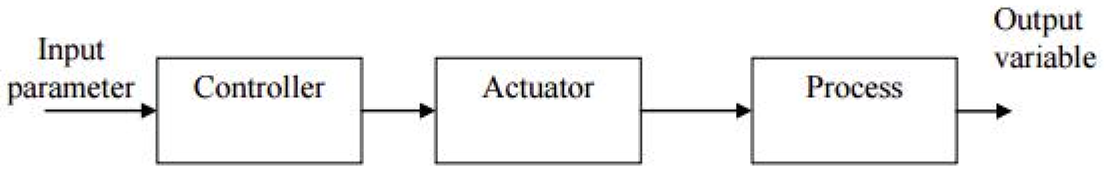
- A closed loop control system is one in which the output variable is compared with an input parameter and any difference between the two is used to drive the output into agreement with the input.
- It is also known as feedback control system.
- A closed loop control system consists of six basic elements which is shown in figure below.



FMS Planning and Control

Control of FMS system

- Here, the controller compares the output value with the input and makes the required adjustment in the process to reduce the difference between them, which is accomplished by actuators.
- Actuators are the hardware devices that physically carry out the control actions such as an electric motor, electric fan.
- A sensor is used to measure the output variable and closed the loop between input and output. In contrast to the closed loop control system an open loop operates without the feedback loop as in figure below.



FMS Planning and Control

Advantage Of Control System

(1) The actions performed by the control system are simple.

(2) The actuating function is very reliable.

(3) Any reaction forces opposing the actuation are negligible to effect the actuation.

FMS Planning and Control

Functions of a FMS computer control system

- **Workstation/processing station control -** Computer control system controls the operations of the individual processing or assembly stations in the factory. For controlling the machining centres, CNC is used.

- **Distribution of control instructions to workstations -** A direct numerical control (DNC) is used in a machining FMS to download the part programs to the machines. The DNC computer control system also stores the programs, allows entering and editing of programs and performs the other DNC functions.

FMS Planning and Control

Functions of a FMS computer control system

- **Production control Computer control system** , based on data entered into the computer, helps to take decisions on part mix and rate of input of the various parts onto the system.

- As a part of the production control, computer control system communicates instructions to the operators for performing different tasks on different work units.

- Also certain production scheduling functions are accomplished at the manufacturing site by the computer control system.

FMS Planning and Control

Functions of a FMS computer control system

- **Material handling system control Computer control** system controls the material handling system and coordinates its activities with those of the workstations. It has two components.

(i) Traffic control This control function is concerned with the management of the primary material handling system that moves work parts between workstations.

(ii) Shuttle control This control function refers to the operation and control of the secondary handling system at each workstation.

FMS Planning and Control

Functions of a FMS computer control system

- **Workpiece monitoring -** The computer control system also monitors

    (i) The status of each cart and/or pallet in the primary and secondary handling systems.

    (ii) The status of each of the various workpiece types.

- **Tool control -** The FMS computer system should monitor and control the status of the cutting tools. Tool control is concerned with

    (i) Tool location The FMS control system should keep track of the cutting tools at each workstation and take necessary steps to provide the required cutting tools.

    (ii) Tool-life monitoring Based on the tool life database for each cutting tool and the record of the machining time usage, FMS computer system should be able to notify the tool replacement time to the operators.

FMS Planning and Control

Functions of a FMS computer control system

- **Quality control -** This function of computer control system is to detect and possibly reject defective work units produced by the system.

- **Failure diagnosis -** This function of computer control system involves diagnosing equipment malfunction, preparing preventive maintenance schedules and maintaining spare parts inventory.

- **Safety monitoring -** This function of computer control system is to protect both human workers in operating the system and the equipment comprising the system.

- **Performance monitoring and reporting -** The FMS computer system can be programmed to generate various reports required by management on system performance. These reports help the management to monitor the system performance and take the corrective measures/control actions required.

Quantitative Analysis of Flexible Manufacturing Systems

The mean transport time in the system is 2.5 min. The FMC produces three parts, A, B and C. The part mix fractions and process routings for the three parts are presented in the table below. The operation frequency $f_{ijk} = 1.0$ for all operations. Determine the

(a) maximum production rate of the FMC

(b) corresponding production rates of each product

(c) utilization of each machine in the system

(d) number of busy servers at each station.

Part j	Part mix p_j	Operation k	Description	Station i	Process time t_{ijk}
A	0.2	1	Load	1	3 min
		2	Mill	2	20 min
		3	Drill	3	12 min
		4	Unload	1	2 min
B	0.3	1	Load	1	3 min
		2	Mill	2	15 min
		3	Drill	3	30 min
		4	Unload	1	2 min
C	0.5	1	Load	1	3 min
		2	Drill	3	14 min
		3	Mill	2	22 min
		4	Unload	1	2 min

Quantitative Analysis of Flexible Manufacturing Systems

(a) Use formula to calculate average workload at each station:

$$WL_i = \sum_j \sum_k t_{ijk} f_{ijk} p_j$$

WL_1 = (3+2)(0.2)(1.0) + (3+2)(0.3)(1.0) + (3+2)(0.5)(1.0) **= 5.0 min**

WL_2 = 20(0.2)(1.0) + 15(0.3)(1.0) + 22(0.5)(1.0) **= 19.5 min**

WL_3 = 12(0.2)(1.0) + 30(0.3)(1.0) + 14(0.5)(1.0) **= 18.4 min**

n_t = 3(0.2)(1.0) + 3(0.3)(1.0) + 3(0.5)(1.0) = 3, **WL_4** = 3(2.5) **= 7.5 min**

Quantitative Analysis of Flexible Manufacturing Systems

Bottleneck station is determined by formula:

$$WL_s = \frac{WL_i}{s_i}$$

The station with the largest WL_i/s_i ratio is the bottleneck station.

Station	WL_i/s_i ratio	
1 (load/unload)	5.0/1 = 5.0 min	
2 (mill)	19.5/1 = 19.5 min	← Bottleneck
3 (drill)	18.4/1 = 18.4 min	
4 (material handling)	7.5/1 = 7.5 min	

Quantitative Analysis of Flexible Manufacturing Systems

Bottleneck is station 2:

Apply formula: $$R_p^* = \frac{s^*}{WL^*}$$

R_p* = 1/19.5 = 0.05128 pc/min **= 3.077 pc/hr**

(b) Production rates for each product, apply formula for each:

$$R_{pj}^* = p_j R_p^*$$

R_pA = 0.05128(0.2) = 0.01026 pc/min **= 0.6154 pc/hr**

R_pB = 0.05128(0.3) = 0.01538 pc/min **= 0.9231 pc/hr**

R_pC = 0.05128(0.5) = 0.02564 pc/min **= 1.5385 pc/hr**

Quantitative Analysis of Flexible Manufacturing Systems

(c) Utilization of each machine in the system; apply formula:

$$U_i = \frac{WL_i}{s_i} R_p *$$

U1	= (5.0/1)(0.05128) = 0.256	**= 25.6%**
U2	= (19.5/1)(0.05128) = 1.0	**= 100%**
U3	= (18.4/1)(0.05128) = 0.944	**= 94.4%**
U4	= (7.5/1)(0.05128) = 0.385	**= 38.5%**

Quantitative Analysis of Flexible Manufacturing Systems

(d) Number of busy servers at each station, apply formula:

$$BS_i = WL_i R_p^*$$

BS1 = (5.0)(0.05128) **= 0.256 servers**

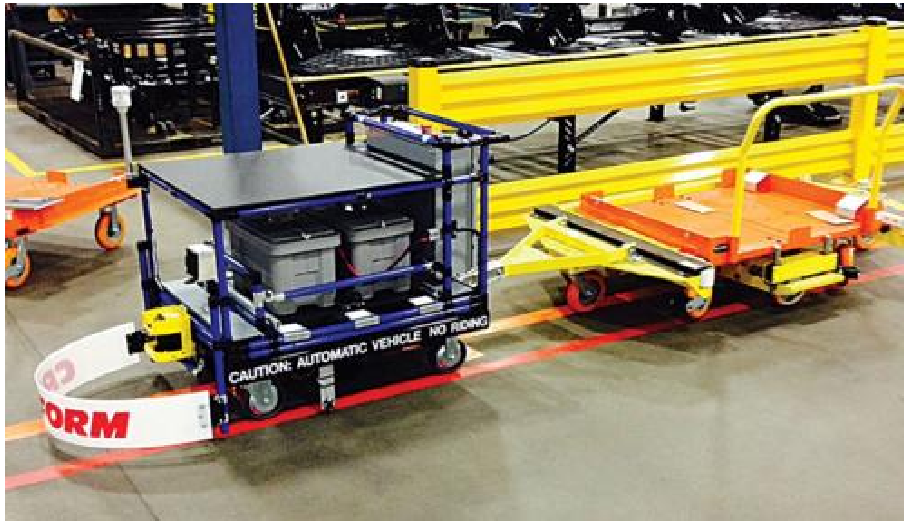
BS2 = (19.5)(0.05128) **= 1.0 servers**

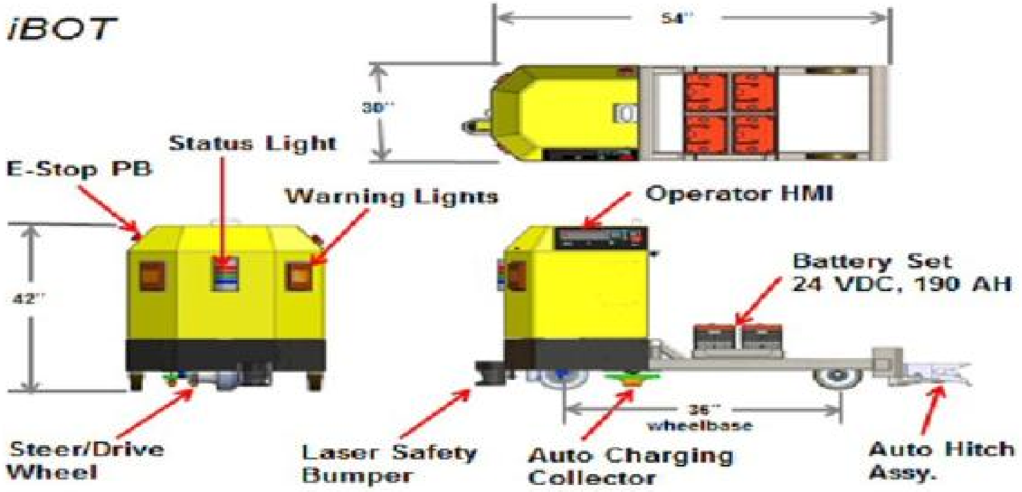
BS3 = (18.4)(0.05128) **= 0.944 servers**

BS4 = (7.5)(0.05128) **= 0.385 servers**

Automated Guided Vehicle System (AGVS)

- Automated guided vehicles (AGVs) are modem material-handling and conveying systems that are more appropriate for FMS applications and automation.
- An AGV is a computer controlled, driverless vehicle used for transporting materials from point-to-point in a manufacturing setting.
- AGVs are powered by means of on-board batteries that allow operation for several hours between recharging.



