COMPUTER INTEGRATED
MANUFACTURING SYSTEMS
(For B.E. Mechanical Engineering Students)

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CHAPTER – 2: PRODUCTION PLANNING AND CONTROL AND COMPUTERISED PROCESS PLANNING


CHAPTER – 3: CELLULAR MANUFACTURING

(Group Technology (GT), Part Families – Parts Classification and coding – Simple Problems in Opitz – Part coding system – Production flow Analysis – Cellular Manufacturing – Composite part concept – Machine cell design and layout – Quantitative analysis in Cellular Manufacturing – Rank OrderClustering Method – Arranging Machines in a GT cell – Hollier Method – Simple Problems.)
CHAPTER – 4: FLEXIBLE MANUFACTURING SYSTEM (FMS) AND AUTOMATED GUIDED VEHICLE SYSTEM (AGVS)


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1.1. INTRODUCTION:

CAD means Computer Aided Design and CAM means Computer Aided Manufacturing.

CAD is defined as the use of computer systems to assist in the creation, modification, analysis (or) optimization of a design.

CAM can be defined as the use of computer systems to plan, manage & control the operations of a manufacturing plant through either direct (or) indirect computer interface with production resources.

Computer system consists of the hardware and software to perform the specialized design functions required by the particular user firm.
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Computer system consists of the hardware and software to perform the specialized design functions required by the particular user firm.
1.2. COMPUTER AIDED DESIGN (CAD):

1.2.1. What is CAD?

It is the technology used to integrate the design activities with the help of computer which includes transformation and modification of images of part geometry, printing the images on a printer or plotter and design data analysis.

CAD can also be defined as the process in which computers are utilised in the creation of model, modification and analysis of a design to get the optimum model.

1.2.2. Why should we go for CAD?

1. For improved documentation, more standardization, better Engineering drawings, reduced drawing errors and clear perception of drawings.

2. The design quality is improved, moreover any problem encountered during design can be rectified and suitable alternatives are suggested. There is an inbuilt feature which checks for any calculation errors and leads to better quality and accuracy of design.

3. The productivity is increased, the synthesis time is greatly reduced as the design engineer has better visualisation of part geometry.

1.2.3. The factors to be considered while selecting a CAD system:

(a) Reliability

(b) Compatibility with other system

(c) Cost Factors

(d) Memory size and storage requirement

(e) Type of peripherals requirement.
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(b) Compatibility with other system (c) Cost Factors
(d) Memory size and storage requirement
(e) Type of peripherals requirement.

1.2.4. Role of Computer in CAD:

(a) Computer improves accuracy of design.
(b) Various dimension and other design attributes can be conveniently manipulated by computers.
(c) Another important role played by Computers is creation of part libraries for standard components. Similarly multiple components can be included in these part libraries.
(d) Moreover, the modification of a model is very simple which helps the designer to look in for further improvement.
(e) Calculation of various geometric properties such as area, volume and dimensioning can be accurately done.

1.2.5. Applications of CAD in simple words:

(a) Finite element analysis.
(b) CNC programming.
(c) Building drawing using Architectural CAD.
(d) Piping system for Engineering Industries.
(e) CAPP (Computer Aided Process Planning).
(f) Kinematic analysis for systems.
(g) Dynamic analysis for systems.

1.2.6. Uses of CAD:

(a) Creating several colour combinations for a product to improve its appeal.
(b) Exploded views of assemblies can be effectively done.
(c) Resizing and Rotation of the objects can also be done for viewing the objects from different angles (different perspectives).
(d) Material requirement for manufacturing a part, cost involved and other details can be predicted.

(e) A complete comprehensive drawing can be made including the dimensions, tolerances and other functional specifications.

(f) Assembly drawings and assembly procedures can be done.

(g) Cross sectional details and other inner details can be effectively created.

(h) Interference checking between mating parts can be done. Eg: cone clutch. Here the female cone and male cone interference can be checked.

(i) Any drawing after completion can be stored in computer file, which can later be printed.

**Note:** How CAD is integrated with CAE and other functions (Activities) is shown below.

**1.2.6.1. Computer Aided Design and Drafting Packages:**

For drafting, Modelling and analysis.

