ME-6703-Computer Integrated Manufacturing

Unit-I

1.1 INTRODUCTION

Computer Integrated Manufacturing (CIM) encompasses the entire range of productdevelopment and manufacturing activities with all the functions being carried out withthe help of dedicated software packages. The data required for various functions are passedfrom one application software to another in a seamless manner. For example, the productdata is created during design. This data has to be transferred from the modeling softwareto manufacturing software without any loss of data. CIM uses a common databasewherever feasible and communication technologies to integrate design, manufacturingand associated business functions that combine the automated segments of a factory ora manufacturing facility. CIM reduces the human component of manufacturing andthereby relieves the process of its slow, expensive and error-prone component. CIM standsfor a holistic and methodological approach to the activities of the manufacturing enterprisein order to achieve vast improvement in its performance.

This methodological approach is applied to all activities from the design of the product to customer support in an integrated way, using various methods, means and techniquesin order to achieve production improvement, cost reduction, fulfillment of scheduleddelivery dates, quality improvement and total flexibility in the manufacturing system.CIM requires all those associated with a company to involve totally in the process of productdevelopment and manufacture. In such a holistic approach, economic, social and humanaspects have the same importance as technical aspects.

CIM also encompasses the whole lot of enabling technologies including total qualitymanagement, business process reengineering, concurrent engineering, workflowautomation, enterprise resource planning and flexible manufacturing.

A distinct feature of manufacturing today is mass customization. This implies thatthough the products are manufactured in large quantities, products must incorporatecustomer-specific changes to satisfy the diverse requirements of the customers. Thisrequires extremely high flexibility in the manufacturing system.

The challenge before the manufacturing engineers is illustrated in Fig.1.1.

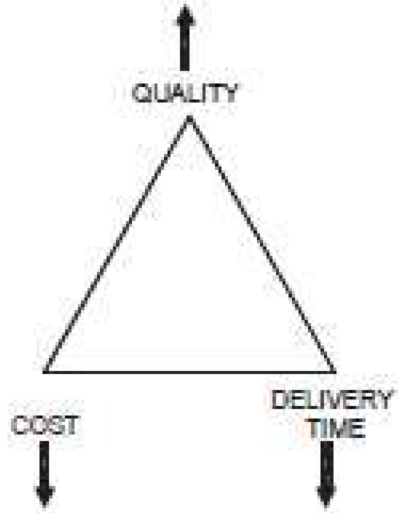


Fig.1.1 Challenges in Manufacturing

Manufacturing industries strive to reduce the cost of the product continuously to remaincompetitive in the face of global competition. In addition, there is the need to improve thequality and performance levels on a continuing basis. Another important requirement is on time delivery. In the context of global outsourcing and long supply chains cutting acrossseveral international borders, the task of continuously reducing delivery times is really anarduous task. CIM has several software tools to address the above needs.

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

- Reduction in inventory
- Lower the cost of the product
- Reduce waste
- Improve quality
- Increase flexibility in manufacturing to achieve immediate and rapid response to:
- Product changes
- Production changes
- Process change
- Equipment change
- Change of personnel

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

The advances in automation have enabled industries to develop islands of automation.Examples are flexible manufacturing cells, robotized work cells, flexible inspection cellsetc. One of the objectives of CIM is to achieve the consolidation and integration of theseislands of automation. This requires sharing of information among different applicationsor sections of a factory, accessing incompatible and heterogeneous data and devices. Theultimate objective is to meet the competition by improved customer satisfaction throughreduction in cost, improvement in quality and reduction in product development time.

CIM makes full use of the capabilities of the digital computer to improvemanufacturing. Two of them are:

i. Variable and Programmable automation
ii. Real time optimization

The computer has the capability to accomplish the above for hardware components ofmanufacturing (the manufacturing machinery and equipment) and software component of manufacturing (the application software, the information flow, database and so on).

The capabilities of the computer are thus exploited not only for the various bits andpieces of manufacturing activity but also for the entire system of manufacturing. Computershave the tremendous potential needed to integrate the entire manufacturing system andthereby evolve the computer integrated manufacturing system.

1.2 TYPES OF MANUFACTURING

The term “manufacturing” covers a broad spectrum of activities. Metal working industries,process industries like chemical plants, oil refineries, food processing industries, electronicindustries making microelectronic components, printed circuit boards, computers andentertainment electronic products etc. are examples of manufacturing industriesManufacturing involves fabrication, assembly and testing in a majority of situations. However,in process industries operations are of a different nature.

Manufacturing industries can be grouped into four categories:

i. Continuous Process Industries

In this type of industry, the production process generally follows a specificsequence. These industries can be easily automated and computers are widelyused for process monitoring, control and optimization. Oil refineries, chemicalplants, food processing industries, etc are examples of continuous processindustries.

ii. Mass Production Industries

Industries manufacturing fasteners (nuts, bolts etc.), integrated chips, automobiles,entertainment electronic products, bicycles, bearings etc. which are all massproduced can be classified as mass production industries. Production lines arespecially designed and optimized to ensure automatic and cost effective operation.Automation can be either fixed type or flexible.

iii. Batch Production (Discrete Manufacturing)

The largest percentage of manufacturing industries can be classified as batchproduction industries. The distinguishing features of this type of manufacture arethe small to medium size of the batch, and varieties of such products to be takenup in a single shop. Due to the variety of components handled, work centersshould have broader specifications. Another important fact is that small batchsize involves loss of production time associated with product changeover

1.3 NATURE AND ROLE OF THE ELEMENTS OF CIM SYSTEM

Nine major elements of a CIM system are in Fig 1.2. They are:

- Marketing
- Product Design
- Planning
- Purchase
- Manufacturing Engineering
- Factory Automation Hardware
- Warehousing
- Logistics and Supply Chain Management
- Finance
- Information Management

Fig.1.2 Major Elements of a CIM System

i. Marketing: The need for a product is identified by the marketing division. Thespecifications of the product, the projection of manufacturing quantities and thestrategy for marketing the product are also decided by the marketing department.Marketing also works out the manufacturing costs to assess the economic viabilityof the product.

ii. Product Design: The design department of the company establishes the initialdatabase for production of a proposed product. In a CIM system this isaccomplished through activities such as geometric modeling and computer aideddesign while considering the product requirements and concepts generated bythe creativity of the design engineer. Configuration management is an importantactivity in many designs. Complex designs are usually carried out by severalteams working simultaneously, located often in different parts of the world. Thedesign process is constrained by the costs that will be incurred in actual productionand by the capabilities of the available production equipment and processes. Thedesign process creates the database required to manufacture the part.

iii. Planning: The planning department takes the database established by thedesign department and enriches it with production data and information toproduce a plan for the production of the product. Planning involves severalsubsystems dealing with materials, facility, process, tools, manpower, capacity,scheduling, outsourcing, assembly, inspection, logistics etc. In a CIM system,this planning process should be constrained by the production costs and bythe production equipment and process capability, in order to generate anoptimized plan.

iv. Purchase: The purchase departments is responsible for placing the purchaseorders and follow up, ensure quality in the production process of the vendor,receive the items, arrange for inspection and supply the items to the stores orarrange timely delivery depending on the production schedule for eventual supplyto manufacture and assembly.

v. Manufacturing Engineering: Manufacturing Engineering is the activity of carryingout the production of the product, involving further enrichment of the databasewith performance data and information about the production equipment andprocesses. In CIM, this requires activities like CNC programming, simulation andcomputer aided scheduling of the production activity. This should include onlinedynamic scheduling and control based on the real time performance of theequipment and processes to assure continuous production activity. Often, theneed to meet fluctuating market demand requires the manufacturing systemflexible and agile.

vi. Factory Automation Hardware: Factory automation equipment further enrichesthe database with equipment and process data, resident either in the operator orthe equipment to carry out the production process. In CIM system this consistsof computer controlled process machinery such as CNC machine tools, flexiblemanufacturing systems (FMS), Computer controlled robots, material handlingsystems, computer controlled assembly systems, flexibly automated inspection systems and so on.

vii. Warehousing: Warehousing is the function involving storage and retrieval ofraw materials, components, finished goods as well as shipment of items. Intoday's complex outsourcing scenario and the need for just-in-time supply ofcomponents and subsystems, logistics and supply chain management assumegreat importance.

viii. Finance: Finance deals with the resources pertaining to money. Planningof investment, working capital, and cash flow control, realization ofreceipts, accounting and allocation of funds are the major tasks of thefinance departments.

1.4 CONCURRENT ENGINEERING

Concurrent engineering or Simultaneous Engineering is a methodology of restructuringthe product development activity in a manufacturing organization using a crossfunctional team approach and is a technique adopted to improve the efficiency ofproduct design and reduce the product development cycle time. This is also sometimesreferred to as

Parallel Engineering. Concurrent Engineering brings together a widespectrum of people from several functional areas in the design and manufacture of aproduct. Representatives from R & D, engineering, manufacturing, materialsmanagement, quality assurance, marketing etc. develop the product as a team. Everyoneinteracts with each other from the start, and they perform their tasks in parallel. Theteam reviews the design from the point of view of marketing, process, tool design andprocurement, operation, facility and capacity planning, design for manufacturability,assembly, testing and maintenance, standardization, procurement of components and sub-assemblies, quality assurance etc as the design is evolved. Even the vendordevelopment department is associated with the prototype development. Any possiblebottleneck in the development process is thoroughly studied and rectified. All thedepartments get a chance to review the design and identify delays and difficulties.

The departments can start their own processes simultaneously. For example, the tooldesign, procurement of material and machinery and recruitment and training ofmanpower which contributes to considerable delay can be taken up simultaneously asthe design development is in progress. Issues are debated thoroughly and conflicts areresolved amicably.

Concurrent Engineering (CE) gives marketing and other groups the opportunity toreview the design during the modeling, prototyping and soft tooling phases ofdevelopment. CAD systems especially 3D modelers can play an important role in earlyproduct development phases. In fact, they can become the core of the CE. They offer avisual check when design changes cost the least.Intensive teamwork between product development, production planning andmanufacturing is essential for satisfactory implementation of concurrent engineering.The teamwork also brings additional advantages ; the co-operation between variousspecialists and systematic application of special methods such as QFD (Quality FunctionDeployment), DFMA (Design for Manufacture and Assembly) and FMEA (Failure Modeand Effect Analysis) ensures quick optimization of design and early detection of possiblefaults in product and production planning. This additionally leads to reduction in leadtime which reduces cost of production and guarantees better quality.

1.5 INTRODUCTION TO AUTOMATION

What is automation?

It is a technology dealing with the application of

- mechatronics
- computers

for production of goods and services.

Automation is broadly classified into

- manufacturing automation
- service automation

We will be primarily concerned with manufacturing automation and therefore with the production of goods.

Examples of manufacturing automation include:

- automatic machine tools to process parts
- automatic assembly machines
- industrial robots
- automatic material handling
- automated storage and retrieval systems
- automatic inspection systems
- feedback control systems

- computer systems for designing products and for analyzing them
- computer systems for automatically transforming designs into parts
- computer systems for planning and decision making to support manufacturing

2. Types of automation

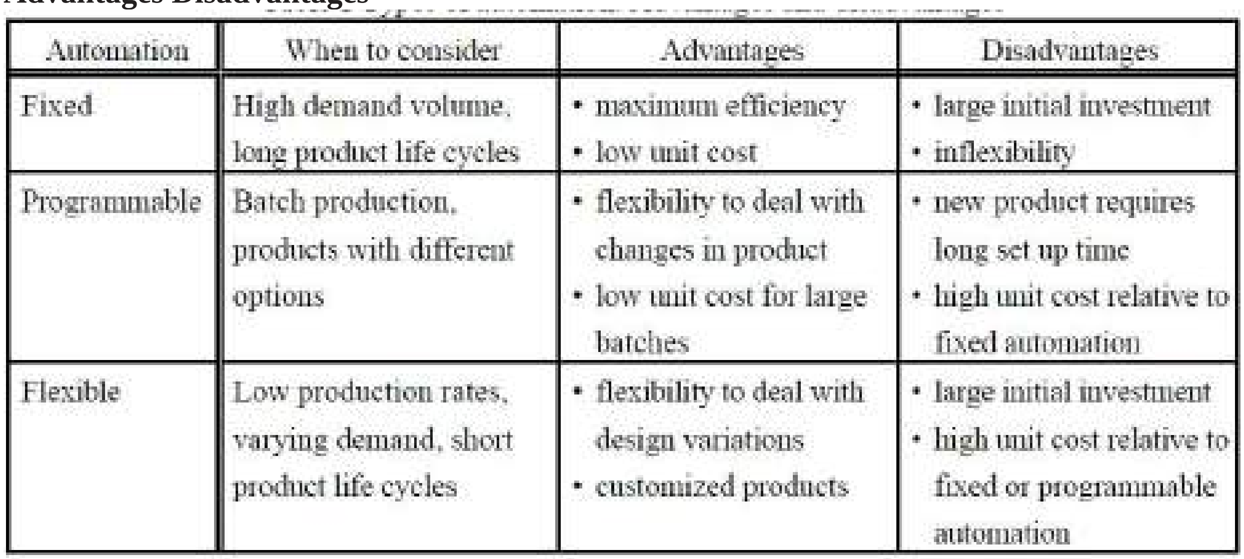
Fixed automation

Fixed automation refers to the use of custom-engineered (special purpose) equipment toautomate a fixed sequence of processing or assembly operations. It is typically associated withhigh production rates and it is relatively difficult to accommodate changes in the product design. Thisis also called hard automation. For example, GE manufactures approximately 2 billion light bulbsper year and uses fairly specialized, high-speed automation equipment. This kind of automationdates back to WWI when the first mechanized assembly lines were used. Fixed automation makessense only when product designs are stable and product life cycles are long. The primarydrawbacks are the large initial investment in equipment and the relative inflexibility.

