IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Introduction to Manufacturing and Production Systems

PROF PRADIP KUMAR RAY

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

IIT KHARAGPUR

NPTEL

Introduction to Manufacturing and Production Systems

- **Lecture-1:** Basic Concepts of Manufacturing Systems, Evolution of Manufacturing Systems
- **Lecture-2:** Types of Manufacturing Systems and Role of Automation
- **Lecture-3:** Product-Process-Flexibility Matrices, Four-Plane Concept of Manufacturing
- **Lecture-4:** Product Design and Manufacturing Systems
- **Lecture-5:** Definitions and Design Criteria for Production Systems

NPTEL

Introduction to Manufacturing and Production Systems

- ✓ **Basic Concepts of Manufacturing Systems,**
- ✓ **Evolution of Manufacturing Systems**

NPTEL

Basic Concepts of Manufacturing Systems

- Manufacturing creates between 60 to 80% of the real wealth of the major industrialized countries.
- Most of the countries have numerous industry and government supported programs to increase manufacturing productivity.
- Within the last six decades, there have been many important innovations in the development of new design aids, manufacturing processes, engineering materials, and manufacturing systems.
- With conventional production know-how, it becomes increasingly difficult and expensive to improve manufacturing processes.

NPTEL

Basic Concepts of Manufacturing Systems

- The computer offers possibilities for improving the manufacturing technology in many areas.
- Computers can directly control production and quality control equipment and quickly adapt themselves to changing customer orders and new products.
- They make possible the instant evaluation of data to assess the flow of information in the plant and to initiate immediate corrective action.
- They optimize the manufacturing process by their capability to integrate the entire manufacturing system.

NPTEL

Basic Concepts of Manufacturing Systems

- Computer-Integrated Manufacturing (CIM) comprises product design, production planning, production control, production processes, quality control, production equipment, and plant facilities.
- The creation of the product starts in the design department, where its function, physical design and manufacturing methods and processes are established.
- Upon completion of the design activities, 70% of the manufacturing costs have been pre-determined.
- This fact stresses the importance of combining design and manufacturing in a comprehensive CIM system.

NPTEL

Evolution of Manufacturing Systems

- Modern manufacturing systems and industrial robots are advanced automation systems that utilize computers as an integral part of their control. Computers are now a vital part of automation.
- They control standalone manufacturing systems, such as machine tools, welders and laser-beam cutters. They run production lines and are beginning to take take over control of an an entire factory.
- Even more challenging are the new robots performing various operations in industrial plants and participating in the full automation of factories.

NPTEL

Evolution of Manufacturing Systems

- It is well to keep in mind that the automatically controlled factory is nothing more than the latest development in the industrial revolution that began in Europe two centuries ago and progressed through the following stages:
- Construction of simple production machines and mechanization started in 1770, at the beginning of this revolution.
- Introduction of mass production came along later. The transfer line is an organization of manufacturing facilities for faster output and shorter production time. the cycle of operations is simple and fixed and designed to produce a certain product.

NPTEL

Evolution of Manufacturing Systems

- Next came machine tools with simple automatic control, such as plugboard controllers to perform a fixed sequence of operations and copying machines in which a stylus moves on a master copy and simultaneously transmits command signals to servo drives.
- The introduction of numerical control (NC) in 1952 opened a new era in automation. NC is based on digital computer principles, which was a new technology at that time.
- The logical extension of NC was computerized numerical control (CNC) for machine tools, in which a minicomputer is included as an integral part of the control cabinet.

NPTEL

Evolution of Manufacturing Systems

- Industrial robots were developed simultaneously with CNC systems. The first commercial robot was manufactured in 1961., but they did not play a major role in manufacturing until the late 1970s.
- A fully automatic factory which employs a Flexible Manufacturing System (FMS) and computer-aided design/computer-aided manufacturing (CAD/CAM) techniques is the next logical extension of FMS.
- **FMS means a facility that includes manufacturing cells; each cell containing a robot serving several CNC machines, and an automatic material-handling system interfaced with a central computer.**

NPTEL

Evolution of Manufacturing Systems

- The new era of automation, which started with the introduction of NC machine tools, was undoubtedly stimulated by the digital computer. Digital technology and computer-enabled the design of more flexible automation systems, namely systems which can be adopted by programming to produce a new product in a short-time.
- Actually, ‘flexibility’ is the keyword which characterize the new era in automation of manufacturing systems.
- Today, manufacturing systems are becoming more and more flexible with progress in computer technology and programming techniques.

NPTEL

Evolution of Manufacturing Systems

- **Manufacturing systems can be divided into small standalone equipment, like robot and CN machine tools, and comprehensive systems with manufacturing cells and FMSs which contain manual standalone systems.**

- Both types of systems are controlled either by a computers, or by a controller based on digital technology.

- They can accept data in their form of programs and are able to process it and provide command signals to actuators which drive slides, rotary axes, or material-handling conveyors.

