UNIT IV

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

Types of Flexibility

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

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

Types of Flexibility

1. Dynamic flexibility

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

2. Static-active flexibility

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

Types of Flexibility

3. Static-passive flexibility

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

FMS- Components

Components/Elements Of FMS:

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

(i) Workstations

(ii)Material handling and storage system

(iii)Computer control system

(iv)Human resources

FMS- Components

1) FMS Workstations

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

(i)Load/unload stations

(ii)Machining stations

(iii)Assembly workstations

(iv)Inspection stations

(v)Other processing stations

FMS- Components

2) Material Handling and Storage System:

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

FMS- Components

Functions of the material handling system

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

FMS- Components

Functions of the material handling system

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

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

Types of Material Handling Equipment

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

(i)Primary handling system

(ii)Secondary handling system.

Types of Material Handling Equipment

(i)Primary Handling System

- It establishes the basic layout of the FMS and is responsible for moving work parts between workstations in the system.
- Table given below summarizes the type of material handling equipment typically used as the primary handling system for the five FMS layouts.

FMS Layout

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

Types of Material Handling Equipment

(ii)Secondary Handling System

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

The functions of the secondary handling systems are:

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

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

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

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

Computer Control System

- The third major component of FMS is the computer control system.
- In flexible manufacturing systems, computers are required to control the automated and semi-automated equipment and to participate in the overall coordination and management of the manufacturing system.
- A typical FMS computer control system consists of a central computer and micro-computers controlling the individual machines and other components.
- The central computer coordinates the activities of the components to achieve smooth overall operation of the system.

Human Resources

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

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

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

(iii)For tool changing and tool setting.

(iv)For equipment maintenance and repair.

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

(vi)To program and operate the computer system.

(vii)To accomplish overall management of the system.


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FMS Application

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

  (i)Machining

  (ii)Assembly

  (iii)Sheet-metal press working

  (iv)Forging

  (v)Plastic injection moulding

  (vi)Welding

  (vii)Textile machinery manufacture

  (viii)Semiconductor component manufacture

Economics of FMS

(i)5–20% reduction in personnel.

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

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

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

(v)40–70% gain in overall production.

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

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

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

Advantages of FMS

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

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

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

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

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

Advantages of FMS

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

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

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

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

Advantages of FMS

9.Other FMS benefits include:

(i) Reduced factory floor space.

(ii) Reduced number of tools and machines required.

(iii) Improved product quality.

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

Disadvantages of FMS

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

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

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

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

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

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

FMS Planning and Control

FMS Planning

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

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

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

FMS Planning and Control

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

FMS Planning and Control

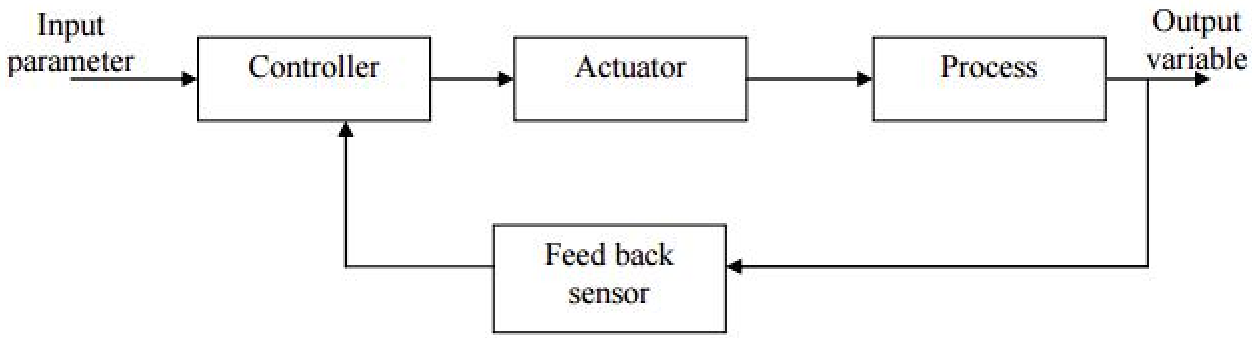
Control of FMS system

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

FMS Planning and Control

Control of FMS system

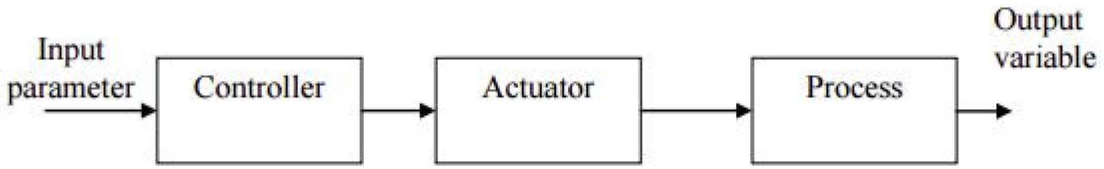
- A closed loop control system is one in which the output variable is compared with an input parameter and any difference between the two is used to drive the output into agreement with the input.
- It is also known as feedback control system.
- A closed loop control system consists of six basic elements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



