

UNIT III

GROUP TECHNOLOGY AND FMS

GROUP TECHNOLOGY

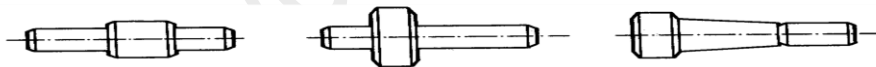
Group technology is a manufacturing technique and philosophy to increase production efficiency by exploiting the “underlying sameness” of component shape, dimensions, process route, etc.

WHY GROUP TECHNOLOGY?

1. Average lot size decreasing
2. part variety increasing
3. increased variety of materials
4. with diverse properties
5. requirements for closer
6. Tolerances

PART FAMILIES (Similarity groupings are called Part Families)

- A *part family* is a collection of parts that are similar either because of geometric shape and size or because similar processing steps are required in their manufacture.
- The parts within a family are different, but their similarities are close enough to merit their inclusion as members of the part family.

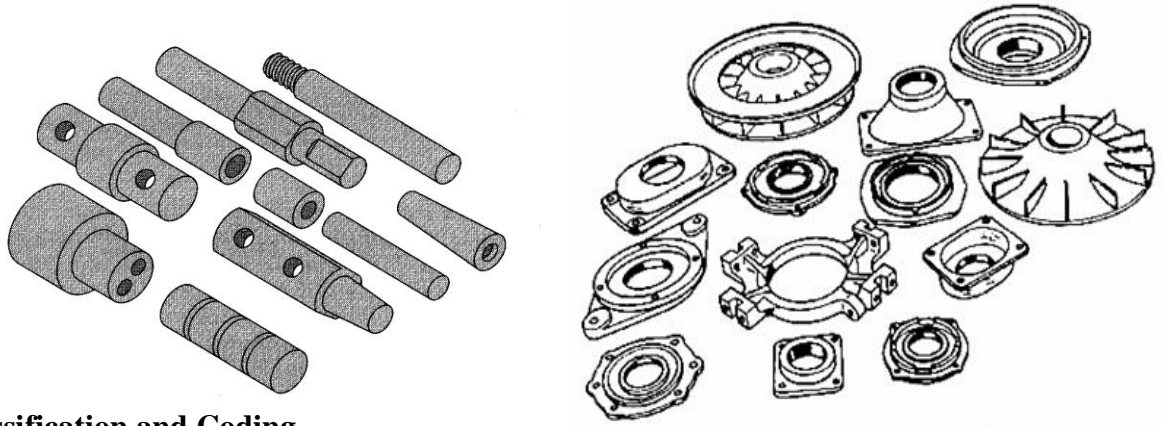


GROUPING PART FAMILIES

- There are three general methods for solving part families grouping. All the three are time consuming and involve the analysis of much of data by properly trained personnel.
- The three methods are:
 - Visual inspection.
 - Parts classification and coding.
 - Production flow analysis.

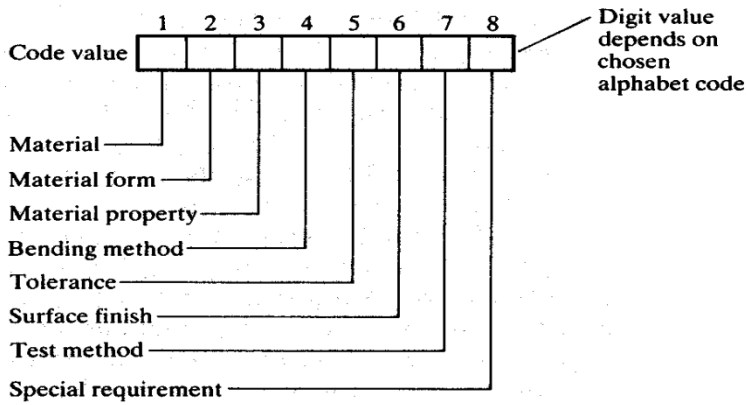
1- Visual Inspection Method

The *visual inspection method* is the least sophisticated and least expensive method. It involves the classification of parts into families by looking at either the physical parts or their photographs and arranging them into groups having similar features.

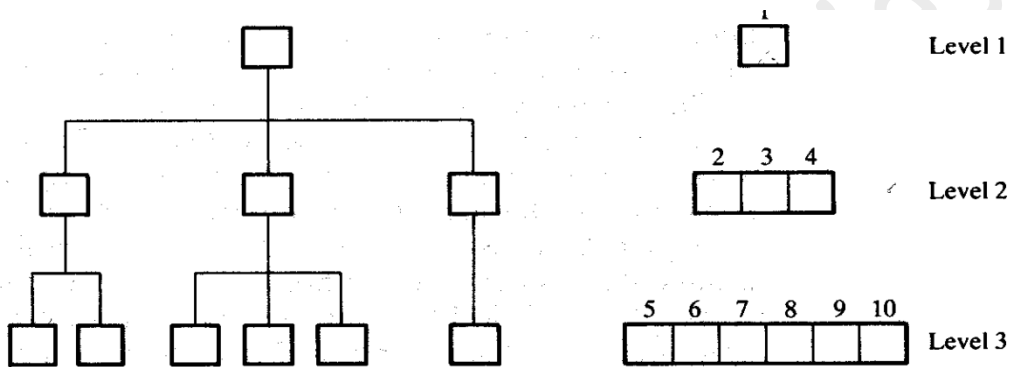


2- Parts classification and Coding

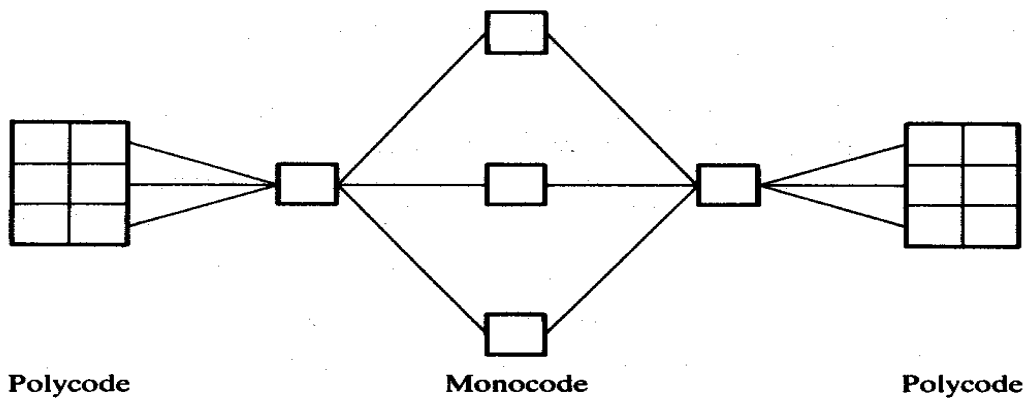
- In parts classification and coding, similarities among parts are identified, and these similarities are related in a coding system.
- Two categories of part similarities can be distinguished:
 1. *Design attributes*, which concerned with part characteristics such as geometry, size and material.
 2. *Manufacturing attributes*, which consider the sequence of processing steps required to make a part.
- Reasons for using a classification and coding system:
 - *Design retrieval*. A designer faced with the task of developing a new part can use a design retrieval system to determine if a similar part already exist. A simple change in an existing part would take much less time than designing a whole new part from scratch.
 - *Automated process planning*. The part code for a new part can be used to search for process plans for existing parts with identical or similar codes.
 - *Machine cell design*. The part codes can be used to design machine cells capable of producing all members of a particular part family, using the composite part concept.
- A part coding system consists of a sequence of symbols that identify the part's design and/or manufacturing attributes.
- The symbols are usually alphanumeric, although most systems use only numbers.
- The three basic coding structures are:
 1. *Chain-type structure*, also 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 the preceding symbols.



2. **Hierarchical structure**, also known as a *monocode*, in which the interpretation of each successive symbol depends on the value of the preceding symbols.