NPTEL

Evolution of Manufacturing Systems

- In standalone systems and simple manufacturing cells, the input data defines the position of moving slides, velocities, type of motion, etc.
- **In more sophisticated manufacturing cells, in which a robot equipped with a vision-aid or tactile feedback device is serving a few CNC machine tools, the system makes decision based upon the feedback signals .**
- In FMSs, the level of decisions performed by the computer is the the most sophistication in manufacturing.
- **Parts moving on the handling conveyor are routed to the appropriate manufacturing cell by the supervisory computer.**

NPTEL

Evolution of Manufacturing Systems

- **If a particular cell is busy, the computer routes the parts to another cell which is able to perform the required operation.**
- With the beginning of mass production, a hitherto unknown a market potential opened up to industry. Suddenly, a variety of high quality products were within the reach of many customers.
- This demand stimulated the design of very complex and inflexible manufacturing systems, which constituted large investments and which were very expensive to modify when the end of the life cycle of a product made a production change necessary.

NPTEL

Evolution of Manufacturing Systems

- During the period fixed automation, a large number of manufacturing processes and methods were developed and became a standard for industry.

NPTEL

List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.

NPTEL

Thank You!!

NPTEL

IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Introduction to Manufacturing and Production Systems

PROF PRADIP KUMAR RAY

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

IIT KHARAGPUR

NPTEL

Introduction to Manufacturing and Production Systems

- ✓ **Types of Manufacturing Systems and Role of Automation**

NPTEL

Types of Manufacturing Systems

- Manufacturing is taking raw materials and transforming them into something that has greater value.

- Manufacturing can be broken down into three basic types :
    i. Continuous Processing,
    ii. Custom or Job Shop
    iii. Batch Processing.

NPTEL

Types of Manufacturing Systems

Continuous Processing

- A Continuous processing operation takes the raw materials and processes them into finished product with very little, if any, work-in-process.
- An oil refinery or a chemical plant is an example.
- These are characterized by very costly equipment and few operators.
- They are also highly instrumented in that 10% to 20% of the capital equipment is in instrumentation.

NPTEL

Types of Manufacturing Systems

Continuous Processing

- They are fully automated. The instruments are connected to the actuating mechanisms. such as valves, and so control the process.

- For some time, continuous processing has been computer controlled, and the computers are integrated.

NPTEL

Types of Manufacturing Systems

Custom or Job Shop Manufacturing

- At the other end of the spectrum is the custom job shop or build-to-order company.
- This type of operation either uses very high technology and makes specialized products like gauges or is an artisan type of business, such as making custom executive furniture.
- Although these companies know how to use computers and could integrate the manufacturing, such a move is not cost justified.

NPTEL

Types of Manufacturing Systems

Batch Processing

- The bulk of manufactured goods are fabricated on a batch basis.
- Each fabricated part is then assembled with other fabricated parts into subassemblies, which are further assembled, and so on.
- An assembly usually cannot begin until all the parts are on hand and ready.
- All fabricated parts remain as WIP until the last part is ready and the assembly is ready. At this point, the product passes to the finished good status.

NPTEL

Types of Manufacturing Systems

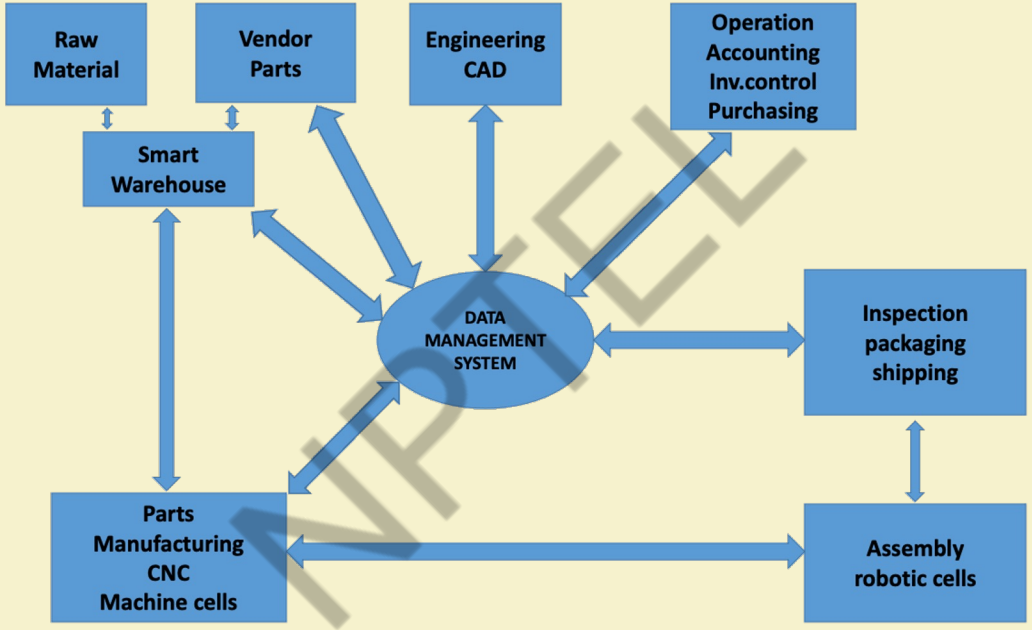


Fig 1. Computer Integrated Manufacturing

Types of Manufacturing Systems

Type of Manufacturing Process

	Piece	Batch	Mass
Primary Motivation	Ability	Flexibility	Volume & cost minimization
Part Variety	Many diff. shapes & sizes	Mostly similar in shape, type of materials	Essentially identical parts with few processes and materials
Flexibility of machine tools	High-can combine several processes in one machine and vary each process	Medium-limited to part family, can change tools, speeds, feeds and dimensions.	Low- usually only minor changes in speeds feeds or part dimensions.
Flexibility to change to a completely different part	Yes	Possible	Impossible