Programmable automation

In programmable automation, the equipment is designed to accommodate a specific class ofproduct changes and the processing or assembly operations can be changed by modifying thecontrol program. It is particularly suited to “batch production,” or the manufacture of a product inmedium lot sizes (generally at regular intervals). The first example of this kind of automation is theJacquard loom (1801) where the weave pattern for a weave fabric could be “pre-programmed.”Once the required quantity of fabric was produced, the loom could be programmed (although thiswas a tedious process) to produce a new weave pattern for the next batch. A more recent exampleis the CNC lathe that produces a specific product in a certain product class (axisymmetric, within acertain diameter, length, tolerance, etc.) according to the “input program.” In programmableautomation, reconfiguring the system for a new product is time consuming because it involvesreprogramming and set up for the machines, and new fixtures and tools.

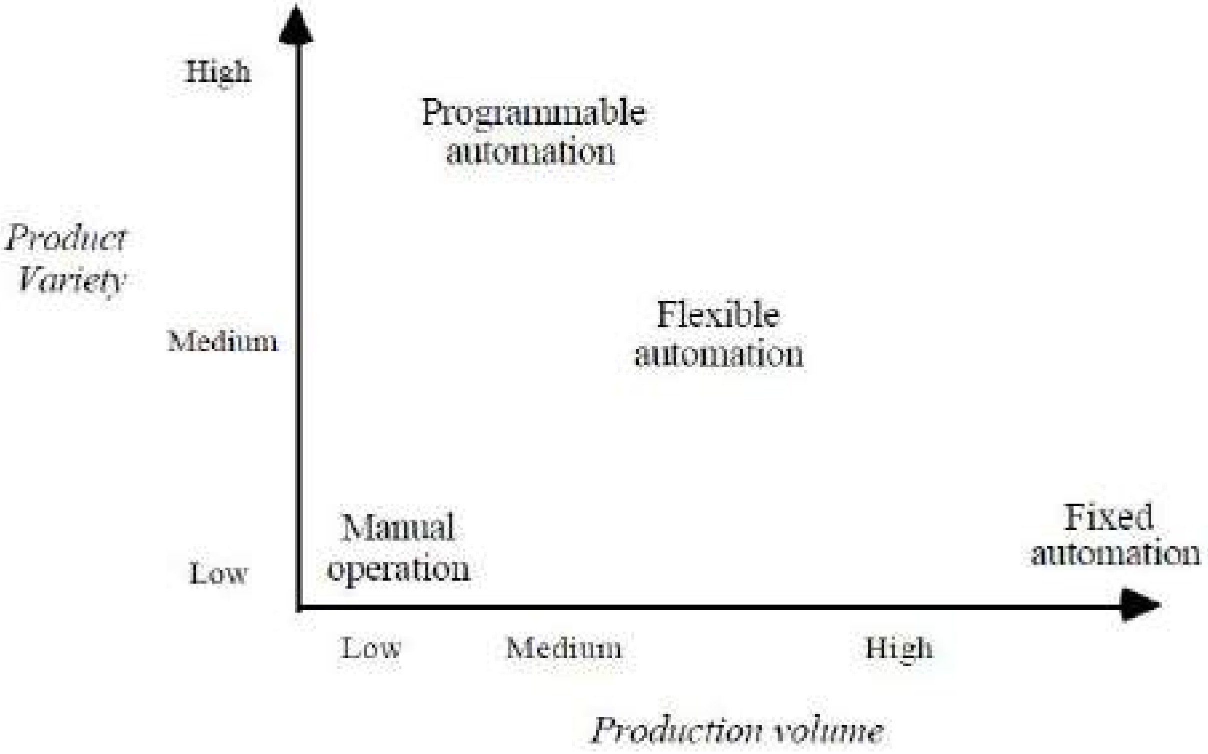
Table 1 Types of automation: Advantages and disadvantagesAutomation When to consider Advantages Disadvantages



Automation	When to consider	Advantages	Disadvantages
Fixed	High demand volume, long product life cycles	• maximum efficiency • low unit cost	• large initial investment • inflexibility
Programmable	Batch production, products with different options	• flexibility to deal with changes in product • low unit cost for large batches	• new product requires long set up time • high unit cost relative to fixed automation
Flexible	Low production rates, varying demand, short product life cycles	• flexibility to deal with design variations • customized products	• large initial investment • high unit cost relative to fixed or programmable automation

Flexible automation

In flexible automation, the equipment is designed to manufacture a variety of products or partsand very little time is spent on changing from one product to another. Thus, a flexiblemanufacturing system can be used to manufacture various combinations of products according toany specified schedule. With a flexible automation system it is possible to quickly incorporatechanges in the product (which may be redesigned in reaction to changing market conditions and toconsumer feedback) or to quickly introduce a new product line. For example, Honda is widely credited with using flexible automation technology to introduce 113 changes to its line ofmotorcycle products in the 1970’s. Flexible automation gives the manufacturer the ability toproduce multiple products cheaply in combination than separately (where the product volume is nothigh enough to justify dedicating a single production line to a single product).



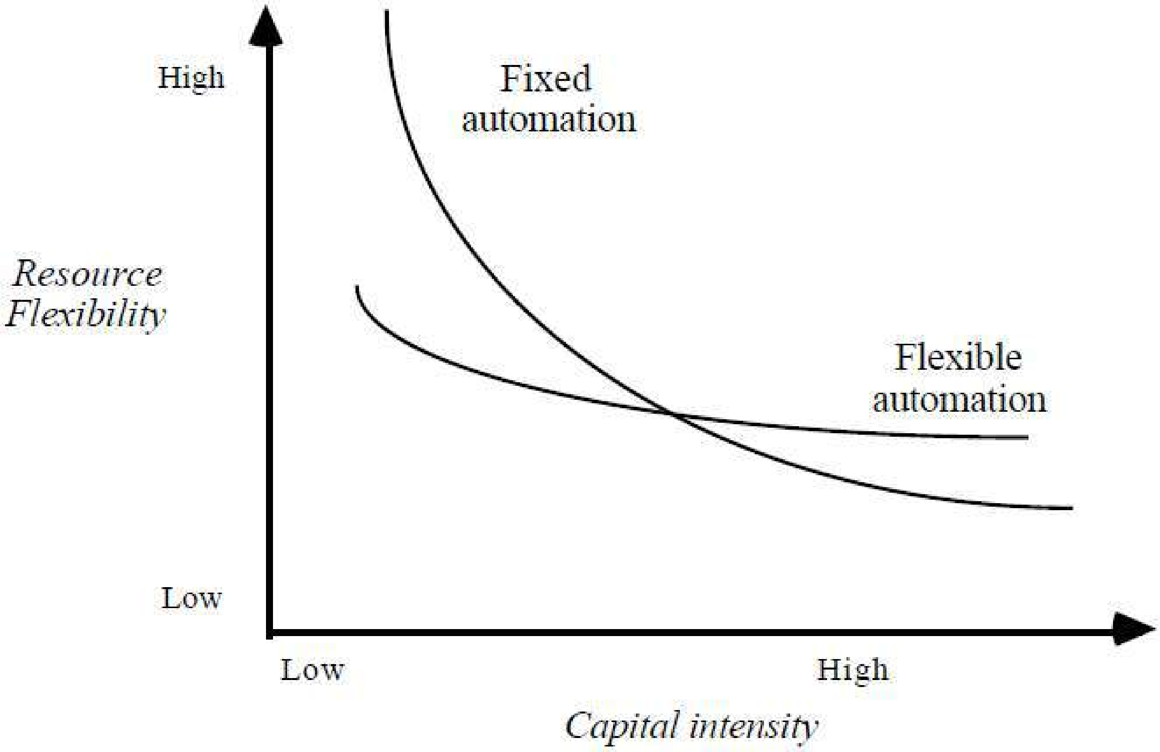
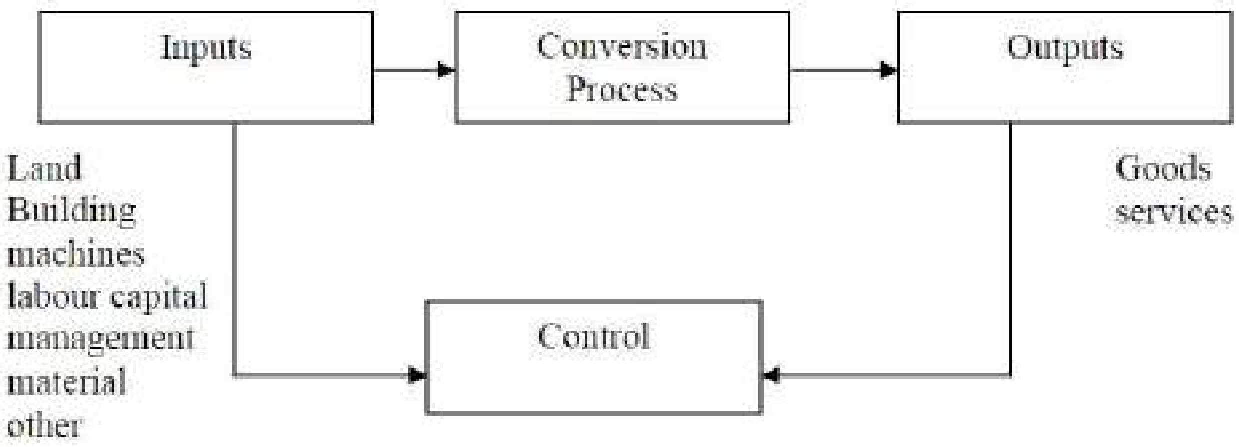


Figure 1 Types of automation

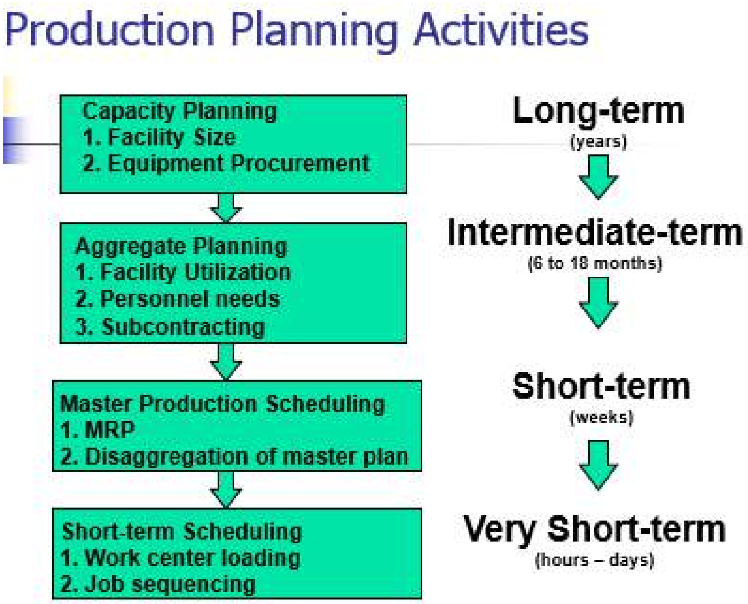
(*Capital intensity* is the mix of equipment and human skills in a production process; the greater therelative cost of the equipment, the greater is the capital intensity. *Resource flexibility* is the easewith which the equipment and the employees can handle a wide variety of products and volumes.)