FMS Planning and Control

Control of FMS system

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



FMS Planning and Control

Advantage Of Control System

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

(2) The actuating function is very reliable.

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

FMS Planning and Control

Functions of a FMS computer control system

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

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

FMS Planning and Control

Functions of a FMS computer control system

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

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

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

FMS Planning and Control

Functions of a FMS computer control system

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

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

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

FMS Planning and Control

Functions of a FMS computer control system

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

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

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

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

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

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

FMS Planning and Control

Functions of a FMS computer control system

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

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

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

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

Quantitative Analysis of Flexible Manufacturing Systems

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

(a) maximum production rate of the FMC

(b) corresponding production rates of each product

(c) utilization of each machine in the system

(d) number of busy servers at each station.

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

Quantitative Analysis of Flexible Manufacturing Systems

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

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

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

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

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

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

Quantitative Analysis of Flexible Manufacturing Systems

Bottleneck station is determined by formula:

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

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

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

Quantitative Analysis of Flexible Manufacturing Systems

Bottleneck is station 2:

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

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

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

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

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

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

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

Quantitative Analysis of Flexible Manufacturing Systems

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

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

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

Quantitative Analysis of Flexible Manufacturing Systems

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

$$BS_i = WL_i R_p *$$

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

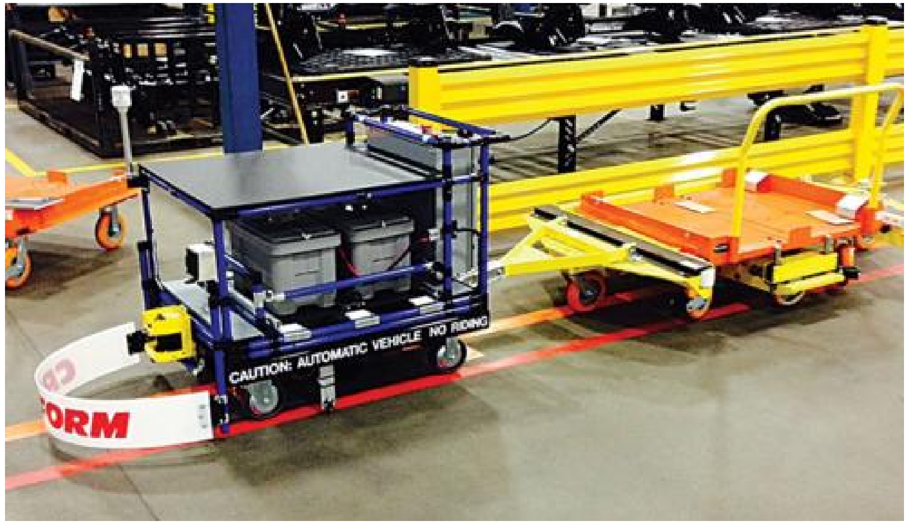
BS2 = (19.5)(0.05128) **= 1.0 servers**

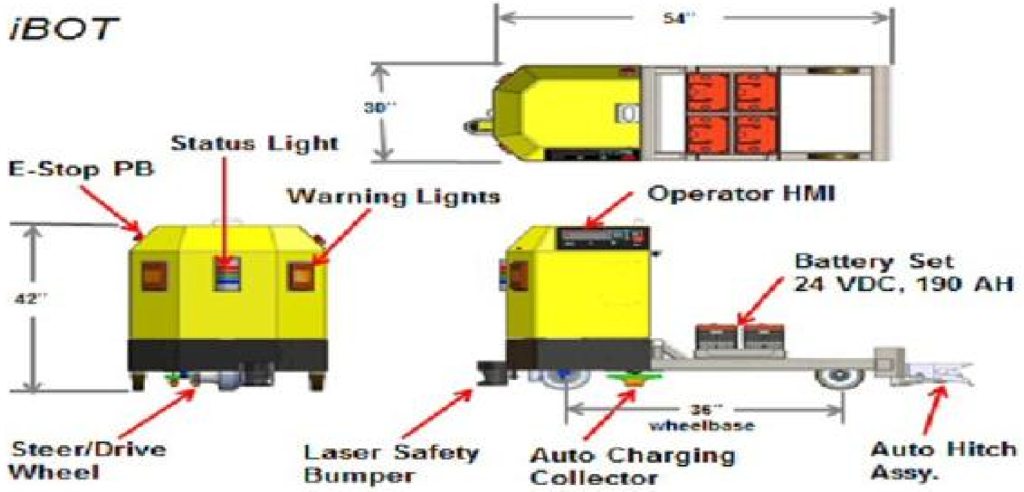
BS3 = (18.4)(0.05128) **= 0.944 servers**

