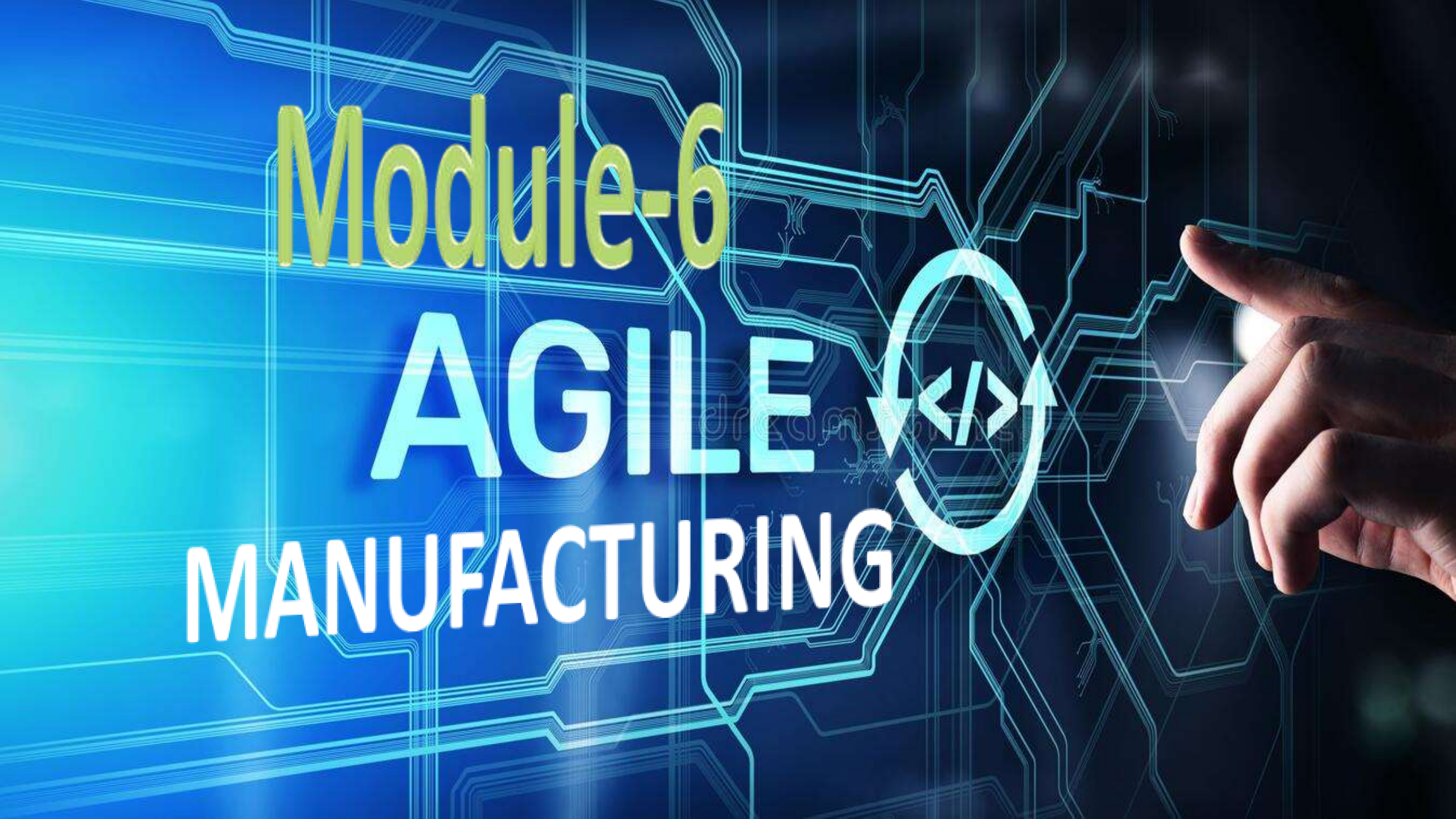

Module-6
AGILE
MANUFACTURING

BVCOENM - Vision & Mission

INSTITUTE

VISION: "Social transformation through dynamic education"

MISSION: To impart quality education to meet the needs of industry, profession and society; and to achieve excellence in teaching, learning and research.

DEPARTMENT

VISION: "To be recognized as leading mechanical engineering discipline by enhancing the knowledge and skills for the sustainable development."

MISSION: *Sociotechnological Skills:* To educate students through various activities including technical education, research and social service.

Centre of Focus: To promote prevailing challenges based projects and activities for socio-economic development.

Competitiveness: To develop competency in graduates for their career development to sustain in challenging environment.

Content

1. Introduction
2. Developing agile manufacturing
3. Integration of Product/Process Development
4. Application of IT/IS concepts
5. Agile supply chain management
6. Design of skill and knowledge and Computer control of Agile manufacturing
7. Flexible manufacturing
8. Lean Manufacturing
9. Value Stream Mapping

Course Outcome

1. Illustrate the need for optimization of resources and its significance
2. Develop ability in integrating knowledge of design along with other aspects of value addition in the conceptualization and manufacturing stage of various products.
3. Demonstrate the concept of value analysis and its relevance.
4. Manage and implement different concepts involved in method study and understanding of work content in different situations.
5. Describe different aspects of work system design and facilities design pertinent to manufacturing industries.
6. ***Illustrate concepts of Agile manufacturing, Lean manufacturing and Flexible manufacturing***

Introduction

- Agility refers to the capability to adapt.
- Agile manufacturing is adopted where a company having processes, tools and trained personnel is required to quickly respond to changing customer needs and market changes, without compromising quality and reducing costs, thus delivering value to the customer.
- The technology has emerged as a follow up from lean production.
- Agility addresses new ways of running companies integrating flexible and nimble organisation, trained people and technology into a meaningful utility.
- Agile manufacturing is enterprise level manufacturing strategy of introducing new products for rapidly changing markets, and having organizational ability to thrive in a competitive environment characterized by continuous/ unforeseen changes by rapidly reconfiguring the human and physical resources to changing environment and market opportunities.

Need for Agile Manufacturing

- As the product life cycle becomes shortened, high product quality becomes necessary for survival. Markets become highly diversified and· global_, and continuous and unexpected changes become the key factors for success. The need for a method of rapidly and cost-effectively developing products, production facilities and supporting software, including design, process planning and shop floor control system has led to the concept of agile manufacturing.

Definition:

Agile manufacturing can be defined as the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets driven by customer-designed products and services.

Focuses of Agile Manufacturing

- Faster response to highly variable customer demand patterns
- Improved productivity;
- Opportunities for system wide innovation, learning and improvement;
- Improved product quality;
- Better utilization of capital and improved return on investment;
- Improved customer and market focus, better understanding of customer needs, and closer customer relationships;
- Flexibility to cope with a wide range of batch sizes including one-of-a-kind production, and a wide range of products (volume and product flexibility);
- Integration of suppliers into product development and manufacturing processes;
- Short-order capability and the ability to rapidly respond to new windows of opportunity;
- Capability to undertake multi-venturing through virtual organizations;
- Reduced indirect labour and other overhead costs;
- More time and opportunities for management to tackle problems;
- System integrity and robustness.