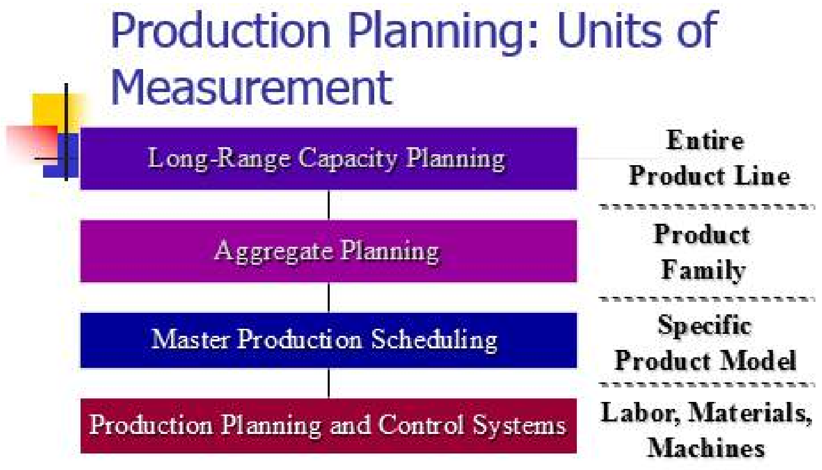
PRODUCTION PLANNING ANDCONTROL AND COMPUTER AIDED PRODUCTION PLANNING

Production is a process whereby raw material is converted into semi-finished products and thereby adds to the value of utility of products, which can be measured as the difference between the value of inputs and value of outputs



- The purpose of the production planning is to ensure that manufacturing run effectively and efficiently and produces products as required by customers





Production Planning: Units of Measurement

Long-Range Capacity Planning	Entire Product Line
Aggregate Planning	Product Family
Master Production Scheduling	Specific Product Model
Production Planning and Control Systems	Labor, Materials, Machines

MANUFACTURING PLANNING AND CONTROL SYSTEM:

The primary objective of a *manufacturing planning and control system* (MPCS) in any organization is to ensure that the desired products are manufactured

- at the right time,
- in the right quantities,
- meeting quality specifications, and
- at minimum cost.

The manufacturing planning and control system (MPCS) in a company is achieved by integrating the activities as:

- determining product demand,
- translating product demand into feasible manufacturing plans,
- establishing detailed planning of material flows,
- capacity to support the overall manufacturing plans, and
- helping to execute these plans by such actions as

  ⇒*detailed cell scheduling*

  ⇒*purchasing*

The benefits achieved through the use of integrated MPCS are:

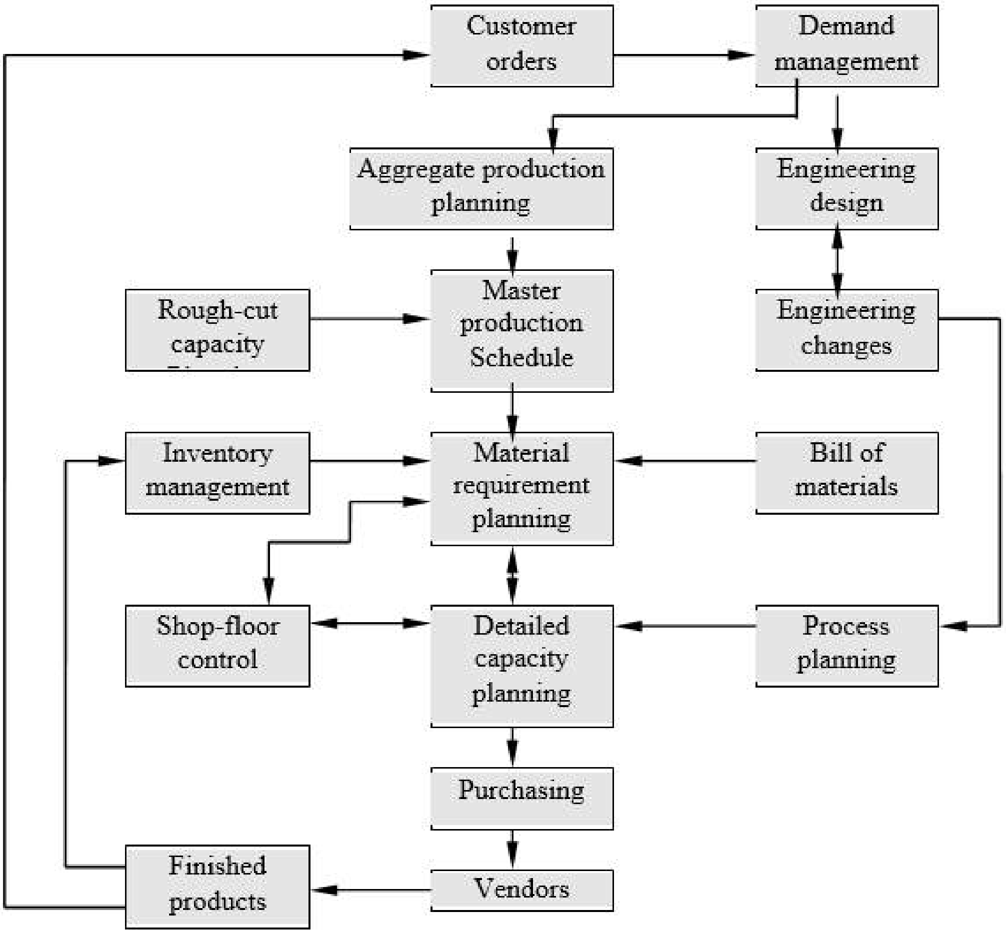
- reduced inventories
- reduced capacity
- reduced labor costs
- reduced overtime costs
- shorter manufacturing lead time
- faster responsiveness to internal and external changes as:

⇒*machine and other equipment failure*
⇒*product mix*
⇒*demand changes*
⇒*etc.*

The major elements of a integrated MPCS are:

- Demand management
- Aggregate production planning
- Master production scheduling
- Rough-cut capacity planning
- Material requirement planning
- Capacity planning
- Order release
- Shop floor scheduling and control

The flow of information among various elements of an MPCS:



DEMAND MANAGEMENT:

Demand for products is the driving force for any production activity.

Demand management is therefore an important input to *production planning*.

Demand managementcontains activities as:

- demand forecasting
- order transaction entry
- customer-contact activities
- physical distribution management

Demand forecasting:

Forecasting is concerned with estimating future demand (or requirement) for products.

Forecasting is necessary for production planning.

There are three approaches to forecasting:

1. The qualitative approach
2. The explanatory approach
3. The descriptive approach

AGGREGATE PRODUCTION PLANNING:

In a high-variety, discrete manufacturing environment, demand for product may fluctuate considerably. On the other end, the resources of the company *(number of machines, number of workers, etc.)* remain constant during the planning horizon *(normally 12 months).* The best approach to obtain feasible solutions is to aggregate the information being processed.

For aggregation purposes the product demand should be expressed in a common measurement unit such as **production hours**. Production planning is concerned primarily with determining optimal production, inventory, and work force levels to meet demand fluctuation.

Basic strategies to absorb the demand fluctuations are:

* Maintain uniform production rate and absorb demand fluctuations.
* Maintain work force but change the production rate by permitting planned overtime, idle time and subcontracting.
* Change the production rate by changing the size of the work force through planned hiring and layoffs.
* Explore the possibility of planned backlogs if customers are willing to accept delays in delivery of products.

A suitable combination of these strategies should be explored to develop an optimal aggregate production plan.

EXAMPLE:

Data on the expected aggregated sales of three products, A, B, and C, over planning horizon of six 4-week periods are as follows:

	Product A		Product B		Product C	
Period	Units	Eq. Cell-hours	Units	Eq. Cell-hours	Units	Eq. Cell-hours
1	60	120	40	80	100	100
2	70	140	50	100	160	160
3	50	100	70	140	210	210
4	55	110	65	130	170	170
5	45	90	55	110	100	100
6	40	80	40	80	80	80

The company has the regular production capacity of 300 *units/period.*

Overtime is allowed up to 60 *units/period*.

The company has developed machining cell-hours as a common unit for aggregation purposes.

Product A &B :2 *cell-hours/unit* Product C : 1 *cell-hours/unit*

Data on the aggregate demand forecast in cell-hours is given in the table below:

Period	Expected Aggregate Demand *(Equivalent Cell-hours)*	Cumulative Aggregate Demand *(Cell-hours)*
1	300	300
2	400	700
3	450	1150
4	410	1560
5	300	1860
6	240	2100

Requirements exceeding overtime capacity may be satisfied by subcontracting.

Two alternative production policies are developed as follows:

PLAN 1: Produce at the constant rate
of 350 *units/period* for the entire planning horizon

PLAN 2: Produce at the rate of 400 *units/period* for the first 4 periods and then at the rate of 250 *units/period* for the subsequent periods.

Analyze these two aggregate production plans.

PLAN 1: Uniform Regular Production Rate Policy

Period	Production rate	Inventory	Back orders	Change in capacity	Overtime	Subcontract
1	350	50	0	+50	50	0
2	350	0	0	0	50	0
3	350	0	100	0	50	0
4	350	0	160	0	50	0
5	350	0	110	0	50	0
6	350	0	0	0	50	0

PLAN 2: Varying Regular Production Rate Policy

Period	Production rate	Inventory	Back orders	Change in capacity	Overtime	Subcontract
1	400	100	0	+100	60	40
2	400	100	0	0	60	40
3	400	50	0	0	60	40
4	400	40	0	0	60	40
5	250	0	10	-50	50	0
6	250	0	0	0	50	0

MASTER PRODUCTION SCHEDULE:

The primary use of *an aggregate production plan* is to level the production schedule so that the production costs are minimized.

However, the output of an aggregate plan does not indicate individual product. This means that the aggregated plan must be *disaggregated* into individual product. The result of such a disaggregation methodologies is what is known as **master production schedule**.

Master production schedule does not present an executable manufacturing plan. Because the capacities and the inventories have not been considered in this stage. Therefore, further analysis for the material and capacity requirements is required to develop an executable manufacturing plan.

ROUGH-CUT CAPACITY PLAN:

The objective of rough-cut capacity planning is to ensure that the master production schedule is feasible. For each product family the average amount of work needed an key work centers per unit per unit can be calculated from each item's bill of materials and production routings *(process planning sheets).*

EXAMPLE:

Consider two families of steel cylinders and the resource profile developed in standard hours of resources per 200 units of end-product family as follows:

Work center	Product Family 1 *(Standard Hours per 200 Units)*	Product Family 2 *(Standard Hours per 200 Units)*	Total resources required for all families
1100	14	7	21
2100	7	20	27
3100	6	14	20
4500	25	9	34
6500	9	16	25

The available resources are compared with the resource requirements profile obtained for all the work centers considering all the product families. If the available resources are less than required, then decisions related to *overtime, subcontracting, hiring workers* must be made.

MATERIAL REQUIREMENTS PLANNING:

The *material requirements planning system is* system essentially an information system consisting of logical procedure for managing inventories of component assemblies, subassemblies, parts, and raw materials in a manufacturing environment.

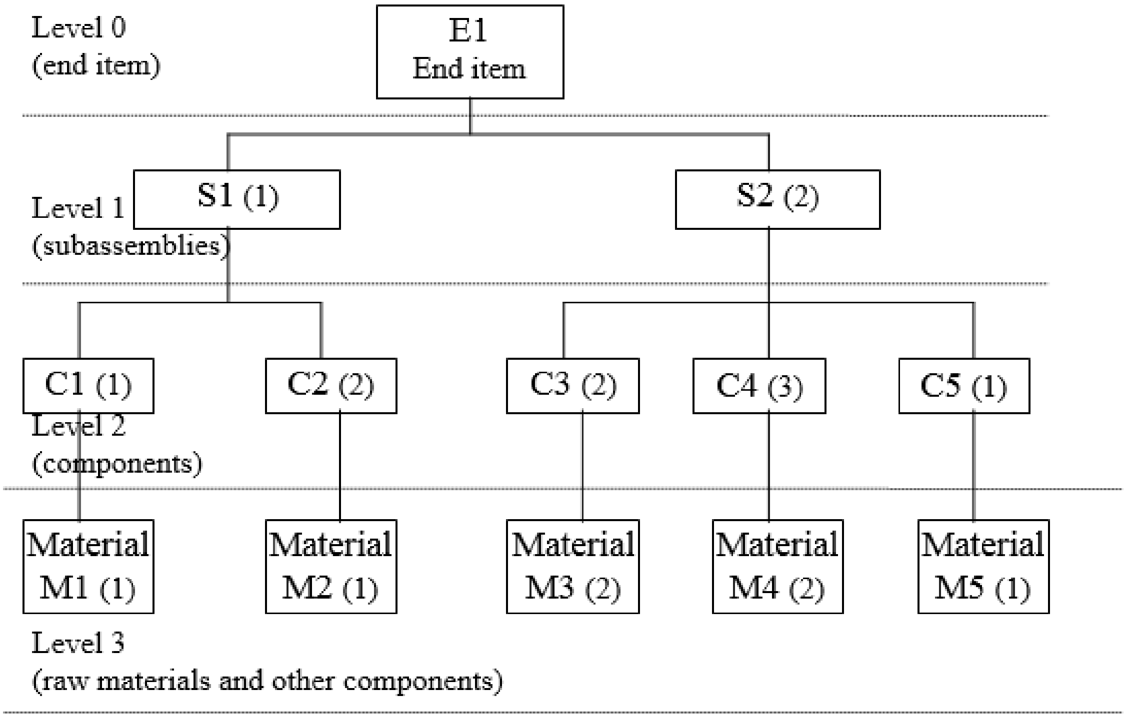
The primary objective of an MRP system is to determine how many of each item in the bill of materials must be manufactured or purchased and when.