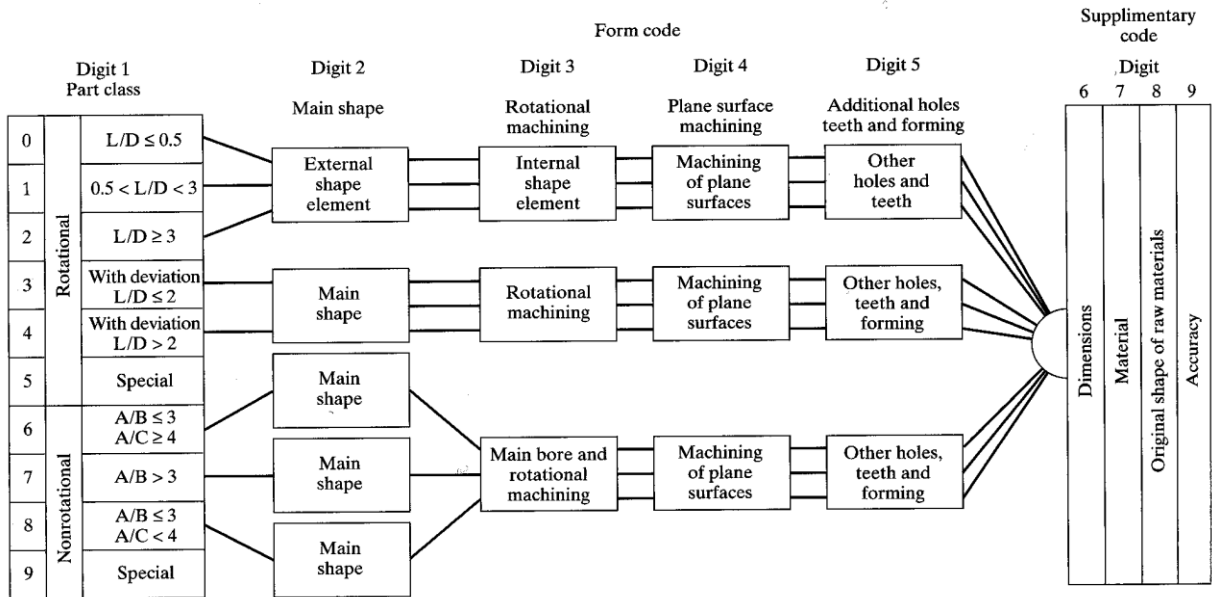


3. **Hybrid structure**, a combination of hierarchical and chain-type structures.



Opitz Classification and Coding System

- It is intended for machined parts and uses the following digits sequence
 - Form Code 1 2 3 4 5 *for design attributes*
 - Supplementary Code 6 7 8 9 *for manufacturing attributes*
 - Secondary Code A B C D *for production operation type & sequence*

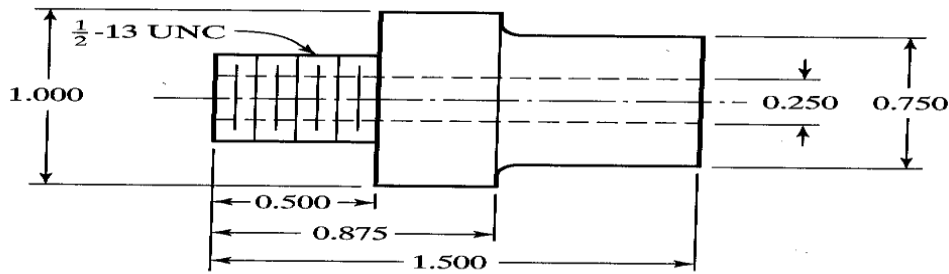


Digits (1-5) for Rotational parts in the Optiz System

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

Example: Optiz part coding System

- Given the rotational part design below, determine the form code in the Optiz parts classification and coding system.



Solution

- *Length-to-diameter ratio:* $L/D = 1.5$ Digit 1 = 1
- *External shape:* both ends stepped with screw thread on one end Digit 2 = 5
- *Internal shape:* part contains a through hole Digit 3 = 1
- *Plane surface machining:* none Digit 4 = 0
- *Auxiliary holes, gear teeth, etc.:* none Digit 5 = 0

The form code in the Optiz system is 15100

3- Production Flow Analysis (PFA)

- Production flow analysis (PFA) is a method for identifying part families and associated machine groupings that uses the information contained on process plans rather than on part drawings.
- Workparts with identical or similar process plans are classified into part families. These families can then be used to form logical machine cells in a group technology layout.
- The procedure in production flow analysis must begin by defining the scope of the study, which means deciding on the population of parts to be analyzed.
- The procedure of Production flow analysis (PFA) consists of the following steps:
 - *Data Collection.* The minimum data needed in the analysis are the part number and operation sequence, which is obtained from process plans.
 - *Sortation of process plans.* A sortation procedure is used to group parts with identical process plans.
 - *PFA Chart.* The processes used for each group are then displayed in a PFA chart as shown below.

Machines	Parts								
	A	B	C	D	E	F	G	H	I
1	1			1				1	
2					1				1
3			1		1				1
4		1				1			
5	1							1	
6			1						1
7		1				1	1		

4. Clustering Analysis. From the pattern of data in the PFA chart, related groupings are identified and rearranged into a new pattern that brings together groups with similar machine sequences.

Machines	Parts								
	C	E	I	A	D	H	F	G	B
3	1	1	1						
2		1	1						
6	1		1						
1				1	1	1			
5				1		1			
7							1	1	1
4							1		1

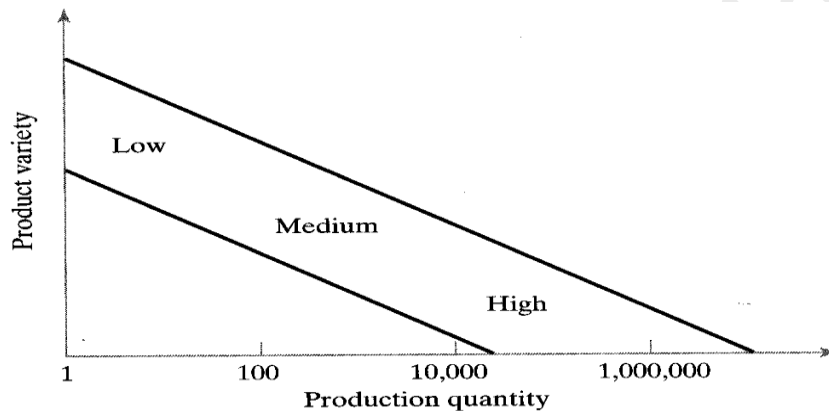
BENEFITS OF GT

- Facilitates formation of part families and machine cells
- Quick retrieval of designs, drawings, & process plans
- Reduces design duplication
- Provides reliable workpiece statistics
- Facilitates accurate estimation of machine tool requirements and logical machine loadings
- Permits rationalization of tooling setups, reduces setup time, and reduces production throughput time
- Allows rationalization and improvement in tool design
- Aids production planning and scheduling procedures
- Improves cost estimation and facilitates cost accounting procedures

- Provides for better machine tool utilization and better use of tools, fixtures, & people
- Facilitates NC part programming.