Developing agile manufacturing

There are four key elements for agile manufacturing:

1. *Strategic planning*
2. *Product design*
3. *Virtual enterprise*
4. *Automation and Information Technology*

Strategic Planning

Product cluster, Market cluster, Competitive strategies, Financial Planning, Planning Horizon, core competencies

Product design

Availability of resources and technologies, skills, Design for manufacture and Assembly , Concurrent Engineering (CE), Group Technology (GT) , Computer-Supported Cooperative Work (CSCW)

Agile manufacturing strategies/techniques

Automation and IT

Flexible Manufacturing System, ERP, SAP, CIM, CAD/CAM, Computer Aided Engineering (CAE) , CAPP, AGVs, Robots, E-Commerce

Virtual enterprise

Virtual Manufacturing (VM), Partnership formation, Integration of core competencies, Supply chain, Temporary alliances, Prequalifying partners/partner selection, Data Management Framework(

Developing agile manufacturing

1. ***Strategic planning :-*** It takes into account the long-term interest of the company in determining suitable business and operational policies. As the complexity of the market and production increases on a global scale, new extended enterprise objectives, drivers, performance indicators and boundary conditions are being defined within the framework of agile manufacturing. Suitable frameworks should be established to develop a management system for an agile manufacturing enterprise incorporating the information flow and performance measurements. In developing AMS , performance measures based on both the financial and non-financial performance measures are required.
2. ***Product design :-*** The agile manufacturing system should be able to produce a variety of components at low cost and in a short time period. the role of enabling processes and techniques, such as Computer Aided Design (CAD) and Computer Aided Engineering (CAE), and formal methods, such as Design for Manufacture and Assembly, to achieve reduced product development cycles, whilst improving the quality of products. Implementing a Concurrent Engineering (CE) strategy is required for concurrently designing both the product and the downstream processes for production and support . For quick design evaluation in an AM environment, a STEP-based product model approach is used to generate the Group Technology (GT) code of a candidate product design, and additional information critical to the product's manufacture.

Developing agile manufacturing

3. *Virtual enterprise:-* A virtual organization is the integration of complementary core competencies distributed among a number of carefully chosen, but real organizations all with similar supply chains focusing on speed to market, cost reduction and quality. Virtual Manufacturing (VM) is an integrated synthetic-manufacturing environment used to enhance all levels of decision and control in a manufacturing enterprise. The agile enterprise requires VM to respond to changing market requirements quickly. VM environments are being proposed to improve responsiveness, improve product and process design, reduce manufacturing risks, improve manufacturing design and operation, support manufacturing system changes, enhance product service and repair, increase manufacturing understanding, and provide a vehicle for manufacturing training and research. In partnership development, there is a need for information on three functions of AM that include prequalifying partners, evaluating a product design with respect to the capabilities of potential partners, and selecting the optimal set of partners for the manufacture of a given product.

Developing agile manufacturing

4. ***Automation and Information Technology:-*** *I*n Agile manufacturing requires an intelligent CE design support system that can provide rapid evaluation of engineering designs and design changes. Often, this process results in modified products that require adjustment and retooling of the manufacturing processes that produce the product. There are several computer-integrated systems that could be used for AM, some of them are : MRPII, Internet, CAD/CAE, ERP, Multimedia, and Electronic Commerce. In a global manufacturing environment, IT plays a dominant role of integrating physically distributed manufacturing firms. AM can be supported by enabling technologies such as robotics, Automated guided vehicle systems (AGVSs), Numerically Controlled (NC) machine tools, CAD/CAM, rapid prototyping tools, Internet, World Wide Web (WWW), Electronic Data Interchange (EDI), Multimedia and Electronic Commerce. Two methods, the time-based process enacting model and just-in-time process management are embedded into a process-centered software engineering environment called Prime, and a Web-based information-sharing environment, Wide-Area Information Network (WAIN) to ease the operations of ASP. Together with other software engineering tools, Prime and WAIN form the network centric Agile Software Engineering Environment (ASEE) . Internet assisted manufacturing system uses the Internet as an interface between a user and the Central Network Server (CNS) and allows a local user to operate remote machines connected to the Internet.

Integration of Product/Process Development

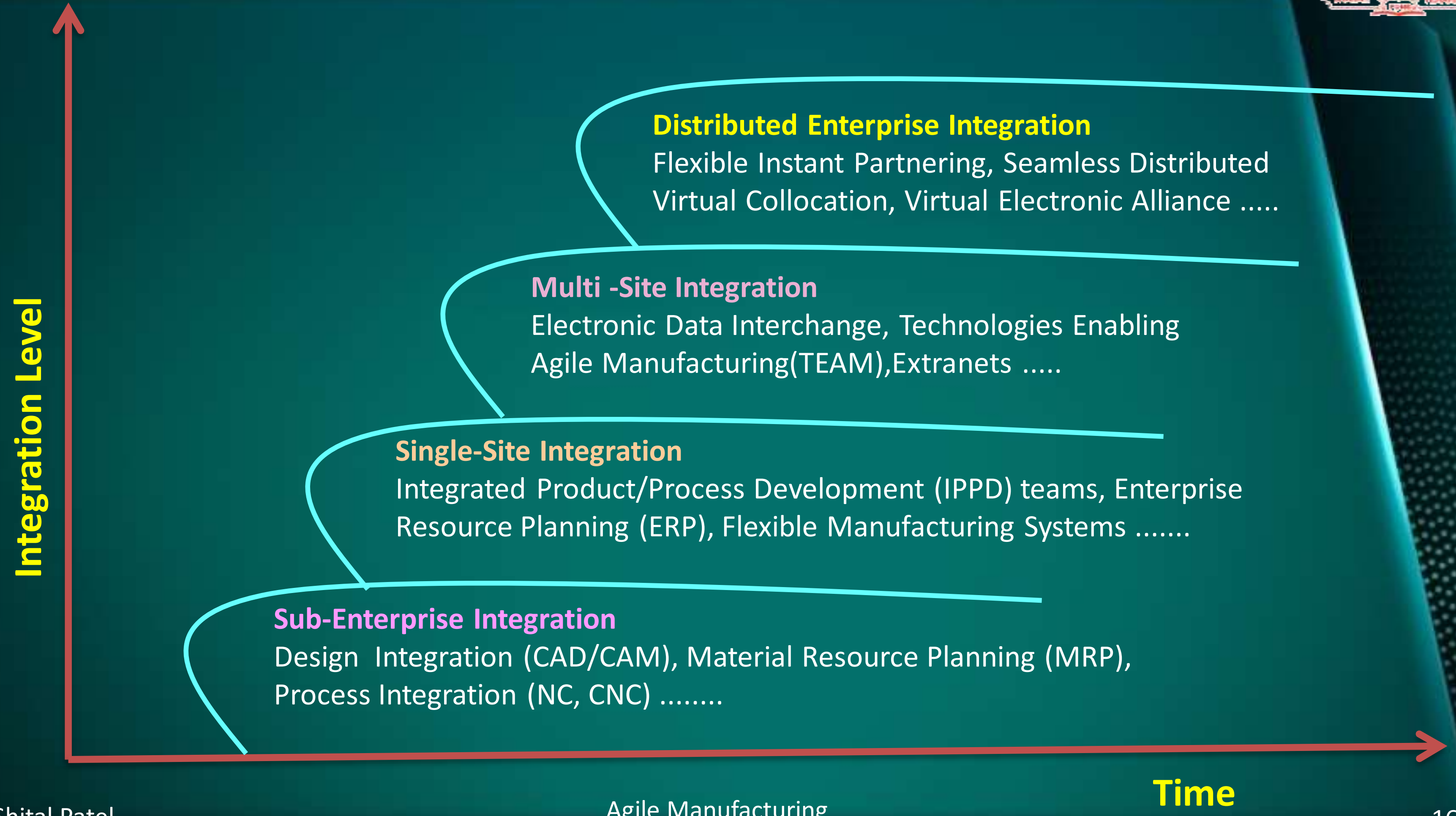
- Systems engineering approach provides a top down, system decomposition approach so that complex systems could be broken down into subsystems, components, and parts that could be developed and manufactured by subcontractors, suppliers, and vendors.
- The objective is to support creation and operation of extremely efficient, flexible, and responsive extended manufacturing enterprises, the path to reach this will require capturing the wisdom achieved at each of the enterprise integration levels. Several sub-enterprise elements have already been integrated.
- The goals of Integrated Product Realization are being supported with integration of CAD, CAM, and computer-aided manufacturing planning systems, coupled with the use of integrated product teams (IPTs), leveraging the emerging disciplines of *Integrated Product/Process Development (IPPD).*
- The IPPD focus should be at the front end, i.e. in design and development.