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

Automated Guided Vehicle System (AGVS)

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



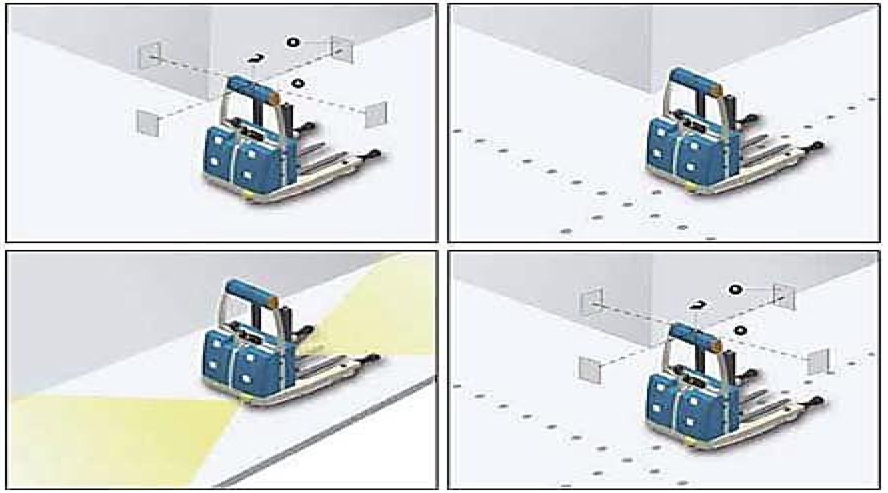


Automated Guided Vehicle System (AGVS)

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

Automated Guided Vehicle System (AGVS)

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



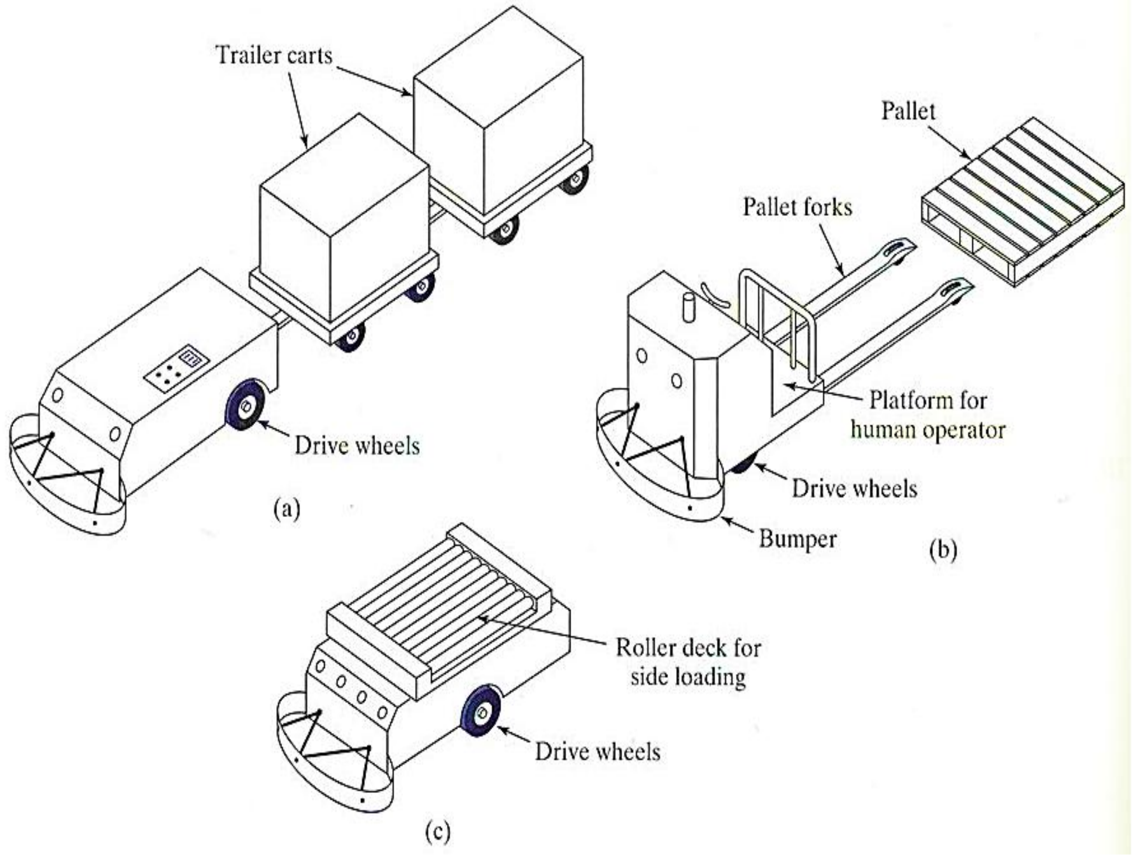
Automated Guided Vehicle System (AGVS)