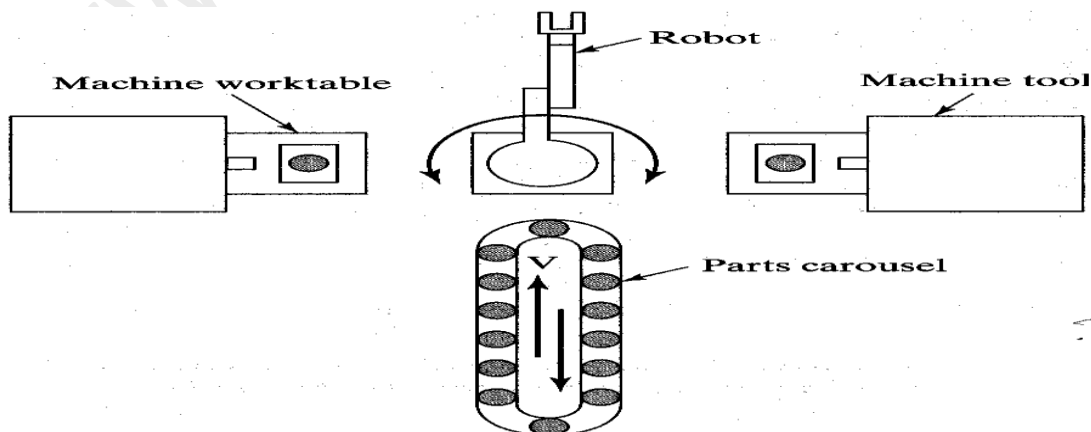
INTRODUCTION TO FLEXIBLE MANUFACTURING SYSTEM (FMS)

- A *flexible manufacturing system (FMS)* is a highly automated GT machine cell, consisting of a group or processing workstations (usually CNC machine tools), interconnected by an automated material handling and storage system, and controlled by a distributed computer system.
- The reason the FMS is called *flexible* is that it is capable of processing a variety of different part styles simultaneously at the various workstations, and the mix of part styles and quantities of production can be adjusted in response to changing demand patterns.
- The FMS is most suited for the mid-variety, mid-volume production range



What Make It Flexible?

- Three capabilities that a manufacturing system must possess to be flexible.
 1. The ability to identify and distinguish among the different part styles processed by the system.
 2. Quick changeover of operating instructions, and
 3. Quick changeover of physical setup.



Tests of Flexibility

- To qualify as being flexible, a manufacturing system should satisfy several criteria. The following are four reasonable tests of flexibility in an automated manufacturing system:
 - Part variety test.* Can the system process different part styles in a nonbatch mode?.
 - Schedule change test.* Can the system readily accept changes in production schedule, and changes in either part mix or production quantity.
 - Error recovery test.* Can the system recover quickly from equipment breakdowns, so that the production is not completely disrupted.
 - New part test.* Can new part designs be introduced into the existing product mix with relative ease.
- If the answer to all of these questions is “YES” for a given manufacturing system, then the system can be considered flexible.

Types of Flexibility in Manufacturing

<i>Flexibility Type</i>	<i>Definition</i>	<i>Depends on Factors Such As:</i>
<i>Machine flexibility</i>	Capability to adapt a given machine (workstation) in the system to a wide range of production operations and part styles. The greater the range of operations and part styles, the greater the machine flexibility.	Setup or changeover time. Ease of machine reprogramming (ease with which part programs can be downloaded to machines). Tool storage capacity of machines. Skill and versatility of workers in the system.
<i>Production flexibility</i>	The range or universe of part styles that can be produced on the system.	Machine flexibility of individual stations. Range of machine flexibilities of all stations in the system.
<i>Mix flexibility</i>	Ability to change the product mix while maintaining the same total production quantity; that is, producing the same parts only in different proportions.	Similarity of parts in the mix. Relative work content times of parts produced. Machine flexibility.
<i>Product flexibility</i>	Ease with which design changes can be accommodated. Ease with which new products can be introduced.	How closely the new part design matches the existing part family. Off-line part program preparation. Machine flexibility.
<i>Routing flexibility</i>	Capacity to produce parts through alternative workstation sequences in response to equipment breakdowns, tool failures, and other interruptions at individual stations.	Similarity of parts in the mix. Similarity of workstations. Duplication of workstations. Cross-training of manual workers. Common tooling.
<i>Volume flexibility</i>	Ability to economically produce parts in high and low total quantities of production, given the fixed investment in the system.	Level of manual labor performing production. Amount invested in capital equipment.
<i>Expansion flexibility</i>	Ease with which the system can be expanded to increase total production quantities.	Expense of adding workstations. Ease with which layout can be expanded. Type of part handling system used. Ease with which properly trained workers can be added.

Comparison of Four Criteria of Flexibility in a Manufacturing System and the Seven Types of Flexibility

<i>Flexibility Tests or Criteria</i>	<i>Type of Flexibility (Table 16.1)</i>
1. Part variety test. Can the system process different part styles in a non-batch mode?	Machine flexibility Production flexibility
2. Schedule change test. Can the system readily accept changes in production schedule, changes in either part mix or production quantities?	Mix flexibility Volume flexibility Expansion flexibility
3. Error recovery test. Can the system recover gracefully from equipment malfunctions and breakdowns, so that production is not completely disrupted?	Routing flexibility
4. New part test. Can new part designs be introduced into the existing product mix with relative ease?	Product flexibility

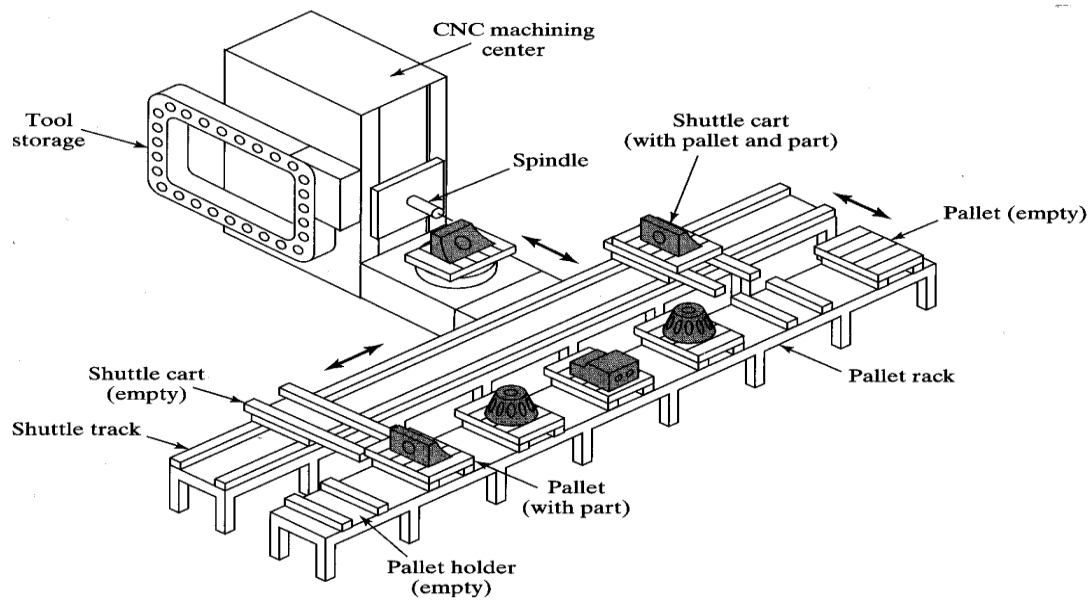
Number of Machines

- Flexible manufacturing systems can be distinguished according to the number of machines in the system. The following are typical categories:
 - Single machine cell (Type I A)
 - Flexible manufacturing cell (usually type II A, sometimes type III A)
 - Flexible manufacturing system (usually Type II A, sometimes type III A)