Integration of Product/Process Development

- Integrated Product/Process Development (IPPD) has been identified as a key element in future manufacturing systems. While some use of IPPD is being applied in industry and government; in reality, it can not be fully executed without a "new systems approach" methodology and the creation of a robust design environment for its implementation.
- This "new systems approach" methodology must capture, especially for complex systems, the key elements of the quality revolution, as well as the traditional systems engineering methods/tools.
- It must reflect the complex system design trade-offs that have to be addressed early in the design process, as well as take advantage of the information technologies that are creating the necessary computer integrated environment.
- This computer-integrated environment must provide for robust design simulation, where probabilistic approaches are used for both product and process design.
- Development of the "new systems approach" methodology, along with the creation of the accompanying robust design environment, is being prototyped as IPPD through RDS.
- A number of companies and government agencies are beginning to use and evaluate this prototype, which should help it mature and provide a foundation for the next generation agile manufacturing systems.

Integration of Product/Process Development

IPPD will mature with creation of enabling tools that support complete integration of all functions and disciplines involved in converting product from initial concept to completed units ready for delivery. Finally, for IPPD to be properly implemented a "new systems methodology", that couples *systems engineering decomposition* methods/tools (mostly deterministic) with *quality engineering recomposition* methods/tools (mostly probabilistic) must be formulated.



Distributed Enterprise Integration
Flexible Instant Partnering, Seamless Distributed Virtual Collocation, Virtual Electronic Alliance .....
Multi -Site Integration
Electronic Data Interchange, Technologies Enabling Agile Manufacturing(TEAM),Extranets .....
Single-Site Integration
Integrated Product/Process Development (IPPD) teams, Enterprise Resource Planning (ERP), Flexible Manufacturing Systems ....
Sub-Enterprise Integration
Design Integration (CAD/CAM), Material Resource Planning (MRP), Process Integration (NC, CNC) ....
Integration Level
Time