1. Auto CAD
2. Pro-Engineer (PRO-E)
3. Ideas
4. Unigraphics
5. Mechanical Desktop
6. ANSYS
7. Nastran
8. Pro-Mechanica
9. CATIA

1.2.7. Reasons for Implementing a CAD:

* To create and modify appearance of objects.
* It improves the productivity of the designer.
* Improves communication.
* Improves the efficiency of Design.
* Create database for manufacturing.

1.2.8. Benefits of CAD:

1. Increased design and productivity.
2. Flexibility in design.
3. Improved design analysis.
4. Greater accuracy in design.
5. Easier creation and correction of engineering drawings.
7. Faster new product design.
8. Shorter lead time.
### 1.2.9. Applications of CAD:

#### Table 1.1

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<tr>
<td>Analysis</td>
<td>Interference checking, Fit analysis, Weight balance, Volume and area properties, Structural analysis, Tolerance checking, Kinematic analysis</td>
</tr>
<tr>
<td>Documentation</td>
<td>Drawing generation, Bill of materials, Image reading.</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Process planning, NC machine simulation, NC part program generation, NC part program verification, Inspection programming, Factory layout, Robot programming and verification.</td>
</tr>
<tr>
<td>Management</td>
<td>Review and release, Engineering changes, Project control, Project monitoring, Selection of standard parts and assembly, Design standards.</td>
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1.3. DESIGN PROCESS IN CAD SYSTEM (OR) ELEMENTS OF A CAD:

The various design related tasks which are performed by a modern computer aided design system can be grouped into four functional areas:

1. Geometric modelling
2. Engineering analysis
3. Design review and evaluation
4. Automated drafting

*Fig. 1.1: Application of computers to the design process*

These four areas correspond to the final four phases in Shigley’s general design process, illustrated in *Fig. 1.1*. Geometric modeling corresponds to the synthesis phase in which the physical design project takes from on the ICG system. Engineering analysis corresponds to phase 4, dealing
with analysis and optimization. Design review and evaluation is the fifth step in the general design procedure. Automated drafting involves a procedure for converting the design image data residing in computer memory into a hard-copy document. It represents an important method for presentation (phase 6) of the design. The following four sections explore each of these four CAD functions.

1.3.1. Geometric modelling:

In computer-aided design, geometric modelling is concerned with the computer-compatible mathematical description of the geometry of an object. The mathematical description allows the image of the object to be displayed and manipulated on a graphics terminal through signals from the CPU of the CAD system. The software that provides geometric modelling capabilities must be designed for efficient use both by the computer and the human designer.

To use geometric modeling, the designer constructs the graphical image of the object on the CRT screen of the ICG system by inputing three types of commands to the computer. The first type of command generates basic geometric elements such as points, lines and circles. The second command type is used to accomplish scaling, rotation or other transformations of these elements. The third type of command causes the various elements to be joined into the desired shape of the object being created on the ICG system. During this geometric modelling process, the computer converts the commands into a mathematical model, stores it in the computer data files and displays it as an image on the CRT screen. The model can subsequently be called from the data files for review, analysis or alteration.

There are several different methods of representing the object in geometric modelling. The basic form uses wire frames to represent the object. In this form, the object is displayed by interconnecting lines, as shown in Fig. 1.2. Wire-frame
geometric modeling is classified into three types, depending on the capabilities of the ICG system. The three types are:

1. **2D.** Two-dimensional representation is used for a flat object.

2. **2½ D.** This goes somewhat beyond the 2D capability by permitting a three-dimensional object to be represented as long as it has no side-wall details.

3. **3D.** This allows for full three-dimensional modelling of a more complex geometry.

### 1.3.2. Engineering Analysis:

* In the formulation of nearly any Engineering design project, some types of analysis is required.

* The analysis may involve stress-strain calculations, heat transfer or use of differential equations to describe the dynamic behaviour of the system being designed.

* CAD/CAM systems often include engineering analysis software which can be called to operate on the current design model.
Example:

1. Analysis of mass properties
2. Finite element analysis

3. Design, Review & evaluation:

* Checking the accuracy of the design can be accomplished conveniently on the graphics terminal.

* A procedure called layering is often helpful in design review.
  
  Eg: A good application of layering involves overlaying the geometric image of the final shape of the machined part on the top of the image in the rough casting.

* Another procedure for design review is interference checking.

4. Automated drafting:

* It involves the creation of hardcopy engineering drawings directly from the CAD database.

* CAD systems can increase productivity in the drafting function more over 5 times of manual drafting.