1. Single Machine Cell (SMC)

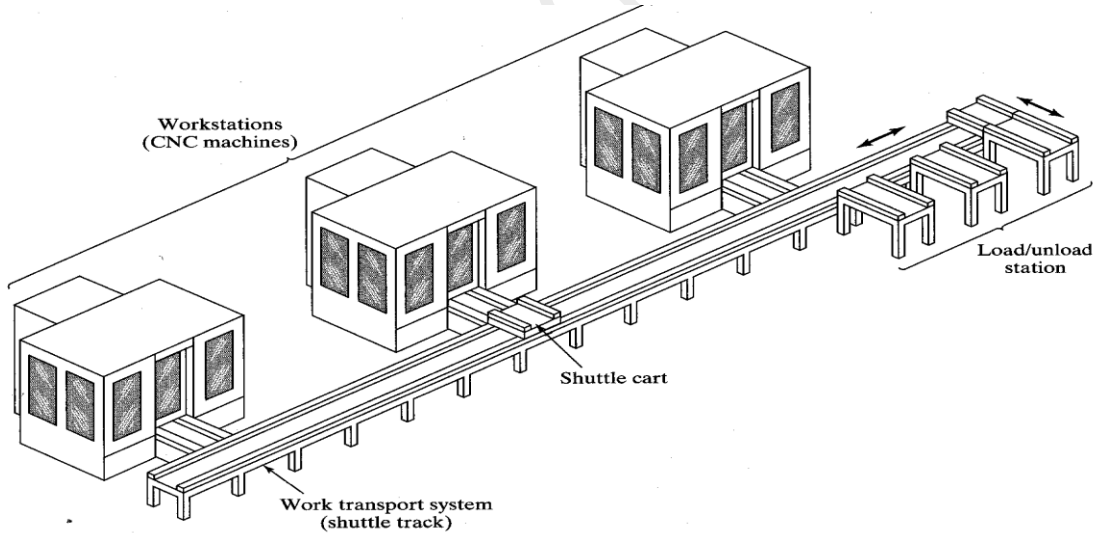
A single machine cell consists of one CNC machining center combined with a parts storage system for unattended operation.

Completed parts are periodically unloaded from the parts storage unit, and raw workparts are loaded into it



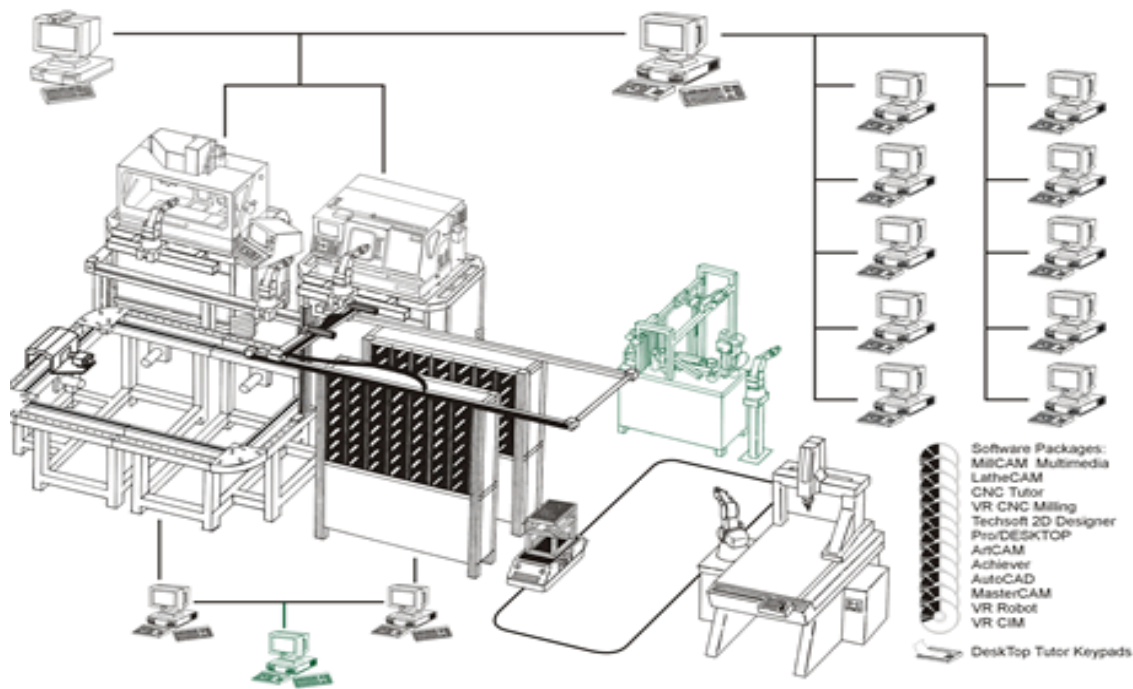
Flexible Manufacturing Cell (FMC)

- A flexible manufacturing cell consists of two or three processing workstations (typically CNC machining centers) plus a part handling system.
- The part handling system is connected to a load/unload station.

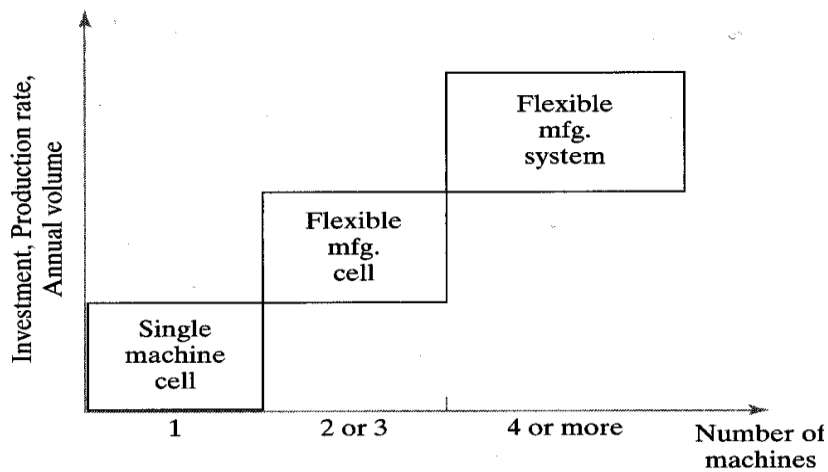


Flexible Manufacturing System (FMS)

- A flexible manufacturing system has four or more processing workstations connected mechanically by a common part handling system and electronically by a distributed computer system.



Some of the distinguishing characteristics of the three categories of flexible manufacturing cells and systems are summarized in figure below



Flexibility Criteria Applied to the Three Types of Manufacturing Cells and Systems

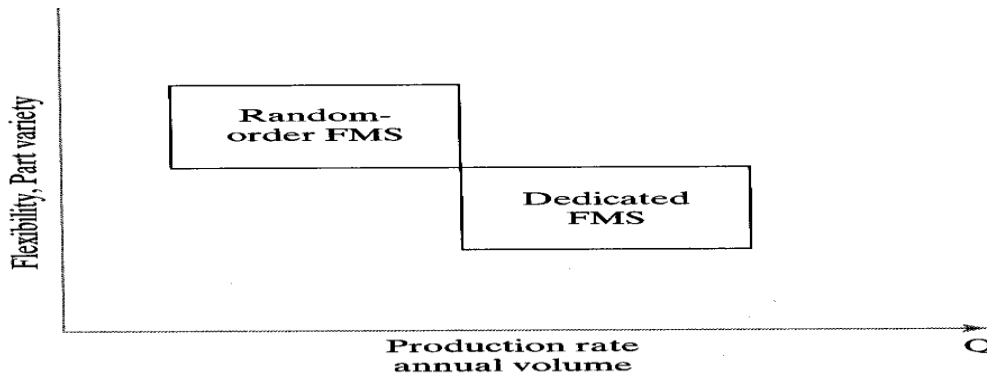
Flexibility Criteria (Tests of Flexibility)

<i>System Type</i>	<i>1. Part Variety</i>	<i>2. Schedule Change</i>	<i>3. Error Recovery</i>	<i>4. New Part</i>
Single machine cell (SMC)	Yes, but processing is sequential, not simultaneous.	Yes	Limited recovery due to only one machine.	Yes
Flexible manufacturing cell (FMC)	Yes, simultaneous production of different parts.	Yes	Error recovery limited by fewer machines than FMS.	Yes
Flexible manufacturing system (FMS)	Yes, simultaneous production of different parts.	Yes	Machine redundancy minimizes effect of machine breakdowns.	Yes

Level of Flexibility

- Another classification of FMS is according to the level of flexibility designed into the system. Two categories are distinguished here:
 - Dedicated FMS
 - Random-order FMS
- A **dedicated FMS** is designed to produce a limited variety of part styles, and the complete universe of parts to be made on the system is known in advance.
- A **random-order FMS** is more appropriate when
 - the part family is large,
 - there are substantial variations in part configurations,
 - there will be new part designs introduced into the system and engineering changes in parts currently produced, and
 - the production schedule is subjected to change from day-to-day.