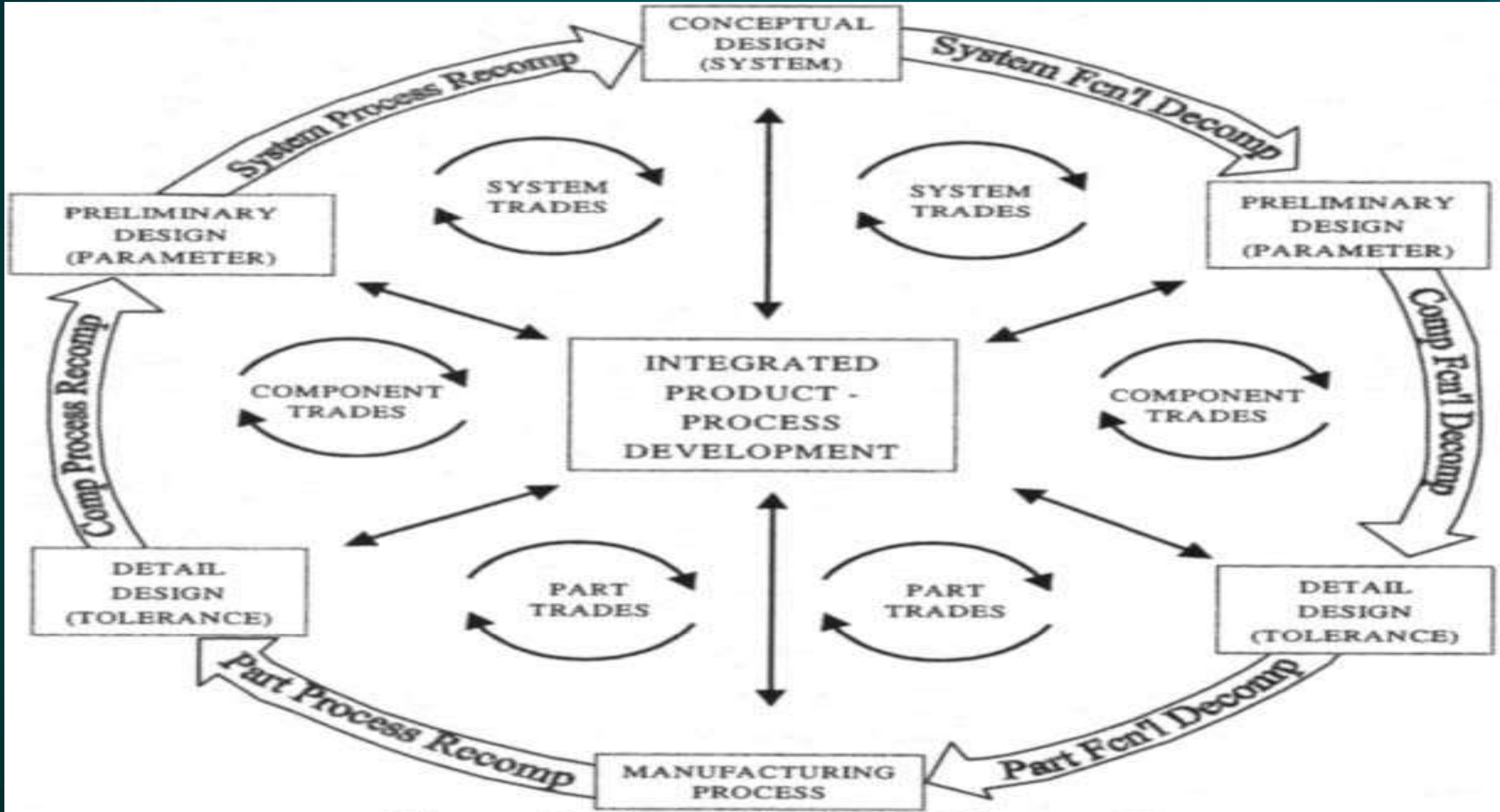


Figure 6. Hierarchical IPPD Process Flow

Application of IT/IS concepts

- IT has a key role to play in achieving manufacturing agility and can affect all the major functions of a manufacturing system. On balance, IT facilitates the operation of an agile manufacturing system and in the main acts as an enabler. However, the support of senior management is necessary for the achievement of manufacturing agility. It has been shown that the introduction of a new IT intervention may generate uncertainty within the workforce and the support of senior management is vital in maintaining the manufacturing process. On some occasions, the introduction of IT has created problems with the workforce and other members of staff(Wilson, 1994), so top management must be cautious in this task. If IT increases management control by top management, this needs to be applied without creating undue stress and concerns.
- The current technological environment enables businesses to virtually organize. As information technology(IT) has advanced, coordination costs have declined significantly, and companies are now able to form partnerships where separate firms specialize and activities are coordinated through decentralized information systems.

Application of IT/IS concepts

- ***Marketing and Retailing :-*** The development of IT may help to improve product marketing and retailing in several ways. Bar-coding, product recognition systems, Internet Protocol(IP) international toll-free telephone service and Electronic Point Of Sales (EPOS) are in wide use and help to increase the accuracy and speed of sales which lead to improved customer service.
- ***Product Development :-*** The capacity to innovate increases with the use of IT. Computer-aided design (CAD) and artificial intelligence (AI) technologies are a fundamental aid in the design process because, through CAD and expert systems, the design of products according to consumers' needs can be undertaken at a faster rate and the innovation can be greater. Moreover, an effective new product design and development process requires information from different departments (production, marketing and R&D) and IT should aid the effective and speedy transmission of this information and design decision making, e.g. through IP video conferencing and IP telephone messaging facilities.

Application of IT/IS concepts

- ***Production Operation :-*** IT has been found useful in the task of process flow management. Automation helps to reduce deviations in the production process, because machines usually demonstrate less variability than workers and increases the speed of production processes with a significant quality enhancement . IT also assists the maintenance function through the use of remote sensors and telemetering systems to detect the need for machine maintenance and diagnose what needs to be done; this can be carried out at a location far away from the main plant.
- ***Supplier Relations :-*** As in the case of customers, systems of electronic data interchange (EDI) can help to develop improved communication links with suppliers. The electronic transmission of data can be used to place orders, send product specifications, design details, etc., along with confirmation of invoices and paying for suppliers . investments in IT to support both the sharing of Just-in-time (JIT) schedules and the establishment of integrated information links **are** related to significant reduction in the level of shipment discrepancies.

Agile supply chain management

- Supply chain management is the management of activities and processes associated with the flow and transformation of goods from raw materials through the end user and to disposal or back into the system. Materials also include related information flows.
- Supply chain management evolution has provided a number of practices that directly relate to improving agility within and between organizations. Each of the major performance factors of agility, robustness, time, cost, flexibility, dependability, are all affected by the management of the supply chain. An agile supply chain is a necessary prerequisite for the formation of virtual enterprises.
- We shall look at four areas (supplier relationships, customer relationships, internal organizational processes, and system) of the supply chain to present these emerging and "best" practices.

Agile supply chain management

- ***Supplier Relationships :-*** A good supplier relationship may be based on the following factors: low price, excellent quality, on-time delivery, reactive and helpful, technically innovative, and trust. The following have been defined as exemplary practices for strategic supplier relationships:

1. Development of long-term, performance-oriented supplier partnerships
2. Continuous quality improvement and joint learning by both the customer and its supplier base.
3. Focus on total cost of ownership, not just on price.
4. Companies are taking a boundary less view of their participation in the value chain.
5. Long-term contracts

Agile supply chain management

6. Multi-level relationship across the organization including bi-company project teams;
7. Critical buying decision based on value;
8. Early involvement in marketing, design and product development cycle;
9. Exchange of information including not only information on work-in-progress but information on basic costs and insight into long-term strategy;
10. Integrated quality control;
11. Mutual support and joint problem solving;
12. Joint teams sharing information and expertise and sharing in the benefits;
13. A genuine insight into the buy decision and market forces both up and down the value chain; and
14. Two or three suppliers at most, with single sourcing agreements common, thus enabling the purchasing, engineering, production, and quality personnel to work more closely with the surviving few.

Agile supply chain management

- ***Customer Relationships :-*** Customer relationship issues focus on linking the customer to the supply chain. Much of the traditional functional responsibility for customer strategies has been within the domain of the marketing function. In agile organizations this relationship needs to be extended to include engineering, logistics, manufacturing and purchasing, among other functions.
- Linking the customer to the supply chain will require data and communication integration. A customer service strategy can be established with a simple methodology that includes the following major steps: 1) external audit; 2) internal audit; 3) evaluation of customer perceptions; and 4) identification of opportunities
- Agile suppliers are also reducing their customer base. A good customer-supplier relationship: 1) recognizes that a partnership is a two-way street; 2) rewards the best suppliers, and 3) encourages supplier involvement in product development

Agile supply chain management

- ***Organizational Process Issues :-*** Some internal management issues that should be considered are the roles of purchasing as a strategic function and as a support mechanism for other strategic areas. For this to occur purchasing has to go through an evolution to include the development of new skills (education), having top management commitment, and reductions of organizational barriers. Supplier development programs are an integral aspect of supply chain management practices. A supplier development program can be defined as any systematic organizational effort to create and maintain a network of suppliers.
- Supply chain management personnel will necessarily have to be cross-functional if the strategic aspects (which cross functional boundaries) occur.
- Supplier selection is an activity requiting a significant amount of managerial resources. Supplier or vendor selection identifies and selects the supplier of materials and products. Instead, minimize total cost and move toward a single supplier for any one item, on a long-term relationship of loyalty and trust.