NPTEL

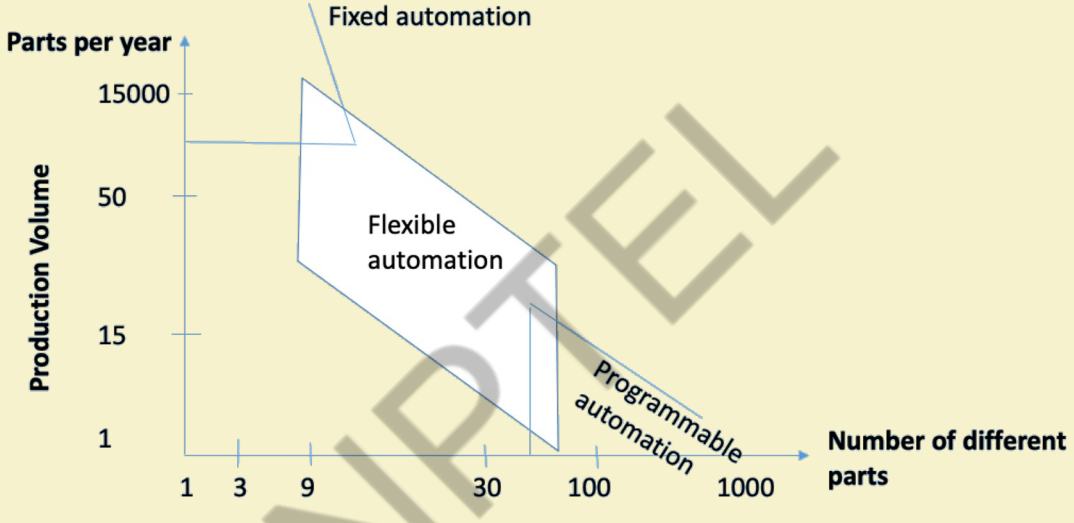
Types of Manufacturing Systems

Type of Manufacturing Process

	Piece	Batch	Mass
Flexibility to change to similar, but different part	Yes	Yes, if previously planned	Very limited
Flexibility to change of materials	Yes	Limited	Extremely Limited
Flexibility of plant layout	Smaller machine tools can be added	Some flexibility, but difficult to install new machines in system.	Carefully planned, but not flexible, not usually possible to install new machines in system.

NPTEL

Types of Manufacturing Systems



The chart shows the relationships of fixed automation, programmable automation, and flexible automation as a function of production volume and product variety batch basis.

Fig 2. Automation and Product Characteristics

NPTEL

Role of Automation

- As we move to larger and larger batch sizes, it pays for us to use more and more hard automation.
- Hard automation refers to a piece of equipment dedicated to a particular part and process.
- A crankshaft fabrication line in an engine plant uses a great deal of hard automation, as does a beer bottling plant.
- Although these machines are fast and efficient, re-programmability is not one of their hallmarks.

NPTEL

Role of Automation

- Even so, tasks such as infeed and outfeed are usually under computer supervision.
- The line between hard and soft (Computer-controlled) automation is, at best, fuzzy.
- These are installations using computer controlled robots for which the programs, machine settings, and tooling have not been changed in three years.

NPTEL

List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.

NPTEL

Thank You!!

NPTEL

IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Introduction to Manufacturing and Production Systems

PROF PRADIP KUMAR RAY

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

IIT KHARAGPUR

NPTEL

Introduction to Manufacturing and Production Systems

- ✓ **Product-Process-Flexibility Matrices, Four-Plane Concept of Manufacturing**

NPTEL

The Product-Process Matrix

- Just as a product traverses its life cycle through the initial stage of low volume and less standardization to the final stage of high volume and high standardization, the process also evolves through the types of flow characterized as jumbled, batch, assembly line, and continuous.

- A product-process matrix has been defined, in which the different stages of the product and process life cycles are plotted along two axes.