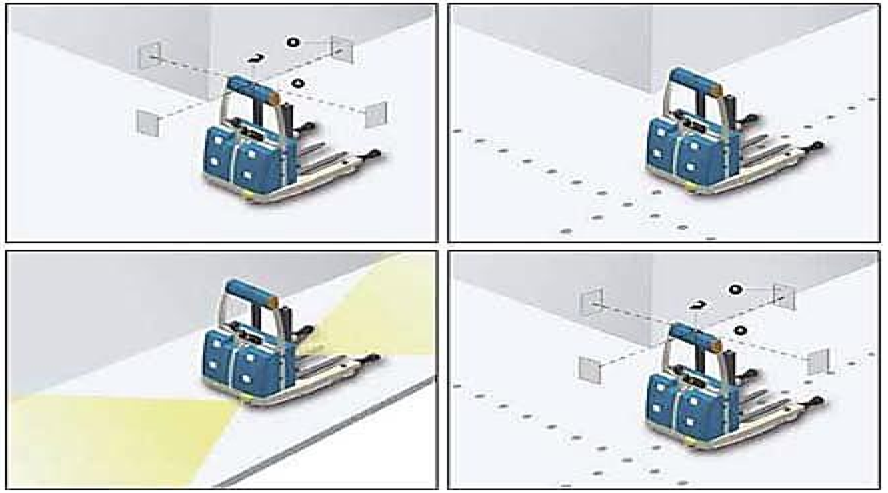


Automated Guided Vehicle System (AGVS)

- Technology: About 90% of all AGVs are wire-guided vehicles. A wire embedded about an inch deep in the floor, emits low-level signal (0.5 ampere current), which the antenna of the carrier picks up and the on-board controller analyses to determine the route.
- Wire-guided systems work best on floors with uncomplicated paths and limited distances.
- Some recent developments are taped or striped paths with painted lines or metal film defining the route.
- The carrier's ultraviolet (UV) light source illuminates the painted lines and reads the brightness of the reflected light to estimate its distance from the path.
- Another recent technology is a chemical strip that is laid over any surface and needs little maintenance.

Automated Guided Vehicle System (AGVS)

- A Painted, taped or chemical base paths have no distance limit.
- Route changes can be made easily without interrupting production.
- In a FMS/CIM plant, AGVs are integrated with other plant resources and equipment through their controllers.
- The controller links the vehicle with the guide path and is thus the 'brain' of the entire AGV system.



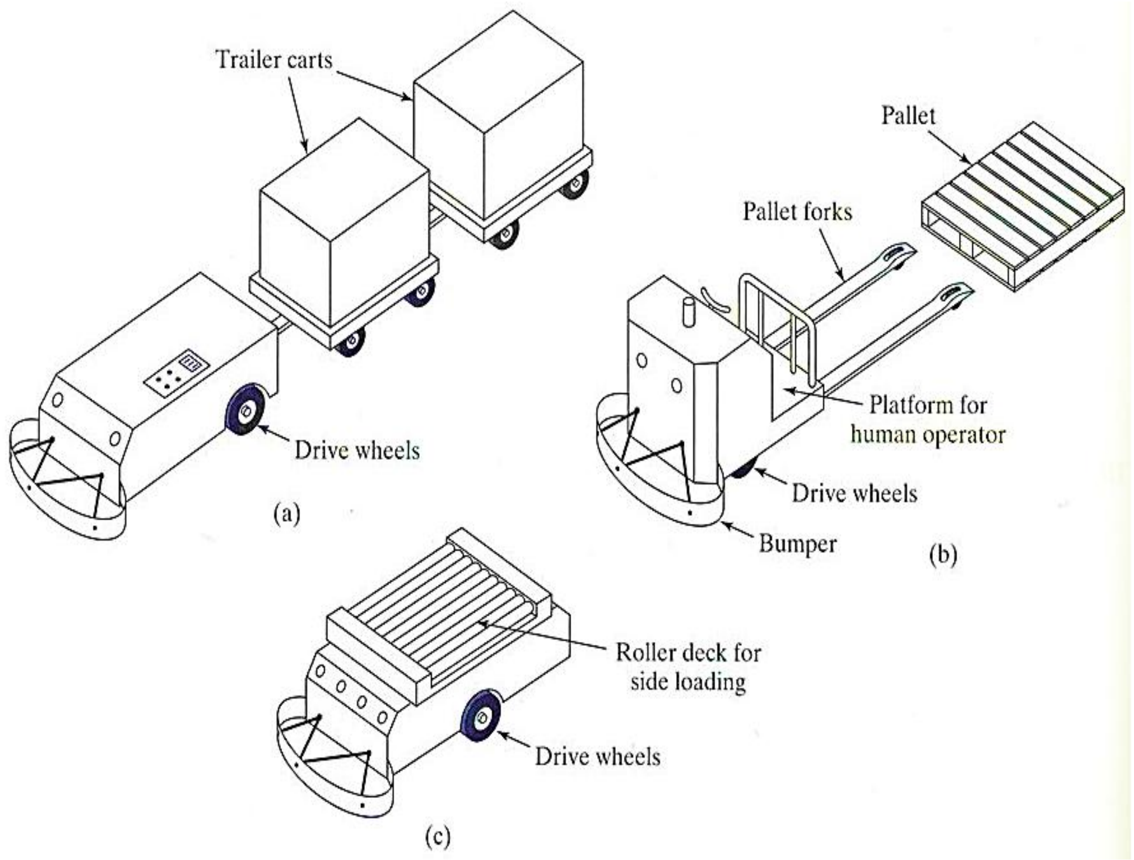
Automated Guided Vehicle System (AGVS)

The various types of AGVs are:

(a)Driverless trains

(b)AGVs pallet trucks

(c)AGVs unit load carriers



Automated Guided Vehicle System (AGVS)

AGVs is generally used:

- For moving pallet loads in factory or warehouse.
- For moving work-in-process along variable routes in low and medium production.

Automated Guided Vehicle System (AGVS)

AGVS Advantages

- Just-in-time deliveries.
- Reduced labour and operational costs.
- Reduced product damage.
- Higher operational efficiency and reliability (efficient transport management, no errors).
- Increased safety.
- Flexibility towards future modifications.

Automated Guided Vehicle System (AGVS)

Applications AGVS

- Pharmaceutical
- Chemical
- Manufacturing
- Automotive
- Paper and print
- Food and beverage
- Hospital
- Warehousing
- Theme parks







Automated Guided Vehicle System (AGVS)

Vehicle Guidance technology

- There are four types of Vehicle Guidance technology

(i) Laser Guidance Technology

(ii) Magnetic Spot Guidance Technology

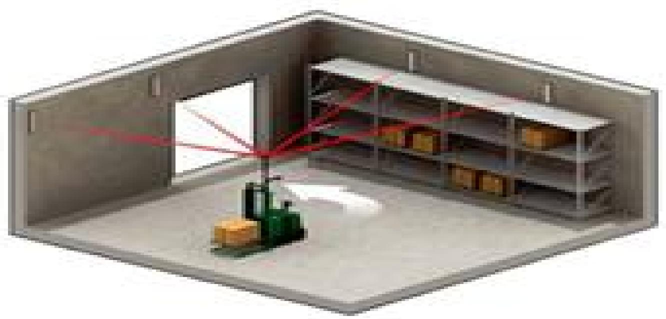
(iii) Magnetic Tape Guidance Technology

(iv) Inductive Guidance Technology (Wire Guidance)

Automated Guided Vehicle System (AGVS)

Laser Guidance Technology

- Area is mapped and stored in the vehicle's computer memory.
- It has multiple, fixed reference points, reflective strips, located within the operating area that can be detected by a laser head that is mounted on the vehicle.
- Here, guide path is easily changed and expanded.
- It is most flexible for vehicle movement.
- It is the most reliable and secure form of navigation.



- It is the most accurate form of guidance , system can be expanded without alteration to the facility.
- It provides most dynamic control of blocking and traffic management.

Automated Guided Vehicle System (AGVS)

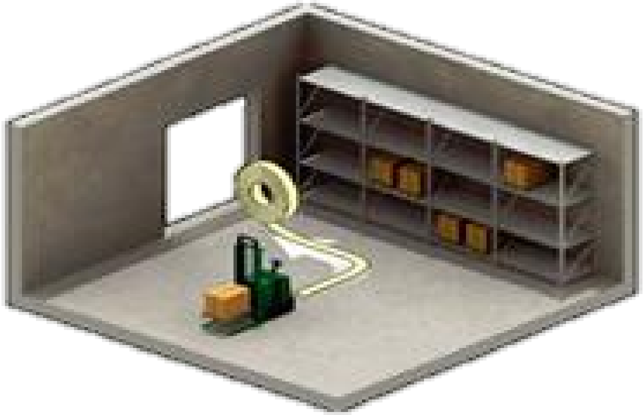
Magnetic Spot Guidance Technology

- Guide path is marked with magnetic pucks that are placed on or in the floor.
- Guide path sensor is mounted on the vehicle.
- Here paths are open, the systems guide path can be changed.
- In this extensive layouts can complicate the layout of magnetic pucks.
- Depending on the accuracy of the magnetic sensor, calibration of the position may be required for different vehicles.
- System can be expanded without damage or major alteration to the facility.