Agile supply chain management

- **Supply Chain System :-** Continuous improvement is essentially the feedback loop of the supply chain management system, where feedback among and between organizations means strengthening the supply chain links. The continuous improvement link allows for full system analysis.

Continuous improvement:

1. Necessitates a multidimensional, multiorganizational effort simultaneously focused on quality, productivity, innovation, inventory, etc.. In other words, continuous improvement is an integrated system that requires a number of performance measurement improvements be combined into a single strategy.
2. Advances in stages where dedication, is followed by sustenance, and continuity.
3. Requires a model to guide implementation.
4. Should be custom-fit to the circumstances within and between organizations.
5. Requires change management including group efforts, facilitating leadership, and a foundation on appropriate performance measurement .

Agile supply chain management

- STRATEGIC ALLIANCES AND PARTNER SELECTION :- Although choosing the right supplier for a given job is the most fundamental and important decision a buyer makes, it may also be one of the most difficult ones, it becomes more complex as the selection evolves to the level of partnerships. Supplier evaluation and motivation plans typically involve the utilization of one or more of the following approaches: 1) Formal quantitative rating systems; 2) In-depth performance reviews, and 3) On-going communications and development of business partnerships.
- To be able to complete a comprehensive evaluation of suppliers a number of criteria can be used. Supplier could be screened technically on a number of variables, some of these have included: 1) Emphasis on quality at the source; 2) Design competency; 3) Process capability; 4) Declining nonconformities; 5) Declining WIP, Lead-time, space, flow distance; 6) Operators cross-trained, doing preventive maintenance; 7) Operators able to present SPC and quick setup; 8) Operators able to chart problems and process issues; 9) Hours of operator training in TQC/JIT; 10) Concurrent design; 11) Equipment / labor flexibility; 12) Dedicated capacity; 13) Production and process innovation.

Computer control of Agile manufacturing

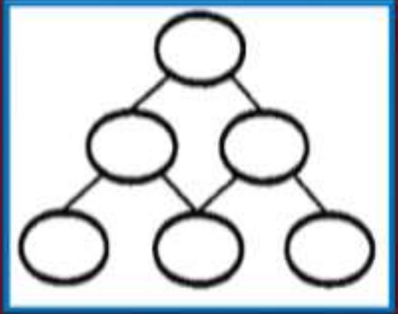
- Global competitive pressures in manufacturing have resulted in fundamental changes in the manufacturing environment. This can be seen in the current trend towards highly automated systems that are intended to adapt quickly to change while providing extensibility through a modular, distributed design. In order to realize the flexibility and productivity that these advanced systems promise, the computerized control system has become a central element in the design of agile manufacturing systems.
- The basic responsibilities of a manufacturing control system are the sequencing and scheduling of orders, monitoring and execution of detailed plans, and monitoring of system status. The main challenge in manufacturing systems control research has been to develop a system that can not only deal with these requirements, but is also responsive to disruptions in the manufacturing environment (e.g., machine failures, operator absences, material shortage, changes in demand, and absent or inaccurate status information). Ideally, the control system will have this responsiveness embodied in its design in such a way that when changes do occur on the shop floor, changes do not have to be made to the control software (or, the changes that have to be made are minimal).

Computer control of Agile manufacturing

- It is experienced that traditional centralised forms of control where information is stored and calculations take place in one location or control computer cannot meet these requirements, particularly in an environment that is haracteristically concurrent, asynchronous, and decentralised.
- As a result, recent work in manufacturing systems control has focused on moving away from centralised forms of control, towards a decentralised approach, involving the use of a number of interacting decision-makers.
- A primary concern of recent research in this area has been the choice of architecture, or in other words, how the decision-making agents in a control system should be organized to effectively achieve overall manufacturing system objectives.
- To achieve the reconfigurability and adaptability required of agile manufacturing systems, it appears that the control system cannot be limited to a single static structure.
- This has led to the question of how one can best organise these systems and has led industrial and academic researchers to the development of a spectrum of decentralised control architectures ranging from hierarchical to non-hierarchical or heterarchical control architectures .
- Experimental results have indicated that control architectures that are hybrids of heterarchical and hierarchical control architectures offer reconfigurability as well as better manufacturing system performance than either extreme of the control architecture spectrum.

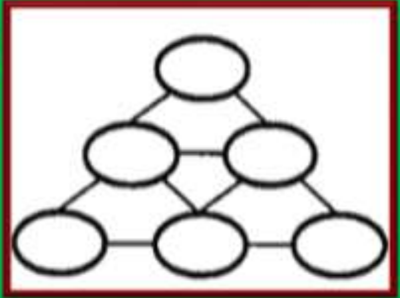
Hierarchical

Completely centralised



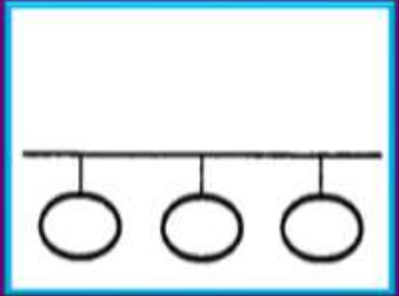
Oligarchical

Communication paths are less rigid



Heterarchical

A completely decentralised approach where individual controllers are assigned to subsystems and may work independently or may share information