A comparison of dedicated and random-order FMS types

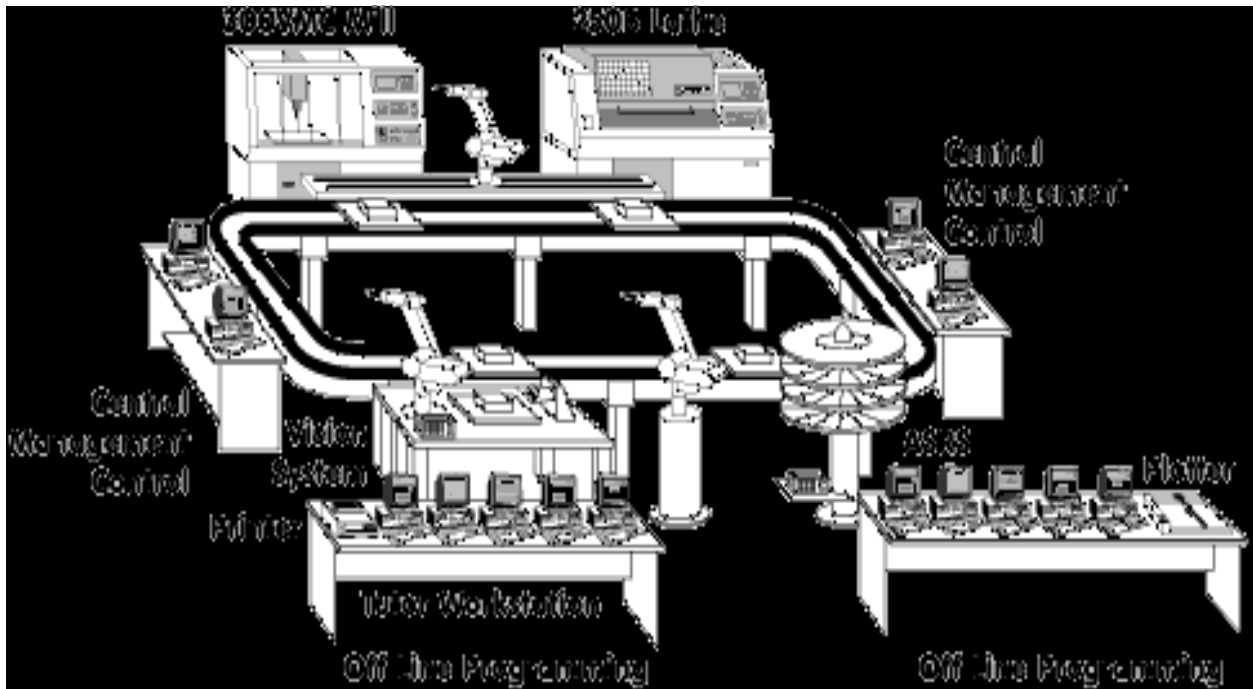


Flexibility Criteria Applied to Dedicated FMS and Random-order FMS

System Type	Flexibility Criteria (Tests of Flexibility)			
	1. Part Variety	2. Schedule Change	3. Error recovery	4. New part
Dedicated FMS	Limited. All parts known in advance.	Limited changes can be tolerated.	Limited by sequential processes.	No. New part introductions difficult.
Random-order FMS	Yes. Substantial part variations possible.	Frequent and significant changes possible.	Machine redundancy minimizes effect of machine breakdowns.	Yes. System designed for new part introductions.

Components of FMS

- There are several basic components of an FMS:
 1. Workstations.
 2. Material handling and storage systems.
 3. Computer control system.
 4. People are required to manage and operate the system



WORKSTATIONS

- Following are the types of workstations typically found in an FMS:
 1. Load/Unload Stations.
 2. Machining Stations.
 3. Other processing Stations. (punching, shearing, welding, etc.)
 4. Assembly Station.
 5. Other Stations and Equipment. (Inspection, Vision, etc)

Material Handling and Storage System

- *Functions of the Handling System*
 1. Independent movement of workparts between stations.
 2. Handle a variety of workpart configurations.
 3. Temporary storage.
 4. Convenient access for loading and unloading workparts.
 5. Compatible with computer control.

- *Material Handling Equipment*

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

- Primary handling system establishes the basic layout of the FMS and is responsible for moving workparts between stations in the system. (Conveyor)

Material Handling and Storage System

2. Secondary handling system consists of transfer devices, automatic pallet changing, and similar mechanisms located at the workstations in the FMS.

- The function of the secondary handling system is to transfer work from the primary system to the machine tool or other processing station and to position the parts with sufficient accuracy and repeatability to perform the process or assembly operation.

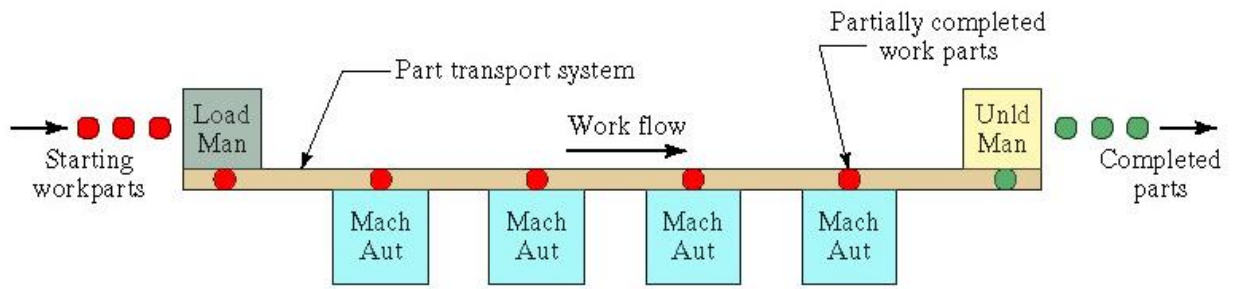
FMS Layout Configurations

The material handling system establishes the FMS layout. Most layout configurations found in today's FMS are:

1. *In-line layout*
2. *Loop layout*
3. *Rectangular layout*
4. *Ladder Layout*
5. *Open Field*
6. *Robot Centred*