Automated Guided Vehicle System (AGVS)

Magnetic Tape Guidance Technology

- Guide path is marked with a magnetic tape that is placed on the floor surface.
- Guide path sensor is mounted on the vehicle.
- In this ,paths are continuous.
- Paths are fixed, the systems guide path can be changed easily and quickly.
- Tape may have to be epoxy coated to floor.
- It is recommended for Automatic Guided Carts (AGC).



Automated Guided Vehicle System (AGVS)

Inductive Guidance Technology (Wire Guidance)

- In this method, floor is cut and a wire is imbedded to represent the guide path.
- Guide path sensor is mounted on the vehicle.
- Here the paths are well marked on the floor.
- Paths are continuous, fixed, the systems guide path is not easily changed.
- Expansion of the facility is not as flexible as some other navigation technologies and may be limited due to constraints.

Vehicle Management & Safety

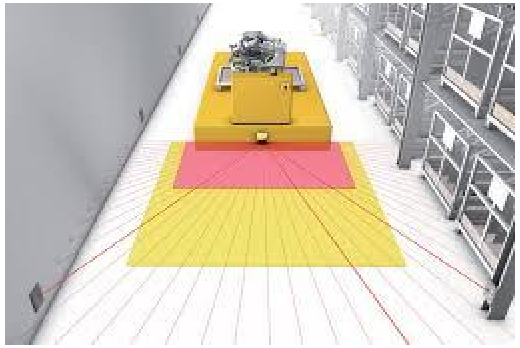
Aspects of vehicle management

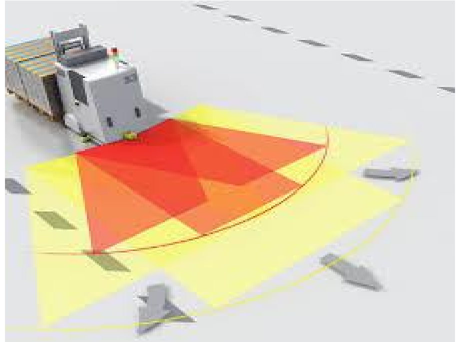
- Forward (on-board vehicle) sensing.
- Zone control.
- Vehicle dispatching

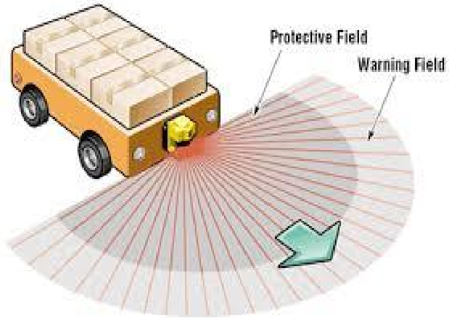
  (i)On-board control panel

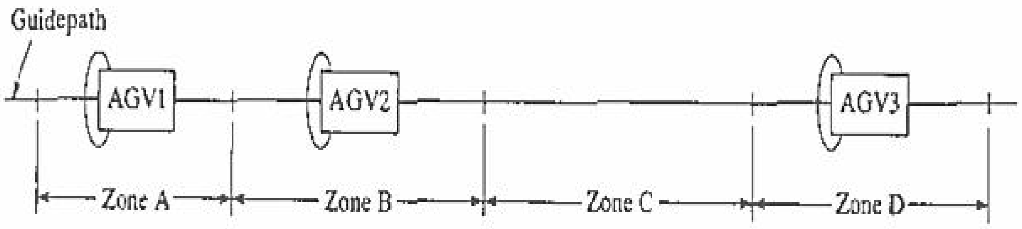
  (ii)Remote call stations

  (iii)Central computer control









Automated Guided Vehicle System (AGVS)

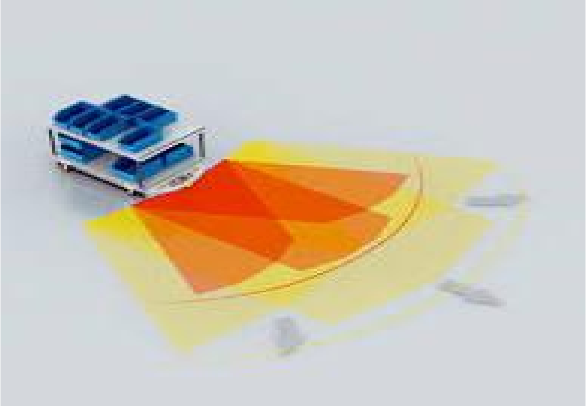
Vehicle Safety

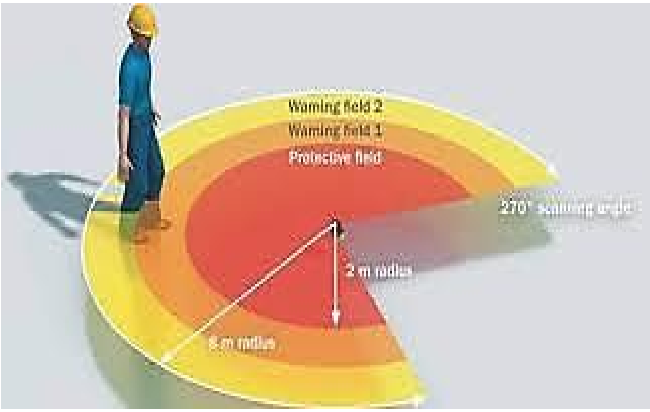
- An inherent safety feature of an AGV is that its traveling speed is slower than the normal walking pace of a human.
- Automatic stopping of the vehicle takes place if it strays more than a short distance, typically 50-150 mm.
- Vehicles are programmed either to stop when an obstacle is sensed ahead or to slow down.
- When the safety bumper makes contact with an object, the vehicle is programmed to brake immediately.
- Travel velocity of AGV is slower than typical walking speed of human worker.

Automated Guided Vehicle System (AGVS)

Vehicle Safety

- Automatic stopping of vehicle takes place if it strays from guide path.
- It has a obstacle detection system in forward direction.
- Use of ultrasonic sensors are common Emergency in bumper - brakes vehicle when contact is made with forward object.
- It has warning lights (blinking or rotating red lights)





Automated Guided Vehicle System (AGVS)

Vehicle Safety

- **Rail-Guided Vehicles -** These are self-propelled vehicles that ride on a fixed-rail system. These vehicles operate independently and are driven by electric motors that pick up power from an electrified rail.

- **Overhead monorail -** It is suspended overhead from the ceiling.

- **On-floor - parallel fixed rails**, here tracks generally protrude up from the floor. Routing variations are possible. It consists of switches, turntables and other special track sections.

UNIT V

INDUSTRIAL ROBOTICS

ROBOT ANATOMY AND RELATED ATTRIBUTES

- The anatomy of industrial robots deals with the assembling of outer components of a robot such as wrist, arm and body.
- Before jumping into robot configurations, here are some of the key facts about robot anatomy.

(a) Joints and Links

(b) Common Robot Configurations

JOINTS AND LINKS

- The manipulator of an industrial robot consists of a series of joints and links.
- Robot anatomy deals with the study of different joints and links and other aspects of the manipulator's physical construction.
- A robotic joint provides relative motion between two links of the robot.
- Each joint, or axis, provides a certain degree-of-freedom (dof) of motion.
- In most of the cases, only one degree-of-freedom is associated with each joint.
- Robot's complexity can be classified according to the total number of degrees -of-freedom they possess.
- Each joint is connected to two links, an input link and an output link.

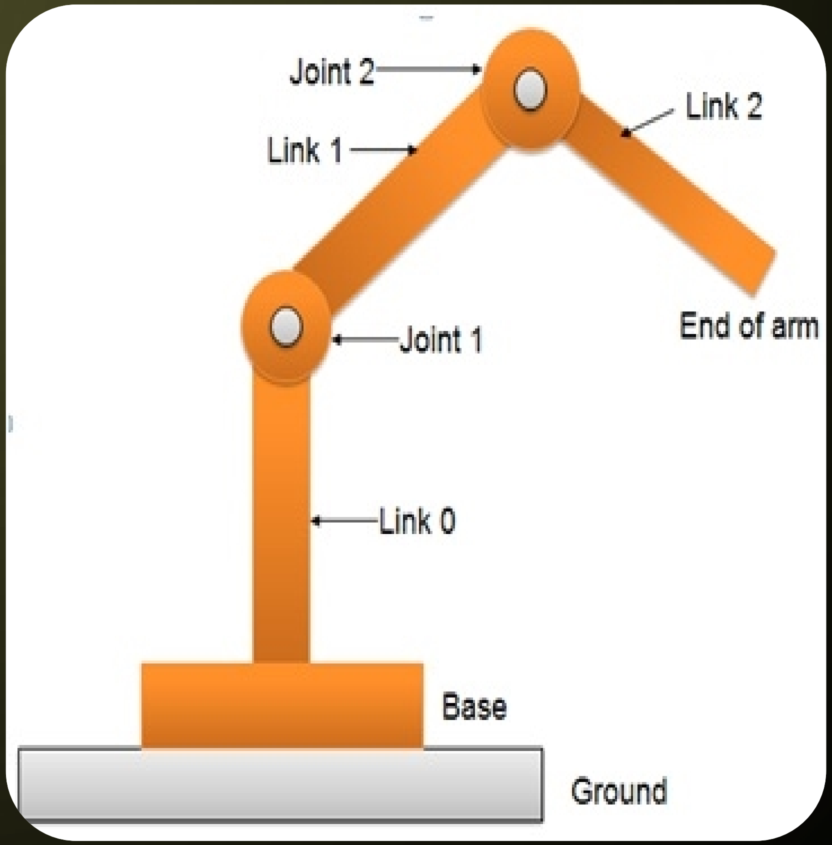
JOINTS AND LINKS

- A Joint provides controlled relative movement between the input link and output link. A robotic link is the rigid component of the robot manipulator.

- Most of the robots are mounted upon a stationary base, such as the floor. From this base, a joint-link numbering scheme may be recognized as shown in Figure.