* This feature includes automatic drawing, hatched areas, scaling, zoom, etc.

1.4. COMPUTER AIDED MANUFACTURING (CAM):

Computer Aided Manufacturing:

The computer systems are used to plan, manage and control the operations of the production plant through the computer interface with the plant’s production resources. This is known as Computer Aided Manufacturing. CAM is most closely associated with process planning and numerical control (NC) part programming.
The functions of CAM are given below.

1. Computer Aided Process Planning (CAPP)
2. CNC Part Programming
3. Computer Aided Work Standards
4. Production Scheduling
5. Materials Requirements Planning (MRP)
6. Shop Floor Control

The advantages of Computer Aided Manufacturing:

The computer application in manufacturing makes use of common database. The data is transferred from one function to another automatically to give a base for the concept of Computer Integrated Manufacturing (CIM).

The other advantages of CAM are given below:

1. Increased Productivity.
2. Shorter lead time
3. Improved reliability.
4. Freedom in modifying design.
5. Flexibility in operations.
6. Reduced scrap and rework.
7. Reduced Maintenance.
8. Better Control of Management.
The application of CAM can be classified into two categories:

1. Manufacturing planning
2. Manufacturing control

1.4.1. Manufacturing planning:

In this process computer is used indirectly to support the production function, but there is no direct connection between the computer and process.

Important Applications are:

1. CAPP – Computer Aided process planning
2. Computer Assisted NC part programming
3. Computerized machinability data systems
4. Computerized work standards
5. Cost Estimating

Fig. 1.3: The information processing cycle in a typical manufacturing firm
6. Production and Inventory planning
7. Computer Aided line balancing

1.4.2. Manufacturing control:

Manufacturing control is concerned with managing and controlling the physical operations in the factory.

The following areas to be controlled by manufacturing control,

1. Process monitoring
2. Quality control
3. Shop floor control
4. Inventory control
5. First in time production.

1.4.3. CAD/CAM Interface:

CAD/CAM is concerned with the engineering functions in both design and manufacturing.

CAD/CAM must be interfaced to achieve improvement in manufacturing, improved productivity and quality. The various data (like component geometry data) generated for designing and developing CAD drawings can be reused for manufacturing instruction. These data can be used for CNC production processes. Computer aided process planning (CAPP), Computer aided production planning and control (PPC) and shop floor control (SFC). The CNC production processes CAPP, PPC and SFC with the aid of computers are known as Computer Aided Manufacturing (CAM). So the current trends in manufacturing is to interface the CAD and CAM. The both CAD and CAM are sharing common database to eliminate the unwanted wall separating the design and manufacturing functions. Refer Fig. 1.4(a).
The CAD/CAM interface allows the manufacturing function to influence the design process and also to make the designers to know the effects of design features on the manufacturing function.

**Advantages of CAD/CAM Interface:**

1. Productivity can be increased due to fast mathematical calculations, data storage and retrieval.

2. Quality can be improved since the designer can select best design among the various design alternatives easily by knowing their effects on manufacturing function.

3. Communication is improved. The design documents like drawings, part lists, bill of materials and specifications are sent to common data base which are utilized by manufacturing department.
4. By using 3-D Computer models, rapid prototype is developed with less cost. It eliminates the expensive prototypes.

5. Customers taste can be responded and implemented on the design, result in manufacturing.

The following diagram **Fig. 1.4(b)** haws the concept of CAD/CAM interface.

![CAD/CAM Interface Diagram](image)

**Fig. 1.4(b): CAD/CAM Interface**

In CAD department, the part 3D model is developed in the computer terminal using CAD softwares like AutoCAD, PRO-Engineering, Ideas, Unigraphics etc. This is known an Geometrical modelling. This part is analysed using Finite Element analysis for the structure and its mechanical behaviour using FEM softwares like Ansys and Nastron. Kinematic studies are performed using softwares like ADAMS. Then the design is reviewed and evaluated for its effect on manufacturing function. Thereafter the engineering drawings are produced.

The manufacturing department utilizes the geometric description from the common database. It prepares the process planning and develops CNC programs for machine tools. It instructs Robots to handle the rolls and workpieces. It schedules the plant operations with production planning and control system.
1.4.4. CAD/CAM Vs CIM:

CAD/CAM includes design, manufacturing planning & control.

CIM means engineering functions of CAD/CAM & firm's business that are related to manufacturing.