The various types of AGVs are:

(a)Driverless trains

(b)AGVs pallet trucks

(c)AGVs unit load carriers



Automated Guided Vehicle System (AGVS)

AGVs is generally used:

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

Automated Guided Vehicle System (AGVS)

AGVS Advantages

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

Automated Guided Vehicle System (AGVS)

Applications AGVS

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







Automated Guided Vehicle System (AGVS)

Vehicle Guidance technology

- There are four types of Vehicle Guidance technology

(i) Laser Guidance Technology

(ii) Magnetic Spot Guidance Technology

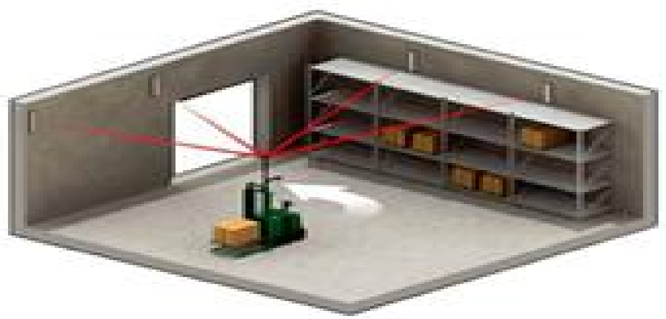
(iii) Magnetic Tape Guidance Technology

(iv) Inductive Guidance Technology (Wire Guidance)

Automated Guided Vehicle System (AGVS)

Laser Guidance Technology

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



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

Automated Guided Vehicle System (AGVS)

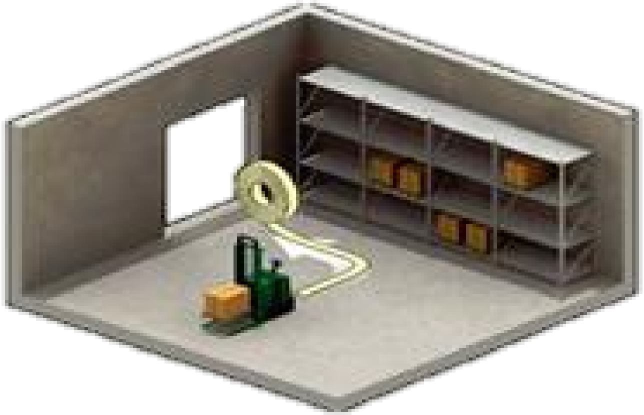
Magnetic Spot Guidance Technology

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

Automated Guided Vehicle System (AGVS)

Magnetic Tape Guidance Technology

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



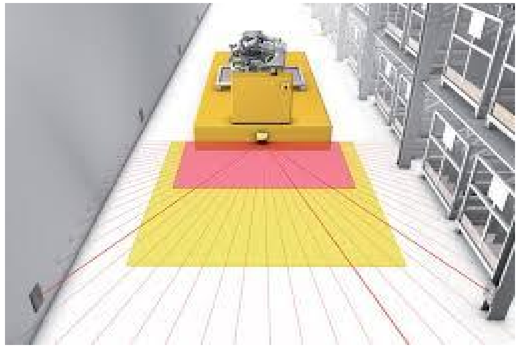
Automated Guided Vehicle System (AGVS)