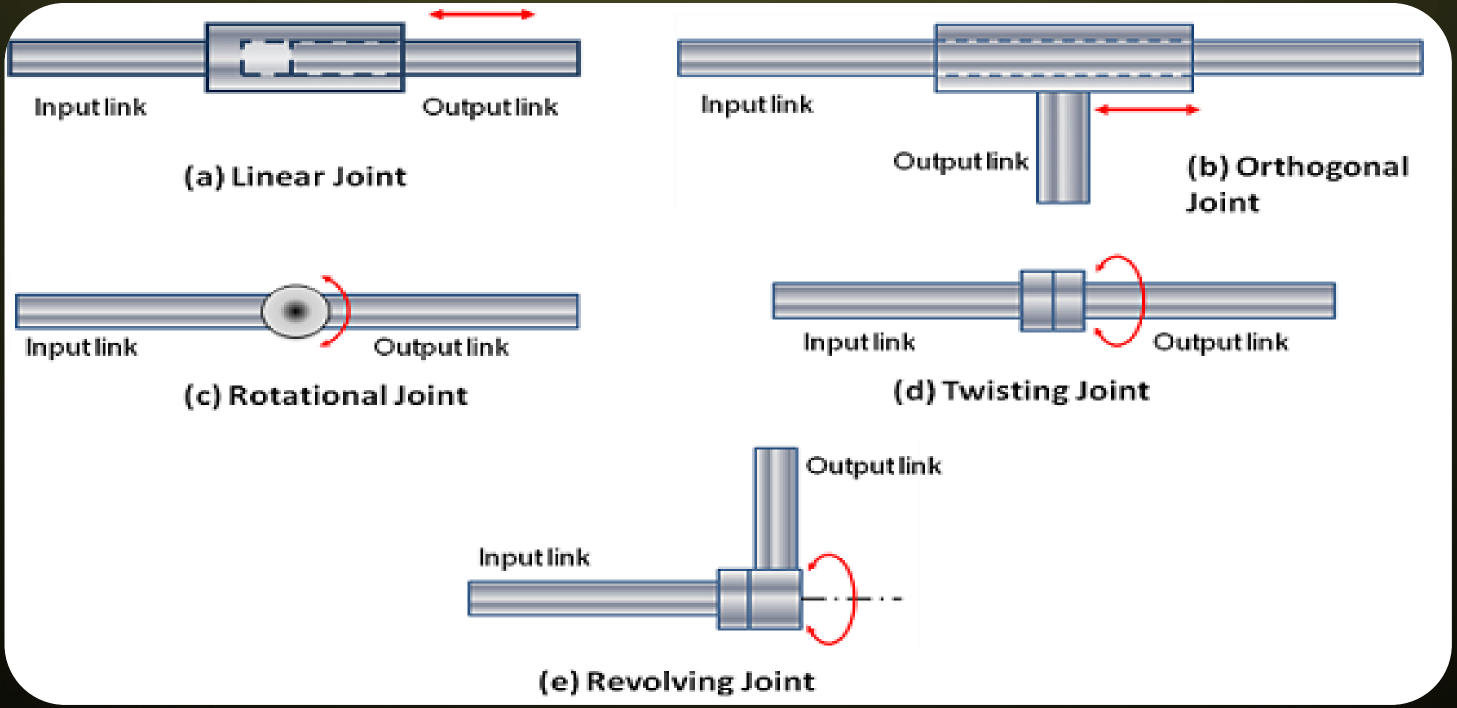
JOINTS AND LINKS

- The robotic base and its connection to the first joint are termed as link-0.
- The first joint in the sequence is joint-1.
- Link-0 is the input link for joint-1, while the output link from joint-1 is link-1 which leads to joint-2.
- Link 1 is the output link for joint-1 and the input link for joint-2.
- This joint-link-numbering scheme is further followed for all joints and links in the robotic systems.



JOINTS AND LINKS

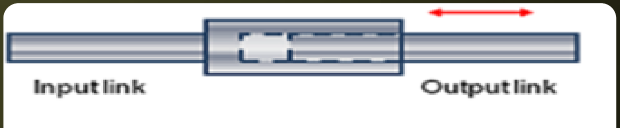
- Nearly all industrial robots have mechanical joints that can be classified into following five types as shown in Figure below.



JOINTS AND LINKS

a) Linear joint (type L joint)

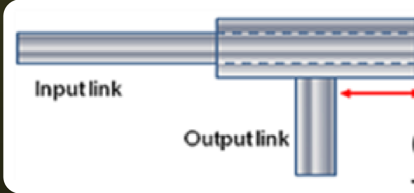
- The relative movement between the input link and the output link is a translational sliding motion, with the axes of the two links being parallel.



(a) Linear Joint

b) Orthogonal joint (type U joint)

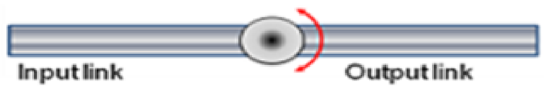
- This also has a translational sliding motion, but the input and output links are perpendicular to each other during the move.



(b) Orthogonal Joint

c) Rotational joint (type R joint)

- This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.

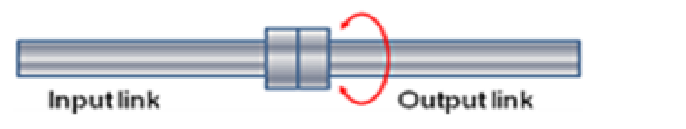


(c) Rotational Joint

JOINTS AND LINKS

d) Twisting joint (type T joint)

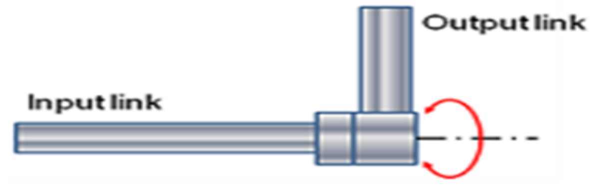
- This joint also involves rotary motion, but the axis or rotation is parallel to the axes of the two links.



(d) Twisting Joint

e) Revolving joint (type V-joint, V from the "v" in revolving)

- In this type, axis of input link is parallel to the axis of rotation of the joint. Axis of the output link is perpendicular to the axis of rotation.



(e) Revolving Joint

COMMON ROBOT CONFIGURATIONS

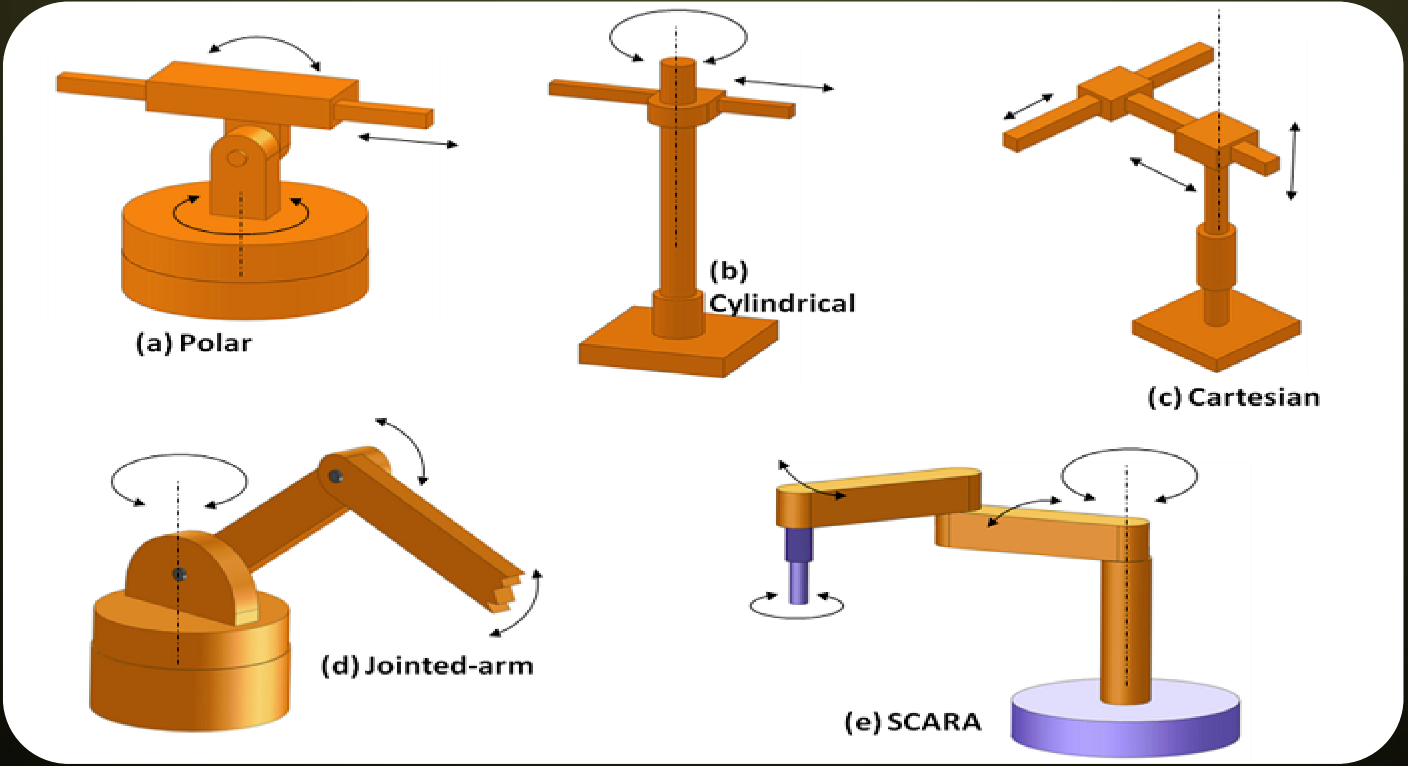
- Basically the robot manipulator has two parts viz.

- A body-and-arm assembly with three degrees-of-freedom and A wrist assembly with two or three degrees-of-freedom.

- For body-and-arm configurations, different combinations of joint types are possible for a three-degree-of-freedom robot manipulator.