![Fig. 1.5: The scope of CAM/CAD and CIM](image)

1.5. CONCURRENT ENGINEERING:

In olden days, in the conventional manufacturing process, the details about how to achieve quality of product, cost of product and variety of products are not given back to the designer at sufficiently early stage. Hence, the whole process takes too long. But, the current trends in manufacturing engineering break the firewall between the designer and manufacturing personnel to achieve high quality product throughout the **product development phase**. The current trends in manufacturing technology requires high quality with acceptable levels of defects (or) **zero defects**. So the achievement of high quality is the responsibility of everyone in an organization. The quality will be lost if there is a demarcation between design and manufacturing department. To get high quality, the design should be modified to meet the manufacturing requirements at an early stage.
Hence the design and the manufacturing system should be developed simultaneously. This is known as **simultaneous engineering** or **concurrent engineering**.

In concurrent engineering, the design is developed by the experts from various fields like materials, manufacturing processes, assembly, inspection, maintenance and marketing.

The life cycle of a product consists of design phase, the manufacturing phase and the end-of-life phase. In conventional product cycle, the design and manufacturing are separated and occur sequentially as shown in **Fig. 1.6 (a) & (b)**.

![Fig. 1.6(a): Phases of Product Life Cycle](image)

![Fig. 1.6(b): Sequential Engineering](image)

The process planning bridges the gap between the two phases.

The sequence of operations involved in the manufacturing of a new product are

1. Design
2. Process planning
3. Manufacturing
4. Assembly.

In the conventional manufacturing, these stages proceed sequentially, as shown in **Fig. 1.6(c)**. So the lead time for a new product is more.
But in concurrent engineering, these operations are done in parallel and are overlapped, as shown in Fig. 1.6(d).

Here the lead time for a new product is less. So, in concurrent engineering approach, the whole life cycle of a product is considered concurrently.

Concurrent engineering carry out the design and manufacturing functions at the same time while designing the product. It makes the design engineer and manufacturing engineer to interchange the parameters to obtain optimum design of product and process. The concurrent engineering defines complete life cycle of product from prototype to manufacture, repair, eventual disposal and recycling. It combines the design and process planning into one common activity. It improves the inability of early design decisions. It reduces the life cycle cost of the product tremendously.
The concept of concurrent engineering is shown in Fig. 1.6(e).

![Diagram](image)

**Fig. 1.6(e): The concept of concurrent engineering**

In this, the design coordinator coordinates the suggestions from all the experts of various departments around him.

The design coordinator moves the new design to all the experts. The experts discuss it and suggest design changes. The design is then passed back to the design coordinator. He accepts the suggestions, modifies the design and sends it to the experts again for evaluation. On each integration, there will be fewer and fewer changes and finally optimum design is arrived.

**Design for Manufacture and Assembly DFMA:**

DFM means design of product for ease of manufacture

DFA means design of product for ease of assembly.

Design for manufacture and assembly means that design the product for ease of manufacture and for ease of assembly. i.e. Design a component so that it can be easily manufactured and easily assembled.
It is the integration of product design, assembly and process planning into one common activity. It is one of the techniques for applying concurrent Engineering.

The following are important points to be noted during design for manufacturing and assembly.

1. Number of parts to be designed should be minimum.
2. Variation of part should be minimised.
3. The parts designed should be used for so many functions.
4. Design a part so that it can be easily fabricated.
5. Avoid separate fasteners.
6. Design the part so that it can be easily assembled.
7. Evaluate assembly methods.
8. Avoid flexible components which are difficult to handle.
9. Trade with known and experienced vendors and suppliers.
10. Minimise subassemblies.
11. New technology should not be used unless it is necessary.
13. Use the simple and possible operations.
14. Minimize set up procedures and interventions.

The DFMA reduces the time spent on the design process. The following flow Fig. 1.6(f) shows the steps taken for concurrent engineering using DFMA during design.
Fig. 1.6(f): Concurrent engineering using DFMA technique

In this, the DFA analysis is conducted at first to simplify the product structure.

By this, early cost estimates for the products are obtained for both original design and new design and decide which one is economical. During this process, the best materials and best processes are selected for the various parts of the product. Suggestions for more economic materials and processes are taken into account at this stage. Once the best materials and processes are finalised, a thorough analysis about design for manufacturing (DFM) can be carried out. By this DFM, the detailed design of parts are evaluated. Then prototype can be developed and tested. Finally the product will be manufactured.