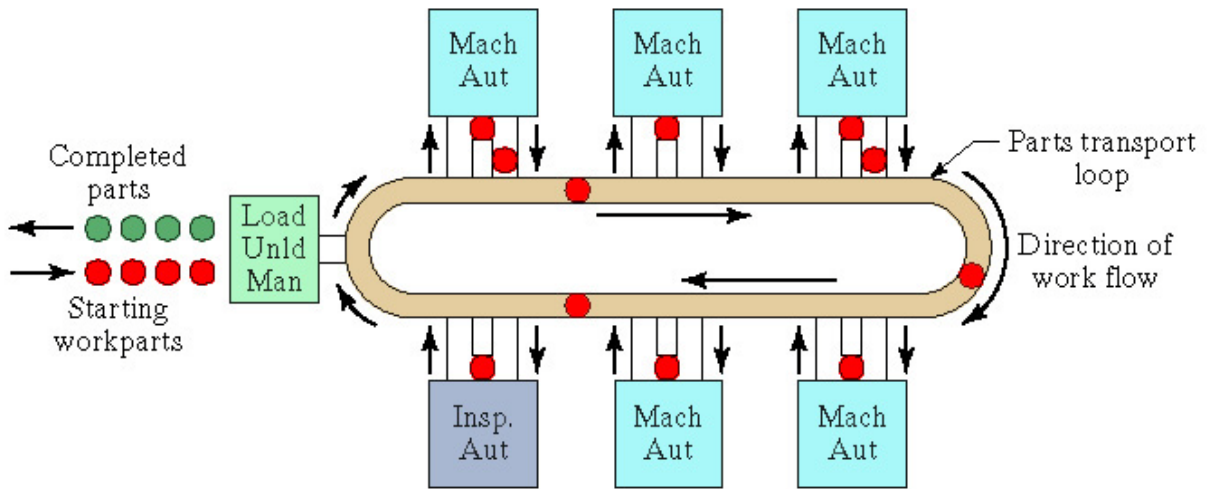
In-Line Layout

In-line The machines and handling system are arranged in a straight line. In Figure parts progress from one workstation to the next in a well-defined sequence with work always moving in one direction and with no back-flow. Similar operation to a transfer line , except the system holds a greater variety of parts. Routing flexibility can be increased by installing a linear transfer system with bi-directional flow, as shown in Figure . Here a secondary handling system is provided at each workstation to separate most of the parts from the primary line. Material handling equipment used: in-line transfer system; conveyor system; or rail-guided vehicle system.



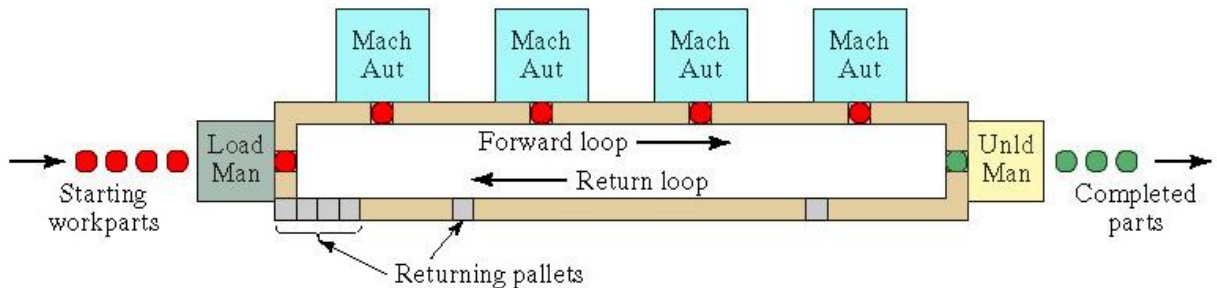
Loop

Workstations are organized in a loop that is served by a looped parts handling system. In Figure parts usually flow in one direction around the loop with the capability to stop and be transferred to any station. Each station has secondary handling equipment so that part can be brought-to and transferred-from the station work head to the material handling loop. Load/unload stations are usually located at one end of the loop.



Rectangular

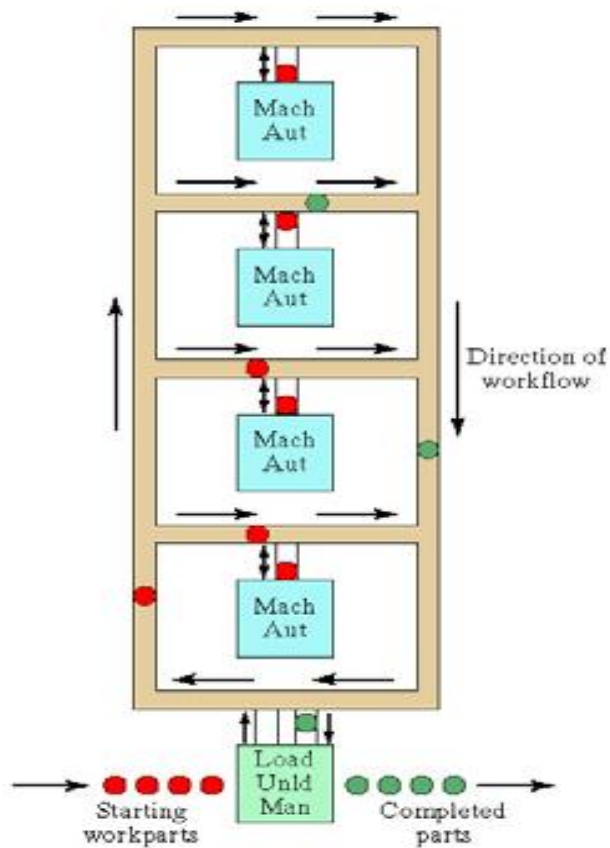
An alternative form is the rectangular layout shown in Figure . This arrangement allows for the return of pallets to the starting position in a straight line arrangement.



Ladder

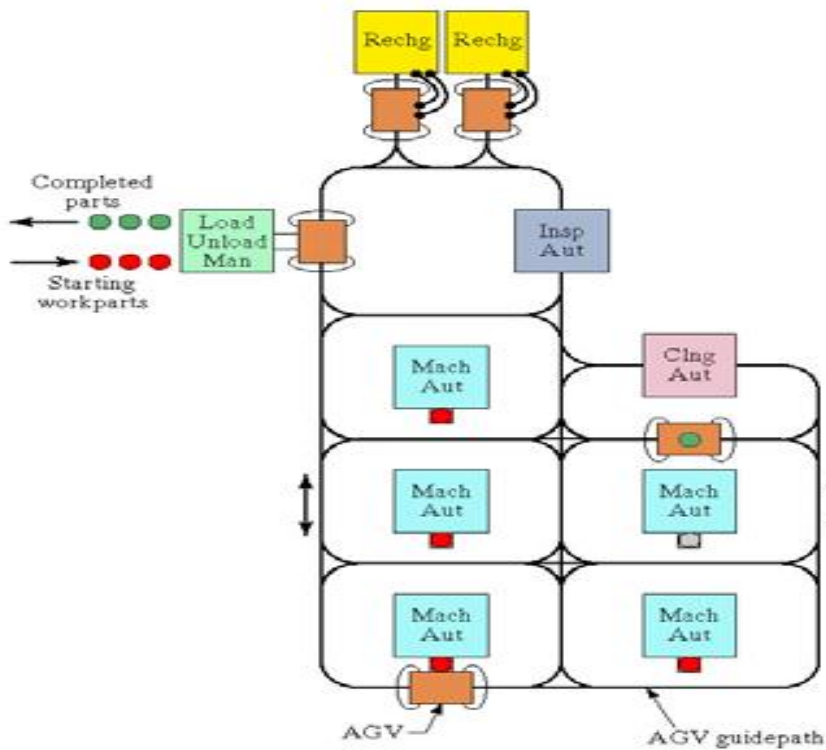
- This consists of a loop with rungs upon which workstations are located. The rungs increase the number of possible ways of getting from one machine to the next, and obviates the need for a secondary material handling system. It reduces average travel

distance and minimizes congestion in the handling system, thereby reducing transport time between stations. See Figure.