COMMON ROBOT CONFIGURATIONS

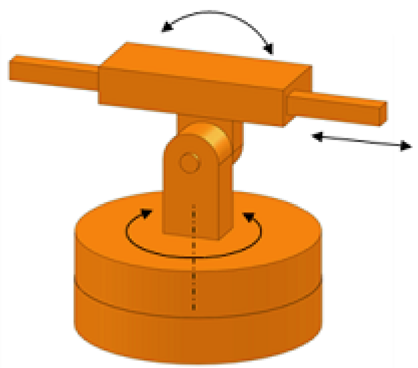
- Five common body-and-arm configurations are outlined below.



COMMON ROBOT CONFIGURATIONS

(i) Polar configuration

- It consists of a sliding arm L-joint, actuated relative to the body, which rotates around both a vertical axis (T-joint)and horizontal axis (R-joint).

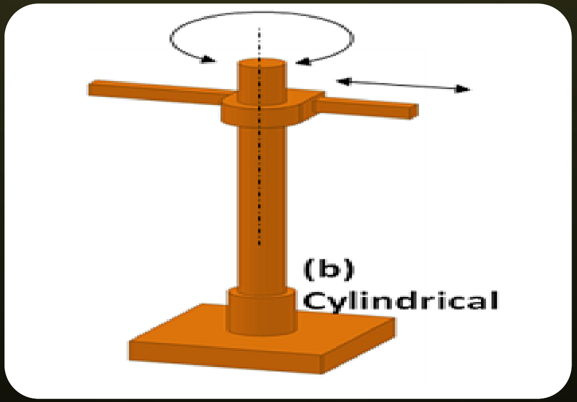


(a) Polar

COMMON ROBOT CONFIGURATIONS

(ii) Cylindrical configuration

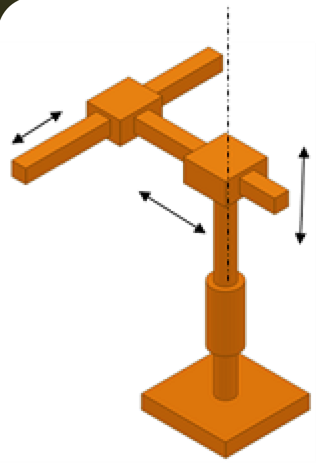
- It consists of a vertical column. An arm assembly is moved up or down relative to the vertical column.
- Arm can be moved in and out relative to the axis of the column. Common configuration is to use a T-joint to rotate the column about its axis.
- An L-joint is used to move the arm assembly vertically along the column, while an O-joint is used to achieve radial movement of the arm.



COMMON ROBOT CONFIGURATIONS

(iii) Cartesian co-ordinate robot

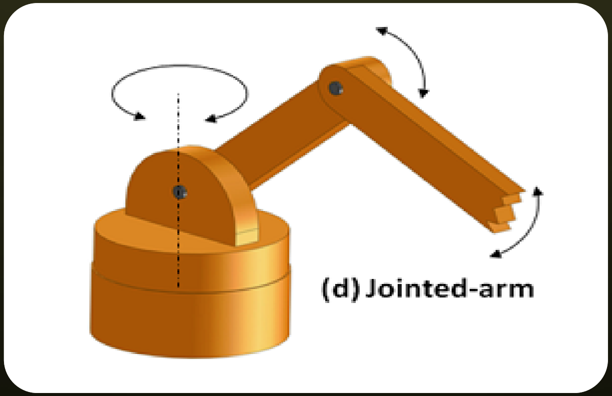
- It is also known as rectilinear robot and x-y-z robot. It consists of three sliding joints, two of which are orthogonal O-joints.


(c) Cartesian

COMMON ROBOT CONFIGURATIONS

(iv) Jointed-arm robot

- It is similar to the configuration of a human arm.
- It consists of a vertical column that swivels about the base using a T-joint. Shoulder joint (R-joint) is located at the top of the column.
- The output link is an elbow joint (another R joint).



COMMON ROBOT CONFIGURATIONS

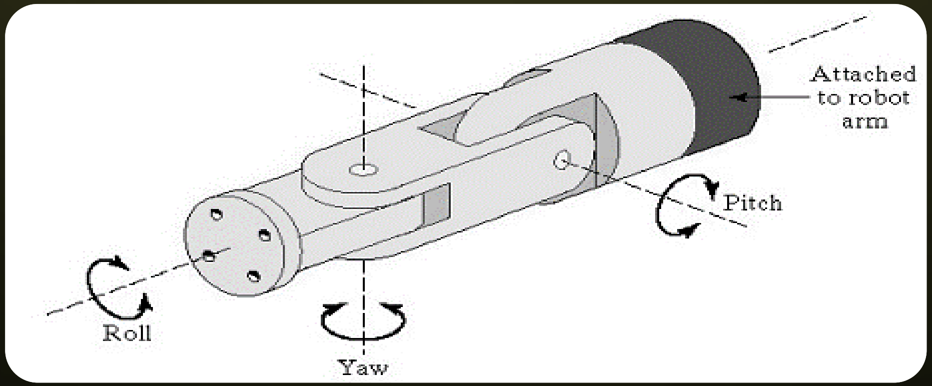
(v) SCARA

- Its full form is ‘Selective Compliance Assembly Robot Arm'.
- It is similar in construction to the jointer-arm robot, except the shoulder and elbow rotational axes are vertical.
- The arm is very rigid in the vertical direction, but compliant in the horizontal direction. Robot wrist assemblies consist of either two or three degrees-of-freedom.

COMMON ROBOT CONFIGURATIONS

(v) SCARA

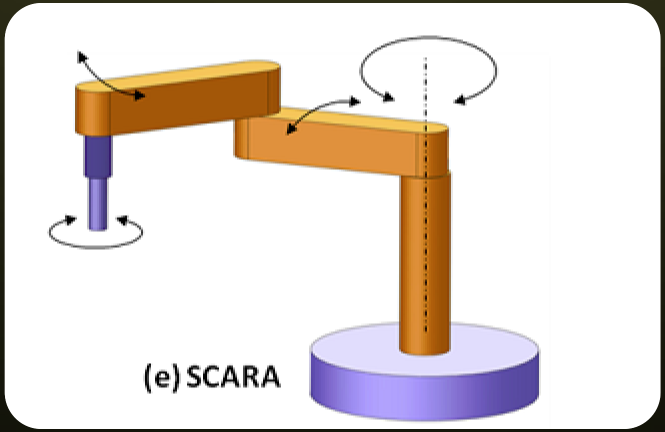
- A typical three-degree-of-freedom wrist joint is depicted in Figure.
- Roll joint is accomplished by use of a T-joint.
- Pitch joint is achieved by recourse to an R-joint. Yaw joint, a right-and-left motion, is gained by deploying a second R-joint.



COMMON ROBOT CONFIGURATIONS

(v) SCARA

- SCARA body and arm configuration does not use a separate wrist assembly.
- Its usual operative environment is for insertion-type assembly operations where wrist joints are unnecessary.
- The other four body and arm configurations more or less follow the wrist-joint configuration by deploying various combinations of rotary joints.



CLASSIFICATION OF ROBOTS

- The three types of drive systems that are generally used for industrial robots are:

(i)Hydraulic drive

(ii)Electric drive

(iii)Pneumatic drive

CLASSIFICATION OF ROBOTS

i) Hydraulic drive

- It gives a robot great speed and strength. They provide high speed and strength, hence they are adopted for large industrial robots.
- This type of drives are preferred in environments in which the use of electric drive robots may cause fire hazards
- Example: In spray painting.

Disadvantages of a hydraulic robot:

- Occupy more floor space for ancillary equipment in addition to that required by the robot.
- There are housekeeping problems such as leaks.

CLASSIFICATION OF ROBOTS

ii) Electric drive

- This provides a robot with less speed and strength. Electric drive systems are adopted for smaller robots.

- Robots supported by electric drive systems are more accurate, exhibit better repeatability and are cleaner to use.

- Electrically driven robots are the most commonly available .

CLASSIFICATION OF ROBOTS

ii) Electric drive

- Electrically driven robots can be classified into two broad categories.

(i)Stepper motor driven.

(ii)Direct Current (DC) servo-motor driven.

- Most stepper motor-driven robots are of the open loop type.
- Feedback loops can be incorporated in stepper-driven robots.
- Servo-driven robots have feedback loops from the driven components back to the driver.