- A balanced manufacturing strategy requires a positioning along the diagonal of this matrix. However, **this is based on conventional manufacturing methods.**

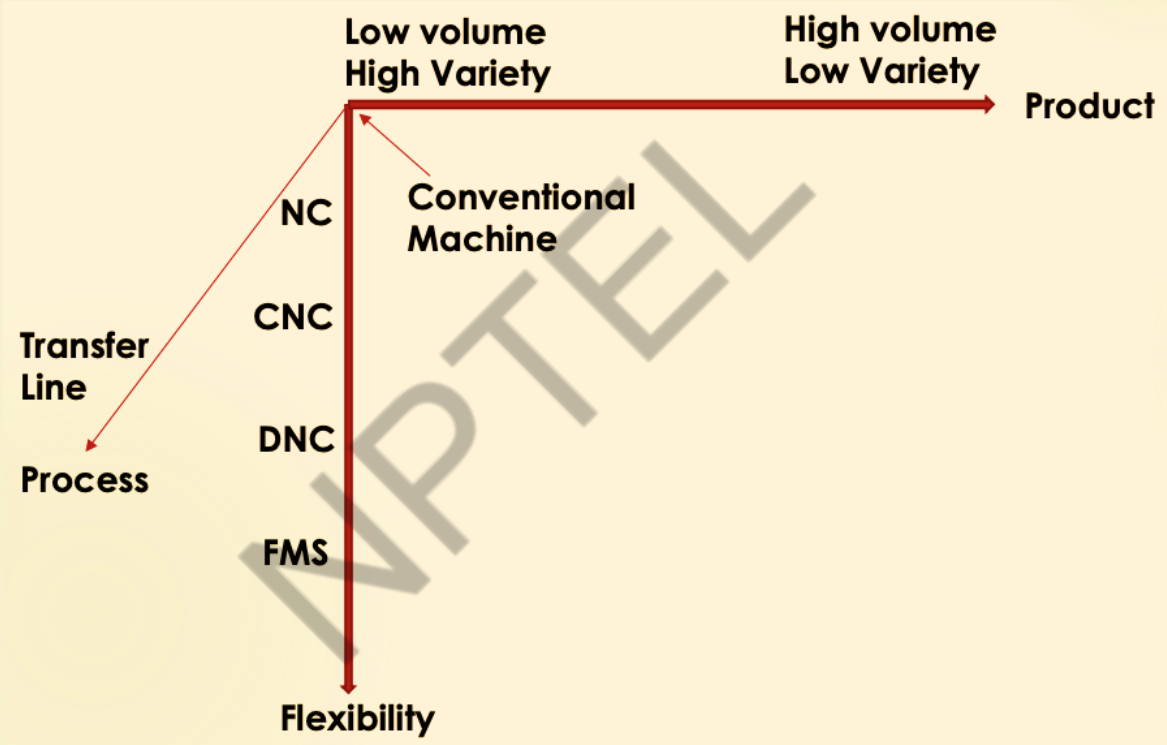
NPTEL

The Product-Process Matrix

- For a given set of part types, a firm has a choice between conventional and flexible modes of manufacture.
- For a given level of flexibility, it is possible to map conventional manufacturing methods into their “flexible” counterparts.
- To capture the impact of flexible manufacture, it is useful to add a third dimension of flexibility to the product-process matrix.

NPTEL

The Product-Process Matrix



NPTEL

The Product-Process Matrix

- The use of special-purpose conventional machines without computer control provides the lowest level of flexibility, while general-purpose conventional machines represent the next higher level of flexibility.

- Stand-alone numerically controlled (NC) machines represents a subsequent stage in which greater flexibility is achieved through paper tape part programming and greater machine versatility.

- CNC and direct numerically (DNC) machines represent stages of increasing process flexibility as more operations come under direct numerical control.

NPTEL

The Product-Process Matrix

- An FMS, in which the machines as well as the movement of parts are centrally controlled, defines the maximum level of flexibility (of certain types) attainable.
- As the technological evolution progresses, the extent of flexibility is likely to increase further.
- For example, two major constraints of most existing FMSs are the lack of flexible tool delivery and part fixturing systems.
- The variety of part types which can be manufactured simultaneously is limited by the capacity of tool magazines and the need for dedicated fixtures for individual part types.

NPTEL

The Product-Process Matrix

- However, development work is being undertaken for ensuring automated tool supply and in designing universal fixtures that can accommodate different part geometries.
- If these developments yield the expected results, substantial increases in product flexibility can be affected.
- This dimension highlights the fact that flexibility decisions are not all or nothing; varying degrees of flexibilities are available.
- A flexible manufacturing system (FMS) is an integrated system of CNC machine tools linked by automated material handling.

NPTEL

The Product-Process Matrix

- Because of the versatility of machine tools and the quick (seconds) cutting tool interchange capability, these systems are quite flexible with respect to the number of part types that can be produced simultaneously and in low (sometimes unit) batch sizes.
- These systems can be almost as flexible as, and more complex than, a job shop, while having the ability to obtain the efficiency of a well-balanced assembly line.
- Most FMSs are devoted to the fabrication of metal parts. FMS combines both new technology with new approaches to old manufacturing problems.
- FMS is in fact an approach to a particular set of manufacturing problems rather than any single technological configuration.