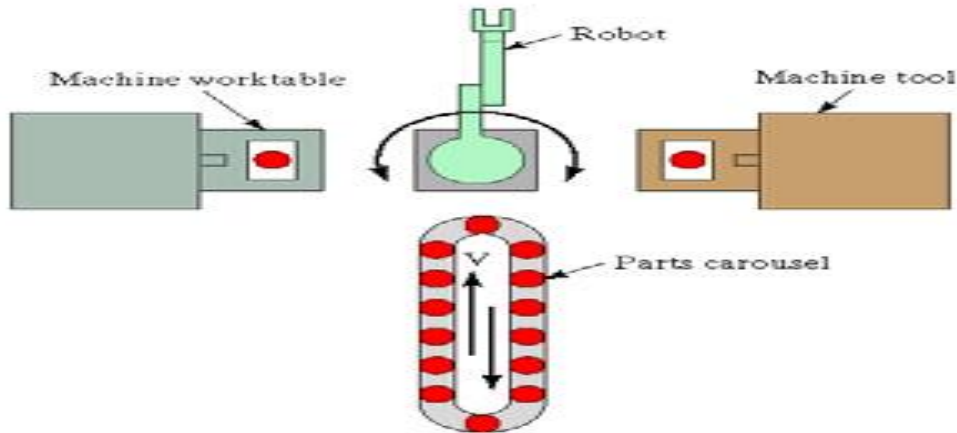
Open Field

Consists of multiple loops and ladders, and may include sidings also. This layout is generally used to process a large family of parts, although the number of different machine types may be limited, and parts are usually routed to different workstations—depending on which one becomes available first. See Figure



Robot Centered

- This layout uses one or more robots as the material handling system (see Figure)



Computer Control System

- The FMS includes a distributed computer system that is interfaced to
 - the workstations,
 - Material handling system, and
 - Other hardware components.
- A typical FMS computer system consists of a central computer and microcomputers.

- Microcomputers controlling the individual machines and other components.
- The central computer coordinates the activities of the components to achieve smooth overall operation of the system
- **Production control**—management of the mix and rate at which various parts are launched into the system is important; alongside data input of a number of essential metrics, such as: daily desired production rates, number of raw workparts available, work-in-progress etc.
- **Traffic control**—management of the primary handling system is essential so that parts arrive at the right location at the right time and in the right condition
- **Shuttle control**—management of the secondary handling system is also important, to ensure the correct delivery of the workpart to the station's workhead
- **Workpiece monitoring**—the computer must monitor the status of each cart or pallet in the primary and secondary handling systems, to ensure that we know the location of every element in the system
- **Tool control**—this is concerned with managing tool location (keeping track of the different tools used at different workstations, which can be a determinant on where a part can be processed), and tool life (keeping track on how much usage the tool has gone through, so as to determine when it should be replaced)
- **Performance monitoring and reporting**—the computer must collect data on the various operations on-going in the FMS and present performance findings based on this
- **Diagnostics**—the computer must be able to diagnose, to a high degree of accuracy, where a problem may be occurring in the FMS

HUMAN RESOURCES

- Human are needed to manage the operations of the FMS. Functions typically performed by human includes:
 - Loading raw work parts into the system,
 - Unloading finished parts (or assemblies) from the system,
 - Changing and setting tools,
 - Equipment maintenance and repair,
 - NC part programming in a machining system, and
 - Programming and operation the computer system.

Flexible Manufacturing System Planning and Implementation Issues

We consider FMS planning and implementation under two heading here:

1. Planning and design issues, and
2. Operational issues.

FMS Planning Issues

- **Part family considerations**

A choice has to be made regarding group technology, and the part family to be produced on the FMS. The FMS cannot be completely flexible, and so cannot handle any part whatsoever; there must be some consideration on the creation of a composite part, with all possible physical attributes of the parts that may be processed in the FMS.

- **Processing requirements**

Once the entire range of possible parts to be processed are known, we must use this information to help choose associated processing requirements for each part, and thus the type of equipment that should be used to process the parts.

- **Physical characteristics of the work parts**

Size and weight of work parts determine size of the machines required to process the parts. It also determines the size of the material handling system needed.

- **Production volume**

Production quantities must be determined, as these tell us how many machines of each type will be required.

- **Design issues for FMSsTypes of workstations**

Workstation choices have to be made, depending on part processing requirements. We must consider position and use of load and unload stations also.

- **Variations in process routings and FMS layout**

If part processing variations are minimal, we may decide to use an in-line flow; if part processing variations are high, we may instead opt for a loop flow, or higher still, for an open field layout.

- **Material handling system**

We must select an appropriate primary and secondary material handling system to suit the layout chosen.

- **Work-in-process and storage capacity**

Determining an appropriate level of WIP allowed is important, as it affects the level of utilization and efficiency of the FMS. Storage capacity must be compatible with the level of WIP chosen.

- **Tooling**

We must determine the number and type of tools required at each workstation. How much duplication of tooling should occur at workstations? Duplication allows for efficient re-routing in the system should breakdowns

- **Pallet fixtures**

For non-rotational parts, selection of a few types of pallet fixtures is important. Factors that influence the decision include: levels of WIP chosen, and differences in part style and size.

Operational Issues

1. Scheduling and dispatching

Scheduling must be considered for the FMS, based upon the Master Production Schedule. Dispatching is concerning with launching the parts into the system at the appropriate times.

2. Machine loading

We must choose how to allocate specific parts to specific machines in the system, based upon their tooling resources and routing considerations of the FMS.

3. Part routing

Routing decisions involve the choice of a route that should be followed by a part in the system. Consideration should be given to other parts travelling in the system, traffic management etc.

4. Part grouping

Part types must be grouped for simultaneous production, given limitations on available tooling and other resources at workstations.

Architecture of FMS

Typical elements of FMS

- Versatile NC machines equipped with automatic tool changing and inprocess gauging, with capability to carry out a variety of operations
- An automated Material Handling System (MHS) to move parts and tools under the control of a central MHS controller. The MHS may comprise conveyers, carts, individual robots, AGVS, or a combination of these elements

- Load/unload station through which the entry and exit of the parts occur. Entering parts are fixtured and loaded onto pallets, and departing parts are defixtured at these stations
- Inspection stations equipped with coordinate measuring machines
- Storage in the form of local buffers adjacent to the machines and/or centralized automatic storage and retrieval system (ASRS) for raw and semi-finished workpieces
- Tool magazines on the machine tool and a centralized tool store provide tool storage
- A Hierarchical Control System (HCS) to coordinate the working of FMS
 - HCS coordinate the working of machines, tools, and MHS and the movement of workpieces
 - HCS generally comprises a local area network interconnecting the programmable controllers (PCs) of the machine tools, MHS controller, the supervisory controller, and a DataBase Management System (DBMS)
 - DBMS contains part programs, scheduling information, tool database (tool type, tool life, remaining life), and route sheets