CLASSIFICATION OF ROBOTS

iii) Pneumatic drive

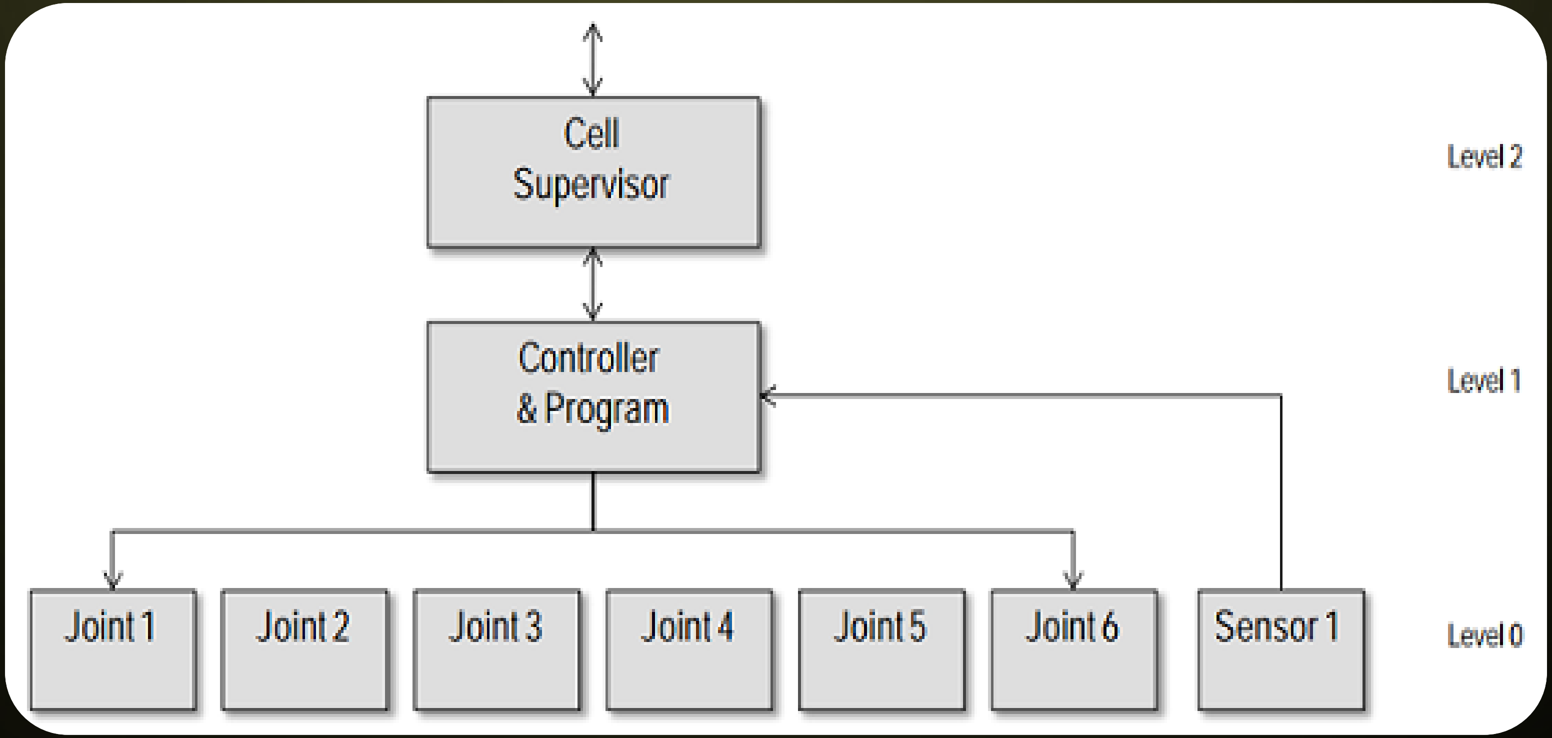
- Generally used for smaller robots.
- Have fewer axes of movement.
- Carry out simple pick-and-place material-handling operations, such as picking up an object at one location and placing it at another location.
- These operations are generally simple and have short cycle times.
- Here pneumatic power can be used for sliding or rotational joints.
- Pneumatic robots are less expensive than electric or hydraulic robots.

ROBOT CONTROL SYSTEMS

- The Joint movements must be controlled if the robot is to perform as desired.
- Micro-processor-based controllers are regularly used to perform this control action.
- Controller is organised in a hierarchical fashion, as illustrated in Figure.
- Each joint can feed back control data individually, with an overarching supervisory controller co-ordinating the combined actuations of the joints according to the sequence of the robot programme.

ROBOT CONTROL SYSTEMS

- Controller is organised in a hierarchical fashion, as illustrated in Figure.



ROBOT CONTROL SYSTEMS

Hierarchical control structure

(a) Limited Sequence Control

- Elementary control type, it is used for simple motion cycles, such as pick and place operations.
- It is implemented by fixing limits or mechanical stops for each joint and sequencing the movement of joints to accomplish operation.
- Feedback loops may be used to inform the controller that the action has been performed, so that the programme can move to the next step.
- No servo-control exists for precise positioning of joint. Many pneumatically driven robots are this type.

ROBOT CONTROL SYSTEMS

Hierarchical control structure

(b) Playback with Point to Point Control

- Playback control uses a controller with memory to record motion sequences in a work cycle, as well as associated locations and other parameters and then plays back the work cycle during programme execution.
- Point to point control means individual robot positions are recorded in the memory.
- These positions include both mechanical stops for each joint and the set of values that represent locations in the range of each joint.
- Feedback control is used to confirm that the individual joints achieve the specified locations in the programme.

ROBOT CONTROL SYSTEMS

Hierarchical control structure

(c) Playback with Continuous Path Control

- Playback is as described above.
- Continuous path control refers to a control system capable of continuous simultaneous control of two or more axes.
- Greater storage capacity—the number of locations that can be stored is greater than in point to point and interpolation calculations may be used, especially linear and circular interpolations.

ROBOT CONTROL SYSTEMS

Hierarchical control structure

(d) Intelligent Control

- An intelligent robot is one that exhibits behaviour that makes it seem intelligent.
- For example, capacities to interact with its ambient surroundings, decision-making capabilities, communication with humans; computational analysis during the work cycle and responsiveness to advanced sensor inputs.
- They may also possess the playback facilities of the above two instances.
- Requires a high level of computer control and an advanced programming language to input the decision-making logic and other 'intelligence' into the memory.

END EFFECTORS

- It is commonly known as robot hand.
- It is mounted on the wrist, enables the robot to perform specified tasks.
- Various types of end-effectors are designed for the same robot to make it more flexible and versatile.
- End-effectors are categorised into two major types:

1. Grippers
2. Tools

END EFFECTORS - GRIPPERS

- Grippers grasp and manipulate objects during the work cycle.
- Typically the objects grasped are work parts that need to be loaded or unloaded from one station to another.
- It may be custom-designed to suit the physical specifications of the work parts they have to grasp.

END EFFECTORS - GRIPPERS

- End effectors, grippers are described in detail in table below.

Type	comment
Mechanical gripper	Two or more fingers that can be actuated by robot controller to open and close on a work part.
Vacuum gripper	Suction cups are used to hold flat objects.
Magnetised devices	Making use of the principles of magnetism, these are used for holding ferrous work parts.
Adhesive devices	Deploying adhesive substances these hold flexible materials, such as fabric.
Simple mechanical devices	For example, hooks and scoops.

END EFFECTORS - GRIPPERS

- End effectors, grippers are described in detail in table below.

Type	comment
Dual grippers	Mechanical gripper with two gripping devices in one end effector for machine loading and unloading. Reduces cycle time per part by gripping two work parts at the same time.
Interchangeable fingers	Mechanical gripper whereby, to accommodate different work part sizes, different fingers may be attached.
Sensory feedback fingers	Mechanical gripper with sensory feedback capabilities in the fingers to aid locating the work part and to determine correct grip force to apply (for fragile work parts).

END EFFECTORS - GRIPPERS

- End effectors, grippers are described in detail in table below.

Type	comment
Multiple fingered grippers	Mechanical gripper with the general anatomy of the human hand.
Standard grippers	Mechanical grippers that are commercially available, thus reducing the need to custom-design a gripper for each separate robot application.

END EFFECTORS - TOOLS

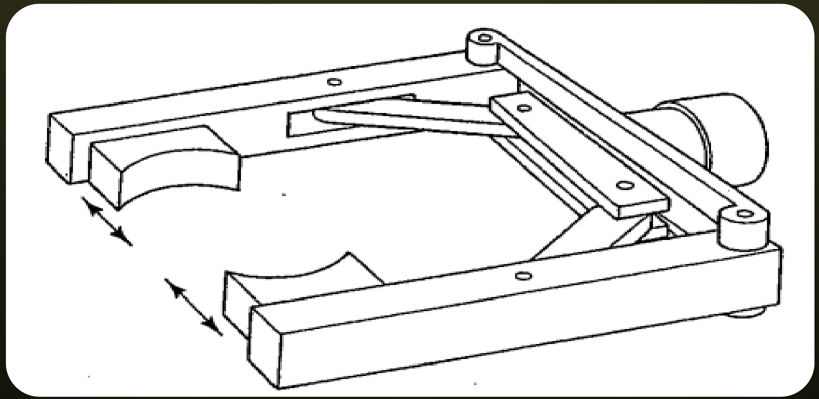
- The robot end effecter may also use tools.
- Tools are used to perform processing operations on the work part.
- Typically the robot uses the tool relative to a stationary or slowly moving object.
- In this way the process is carried out.

END EFFECTORS - TOOLS

- Examples of the tools used as end effectors by roots to perform processing applications include:
    - Spot welding gun
    - Arc welding tool
    - Spray painting gun
    - Rotating spindle for drilling, routing, grinding, etc.
    - Assembly tool (e.g. automatic screwdriver)
    - Heating torch
    - Water-jet cutting tool

END EFFECTORS

- For each instance, the robot controls both the position of the work part and the position of the tool relative to the work part.
- For this purpose, the robot must be able to transmit control signals to the tool for starting, stopping and otherwise regulating the tools actions.
- Figure illustrates a sample gripper and tool.



SENSORS IN ROBOTICS

- Two basic categories of sensors used in industrial robots:

(i)Internal sensors

(ii)External sensors

SENSORS IN ROBOTICS

(i) Internal sensors

- Internal sensors are used to monitor and control the various joints of the robot.
- They form a feedback control loop with the robot controller.
- Examples of internal sensors include potentiometers and optical encoders, while tachometers of various types can be deployed to control the speed of the robot arm.