Computer control of Agile manufacturing

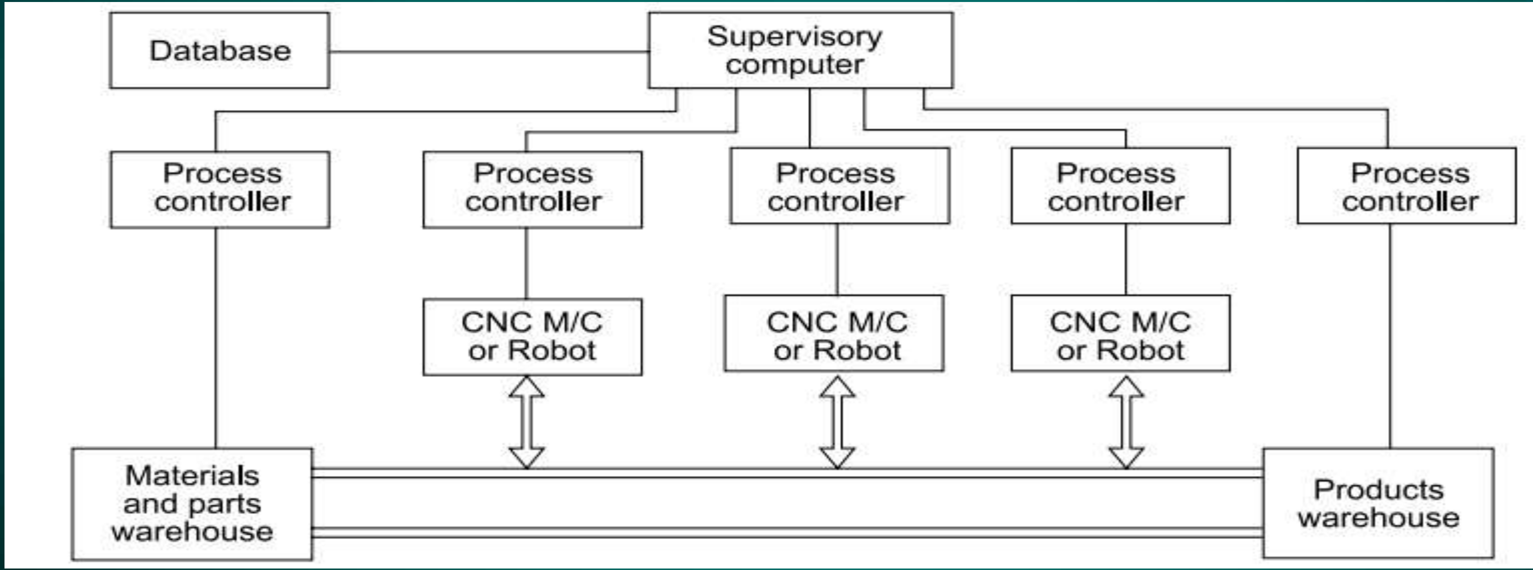
- Thus, recent work in the area of multi-agent systems and holonic manufacturing systems points in the direction of hybrid architectures that provide the benefits of centralised elements and functionality while maintaining the robustness and agility of heterarchical architectures .
- If these partial hierarchies are to be adaptable and reconfigurable, the control system will also have to be capable of responding to changes in the manufacturing environment.
- In other words, partial "dynamic" hierarchies will result that should not only be thought of as hybrids of heterarchical and hierarchical control architectures, but should also be thought of as metamorphic control systems.
- That is, these systems will adapt their architecture to respond to changes in the manufacturing environment.

Flexible manufacturing

- Computer Aided Manufacturing (CAM) is very useful for small-lot production. If the machine tools feature NC or CNC technology, it gives tremendous flexibility to the operations and numerous parts in the 'family' can be addressed with no change-over . For an efficient and flexible manufacturing system (which could address a diverse requirement efficiently) the availability of a suitable material handling system is very important.
- When the material handling function between machines in such a GT cell is brought under computer control, we have a Flexible Manufacturing System (FMS). Thus an FMS generally has the following three components:
  1. CNC machine tools;
  2. Computer controlled material handling system; and
  3. Supervisory computer control network.
- FMS systems are generally very useful for production involving an intermediate range of variety and an intermediate amount of volume.

Flexible manufacturing

"A Flexible Manufacturing System (FMS) is a production system where a discrete number of raw parts are processed and assembled by controlled machines and/or robots“



Flexible manufacturing

FMS technology can be applied to the following production situations:

- The plant either produces parts in batches or uses manned GT cells, and management wants to automate.
- It is possible to group the parts into part families, whose similarities permit them to be processed on the machines in the flexible manufacturing system. Part similarities can be interpreted to mean that
  – the parts belong to a common product and/or
  – the parts possess similar geometries.
- In either case, the processing requirements of the parts must be sufficiently similar to allow them to be made on the FMS.
- The parts or products made by the facility are in the mid-volume, mid-variety production range. If annual production range is below 5,000 to 75,000 parts year, an FMS is likely to be an expensive alternative. If production volume is above this range, then a more specialized. production system should probably be considered.

Flexible manufacturing

FMS Vs Manually Operated Machine Cell	
Flexible Manufacturing System	***Manually Operated Machine***
• Requires greater capital investment to install new equipment • Technologically more sophisticated for the human resources • Potential benefits are substantial-increased machine utilization, reduced factory floor space, greater responsiveness to change, lower inventory and manufacturing lead times, and higher labor productivity.	• Only existing equipment to be rearranged • Less sophisticated for human resources Potential benefits are less

Flexible manufacturing

Types of FMS: Flexible manufacturing systems can be classified according to the number of machines -used in the system and on the level of flexibility designed into the system.

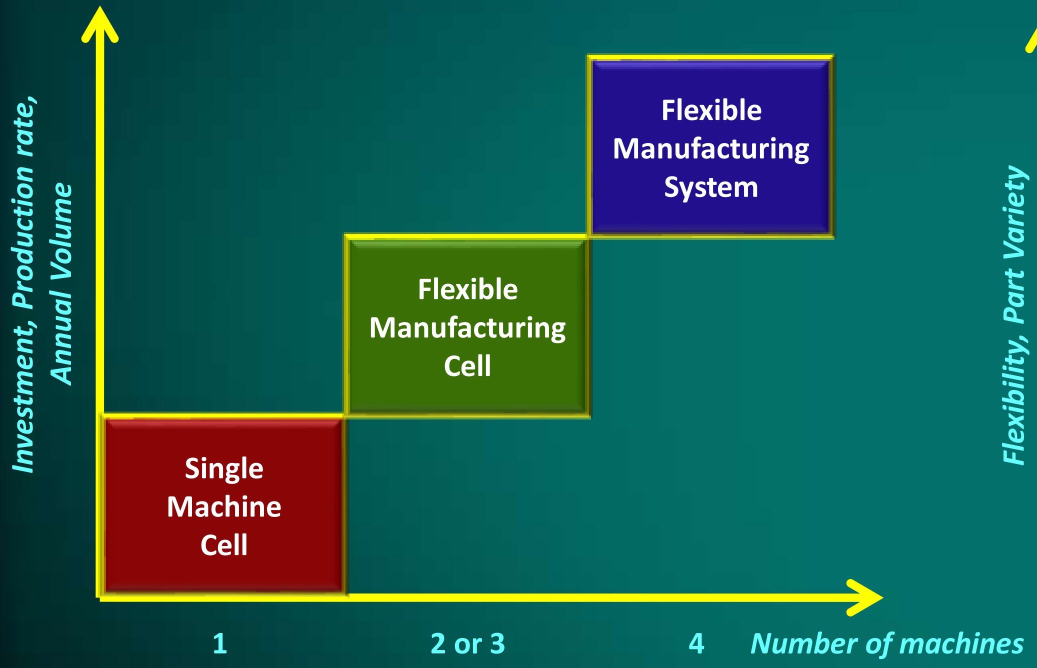
- *According to number of machines:* The following are typical categories:

  I. Single machine cell, 2. Flexible manufacturing cell, and 3. Flexible manufacturing system.

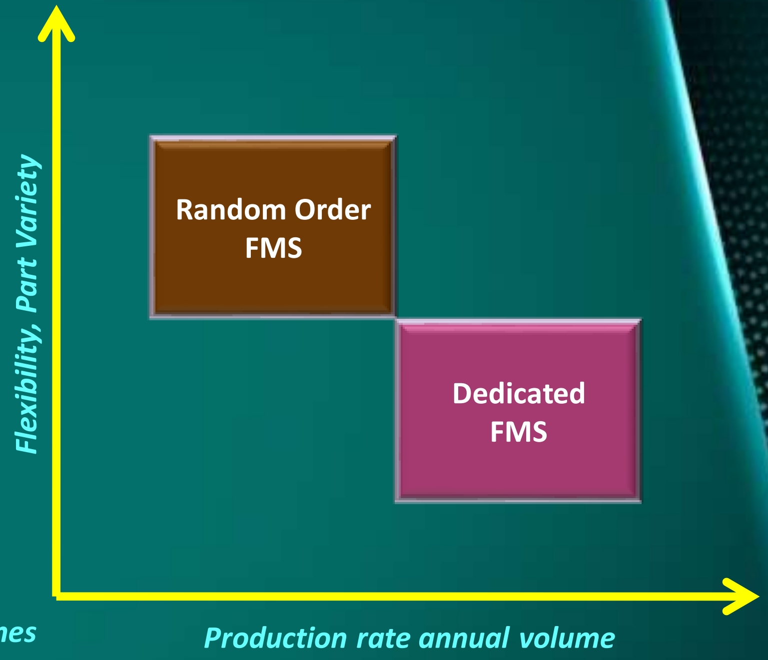
1. *Single machine cell:* It consists of one CNC machining center combined with a parts storage system for unattended operation. Completed parts are unloaded periodically from the parts storage unit, and raw work parts are loaded into it. The cell can be designed to operate in a batch mode (machine processes parts of a single style in specified lot sizes .and then changed over to process a batch of next part style), a flexible mode (capable of processing different part styles, responding to changes in production schedule, and accepting new part introductions), or /and combination of the two.
2. *Flexible manufacturing cell:* A flexible manufacturing cell (FMC) consists of two or three processing workstations (typically CNC machining centers or turning centers) plus a parts handling system. The parts handling system is connected to a load/unload station and usually includes a limited parts storage capacity.
3. *Flexible manufacturing system:* A FMS has four or more processing stations connected mechanically by a common parts handling system and electronically by a distributed computer system. An important distinction between a FMS and a FMC is in the number of machines: a FMC has two or three machines, while a FMS has four or more.

Flexible manufacturing

According to number of machines



According to the level of flexibility



Flexible manufacturing

According to the level of flexibility: The two categories of flexibility are:

1.Dedicated FMS 2. Random-order FMS

1. ***Dedicated 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. The part family is likely to be based on product commonality rather than geometric similarity. The product design is considered stable, so the system can be designed with a certain amount of process specialization to make the operations more efficient. Instead of using general purpose machines, the machines can be designed for the specific processes required to make the limited part family, thus increasing the production rate of the system.
2. ***Random-order FMS:*** A random-order FMS is more appropriate when the part family is large, there are large variations in part configurations, new part designs will be introduced into the system and engineering changes will occur in parts currently produced, and the production schedule is subject to change from day to day. To accommodate these variations, the random-order FMS must be more flexible than the dedicated FMS. It is equipped with general purpose machines to deal with the variations in product and is capable of processing parts in various sequences (random order). A more sophisticated computer control system is required for this FMS type.

Flexible manufacturing

Components of FMS: The several components of a FMS are:

1. ***Processing Stations:*** Typically the processing stations are computer numerical control (CNC) machine tools, that perform machining operations on families of parts. They are designed with other types of equipments including inspection stations, assembly work heads, and sheet metal processing. Most of the machines in. FMS utilize randomly selectable heads to perform functions such as drilling, tapping etc.
2. ***Material Handling and Storage System:*** Various types of material handling equipment are used to transport the work parts and sub assemblies between the processing stations. For work transportation individual conveyors are used. The load and unload stations are used for loading and unloading of raw materials and finished parts. The material handling and storage system in a flexible manufacturing system performs the following functions:
   - Allows random, independent movement of work parts between stations.
   - Enables handling of a variety of work part configurations.
   - Provides temporary storage.
   - Provides convenient access for loading and unloading work parts-The handling system must include locations for load/unload stations.
   - Creates compatibility with computer control—The handling system must be under the direct control of the computer system which directs it to the various workstations, load/unload stations, and storage areas

Flexible manufacturing

3. ***Auxiliary Equipments:*** Apart from the machine tools, FMS can also include cleaning, automated measurement and inspection equipment.
4. ***Computer Control System:*** Computer control is used to co-ordinate the activities of the processing stations and material handling system. It oversees the operation of an entire FMS. Some of the main functions of the controller are:
   - Machine control (CNC, DNC)
   - Production control
   - Distribution of control instructions to workstations
   - Tools control
   - Tool life monitoring
   - Traffic control-Management of primary material handling system
   - Shuttle control-Control of the secondary handling system at each workstation
   - Work piece monitoring
   - Performance monitoring and reporting
   - Diagnostics-To plan preventive maintenance in the system.

Flexible manufacturing

FMS Benefits:

- Increased machine utilization
- Reduced capital investment
- Fewer machines required
- Reduction in the amount ·of factory floor space required
- Greater responsiveness to change
- Reduced inventory requirements
- Lower manufacturing lead times
- Reduced direct labor requirements and higher labor productivity
- Opportunity for unattended production
- Consistent quality
- Better control ·of work.

Lean Manufacturing

- The core idea of lean manufacturing is simple *i.e.* relentlessly work on eliminating waste from the manufacturing process. Waste is defined as any activity that does not add value from the customer's perspective.
- Lean manufacturing basically involves. the assessment of each of the company's activities - the efficiency and effectiveness of its various operations, the reason for retaining. specific operations and manpower, the efficiency of equipment and machinery in the operation, number of people involved in particular operation and detailed analysis of costs associated with each activity including both productive and non productive operations and taking appropriate steps to improve operations by eliminating unnecessary operations.
- Objective :- To eliminate non value-added activities from the customer delivery cycle in the operations.
- Philosophy :- Lean is an attitude and philosophy about continuous improvement and striving for a state of perfection, where every action creates value for customers and society.
- Initial Lean thinking were evident in Arsenal in Venice in the 1450s, but Henry Ford was first to truly integrate an entire production process at Highland Park, MI, in 1913 where he synthesized interchangeable parts with standard work and moving conveyors and created flow production.

Lean Manufacturing

PRINCIPLES OF LEAN MANUFACTURING :-

1. **Value** :- Higher focus is placed on what the customer will pay for very specific products, features and service offerings.
2. **Value Streams :-** A value. stream includes all the processes, steps, and materials necessary to place the · product (or service) in the hands of the customer.
3. **Flow** :- Just as water flows freely downstream, the value chain should experience a smooth progression from start to finish.
4. **Pull** :- Rather than "pushing" production based on a forecast or schedule, those who take the pull approach ideally don't make anything until the customer (internal or external) orders it.
5. **Perfection** :- Lean thinkers implement systems and measurements that continuously seek opportunities to improve, speed, and reduce the cost of each step of the value stream. Moving closer to perfection requires the involvement of every member of the team from the C-suite to the front lines.