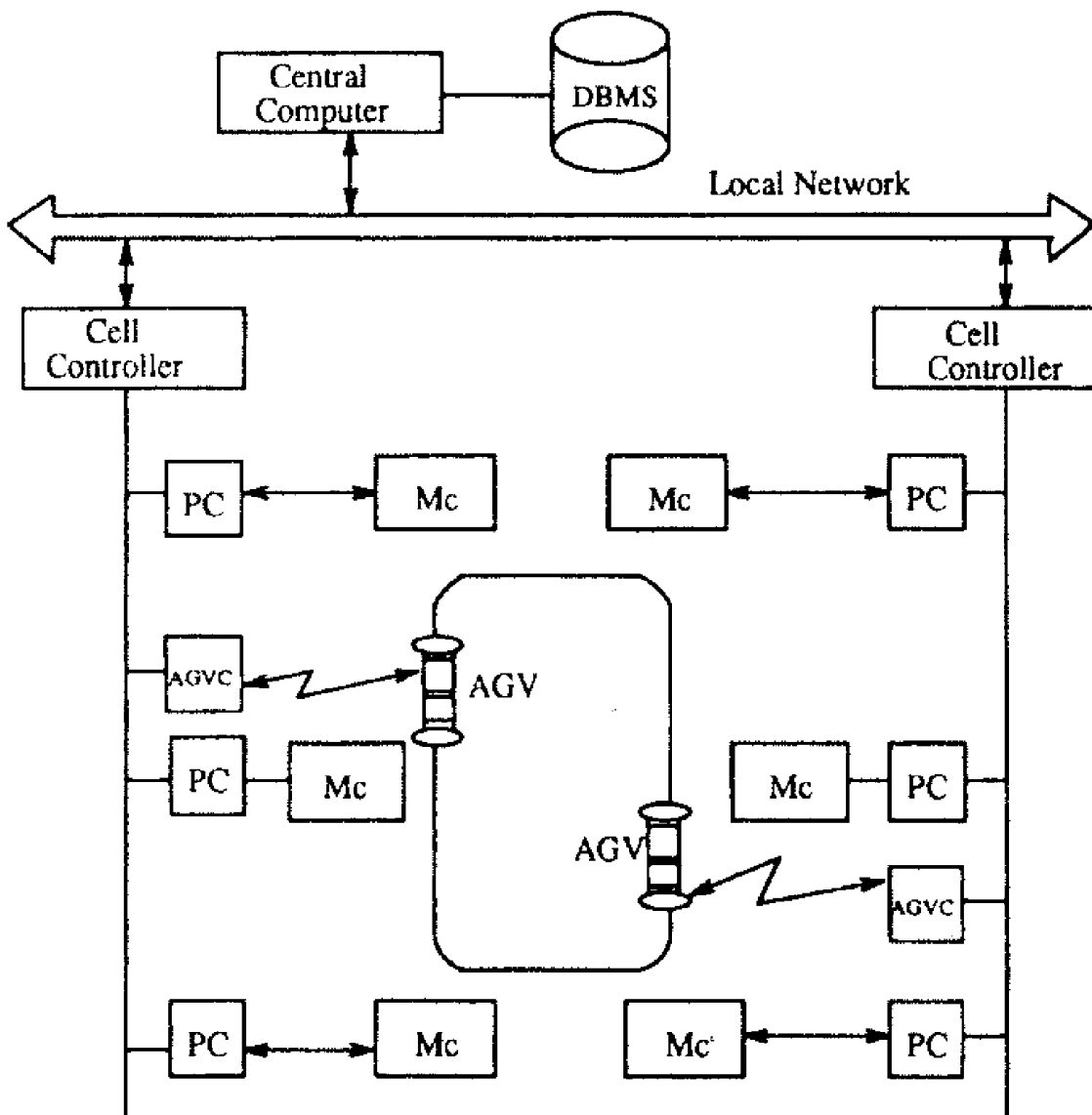
Typical routing table for an FMS with 5 machines and 3 part types

Part type	Op # 1	Op # 2	Op # 3
Type 1	M1/M2	M3	M4/M5
Type 2	M1/M2/M3	M2/M3	M5
Type 3	M1/M5	M4	M3/M2

Two kind of integration

- Material flow integration provided by the MHS and computer control
- Information integration provided by the Local Area Network (LAN)-based computer control system and DBMS

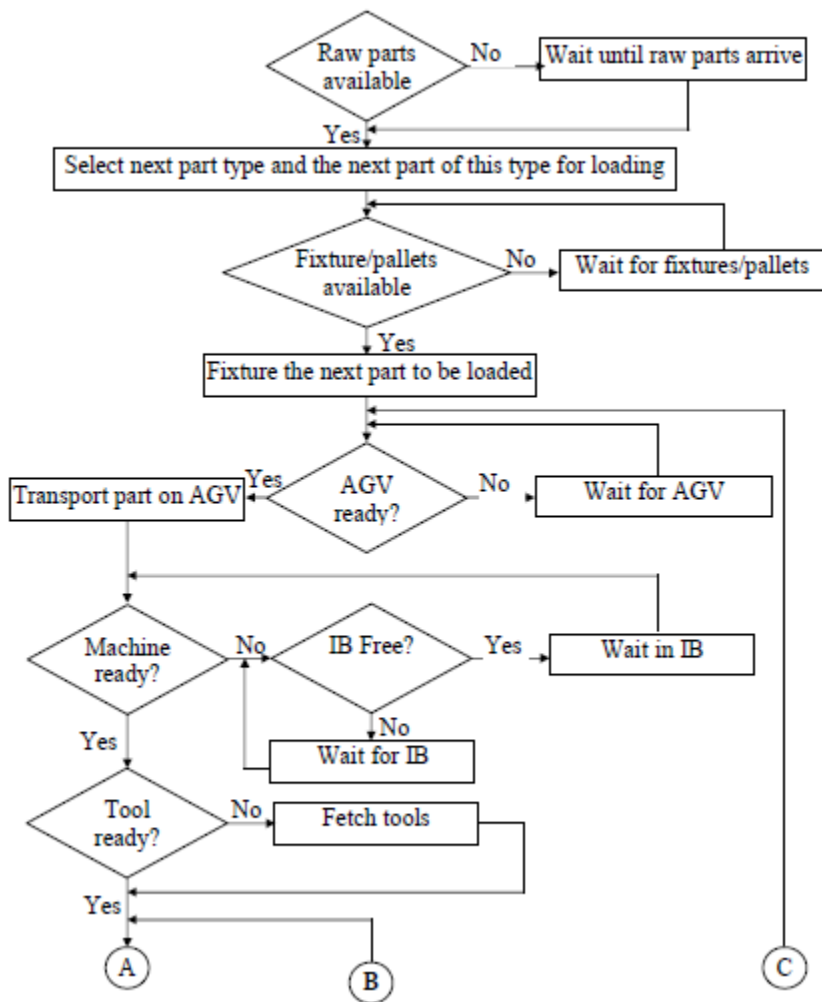
Typical Architecture of FMS



Typical Sequence of Operation

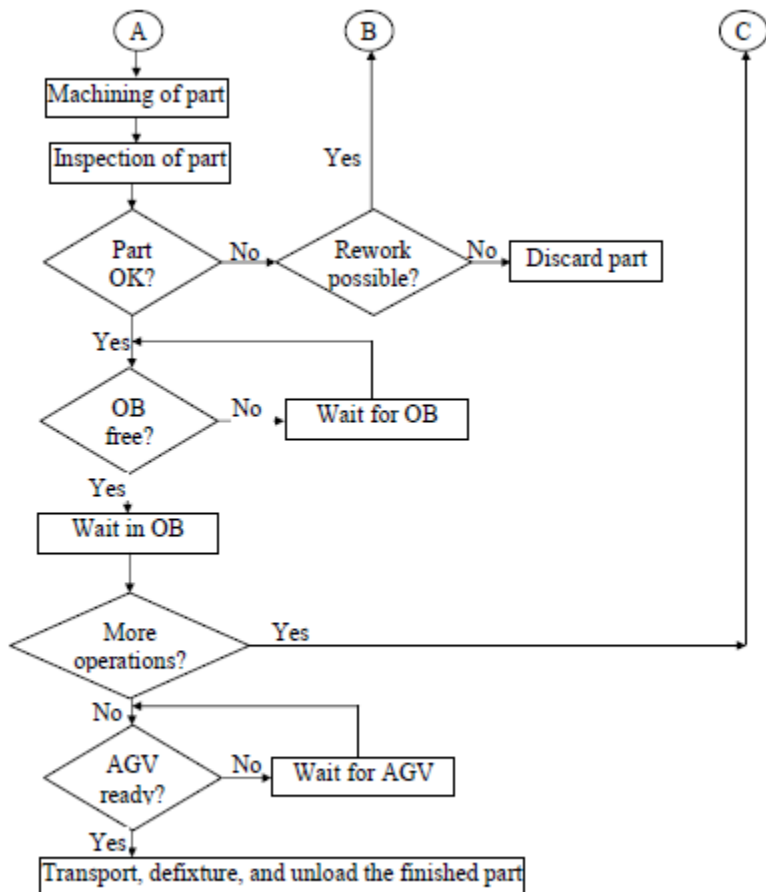
- Supervisory computer provides the information for the next workpiece to be fixtured onto pallets at a load/unload station
- Incoming raw workpieces are fixtured onto pallets at a load/unload station
- Based on the route sheet information the processing station is identified
- MHS move the workpieces to the workstation for processing
- Completed workpieces are moved from workstations to load/unload station to defixture.

FMS Flow Chart



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IB – Input Buffer, OB – Output Buffer

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