SENSORS IN ROBOTICS

(ii) External sensors

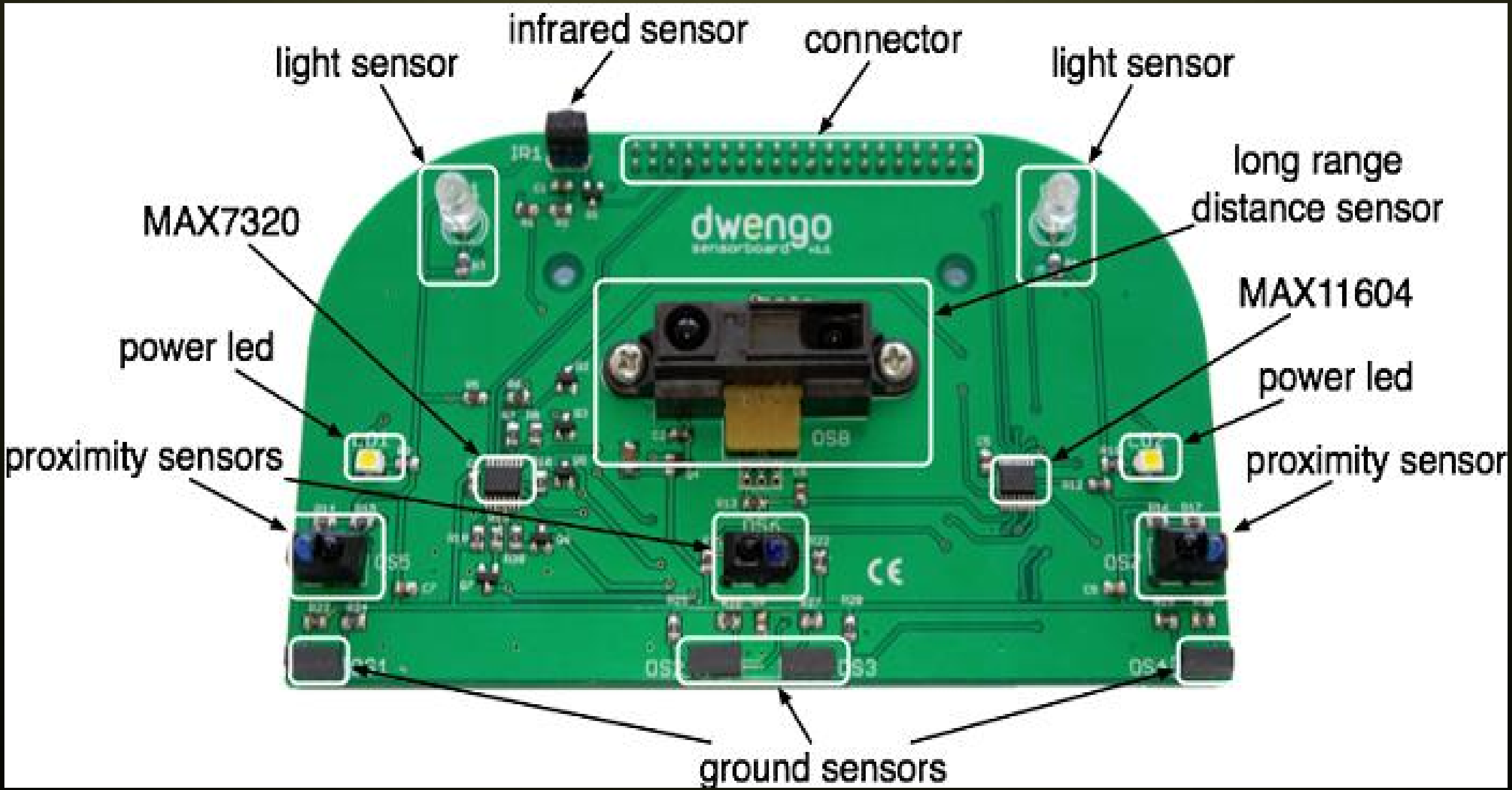
- These are external to the robot itself.

- They are used when we wish to control the operations of the robot with other pieces of equipment in the robotic work cell.

- External sensors can be relatively simple devices, such as limit switches that determine whether a part has been positioned properly or whether a part is ready to be picked up from an unloading bay.

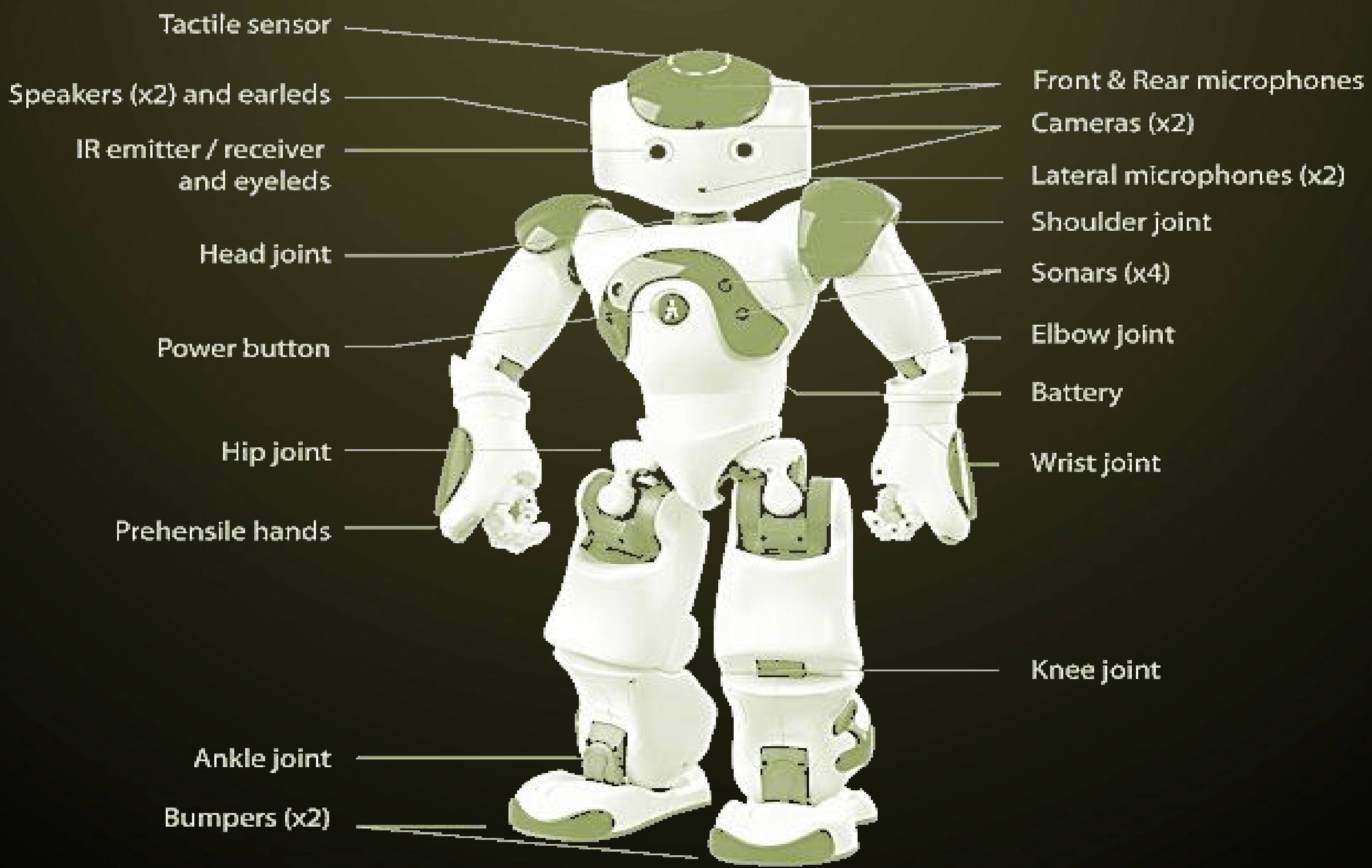
SENSORS IN ROBOTICS

- Micro Sensor board



SENSORS IN ROBOTICS

- Advanced sensor model technologies for robotics



END EFFECTORS - GRIPPERS

- A number of advanced sensor technologies may also be used; these are outlined in Table.

Sensor Type	Description
Tactile sensors	Used to determine whether contact is made between sensor and another object. Two types: touch sensors which indicate when contact is made and force sensors which indicate the magnitude of the force with the object.
Proximity sensors	Used to determine how close an object is to the sensor. Also called a range sensor.
Optical sensors	Photocells and other photometric devices that are used to detect the presence or absence of objects. Often used in conjunction to proximity sensors.

END EFFECTORS - GRIPPERS

- A number of advanced sensor technologies may also be used; these are outlined in Table.

Sensor Type	Description
Machine vision	Used in robotics for inspection, parts identification, guidance and other uses.
Miscellaneous category	temperature, fluid pressure, fluid flow, electrical voltage, current and other physical properties.

ROBOT ACCURACY AND REPEATABILITY

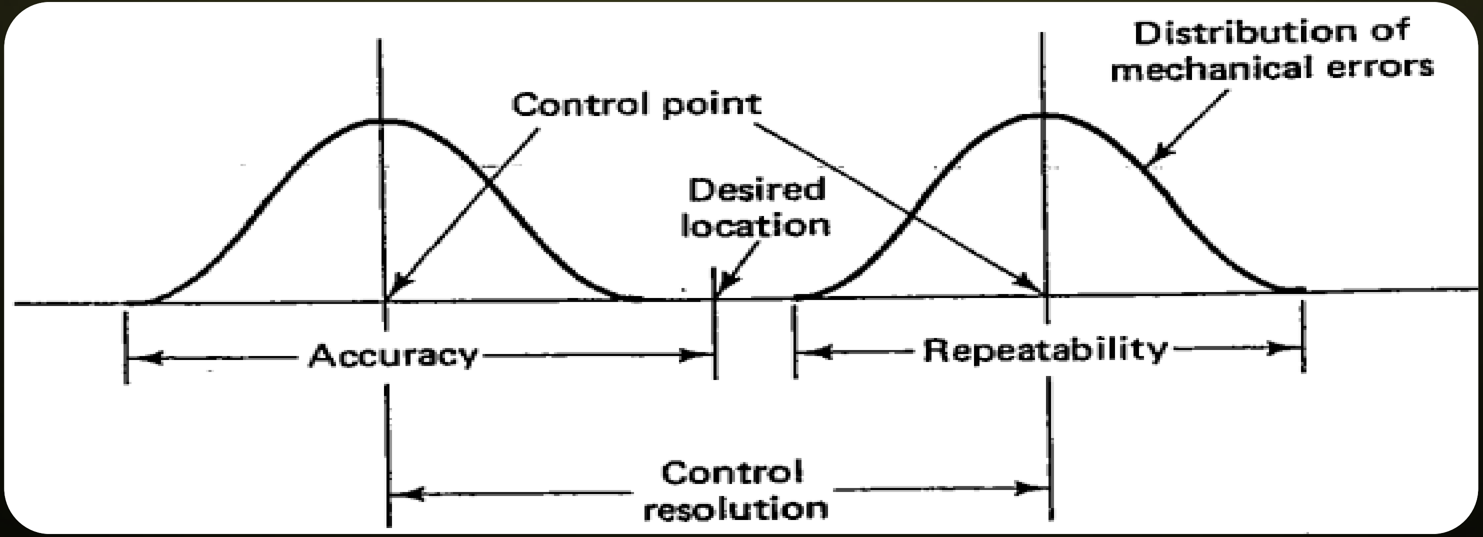
- The capacity of the robot to position and orient the end of its wrist with accuracy and repeatability is an important control attribute in nearly all industrial applications.