The key concept used in determining material requirements are:

- Product structure and bill of materials
- Independent versus dependent demand
- Parts explosion
- Gross requirement
- Common-use items
- Scheduled receipts
- On-hand inventories
- Net requirements
- Plant order releases
- Lead time

Product structure and Bill of Materials:

Product is the single most important identity in an organization. A product may be made from one or more assemblies, subassemblies and components. A **bill of material** is an engineering document that specifies that the components and subassemblies required to make each end item *(product)*.



Independent versus Dependent Demand:

The demand for the end item originates from customer order and forecasts.

Such a demand for end items and spare parts is called **independent demand**.The demand by a parent item for its components is called **dependent demand**.

Parts Explosion:

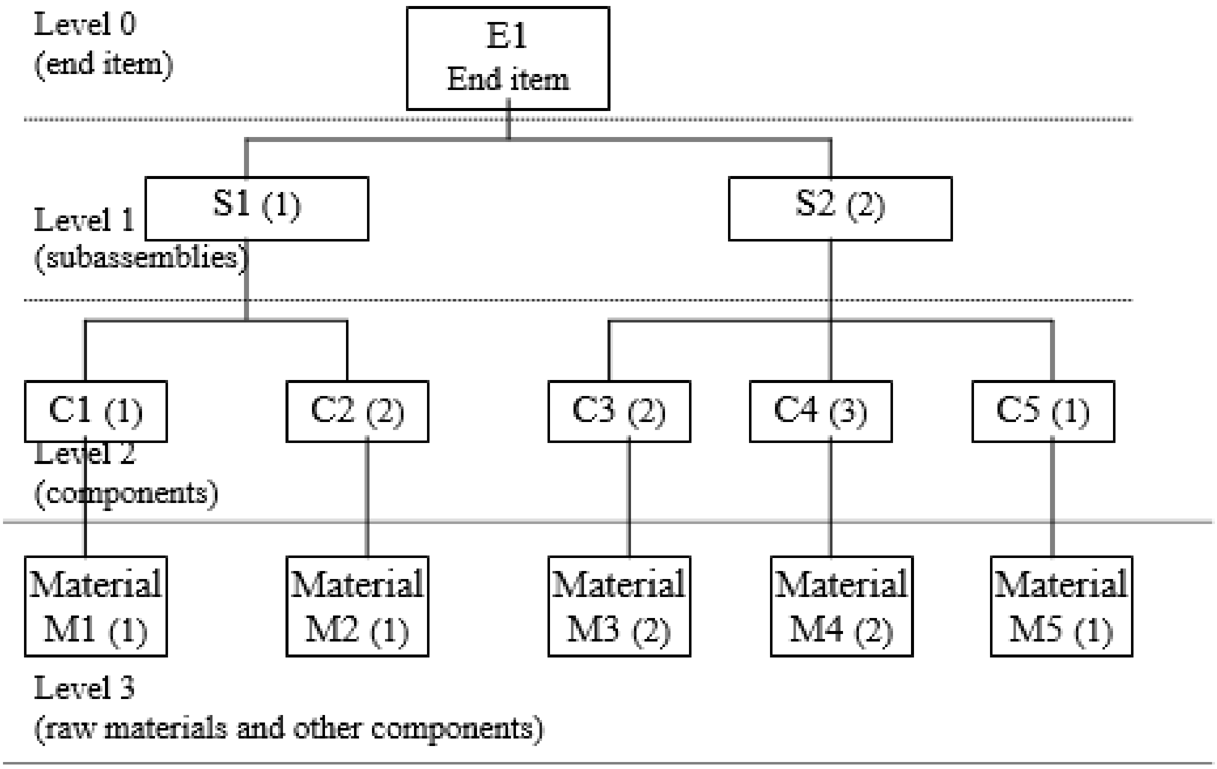
The process of determining gross requirements for component items that *is requirements for the subassemblies, components, and raw materials* for a given number of end-item units is known as **parts explosion**.

Part explosion represents the explosion of *parents* into their *components*.

Gross Requirements of Component Items:

Gross requirement of component items is the total number of component items required to manufacture the end products. Gross requirement of component items is computed by using the information from the *product information* and the *bill of materials.*

EXAMPLE:
If the demand for end-item E1 is 50, determine the gross requirements for the item components.



Demand of S1 = 1 x demand of E1 = 50 units
Demand of S2 = 2 x demand of E1 = 100 units
Demand of C1 = 1 x demand of S1 = 50 units
Demand of C2 = 2 x demand of S1 = 100 units
Demand of C3 = 2 x demand of S2 = 200 units
Demand of C4 = 3 x demand of S2 = 300 units
Demand of C5 = 1 x demand of S2 = 100 units

Common-Use Items:

They are the component items which are used different subassemblies of different end-products. These items must be added to have more economic purchasing.

On-Hand Inventory, Scheduled Receipts, and Net Requirements:

On-hand inventory is the available items in stock from the previous period. **Scheduled receipt** is the items already been ordered but not been received from the vendors yet.**Net requirements** is found by subtracting the *on-hand inventoryand scheduled receipts* from the *gross requirements*.

Planned Order Release:

Planned order releases refer to the process of releasing a lot of every component item for production or purchase. Determination of lot size is an economic issue. The trade-off is between *the inventory holding costs* and the *set up costs*.

Lot sizes in MRP system are determined for component items for each stage sequentially starting with *level 1*, then *level 2* and so on.

Lead Time and Lead Time Offsetting:

The **lead time** is the time it takes to produce or purchase a part. The lead time depends on:

1. setup time
2. production time
3. lot size
4. sequence of machines on which operations are performed
5. queuing delays

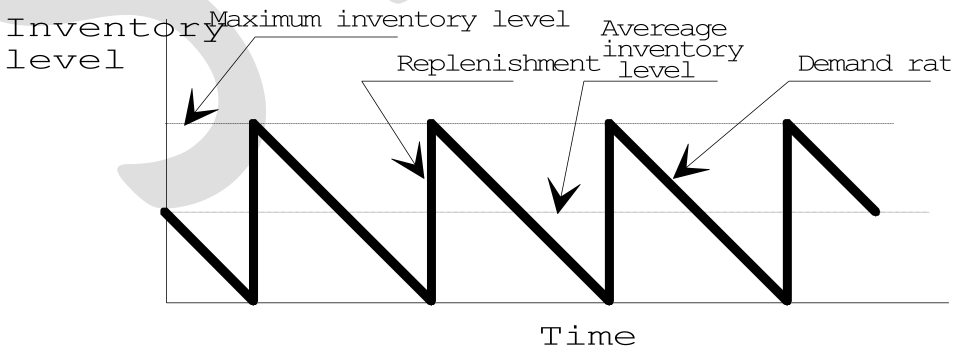
The **purchasing lead time** is the time between placing an order with a vendor and receipt of the order.

The manufacture or purchase of component items must be **offset** by at least their *lead times* to ensure availability of these items for assembly into their parent items at the desired time.

Economic Order Quantity:

In order to balance the costs of keeping the items in inventory and the costs of setup, the concept of *Economic Order Quantity* (EOQ) is introduced.

Normally, the ordering policy is set as displayed below, where the demand is fairly constant:



MRP EXAMPLE:

Period (weeks)									
1	2	3	4	5	6	7	8	9	10

End item E1; lead time 3 weeks										
Gross requirements			20	30	10	40	50	30	30	40
On-hand inventory	(50)									
Scheduled receipt										
Net requirements					10	40	50	30	30	40
Planned order release		10	40	50	30	30	40			

CAPACITY PLANNING:

The output of MRP does not produce an executable manufacturing plan, because it contains material requirement information only but does not contain information about the manufacturing capacity of the plant.

To develop an executable manufacturing plan, it is essential to establish the feasibility of the planned order releases obtained from the MRP system.

Capacity planning is concerned with ensuring the feasibility of production plans by determining resources such as labour and equipment with a view to developing what is known as an executable manufacturing plan.

The process of capacity planning is complex and involves a number of decisions:

- Exploring overtime/multiple shifts/subcontracting options
- Developing alternative process plans for effective resource utilization
- Splitting lots
- Increasing or decreasing employment levels to respond to capacity changes
- Inventory options
- Increasing capacity by adding capital equipment such as machine tools

ORDER RELEASE:

Once an executable manufacturing plans are obtained, the orders are released to the shop floor. Order release documents should include:

- Material inventories allocated to the order.
- Routing sheets having information on:
  - ⇒operation sequences,
  - ⇒machines,
  - ⇒work centers,
  - ⇒tool and fixture allocations,
  - ⇒batch sizes,
  - ⇒standard machine time allowed for each operation, etc.
- Appropriate shop floor records such as cards, move cards, and part lists for assembly jobs.

The order release triggers a number of activities at the shop floor:

- Scheduling of job orders on the work centers.
- Sequencing of jobs on a work center.
- Allocation of jigs and fixture.
- Loading of work centers considering optimal cutting conditions *(cutting speeds, feed rates, depth of cuts)*.
- Coordination of material handling, storage, warehousing, and machine tools.

SHOP FLOOR CONTROL:

When the planned orders are released to the shop floor for manufacturing, the primary objective is to deliver the product at the right time, in the right quantities, meeting quality specifications. But some unexpected event *(machine breakdown for example)* may cause delays.

In order to take action *(changing the scheduling for example)*, the up to date information from the shop floor must be send to the management a fast and a steady manner.

A number of methods are used for data collection in industries, such as:

* Hand written reports.
* Manual data entry terminals.
* Bar code readers and sensors such as optical and magnetic reading devices that automatically update an item's progress through the shop floor.
* Voice data entry system.

The major functions of a shop-floor control system are

* to schedule job orders on the work centers,
* to sequence the jobs in order on a work center,
* to provide accurate and timely order status information.

The work order status information includes:

* order batch sizes
* job completion
* remaining jobs and operations

The work order status information is used:

* To monitor the progress of manufacturing activities.
* To determine priorities for scheduling jobs in the shop in response to changes in job order status.

* To maintain and control work in process.
* To provide output data for capacity control purposes.

PROCESS PLANNING

Concurrent engineering requires the integration of all aspects of the product life cycle, that is:

- design,
- manufacturing,
- assembly,
- distribution,
- service,
- disposal

Two important areas in the life cycle of a product are ***design*** and ***manufacturing***. Process planning serves as an ***integration link*** between *design* and *manufacturing*.

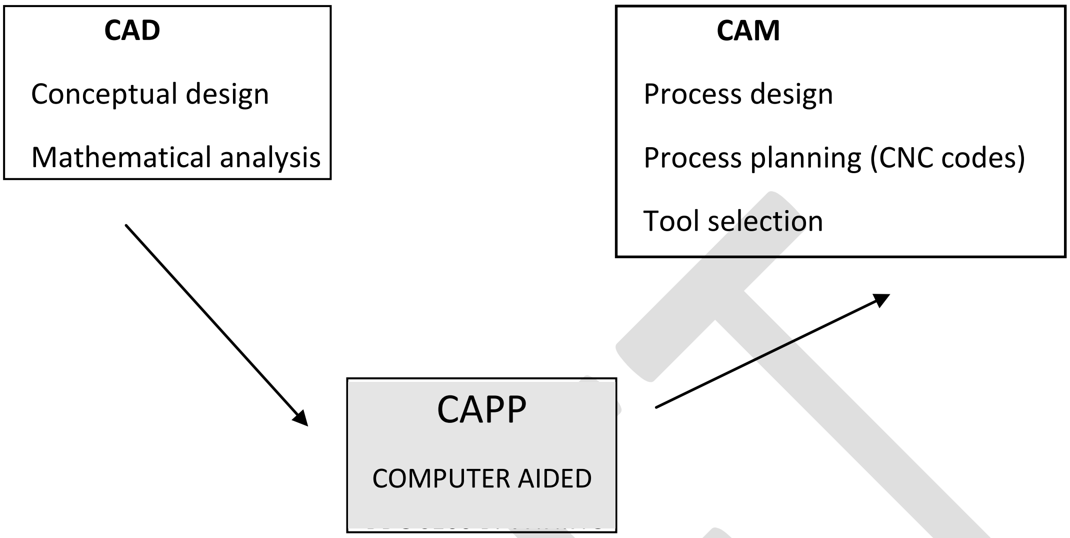
Process planning consists of preparing a set of instructions that describe how to fabricate a part or build an assembly which will satisfy engineering design specifications.

The resulting set of instructions may include any or all of the following:

- operation sequence,
- machines,
- tools,
- materials,
- tolerances,
- cutting parameters,
- processes (such as how to heat-treat),
- jigs,
- fixtures,
- time standards,
- setup details,
- inspection criteria,
- gauges,
- graphical representations of the part in various stages of completion

Process planning emerges as a key factor in CAD/CAM integration because it is the link between CAD and CAM. After engineering designs are communicated to manufacturing, either on paper or electronic media, the process planning function converts the designs into instructions used to make the specified part.

CIM cannot occur until this process is automated; consequently, automated process planning is the link between CAD and CAM.