NPTEL

Four-Plane Concept of Manufacturing

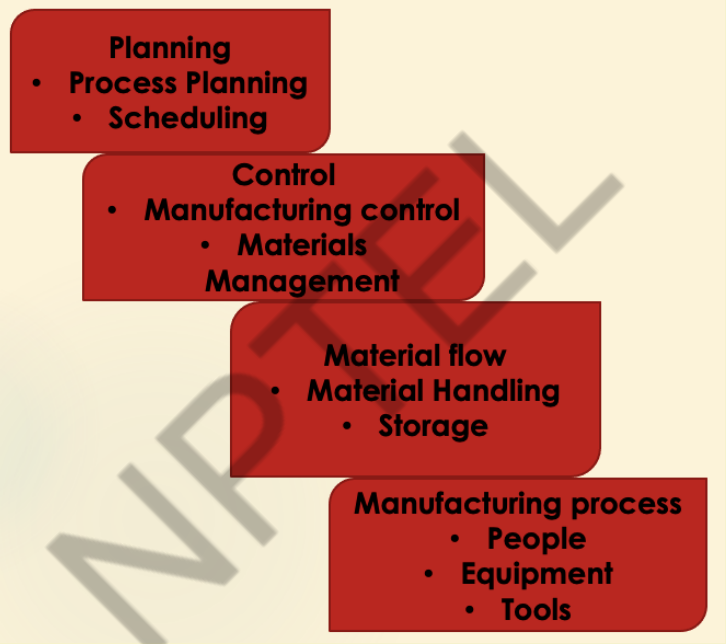


Fig 1. Manufacturing Control System

Four-Plane Concept of Manufacturing

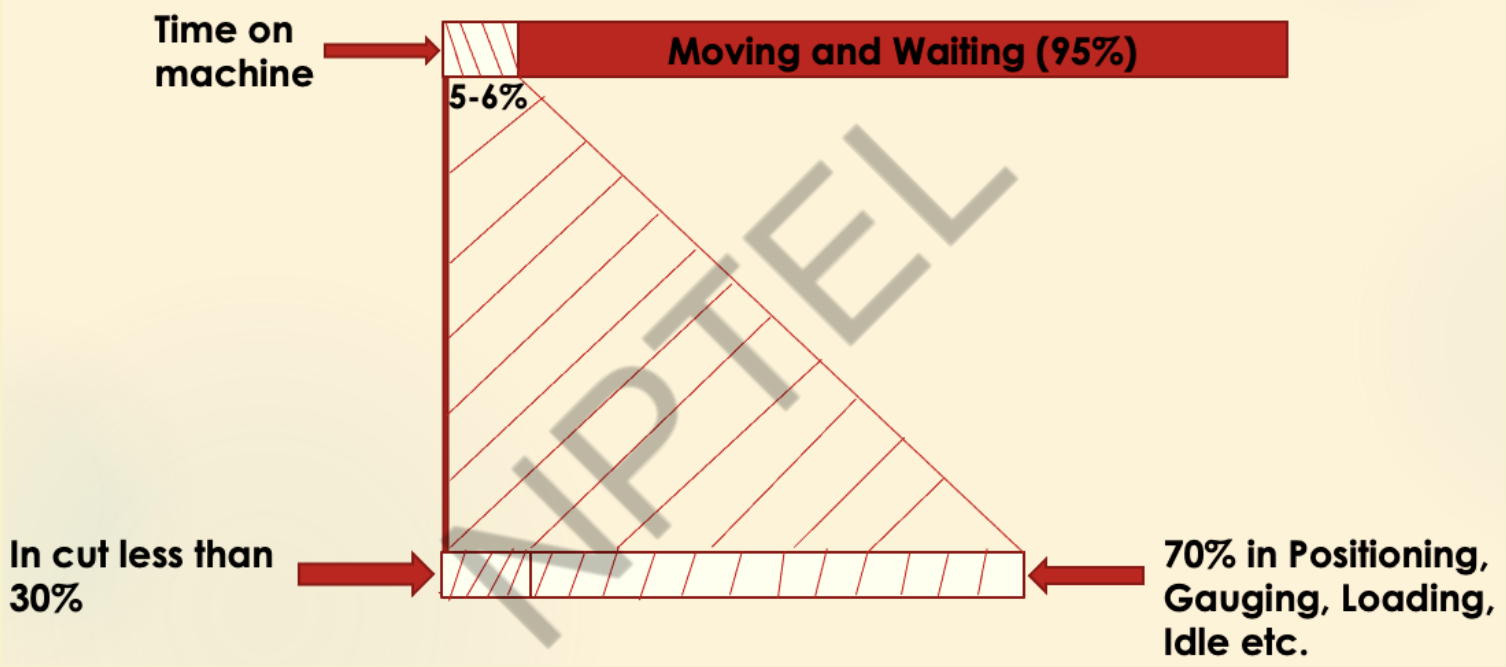
- There are many different methods used to represent a manufacturing system.

- The most important asset the firm possesses is manufacturing know-how. It requires planning, scheduling, controlling, machining, and material movement operations as well as resources to convert the knowledge into a product.

- The first three functions are of major interest. The manufacturing machines are of secondary interest.

NPTEL

Four-Plane Concept of Manufacturing



NPTEL

Four-Plane Concept of Manufacturing

- It is well known that the average machine tool is used only 6% of the time available . The production time could be improved by automatic loading, the use of GT and the employment of 2nd and 3rd shift.
- Whereas early automation endeavors were concentrated on the improvement of machining operation, at present attention is focused on the 95% nonproductive moving and waiting time.
- As a matter of fact, most of the present research effort in manufacturing is concerned with the possibility of reducing this idle time, thereby increasing machine utilization and productivity. Since this task is very difficult to perform with conventional automation tools, the computer plays an ever increasing role.