The goals of concurrent engineering are given below.

1. Avoid expensive components which are unnecessarily expensive to produce. (e.g) surface furnish smoother than necessary should be avoided.
2. Reduce the material costs (or) make the optimum choice of materials and the optimum choice of processes.

1.6. INTRODUCTION OF CIM:

The term CIM – comprises three words – Computer, Integrated and Manufacturing with all three words are equally significant.

CIM is the application of computers in manufacturing, in an integrated way.

The middle term integrated in CIM is very appropriate. It brings the home point that integration of all resources – capital, human, technology and equipment – which are vital to success in manufacturing.

Although computers and computer communication have been with us since 1950’s, CIM is relatively new. It began to draw attention only in the 1980’s.

**CIM is an umbrella term under which all functions of manufacturing and associated attributes such as CAD/CAM, Flexible Manufacturing System and Computer Aided Process Planning etc.**

CIM surrounds the entire range of product development and manufacturing activities with all the functions being carried out with the help of software packages.

**For example:**

The product data is created during design. This data has to be transferred from the modelling software to manufacturing software without any loss of data.

CIM uses a common database to integrate design, manufacturing and associated business functions that combine the automated segments of a factory.
1.6.1. What is Computer Integrated Manufacturing:

* Basically Computer Integrated Manufacturing (CIM) is the manufacturing approach of using computers to control entire production process.

* CIM is an operating philosophy aiming at greater efficiency across the whole cycle of product, design and manufacturing and Marketing, thereby improving quality, productivity & competitiveness.

1.6.2. Definition:

* There are many definition for CIM according to different aspects. Some of them are given below.

1. CIM is the concept of a totally automated in which all manufacturing process integrated and controlled by a CAD/CAM system.

   — Kochan and Cowan

2. CIM is the application of Computer technology used in order to provide the right information to the right place at the right time, which enables the achievement of its product, process and business goals.

   — Digital Equipment Corporation

3. CIM is the integration of the total manufacturing enterprise through the use of integrated systems and data communication coupled with new management philosophies that improve organization and personal efficiency.

   — CASA/SME

4. CIM is nothing but a data Management and networking problem.

   — Jack Conway

5. All the engineering function of CAD/CAM and business functions of the firm is called CIM.

   — Mikill P Groover
1.7. CASA/SME MODEL OF CIM / CIM WHEEL:

CIM is the integration of total manufacturing enterprise by using integrated system and DATA communication with new managerial philosophies that improves organizational and personnel efficiency.

At the beginning of 80’s CIM wheel was developed. Main idea was the holistic view of the enterprise, on the basis of the CIM.

In center core of the CIM wheel stands the integrated architecture (Integrated System Architecture) with a common database (common DATA), the information administration and communication (information resources management & communication).

On the second / middle level of the enterprise, functions such as factory automation, product and processes and manufacturing planning and control over the components of the integrated architecture links with one another.
The third level is outer rim was considered administrative level. It concerns manufacturing management and personnel management, marketing, strategic planning and financial system. The advancement of the CIM wheel is the manufacturing enterprise wheel.

1.8. NATURE AND ROLE OF THE ELEMENTS OF CIM SYSTEM:

Nine major elements of a CIM system are in Fig. 1.8 they are,

* Marketing
* Product Design
* Planning
* Purchase
* Manufacturing Engineering
* Factory Automation Hardware

Fig. 1.8: Major elements of CIM systems
(i) Marketing:

The need for a product is identified by the marketing division. The specifications of the product, the projection of manufacturing quantities and the strategy for marketing the product are also decided by the marketing department.

Marketing also works out the manufacturing costs to assess the economic viability of the product.

(ii) Product Design:

The design department of the company establishes the initial database for production of a proposed product. In a CIM system this is accomplished through activities such as geometric modeling and computer aided design while considering the product requirements and concepts generated by the creativity of the design engineer. Configuration management is an important activity in many designs. Complex designs are usually carried out by several teams working simultaneously, located often in different parts of the world. The design process is constrained by the costs that will be incurred in actual production and by the capabilities of the available production equipment and processes. The design process creates the database required to manufacture the part.