Some typical **benefits of automated process planning** include:

- 50% increase in process planner productivity
- 40% increase in capacity of existing equipment
- 25% reduction in setup costs
- 12% reduction in tooling
- 10% reduction in scrap and rework
- 10% reduction in shop labor
- 6% reduction in work in process
- 4% reduction in material

If the process **planner's productivity is significantly improved**:

- More time can be spent on methods, improvements and cost-reduction activities.
- Routings can be consistently optimized.
- Manufacturing instructions can be provided in greater detail
- Preproduction lead times can be reduced.
- Responsiveness to engineering charges can be increased.

The **development of process plans** involves a number of activities:

- Analysis of part requirement
- Selection of raw work piece
- Determining manufacturing operations and their sequences
- Selection of machine tools
- Selection of tools, work holding devices, and inspection equipment
- Determining machining conditions and manufacturing time

ANALYSIS OF PART REQUIRENTS:

The part requirements can be defined as:

- part features
    - *process determination*
    - *steps of processes*
- dimensions
    - *machine tool size*
- tolerance specifications
    - *machine tool capability*
    - *CNC code generation*

SELECTION OF RAW WORKPIECE:

It involves such attributes as:

- shape
    - *standard materials*
        - ⇒*rod*
        - ⇒ *blank*
        - ⇒*slab*
        - ⇒ *profile*
    - *pre-shaped materials*
        - ⇒*cast*
        - ⇒*extruded*
        - ⇒*forged*
- size
    - *machine tool size*
- material
    - *cutting conditions*
    - *tool selection*

DETERMINING MANUFACTURING OPTIONS AND THEIR SEQUENCES:

- selection of processes
    - *availability*
    - *suitability*
    - *accuracy requirement*
    - *cost*
- sequence of operations
    - *work holding method*
    - *cutting tool availability*

SELECTION OF MACHINE TOOLS:

- work piece related attributes
    - *part features*
    - *dimensions*
    - *dimensional tolerances*
    - *raw material form*
- machine tool related attributes
    - *process capability*
    - *size*
    - *mode of operation*
        - ⇒*manual*
        - ⇒*semiautomatic*
        - ⇒*automatic*
        - ⇒*CNC*
    - *tooling capabilities*
        - ⇒*type of tool*
        - ⇒*size of tool*
    - *tool changing capability*
        - ⇒*manual*
        - ⇒*automatic*
- production volume related information
    - *production quantity*
    - *order frequency*

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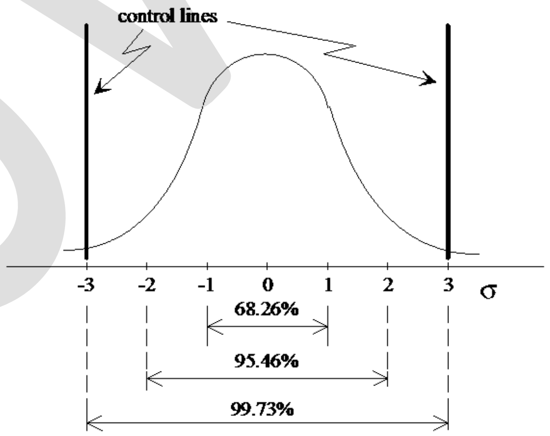
EVALUATION OF MACHINE TOOL ALTERNATIVES:

- Machine tool capability:



SELECTION OF TOOLS, WORKHOLDING DEVICES, AND INSPECTION EQUIPMENT:

- Tools
    - tool material
    - shape

- ◊ size
- ◊ tolerance
- ◊ nose radius

♦ Workholding devices

The primary purpose of a workholding device is to position the workpiece accurately and hold it securely.

- ◊ manually operated devices
  - ⇒*collets*
  - ⇒*mandrel*
  - ⇒*chucks*
  - ⇒*faceplates*
- ◊ designed devices
  - ⇒*power chucks*
  - ⇒*specially designed fixtures and jigs*
- ◊ flexible fixtures used in flexible manufacturing systems

♦ Inspection equipment

- ◊ on-line inspection equipment
- ◊ off-line inspection equipment

DETERMINING CUTTING CONDITION AND MANUFACTURIN TIMES:

Machining conditions

- cutting speed
- feed rate
- depth of cut

Object is to set the cutting conditions in such a way that the economically best production state is achieved.

What is the ***economically best production state?***

It is : 1- Minimum production cost or 2- Maximum production rate

CHOICE OF FEED

Finishing cut: Proper feed rate to provide desired surface quality *(relatively low)*

Roughing cut: Feed rate is not effective as cutting speed over tool life, therefore, feed should be set to maximum possible value

limitations:

maximum tool force that the machine or the tool can stand and the maximum power available

CHOICE OF CUTTING SPEED

Cutting speed is set to provide the optimum tool life.

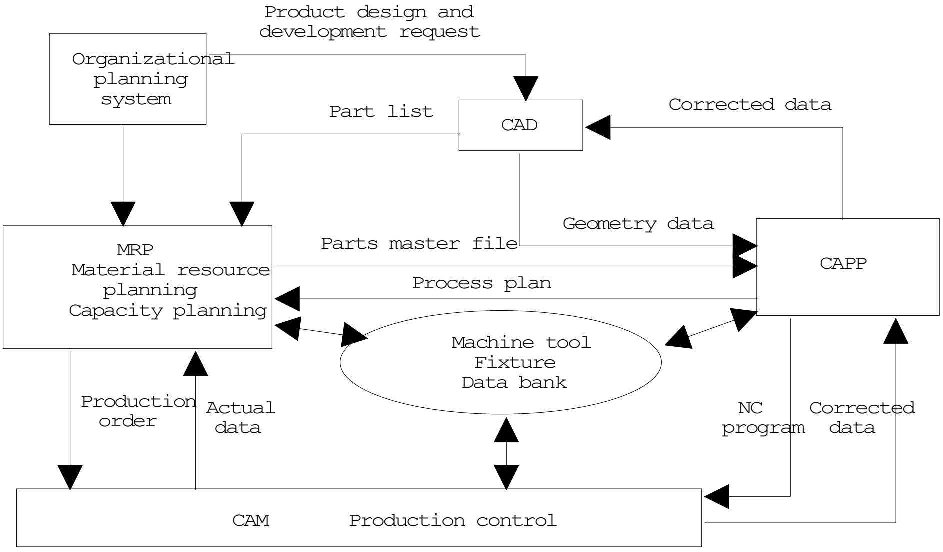
High V :	*low tool life*	**Low V**:	*high tool life*
	high tool cost		*low tool cost*
	high production rate		*low production rate*
	short production time		*long production time*

MANUAL *EXPERIENCE-BASED* PROCESS PLANNING METHOD:

- most widely used method
- time consuming
- inconsistent plans
- requires highly skilled, therefore, costly planners

COMPUTER-AIDED PROCESS PLANNING METHOD:

- it can systematically produce accurate and consistent process plans
- it can reduce the cost and lead time of process planning
- less skilled process planners may be employed
- it increases the productivity of process planners
- manufacturing cost, manufacturing lead time and work standards can easily be interfaced with the CAPP system



A computer-aided process planning framework

There are two basic methods used in *computer-aided process planning*:

- Variant CAPP method
- Generative CAPP method

The Variant CAPP Method:

- process plan is developed for a master part which represent the common features of a family of parts
- a process plan for a new part is created by recalling, identifying, and retrieving an existing plan for a similar part and making necessary modifications for the new part
- to use the method efficiently, parts classifying coding system must be used

<u>Advantages of variant process planning:</u>

- efficient processing and evaluation of complicated activities and decisions, thus reducing the time and labor requirements
- standardized procedures by structuring manufacturing knowledge of the process planers to company's needs
- lower development and hardware costs and shorter development times

<u>Disadvantages of variant process planning:</u>

- maintaining consistency in editing is difficult
- it is difficult to adequately accommodate various combinations of
    - ⇒material,
    - ⇒geometry,
    - ⇒size,
    - ⇒ quality, precision
    - ⇒ alternative processing sequences,
    - ⇒ machine loading
- The quality of the final process plan generated depends to a large extent on the knowledge and the experience of the process planners

The Generative CAPP Method:

In a generative approach, process plans are generated by means of

- decision logic
- formulas
- technology algorithm
- geometry based data

to perform uniquely the many processing decisions for converting a part from raw material to a finished state

There are basically two major components of generative process planning system:

- *a geometry based coding scheme*
- *process knowledge in the form of decision logic and data*

Geometry Based Coding Scheme:

The objective is to define all geometric features for all process-related surfaces together with feature dimensions, locations, and tolerances, and the surface finish desired on the features.

The level of details is much greater in a *generative system* than a *variant system.*

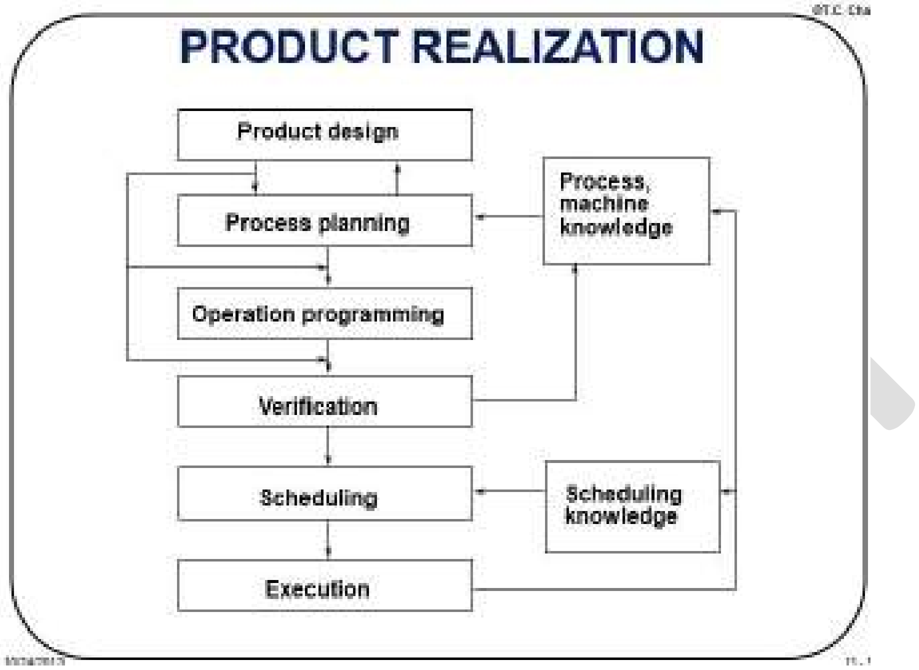
FUTURE TRENDS IN COMPUTER-AIDED PROGESS PLANNING:

One of the major strategies for reducing cost and lead time is to integrate various functional areas such as *design*, *process planning*, *manufacturing*, and *inspection*.

There are a number of difficulties in achieving the goal of complete integration.

For example, each functional area has its own stand-alone relational database and associated database management system. The software and hardware incompatibilities among these systems pose difficulties in full integration. There is a need to develop a single-database technology to address these difficulties.

Other challenges include automated translation of the design dimensions and tolerances into manufacturing dimensions and tolerances considering process capabilities and dimensional chains, automatic recognition of features, and making the CAPP systems affordable to the small and medium-scale manufacturing companies.