NPTEL

List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.

NPTEL

Thank You!!

NPTEL

IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Introduction to Manufacturing and Production Systems

PROF PRADIP KUMAR RAY

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

IIT KHARAGPUR

NPTEL

Introduction to Manufacturing and Production Systems

- ✓ **Product Design and Manufacturing Systems**

NPTEL

Product Design and Manufacturing Systems

- The 21st century business environment can be characterized by expanding global competition and products of increasing variety and lower demand.

- The globalization of economic activity has brought about a sea change in the attitudes of customers. Customer individualization is certain to become the central theme of business.

- **An era of mass customization.**

NPTEL

Product Design and Manufacturing Systems

- In the 1970s, the cost of products was the main lever for obtaining competitive advantage.
- In the 1980s, quality superseded cost and became an important competitive dimension.
- Today, the customer takes both minimum cost and high quality for granted. Factors such as delivery performance and customization and environmental issues such as waste generation are assuming a predominant role in defining the success of organizations in terms of increased market share and profitability.

NPTEL

Product Design and Manufacturing Systems

- The question is, what can we do under these changing circumstances to stay in business and retain competitive advantage?

- As a first step what is needed is the development of the right business strategy to meet the challenges of present and future markets. In doing so, a manufacturing organization has not only to understand what customers want but also to develop internal mechanisms to respond instantly to the changes demanded by the customers.

NPTEL

Product Design and Manufacturing Systems

- The must not only make use of state-of-the-art technologies and concepts but also think in the reverse direction.

- 'Reverse direction' means building products that realize customer expectations. That is, when an organization is deciding about business plans, it has to address several questions.

- Will the customer find any change in what one does as a result of using this? Will the customer be able to define any benefit?

NPTEL

Product Design and Manufacturing Systems

- The next step is to determine the right kind of resources to support the business strategy. This requires the right choice of people, technology, and business processes. What is further needed is a marriage of corporate strategies, technology, people, and business processes with a view to evolving policies so that all the functional organs of an organization (finance, sales and marketing, product engineering, manufacturing, and human resources) work in a synchronized manner to achieve corporate objectives.

- The obvious question then is, how should a manufacturing enterprise work?

NPTEL

Product Design and Manufacturing Systems

- Figure 1. shows how customers play a pivotal role in defining the manufacturing enterprise. Corporate objectives are growth in market share, profitability, work force stability, and other financial measures.

- For example, marketing identifies a range of products, product market segments, and new product ideas to satisfy customer needs. Can a company deliver the kinds of products needed to satisfy order-winning criteria such as cost, quality, lead time, and so on?

NPTEL

Product Design and Manufacturing Systems

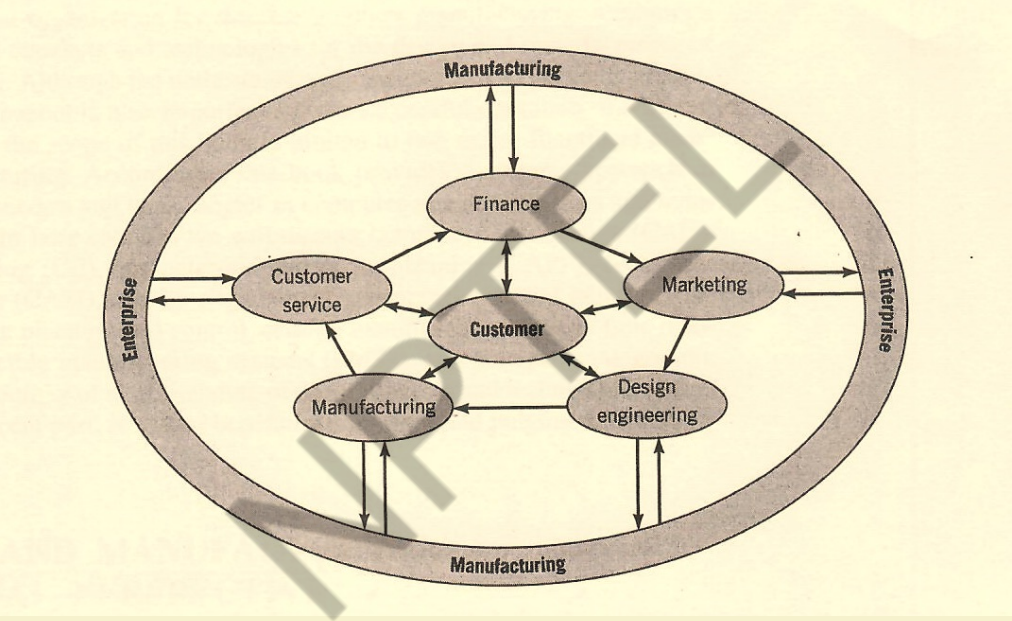


Fig 1. Customer and Manufacturing Enterprise

Design and Manufacturing

Design

- Design and manufacturing are the core activities for realizing a marketable and profitable product. A number of evolutionary changes have taken place over the past couple of decades in the areas of both design and manufacturing.