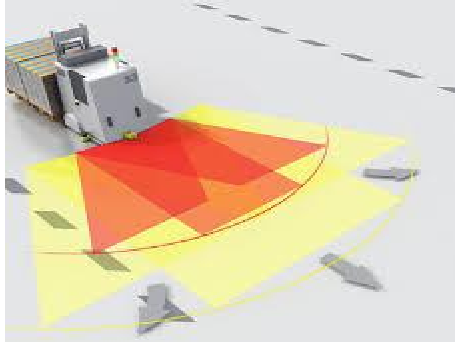
Inductive Guidance Technology (Wire Guidance)

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

Vehicle Management & Safety

Aspects of vehicle management



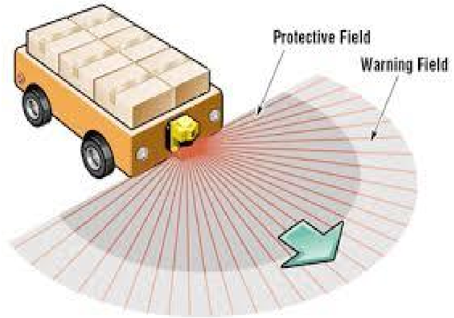


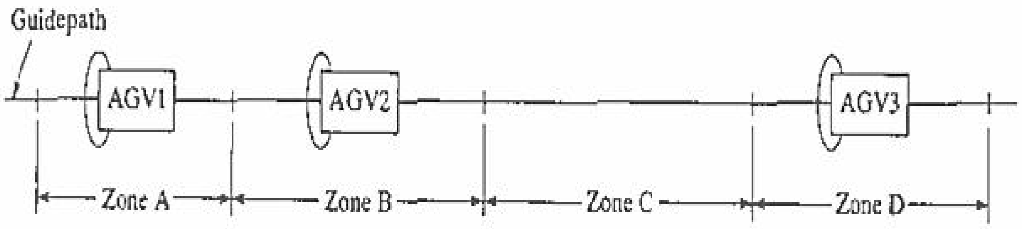
- Forward (on-board vehicle) sensing.
- Zone control.
- Vehicle dispatching

(i)On-board control panel

(ii)Remote call stations

(iii)Central computer control





Automated Guided Vehicle System (AGVS)

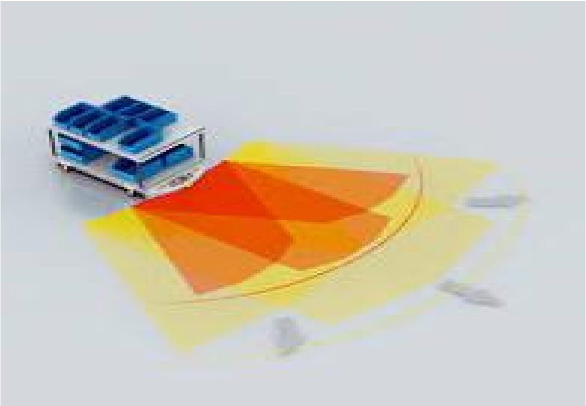
Vehicle Safety

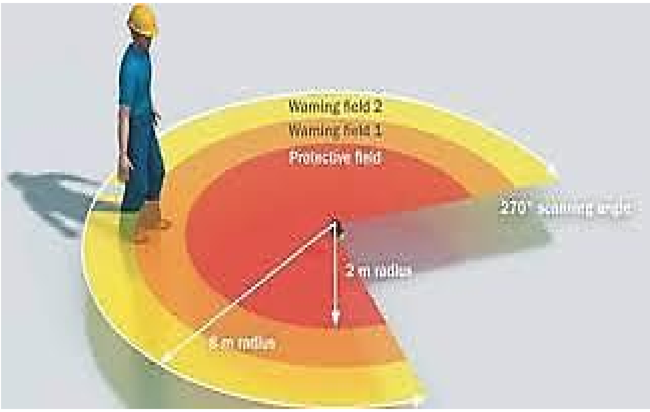
- An inherent safety feature of an AGV is that its traveling speed is slower than the normal walking pace of a human.
- Automatic stopping of the vehicle takes place if it strays more than a short distance, typically 50-150 mm.
- Vehicles are programmed either to stop when an obstacle is sensed ahead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

Automated Guided Vehicle System (AGVS)

Vehicle Safety

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





Automated Guided Vehicle System (AGVS)

Vehicle Safety

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

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

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