PROCESS PLAN

- **Also called : operation sheet, route sheet, operation planning summary, or another similar name.**

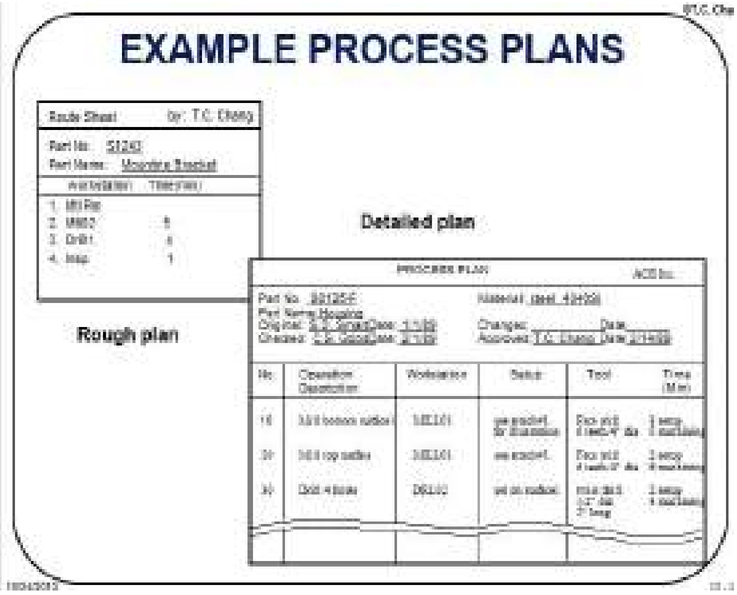
- **The detailed plan contains:**

Route processes process parameters machine and tool selections fixtures

- **How detail the plan is depends on the application.**

- **Operation: a process**

- **Operation Plan (Op-plan): contains the description of an operation, includes tools, machines to be used, process parameters, machining time, etc.**
- **Op-plan sequence: Summary of a process plan**



EXAMPLE PROCESS PLANS

Route Sheet by: T.C. Chang

Rough plan

Detailed plan

PROCESS PLAN

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REQUIREMENTS IN MANUAL PROCESS PLANNING

- **ability to interpret an engineering drawing.**
- **familiar with manufacturing processes and practice.**
- **familiar with tooling and fixtures.**
- **know what resources are available in the shop.**
- **know how to use reference books, such as machinability data handbook.**
- **able to do computations on machining time and cost.**
- **familiar with the raw materials.**
- **know the relative costs of processes, tooling, and raw materials.**

GROUP TECHNOLOGY

Overview of Group Technology (GT)

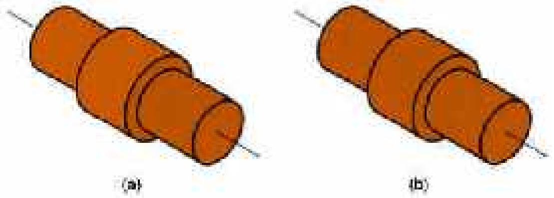
- Parts in the medium production quantity range are usually made in batches
- Disadvantages of batch production:
  - Downtimefor changeovers
  - High inventory carrying costs
- GT minimizes these disadvantages by recognizing that although the parts are different, there are groups of parts that possess similarities
- GT exploits the part similarities by utilizing similar processes and tooling to produce them
- GT can be implemented by manual or automated techniques
- When automated, the term *flexible manufacturing system* is often applied

Group Technology Defined

- An approach to manufacturing in which similar parts are identified and grouped together in order to take advantage of their similarities in design and production
- Similarities among parts permit them to be classified into part families
- In each part family, processing steps are similar
- The improvement is typically achieved by organizing the production facilities into manufacturing cells that specialize in production of certain part families

Part Family

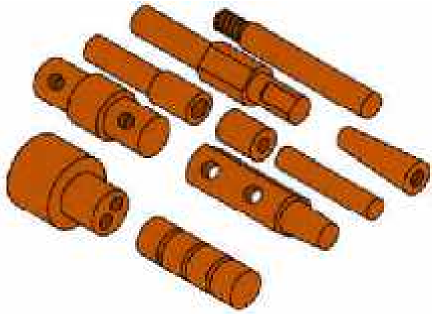
- A group of parts that possess similarities in geometric shape and size, or in the processing steps used in their manufacture
- Part families are a central feature of group technology
- There are always differences among parts in a family
- But the similarities are close enough that the parts can be grouped into the same family



- Two parts that are identical in shape and size but quite different in manufacturing:

(a)1,000,000 units/yr, tolerance = ±0.010 inch, 1015 CR steel, nickel plate

(b)100/yr, tolerance = ±0.001 inch, 18-8 stainless steel



- Ten parts that are different in size and shape, but quite similar in terms of manufacturing
- All parts are machined from cylindrical stock by turning; some parts require drilling and/or milling

Ways to Identify Part Families

1.*Visual inspection* - using best judgment to group parts into appropriate families, based on the parts or photos of the parts

2.*Production flow analysis* - using information contained on route sheets to classify parts

3.*Parts classification and coding* - identifying similarities and differences among parts and relating them by means of a coding scheme

Parts Classification and Coding

 Mostclassification and coding systems are one of the following:

- Systems based on part design attributes
- Systems based on part manufacturing attributes
- Systems based on both design and manufacturing attributes

Part Design Attributes

- Major dimensions
- Basic external shape
- Basic internal shape
- Length/diameter ratio
- Material type
- Part function
- Tolerances
- Surface finish

Part Manufacturing Attributes

- Major process
- Operation sequence
- Batch size
- Annual production

- Machine tools
- Cutting tools
- Material type

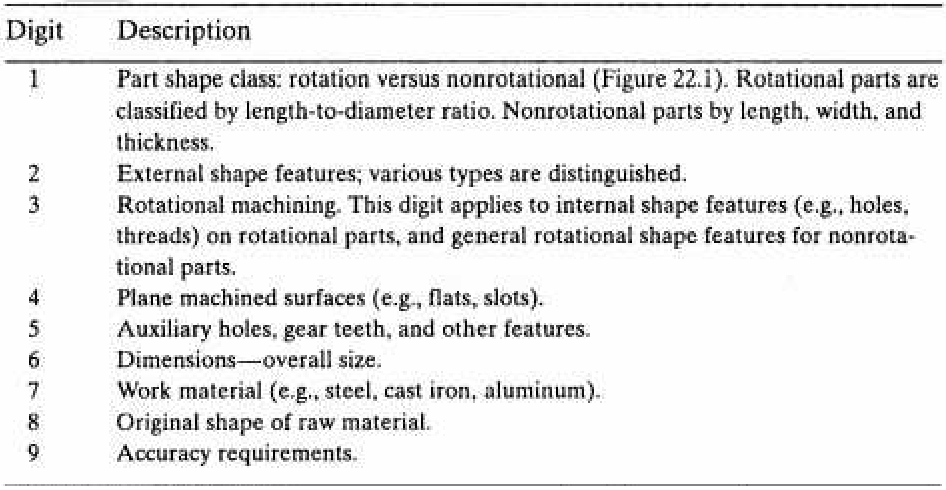
Three structures used in classification and coding schemes

- Hierarchical structure, known as a mono-code, in which the interpretation of each successive symbol depends on the value of the preceding symbols
- Chain-type structure, known as a polycode, in which the interpretation of each symbol in the sequence is always the same; it does not depend on the value of preceding symbols
- Mixed-mode structure, which is a hybrid of the two previous codes

Some of the important systems

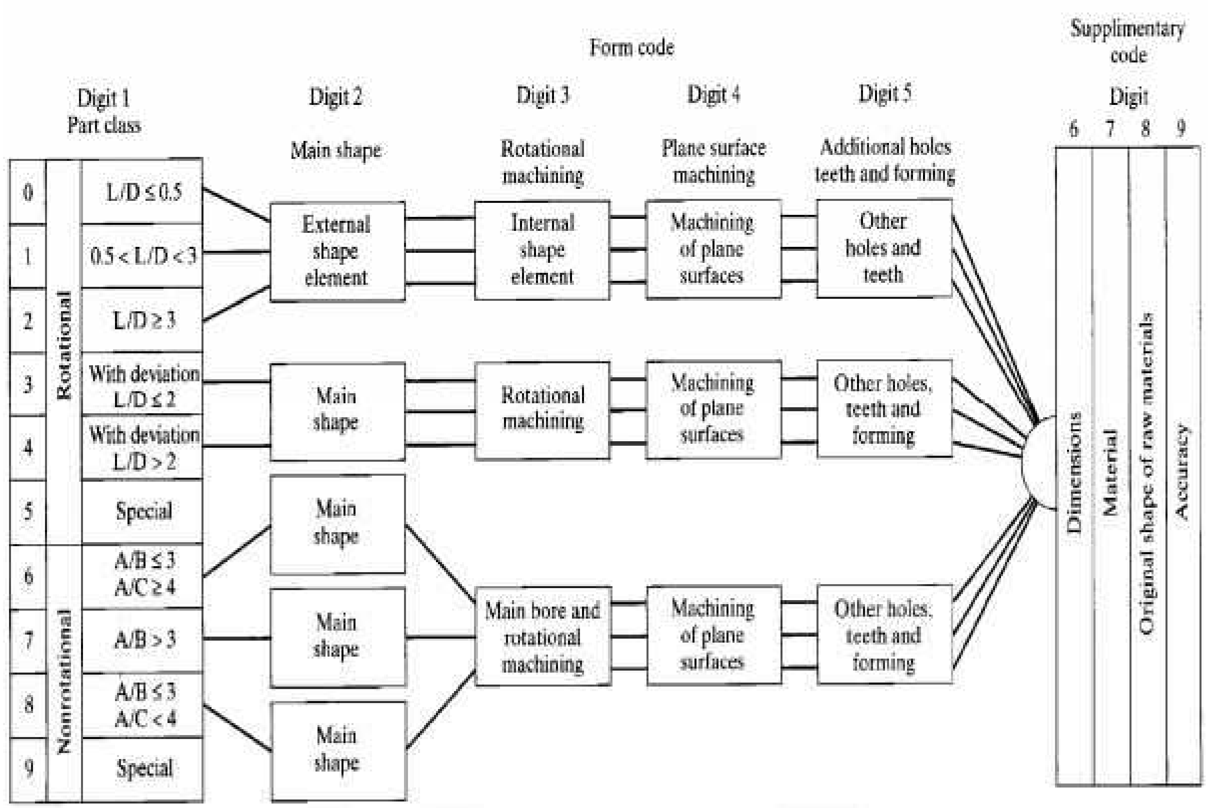
- Opitz classification system – the University of Aachen in Germany, nonproprietary, Chain type.
- Brisch System – (Brisch-Birn Inc.)
- CODE (Manufacturing Data System, Inc.)
- CUTPLAN (Metcut Associates)
- DCLASS (Brigham Young University)
- MultiClass (OIR: Organization for Industrial Research), hierarchical or decision-tree coding structure
- Part Analog System (Lovelace, Lawrence & Co., Inc.)

Basic Structure of the Opitz Parts Classification and Coding System

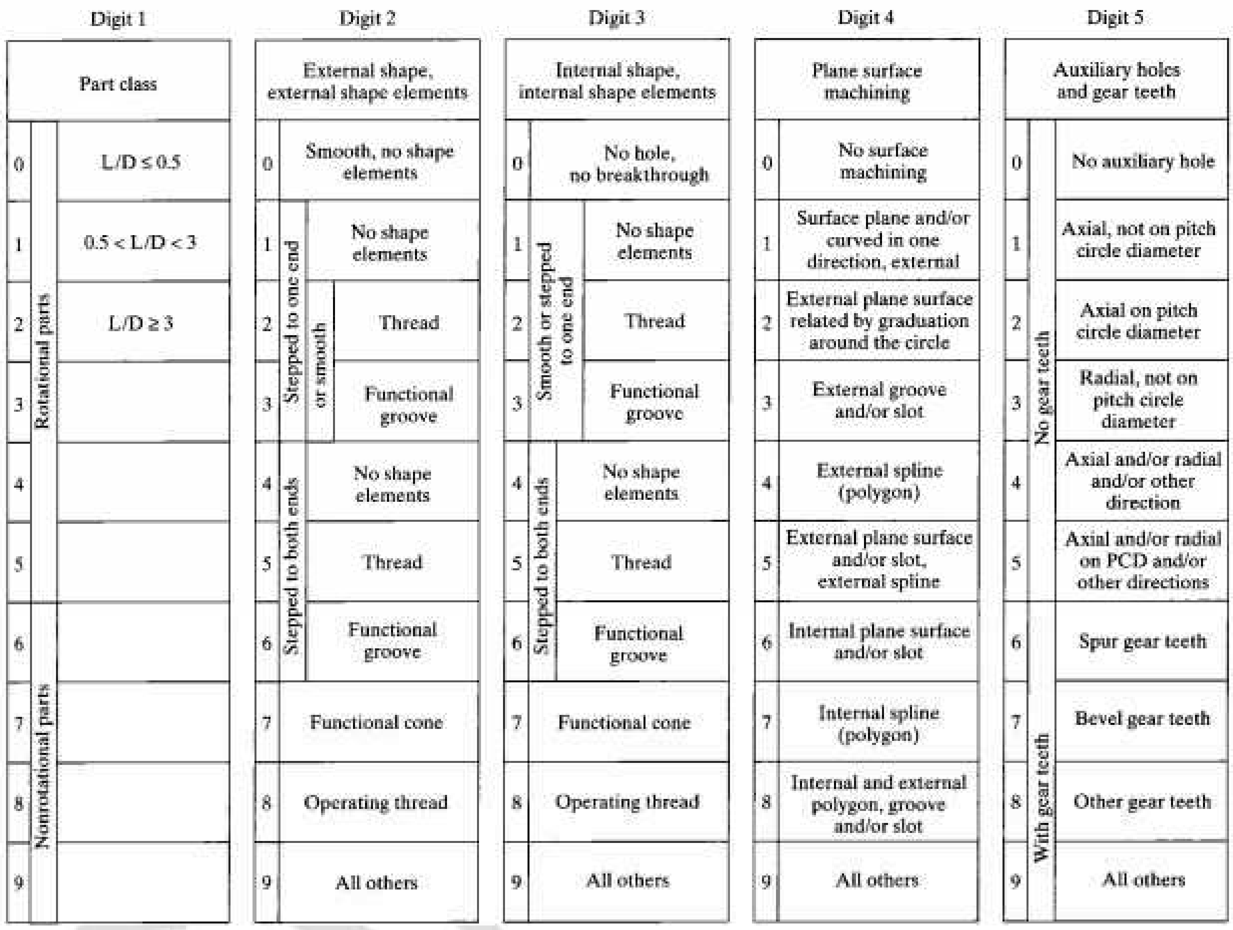


Digit	Description
1	Part shape class: rotation versus nonrotational (Figure 22.1). Rotational parts are classified by length-to-diameter ratio. Nonrotational parts by length, width, and thickness.
2	External shape features; various types are distinguished.
3	Rotational machining. This digit applies to internal shape features (e.g., holes, threads) on rotational parts, and general rotational shape features for nonrotational parts.
4	Plane machined surfaces (e.g., flats, slots).
5	Auxiliary holes, gear teeth, and other features.
6	Dimensions—overall size.
7	Work material (e.g., steel, cast iron, aluminum).
8	Original shape of raw material.
9	Accuracy requirements.