- First: CAD. The major focus in CAD technology development has been on advancing representation completeness. Figure 2 shows the evolution the evolution of CAD/CAM systems over the past three decades.

NPTEL

Design and Manufacturing

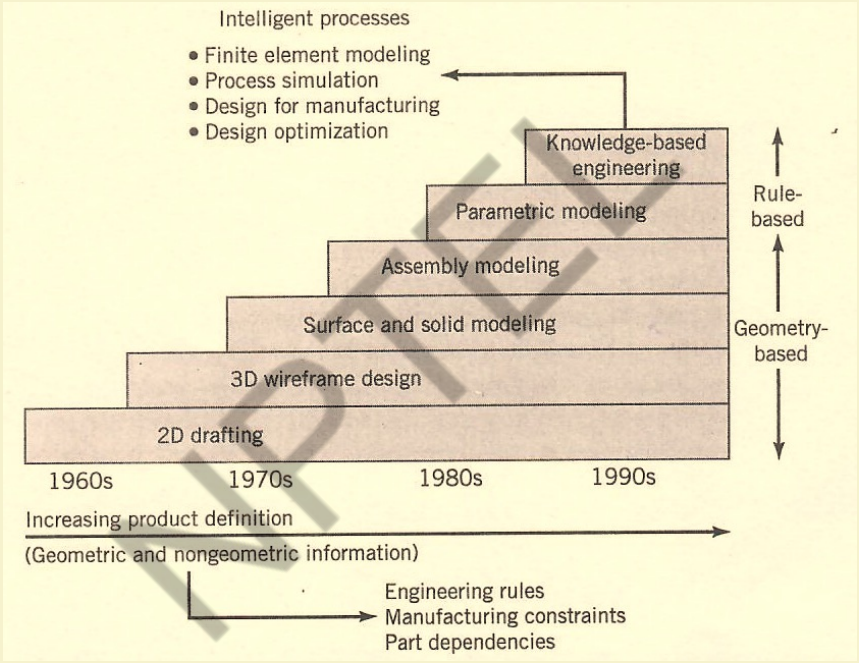


Fig 2. The Evolution of Mechanical CAD/CAM Systems

Design and Manufacturing

- First, there was the development of a two-dimensional (2D) drafting system in the 1960s.
- Then, the extension of 2D drafting systems to three-dimensional (3D) models led to the development of wireframe-based modelling systems.
- However, it was not possible to represent higher-order geometry data such as surface data. To bridge this gap, surface-based models were developed in the early 1970s.
- The need for solid modelling intensified with the development of application programs such as numerical control (NC) verification codes and automation mesh generation.

NPTEL

Design and Manufacturing

- A volume representation of the part is needed for performing topological validity checks. The solid modelling technology has evolved only since the mid-1970s.
- The solid modelling scheme provide mechanisms for defining informationally complete models. However, these schemes have an inherent weakness because they provide a low-level representation of parts.
- That means that to model a part, the designer has to provide model description in terms of geometric and topological entities that constitute a model.

NPTEL

Design and Manufacturing

- The latest evolutionary development in the CAD/CAM industry has been knowledge-based engineering systems that can capture both geometric and nongeometric product information, such as engineering rules, part dependences, and manufacturing constraints, resulting in more informationally complete product definitions.
- The commercial knowledge-based system known as Intelligent-CAD (ICAD) is available from ICAD, Cambridge, Massachusetts.
- Because ICAD is based on the principles of object-oriented modelling technology, it provides a development environment with powerful geometric and artificial intelligence (AI)-based tools.

NPTEL

Design and Manufacturing

Manufacturing

- Manufacturing is not just the transformation of raw materials into value-added output meeting specifications. It has broader meaning.
- **Manufacturing is a series of interrelated activities and operations involving design material selection, planning, production, quality assurance, management and marketing of discrete consumer and durable goods.**
- For a manufacturing organization to remain competitive, it must deliver products to customers at the minimum possible cost, the best possible quality, and the minimum lead time starting from the product conception stage to final delivery, service, and disposal.

NPTEL

Design and Manufacturing

- Present-day manufacturing activities may be classified in two broad categories: continuous-process and discrete-product production.

- A number of interesting developments since then in the areas of numerically controlled machine tools, robotics, material-handling systems and computer control systems have lead to the current state of automated manufacturing technology, such as flexible manufacturing systems.

- We provide a brief historical perspective on each of these.

NPTEL

Design and Manufacturing

Material-Handling Systems

- Material handling is an integral part of any manufacturing system.
- Manufacturing system performance can be significantly improved by using computer-controlled material flow, which reduces waiting time and work-in-process inventory compared with manual loading and unloading and manual material handling systems.

NPTEL

Design and Manufacturing

Robotics

- The word ‘ROBOT’ was first used to mean ‘forced labour’ in a satirical fantasy play, ‘Rossum’s Universal Robots,’ written by Karel Capek in 1921.