- Some assembly applications require that objects be located with a precision of only 0.002 to 0.005 inches.

- Other applications, such as spot welding, usually require accuracies of 0.020 to 0.040 inches.

ROBOT ACCURACY AND REPEATABILITY

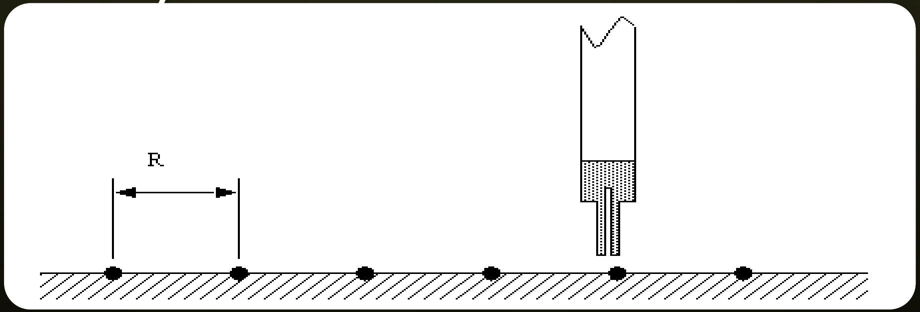
- There are several terms that must defined in the context of this discussion:
  - Control resolution
  - Accuracy
  - Repeatability



ROBOT ACCURACY AND REPEATABILITY

Resolution

- Resolution is based on a limited number of points that the robot can be commanded to reach for, these are shown here as black dots.
- These points are typically separated by a millimetre or less, depending on the type of robot.
- This is further complicated by the fact that the user might ask for a position such as 456.4mm, and the system can only move to the nearest millimetre, 456mm, this is the accuracy error of 0.4mm.



ROBOT ACCURACY AND REPEATABILITY

Accuracy

- "How close does the robot get to the desired point".
- This measures the distance between the specified position, and the actual position of the robot end effector.
- Accuracy is more important when performing off-line programming, because absolute coordinates are used.

ROBOT ACCURACY AND REPEATABILITY

Repeatability

- How close will the robot be to the same position as the same move made before".
- A measure of the error or variability when repeatedly reaching for a single position.
- This is the result of random errors only.
- Repeatability is often smaller than accuracy.

INDUSTRIAL ROBOT APPLICATIONS

- Industrial Robot Applications can be divided into:

(i) Material-handling applications

(ii) Processing Operations

(iii) Assembly Applications

MATERIAL-HANDLING APPLICATIONS

- The robot must have following features to facilitate material handling:

1. The manipulator must be able to lift the parts safely.
2. The robot must have the reach needed.
3. The robot must have cylindrical coordinate type.
4. The robot's controller must have a large enough memory to store all the programmed points so that the robot can move from one location to another.
5. The robot must have the speed necessary for meeting the transfer cycle of the operation.

MATERIAL-HANDLING APPLICATIONS

- This category includes the following:

(1) Part Placement

(2) Palletizing or depalletizing

(3) Machine loading or unloading

(4) Stacking and insertion operations

MATERIAL-HANDLING APPLICATIONS

(1) Part Placement:

- The basic operation in this category is the relatively simple pick-and-place operation.
- This application needs a low-technology robot of the cylindrical coordinate type.
- Only two, three or four joints are required for most of the applications.
- Pneumatically powered robots are often utilized.

MATERIAL-HANDLING APPLICATIONS

(2) Palletizing and/or Depalletizing:

- The applications require robot to stack parts one on top of the other, that is to palletize them or to unstack parts by removing from the top one by one, that is depalletize them.
- Example: Process of taking parts from the assembly line and stacking them on a pallet or vice versa.

MATERIAL-HANDLING APPLICATIONS

(3) Machine loading and/or unloading:

- Robot transfers parts into and/or from a production machine.

There are three possible cases:

- Machine loading in which the robot loads parts into a production machine, but the parts are unloaded by some other means.

Example: A press working operation, where the robot feeds sheet blanks into the press, but the finished parts drop out of the press by gravity.

MATERIAL-HANDLING APPLICATIONS

- Machine loading in which the raw materials are fed into the machine without robot assistance. The robot unloads the part from the machine assisted by vision or no vision.

Example: Bin picking, die casting and plastic moulding.

- Machine loading and unloading that involves both loading and unloading of the work parts by the robot. The robot loads a raw work part into the process and unloads a finished part.

Example: Machine operation

PROCESSING OPERATIONS

- In processing operations, the robot performs some processing actions such as grinding, milling, etc. on the work part.
- The end effector is equipped with the specialised tool required for the process.
- The tool is moved relative to the surface of the work part.
- Robot performs a processing procedure on the part.
- The robot is equipped with some type of process tooling as its end effector.
- Manipulates the tooling relative to the working part during the cycle.

PROCESSING OPERATIONS

- Industrial robot applications in the processing operations include:

(1) Spot welding

(2) Continuous arc welding

(3) Spray painting

(4) Metal cutting and deburring operations

(5) Various machining operations like drilling, grinding, laser and waterjet cutting and riveting.

(6) Rotating and spindle operations

(7) Adhesives and sealant dispensing

ASSEMBLY OPERATIONS

- The applications involve both material handling and the manipulation of a tool.
- They typically include components to build the product and to perform material handling operations.

These are classified as:

- **Batch assembly:** As many as one million products might be assembled. The assembly operation has long production runs.
- **Low-volume:** In this a sample run of ten thousand or less products might be made. The assembly robot cell should be a modular cell.
- One of the well suited area for robotics assembly is the insertion of odd electronic components.

FUTURE APPLICATIONS

The medical applications of the robot

- Routine examinations
- Surgical procedures

Underwater applications

- Involves prospecting for minerals on the floor of the ocean.
- Salvaging of sunken vessels, repair the ship either at sea or in dry dock.
- Mobile firefighters to be used by air force and navy.

FUTURE APPLICATIONS

Surveillance and Guard duty

- Used in military
- Used in power generating plants, oil refineries and other civilian facilities that are potential targets of terrorist groups.

ROBOT PART PROGRAMMING

- It is a path in space to be followed by the manipulator, combined with peripheral actions that support the work cycle.

- To programme a robot , specific commands are entered into the robot's controller memory and this action may be performed in a number of ways.

- For limited sequence robots ,programming occurs when limit switches and mechanical stops are set to control the endpoints of its motions.

ROBOT PART PROGRAMMING

- A sequencing device controls the occurrence of the motions, which in turn controls the movement of the joints that completes the motion cycle.
- For industrial robots with digital computers as controllers three programming methods can be distinguished.

  (a) Lead-through programming

  (b) Computer-like robot programming languages

  (c) Off-line programming.
- Lead-through methodologies and associated programming methods, are outlined in detail in table

ROBOT PART PROGRAMMING - LEAD-THROUGH PROGRAMMING

- Task is ‘taught’ to the robot by manually moving the manipulator through the required motion cycle and simultaneously entering the programme into the controller memory for playback.

- Two methods are used for teaching: powered lead-through and manual lead-through.

ROBOT PART PROGRAMMING - MOTION PROGRAMMING

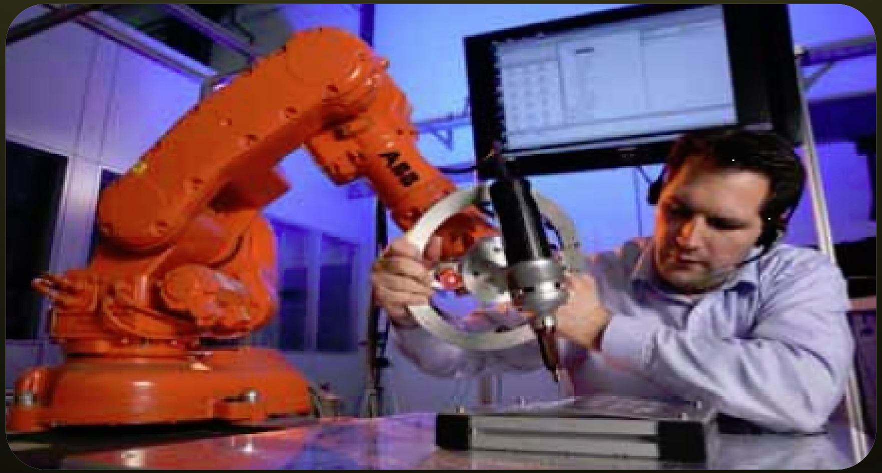
- To overcome difficulties of co-ordinating individual joints associated with lead-through programming, two mechanical methods can be used:
- The world co-ordinate system whereby the origin and axes are defined relative to the robot base and the tool co-ordinate system whereby the alignment of the axis system is defined relative to the orientation of the wrist face plate.
- These methods are typically used with Cartesian co-ordinate robots and not for robots with rotational joints.

ROBOT PART PROGRAMMING - MOTION PROGRAMMING

- The latter robotic types must rely on interpolation processes to gain straight line motion.
- Straight line interpolation where the control computer calculates the necessary points in space that the manipulator must move through to connect two points and Joint interpolation where joints are moved simultaneously at their own constant speed such that all joints start/stop at the same time.

MANUAL LEAD-THROUGH PROGRAMMING

- Manual lead through programming is convenient for programming playback robots with continuous path control where the continuous path is an irregular motion pattern such as in spray painting.
- This programming method requires the operator to physically grasp the end of arm or the tool that is attached to the arm and move it through the motion sequence, recording the path into memory.



MANUAL LEAD-THROUGH PROGRAMMING

- Because the robot arm itself may have significant mass and would therefore be difficult to move, a special programming device often replaces the actual robot for the teaching procedure.

- The programming device has the same joint configuration as the robot and is equipped with a trigger handle (or other control switch) which the operator activates when recording motions into memory.

- The motions are recorded as a series of closely spaced points. During playback the path is recreated by controlling the actual robot arm through the same sequence of points.

ADVANTAGES AND DISADVANTAGES

Advantages

- It can readily be learned by shop personnel.
- It is a logical way to teach a robot.
- It does not require knowledge of computer programming.

Disadvantages

- Downtime regular production must be interrupted to program the robot.
- Limited programming logic capability.
- Not readily compatible with modern computer based technologies.