Basic structure of the Opitz system of parts classification and coding


Form code
Supplimentary code
Digit 1
Part class
Digit 2
Main shape
Digit 3
Rotational machining
Digit 4
Plane surface machining
Digit 5
Additional holes teeth and forming
Digit
6 7 8 9
0
1
2
3
4
5
6
7
8
9
Rotational
Nonrotational
L/D ≤ 0.5
0.5 < L/D < 3
L/D ≥ 3
With deviation L/D ≤ 2
With deviation L/D > 2
Special
A/B ≤ 3 A/C ≥ 4
A/B > 3
A/B ≤ 3 A/C < 4
Special
External shape element
Main shape
Main shape
Main shape
Main shape
Internal shape element
Rotational machining
Main bore and rotational machining
Machining of plane surfaces
Machining of plane surfaces
Machining of plane surfaces
Other holes and teeth
Other holes, teeth and forming
Other holes, teeth and forming
Dimensions
Material
Original shape of raw materials
Accuracy

Form code (digits 1-5) for rotational parts in the Opitz coding system

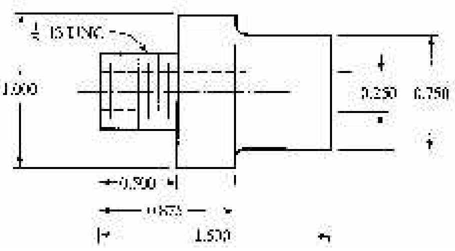


	Digit 1		Digit 2		Digit 3		Digit 4	Digit 5	
		Part class		External shape, external shape elements		Internal shape, internal shape elements	Plane surface machining		Auxiliary holes and gear teeth
0	Rotational parts	L/D ≤ 0.5		Smooth, no shape elements		No hole, no breakthrough	No surface machining	No gear teeth	No auxiliary hole
1		0.5 < L/D < 3	Stepped to one end or smooth	No shape elements	Smooth or stepped to one end	No shape elements	Surface plane and/or curved in one direction, external		Axial, not on pitch circle diameter
2		L/D ≥ 3		Thread		Thread	External plane surface related by graduation around the circle		Axial on pitch circle diameter
3				Functional groove		Functional groove	External groove and/or slot		Radial, not on pitch circle diameter
4			Stepped to both ends	No shape elements	Stepped to both ends	No shape elements	External spline (polygon)		Axial and/or radial and/or other direction
5				Thread		Thread	External plane surface and/or slot, external spline		Axial and/or radial on PCD and/or other directions
6	Nonrotational parts			Functional groove		Functional groove	Internal plane surface and/or slot	With gear teeth	Spur gear teeth
7				Functional cone		Functional cone	Internal spline (polygon)		Bevel gear teeth
8				Operating thread		Operating thread	Internal and external polygon, groove and/or slot		Other gear teeth
9				All others		All others	All others		All others

Example 1: A part coded 20801

- 2 - Parts has L/D ratio >= 3
- 0 - No shape element (external shape elements)
- 8 - Operating thread
- 0 - No surface machining
- 1 - Part is axial

Example 2: given the part design shown define the "form code" using the Opitz system



Step 1: The total length of the part is 1.75, overall diameter 1.25,

L/D = 1.4 (code 1)

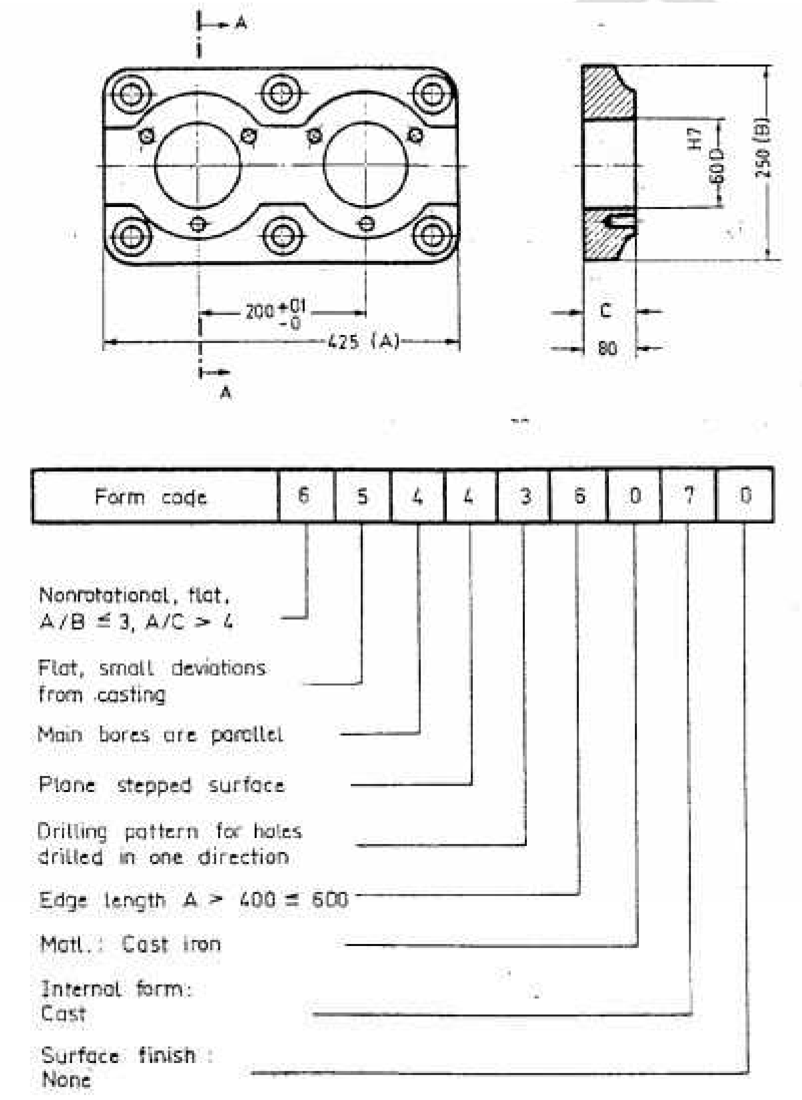
Step 2: External shape - a rotational part that is stepped on both with one thread (code 5)

Step 3: Internal shape - a through hole (code 1)

Step 4: By examining the drawing of the part (code 0)

Step 5: No auxiliary holes and gear teeth (code 0)

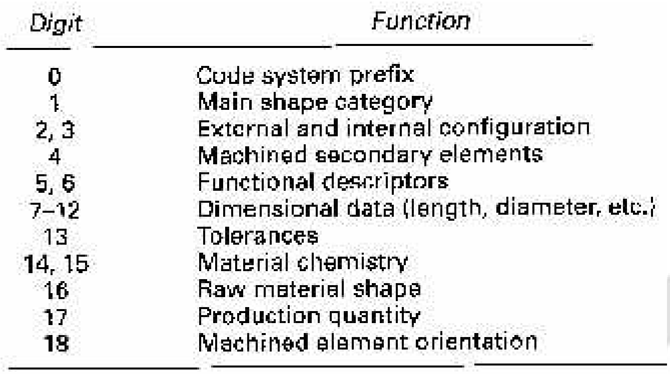
Code: 15100



Square cast-iron flange classified by the Opitz system.

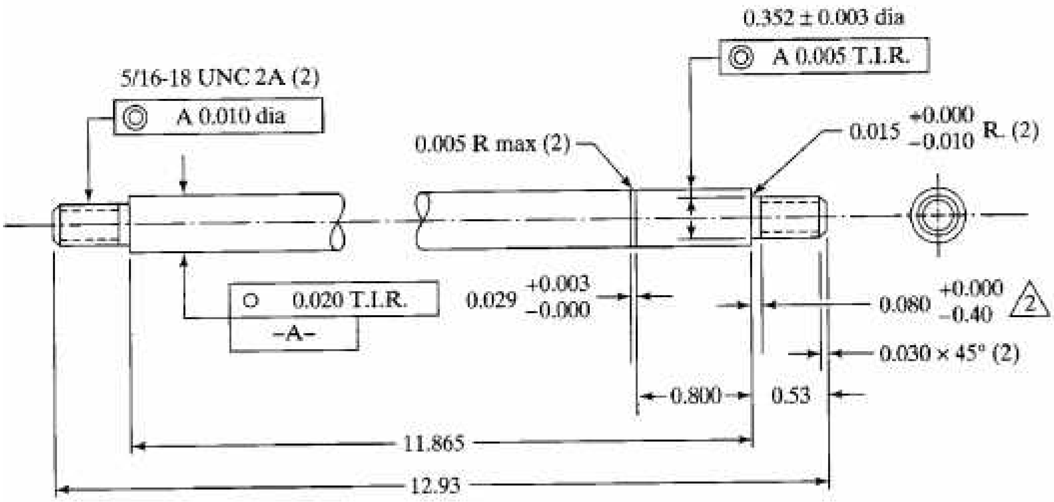
MultiClass – developed by the Organization for Industrial Research (OIR)

- First 18 digits of the Multiclass Classification and Coding System

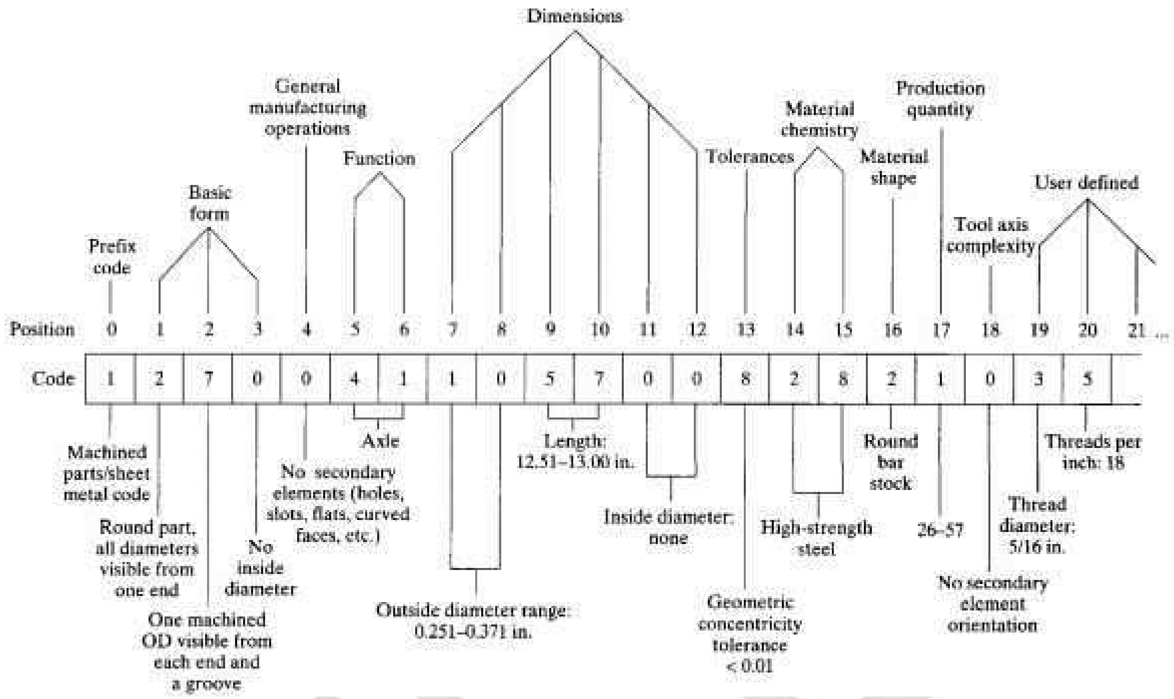


Digit	Function
0	Code system prefix
1	Main shape category
2, 3	External and internal configuration
4	Machined secondary elements
5, 6	Functional descriptors
7–12	Dimensional data (length, diameter, etc.)
13	Tolerances
14, 15	Material chemistry
16	Raw material shape
17	Production quantity
18	Machined element orientation

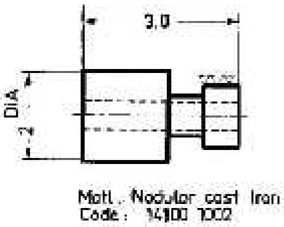
MultiClass Coding System example – the rotational part design