Lean Manufacturing

TOOLS AND TECHNIQUES OF LEAN MANUFACTURING

1. ***Cellular Manufacturing :-*** **It** is an approach in which all equipment and workstations are arranged based on a group of different processes located in close proximity to manufacture a group of similar products.
2. ***Takt Time :-*** This is the "heartbeat" of the customer. Takt time is the average rate at which a company must produce a product or execute transactions based on the customer's requirements and available working time.
   - **Takt= T/D** Where T is Time available for product/service, **D** is a demand for the number of units, T gives information on production pace or units per hours.
3. ***Standardized Works :-*** A process of documented description 6f methods, materials, tools, and processing times required to meet Takt time for any given job. This aids in standardizing the tasks throughout the value stream.

Lean Manufacturing

4. ***One Piece Flow or Continuous Flow :-*** This concept emphasizes reducing the batch size in order to eliminate system constraints. A methodology by which a product or information is produced by moving at a consistent pace from one value-added processing step to the next with no delays in between.
5. ***Pull Systems and Kanban :-*** A methodology by which a customer process signals a supplying process to produce a product or information or deliver product/information when it is needed. Kanban is the signals used within a pull system through scheduling combined with travelling instruction by simple visual devices like cards or containers.
6. ***Five Why's :-*** A thought process by which the question "why" is asked repeatedly to get to the root cause of a problem.
7. ***Quick Changeover :-*** Shorter changeover times are used to reduce batch sizes and produce just-in-time. This concept aids in reducing the setup time to improve flexibility and responsiveness to customer changes.

Lean Manufacturing

8. *Mistake Proofing/Poka Yoke :-* A methodology that prevents an operator from making an error by incorporating preventive in-built responsiveness within the design of product or production process.
9. *Heijunka/ Leveling the Workload :-* The idea that, although customer order patterns may be quite variable, all of our processes should build consistent quantities of work over time (day to day, hour to hour). . This strategy is adopted by intelligently planning different product mix and its volumes over period of times.
10. *Total Productive Maintenance (TPM) :-* A team-based system for improving Overall Equipment Effectiveness '(OEE), which includes availability, performance, and quality. This aids in establishing a strategy for creating employee ownership autonomously for maintenance of equipment. The goal of the TPM program is to markedly increase production while at the same time increasing employee morale and job satisfaction.

    OEE (Overall Equipment Efficiency): *OEE=A* **X** *PE* **X** *Q*

    A -Availability of the machine. *PE* - Performance Efficiency. Q- Refers to quality rate.

Lean Manufacturing

11. ***Five S :-*** 5S is a five step methodology aimed at creating and maintaining an organized visual workplace. This system aids in organizing, cleaning, developing, and sustaining a productive work environment.
12. ***Problem Solving/POCA/PDSA :-*** The **POCA** cycle is a graphical and logical representation of how most individuals have already solved problems. It helps to think that every activity and job is part of a process, that each stage has a customer and that the improvement cycle will send a superior product or service to the final customer.
    - **PLAN:** establish a plan to achieve a goal, **DO:** enact the plan, **CHECK:** measure and analyze the results and **ACT:** implement necessary reforms if results are not as expected .
    - A system for identifying and solving problems to their root cause and then implementing counter measures with monitoring.

Lean Manufacturing

ADVANTAGES AND LIMITATIONS

1. Inventory levels are very low because of use of JIT.
2. Simple and multitask machinery which aids variety products manufacturing.
3. More value to the customer.
4. Reduction in manufacturing lead time.
5. Small is beautiful as against big is beautiful.
6. Integrates people and techniques to improve the work place and strengthens company's competitive position.

Value Stream Mapping

- In lean operations, ‘value’ and ‘waste’ are central concepts.
- there is a difference between ‘adding value to a product/service’ and ‘adding value to the customer’. If the customer wants a simple *masala dosa* that tastes good, there is no value to the customer whether you add mozzarella cheese in its masala or stick a thin silver varkha (wafer) or gold plating on its outer covering. All the latter actions may add value to the product, but do not add value for the customer. In the eyes of the restaurant owner/manager, the dosa may be worth a five hundred bucks, but the customer does not care and does not want to pay for all these embellishments. All these trappings are a waste.
- Value exists only when the customer is willing to ‘pay’ for a product or service.
- Those tasks that the customer is not willing to pay for are ‘non-value added’ or ‘waste’ and these tasks should be designed out of the process or operation, simplified or reduced.
- In order to pinpoint areas where there is ‘waste’, the present material and information flow or stream from the time the inputs are ordered to the receipt of the output/product by the customer has to be traced or ‘mapped’ in sufficient detail regarding the contribution to ‘value’
- A value stream mapping is an enterprise improvement technique to visualize an entire production process by identifying waste

Value Stream Mapping

For every one of the points given below, the question is to be asked: “Does it provide ‘value’? If so, ‘what?’ and ‘how much?” We may call it ‘waste visualisation’.

1. All the processes
2. All the material, energy, manpower and machinery inputs and/or efforts along with the times spent
3. Stoppages/delays and storages
4. Inventories (of raw material, work-in-process and finished goods as well as that of standby manpower and/or of stand-by equipment)
5. Production/operations control activities, scheduling methods, lot sizes
6. Forecasts
7. Purchase and work orders – quantity and frequency
8. Cycle times and lead times
9. Process control and other quality related inspections
10. Transports within and outside the plant or office (distance, frequency, loads, modes)
11. Communications – the parties that are communicating, the information flows, the content, the channels and the frequency, etc.

Value Stream Mapping

STEPS IN VALUE STREAM MAPPING

1. Understand the value desired by the customer
2. Map the ‘present’ state (as indicated earlier in this section
3. Improve the flows and design a ‘future’ state that is ‘lean’, i.e. where fewer resources, less space, less time and less information are needed to provide the value desired by the customer. It is recommended that this design of the ‘lean value stream’ should be a participative effort for better acceptance.
4. Draw up a plan of implementation of this vision of a ‘lean future’. This should be drawn with the agreement of all parties to the implementation.

Value Stream Mapping

Advantages	Disadvantages
• Can be easily and fast performed • Cheap method, there is no need to have a lot of equipment and staff • Simple to learn and understand • Only pen and paper needed for it • Can be a good foundation for another methods • Can be made by staff, who knows the production system well, with VSM specialist's support	• Only one type of product can be analyzed • This method provides only the production processes at certain moment of time • It is difficult to work with new technologies and experiment with it