- Robotics, along with the technological developments in the areas of microprocessor and numerical control, have advanced the frontiers of automation.

NPTEL

Design and Manufacturing

Flexible Manufacturing Systems

- Computer control systems have provided a major impetus to automation.
- The use of mainframe computers in the 1950s and 1960s for planning, scheduling, and controlling batch production became quite commonplace.
- A number of management information systems and database management systems were developed and used for a variety of functions in companies.
- Factory, automation also resulted from advances in local area and wide area networks (LANs and WANs), bar codes, programmable logic controllers (PLCs) and computer controls.

NPTEL

Design and Manufacturing

Flexible Manufacturing Systems

- The technological developments in CNC, DNC, PLC, robotics, AGVs, automated storage and retrieval systems (AS/RSs), automatic tool changers, tool magazines, modular fixturing, local area networks, and associated technologies such as group technology laid foundations for automated manufacturing of a high to medium variety of parts having low to medium levels of demand.
- This lead to the evolution of FMSs in the early 1960s.

NPTEL

List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.

NPTEL

Thank You!!

NPTEL

IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Introduction to Manufacturing and Production Systems

PROF PRADIP KUMAR RAY

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

IIT KHARAGPUR

NPTEL

Introduction to Manufacturing and Production Systems

- ✓ **Definitions and Design Criteria for Production Systems**

NPTEL

Definitions and Design Criteria for Production Systems

Systems Approach to Computer Integrated Design and Manufacturing

- A system can be defined as a collection of components in which individual components are constrained by connecting interrelationships such that the system as a whole fulfills some specific functions in response to varying demands.

- What matters is the overall performance of the product during its life cycle. Therefore, the product life-cycle approach provides a logical framework for understanding and analysis.

NPTEL

Definitions and Design Criteria for Production Systems

- The product life cycle includes the following phases:

  a) Design phase
  b) Manufacturing phase
  c) Product usage phase
  d) Disposal phase

- During the product life cycle, design and manufacturing have major effects on the subsequent phases.
- Consequently, they are responsible for the lion's share of life-cycle cost as shown in Figure. 1

NPTEL

Definitions and Design Criteria for Production Systems

- The issues of product quality and overall lead time are intimately tied to these phases.
- Looking exclusively at a single phase of the life cycle will miss the dependences that exists between them.
- Obviously, what is needed is a systems approach to understand each of the phases and the linkages between them.

NPTEL

Definitions and Design Criteria for Production Systems

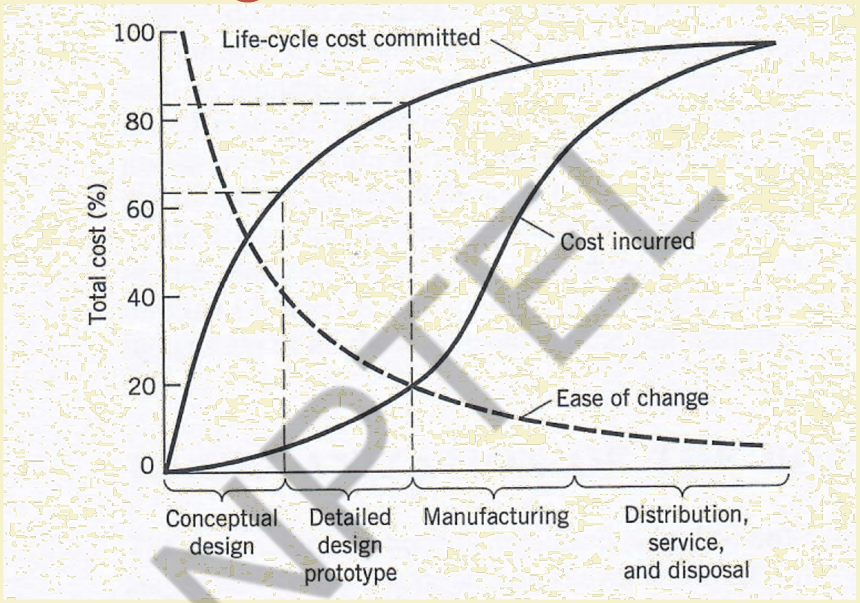


Fig 1. A characteristic curve representing cost incurred and committed during the product life cycle.

NPTEL

Definitions and Design Criteria for Production Systems

The product design process starts with the identification of customer needs and goes through a sequence of activities. These include:

- Identifying the attributes of the need for which the product is being designed and defining the problem domain.
- Generation of preliminary ideas with respect to technical choices, materials, design complexities, and so on.
- Refinement of the product ideas using geometric modelling.

NPTEL

Definitions and Design Criteria for Production Systems

- Analysis of best designs from the point of view of cost, functional requirements, and marketability using such tools as finite-element methods, assembly analysis, and so on.
- Selection of a design that has all the desirable characteristics including manufacturability, serviceability, maintainability, etc.
- Creation of a detailed design providing detailed specifications with respect to materials, tolerances, surface roughness, and so on.

NPTEL

List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.

NPTEL

Thank You!!

NPTEL