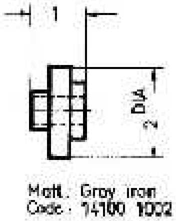


MultiClass code number for the rotational part



Possible ambiguity with a coding system





Benefits of a Well-Designed Classification and Coding System

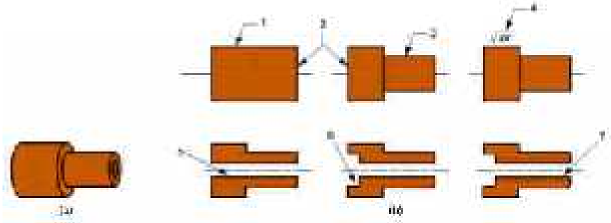
- Facilitates formation of part families
- Permits quick retrieval of part design drawings
- Reduces design duplication
- Promotes design standardization

- Improves cost estimating and cost accounting

- Facilitates NC part programming by allowing new parts to use the same part program as existing parts in the same family
- Computer-aided process planning (CAPP) becomes feasible

Composite Part Concept

- A *composite part* for a given family is a hypothetical part that includes all of the design and manufacturing attributes of the family
- In general, an individual part in the family will have some of the features of the family, but not all of them
- A production cell for the part family would consist of those machines required to make the composite part
- Such a cell would be able to produce any family member, by omitting operations corresponding to features not possessed by that part



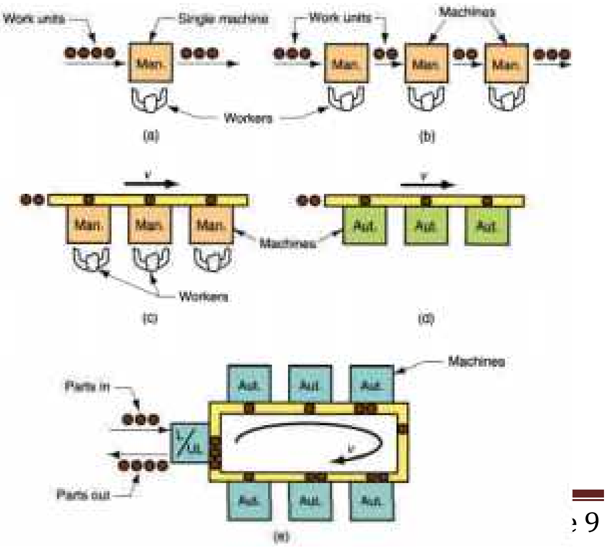
- Composite part concept: (a) the composite part for a family of machined rotational parts, and (b) the individual features of the composite part

Composite Part Features and Corresponding Manufacturing Operations

Design feature	Corresponding operation
1.External cylinder	Turning
2.Face of cylinder	Facing
3.Cylindrical step	Turning
4.Smooth surface	External cylindrical grinding
5.Axial hole	Drilling
6.Counterbore	Counterboring
7.Internal threads	Tapping

Machine Cell Designs (Types of GT cells:)

(a) Single machine
(b) Multiple machines with manual handling
(c) Multiple machines with mechanized handling
(d) Flexible manufacturing cell
(e) Flexible manufacturing system



Benefits of Group Technology

- Standardization of tooling, fixtures, and setups is encouraged
- Material handling is reduced
    - Parts are moved within a machine cell rather than entire factory
- Process planning and production scheduling are simplified
- Work-in-process and manufacturing lead time are reduced
- Improved worker satisfaction in a GT cell
- Higher quality work

Problems in Group Technology

- Identifying the part families (the biggest problem)
    - If the plant makes 10,000 different parts, reviewing all of the part drawings and grouping the parts into families is a substantial task
- Rearranging production machines in the plant into the appropriate machine cells
    - It takes time to plan and accomplish this rearrangement, and the machines are not producing during the changeover

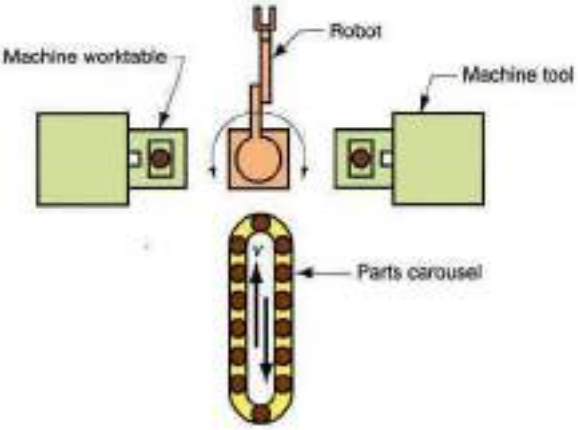
Unit-4(FMS&AVGs)

Flexible Manufacturing System

- A highly automated GT machine cell, consisting of a group of processing stations (usually CNC machine tools), interconnected by an automated material handling and storage system, and controlled by an integrated computer system
- The FMS relies on the principles of GT
  - No manufacturing system can produce an unlimited range of products
  - An FMS is capable of producing a single part family or a limited range of part families

Flexibility Tests in an Automated Manufacturing System

- Automated manufacturing cell with two machine tools and robot. Is it a flexible cell?



- To qualify as being flexible, a manufacturing system should satisfy the following criteria (“yes” answer for each question):

1.Can it process different part styles in a non-batch mode?

2.Can it accept changes in production schedule?

3.Can it respond gracefully to equipment malfunctions and breakdowns?

4.Can it accommodate introduction of new part designs?

If the automated system does not meet these four tests, it should not be classified as a flexible manufacturing or cell.

Is the Robotic Work Cell Flexible?

1.Can it machine different part configurations in a mix rather than in batches?

2.Can production schedule and part mix be changed?

3.Can it operate if one machine breaks down?

- Example: while repairs are being made on the broken machine, can its work be temporarily reassigned to the other machine?

4.As new part designs are developed, can NC part programs be written off-line and then downloaded to the system for execution?

This fourth capability also requires that the tooling in the CNC machines as well as the end effecter of the robot are suited to the new part design.

FMS Components

- Hardware components

  Workstations - CNC machines in a machining type system

  Material handling system - means by which parts are moved between stations

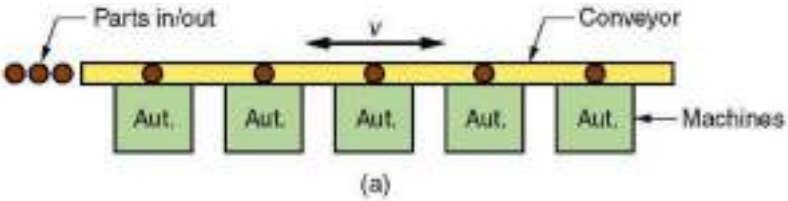
  Central control computer - to coordinate the activities of the components so as to achieve a smooth overall operation of the system
- Software and control functions
- Human labor

Five Types of FMS Layouts

1.In-line
2.Loop
3.Ladder
4.Open field
5.Robot-centered cell

- The basic layout of the FMS is established by the material handling system

Three of the five FMS layout types: (a) in-line

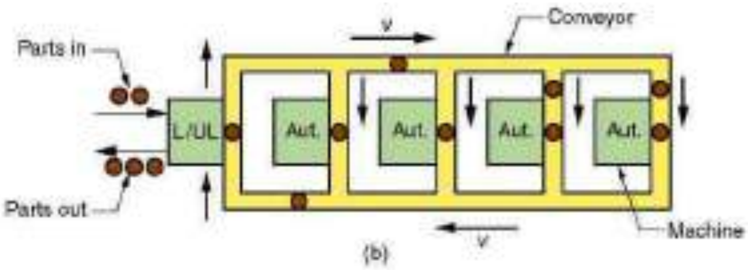


Key: Aut = automated station; L/UL = load/unload station;

Insp = inspection station; AGV = automated guided vehicle;

AGVS = automated guided vehicle system

(b) Ladder layout

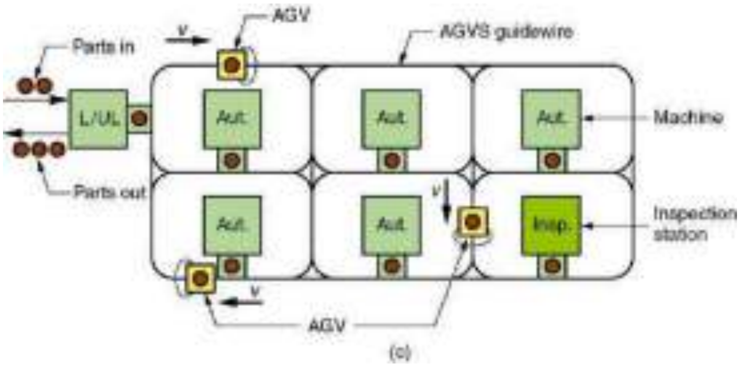


Key: Aut = automated station; L/UL = load/unload station;

Insp = inspection station; AGV = automated guided vehicle;

AGVS = automated guided vehicle system

(c) open field



•Key: Aut = automated station; L/UL = load/unload station;

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Typical Computer Functions in a FMS

☐*NC part programming* - development of NC programs for new parts introduced into the system

☐*Production control* - product mix, machine scheduling, and other planning functions

☐*NC program download* - part program commands must be downloaded to individual stations

☐*Machine control* - individual workstations require controls, usually CNC

More Computer Functions in a FMS

Workpart control - monitor status of each workpart in the system, status of pallet fixtures, orders on loading/unloading pallet fixtures

Tool management - tool inventory control, tool status relative to expected tool life, tool changing and resharpening, and transport to and from tool grinding

Transport control - scheduling and control of work handling system

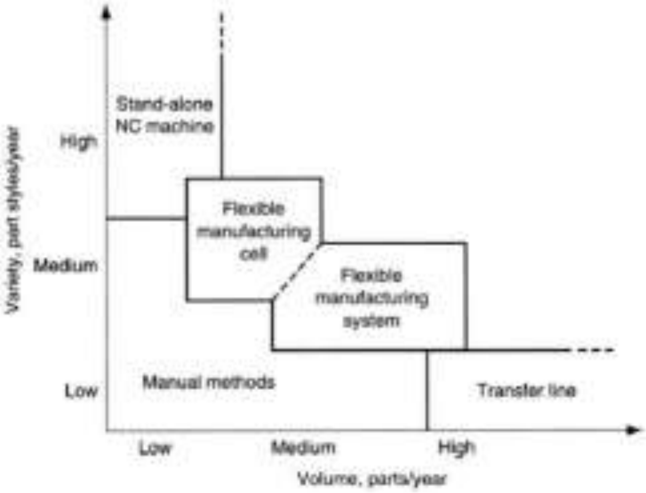
System management - compiles management reports on performance (utilization, piece counts, production rates, etc.)

Duties Performed by Human Labor

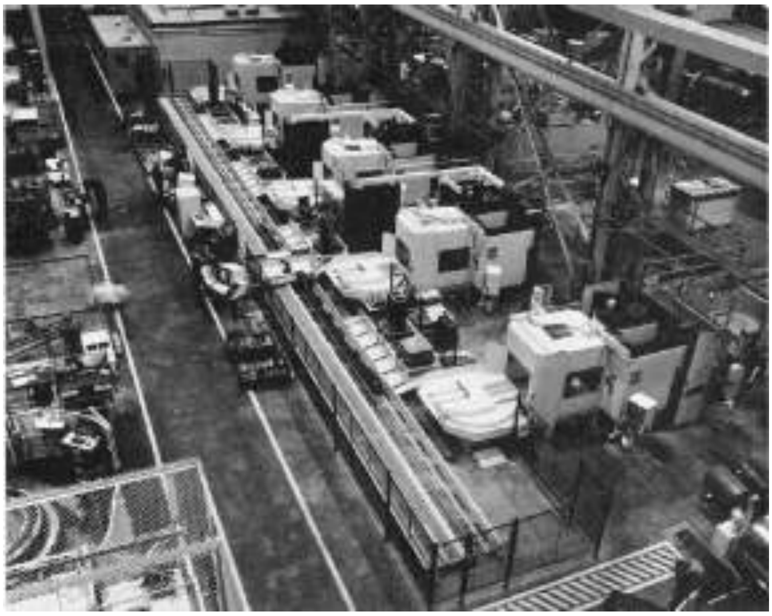
- Loading and unloading parts from the system
- Changing and setting cutting tools
- Maintenance and repair of equipment
- NC part programming
- Programming and operating the computer system
- Overall management of the system

FMS Applications

- Machining – most common application of FMS technology
- Assembly
- Inspection
- Sheet metal processing (punching, shearing, bending, and forming)
- Forging



Application characteristics of flexible manufacturing systems and cells relative to other types of production systems



A five station FMS (courtesy of Cincinnati Milacron)

Typical FMS Benefits

- Higher machine utilization than a conventional machine shop due to better work handling, off-line setups, and improved scheduling
- Reduced work-in-process due to continuous production rather than batch production
- Lower manufacturing lead times
- Greater flexibility in production scheduling