(iii) Planning:

The planning department takes the database established by the design department and enriches it with production data and information to produce a plan for the production of the product. Planning involves several subsystems dealing with materials, facility, process, tools, manpower, capacity, scheduling, outsourcing, assembly, inspection,
logistics etc. In a CIM system, this planning process should be constrained by the production costs and by the production equipment and process capability, in order to generate an optimized plan.

(iv) Purchase:

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

(v) Manufacturing Engineering:

Manufacturing Engineering is the activity of carrying out the production of the product, involving further enrichment of the database with performance data and information about the production equipment and processes. In CIM, this requires activities like CNC programming, simulation and computer aided scheduling of the production activity. This should include online dynamic scheduling and control based on the real time performance of the equipment and processes to assure continuous production activity. Often, the need to meet fluctuating market demand requires the manufacturing system flexible and agile.

(vi) Factory Automation Hardware:

Factory automation equipment further enriches the database with equipment and process data, resident either in the operator or the equipment to carry out the production process. In CIM system this consists of computer controlled process machinery such as CNC machine tools, flexible manufacturing systems (FMS). Computer controlled robots, material handling systems, computer controlled assembly systems, flexibly automated inspection systems and so on.
(vii) **Warehousing:**

Warehousing is the function involving storage and retrieval of raw materials, components, finished goods as well as shipment of items. In today’s complex outsourcing scenario and the need for just-in-time supply of components and subsystems, logistics and supply chain management assume great importance.

(viii) **Finance:**

Finance deals with the resources pertaining to money. Planning of investment, working capital, and cash flow control, realization of receipts, accounting and allocation of funds are the major tasks of the finance departments.

(ix) **Information Management:**

Information Management is perhaps one of the crucial tasks in CIM. This involves master production scheduling, database management, communication, manufacturing systems integration and management information systems.

1.9. **REASONS FOR IMPLEMENTING CIM:**

1. *To solve following issues*
   
   (a) Strategic issue (Lack of information, technologies)
   
   (b) Organization issue (Absence of total management system)
   
   (c) Behavioural issue (Safety, Lack human involvement of CIM)
   
   (d) Technological issues (Incompatible Computer System, short lead life, Frequent job changes)

2. *To coordinate and organise data*

CIM used for various datas

(i.e.) (i) Functional data

(ii) Product data

1.10. **OBJECTIVES/GOAL OF CIM:**

(i) More productivity and efficiency of the product.

(ii) More reability.

(iii) Cost of production, maintenance decreases

(iv) To reduce number of hazardous job.

(v) To eliminate human error.

(vi) To increase quality of product.

1.11. **CIM I Vs CIM II:**

CIM I − It refers to Computer Interfaced Manufacturing

CIM II − It refers to Computer Integrated Manufacturing.

The concept has moved from interfacing to integrating because of the advent of developments in Computer and Communication Technologies.
(iii) Operational data
(iv) Performance data etc.

3. To meet competitive pressures

Any organization to survive successfully, needs to face the following competitive pressures

(i) Increased quality.
(ii) Reduced production, material & labour cost.
(iii) Reduce inventory.

4. To facilitate Simultaneous Engineering

* Concurrent (or) simultaneous engineering is a technology of restructuring the product development.
* Simultaneous Engineering can be easily implement with the CIM.

1.10. OBJECTIVES/GOAL OF CIM:

The main objective are:

(i) More productivity and efficiency of the product.
(ii) More reability.
(iii) Cost of production, maintenance decreases
(iv) To reduce number of hazardous job.
(v) To eliminate human error.
(vi) To increase quality of product.

1.11. CIM I Vs CIM II:

CIM I – It refers to Computer Interfaced Manufacturing
CIM II – It refers to Computer Integrated Manufacturing.

The concept has moved from interfacing to Integrating because of the advent of developments in Computer and Communication Technologies.
The first three generations of computer’s uses vacuum tubes, transistor and Integrated Circuits (IC) etc.

The fourth generation of computers in CIM I used LSI/VLSI (Large scale Integration/very large scale integration) with interfacing the data.

The fifth generation of computers in CIM II used parallel processing with networking environment.

Nowadays the term CIM I and CIM II are not used; Instead the term CIM is used.

**Difference between CIM I & CIM II:**

<table>
<thead>
<tr>
<th></th>
<th>CIM I Vs CIM II</th>
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<tbody>
<tr>
<td>1.</td>
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<tr>
<td>Computer Interfaced</td>
<td>Computer Integrated Manufacturing.</td>
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<td>Manufacturing</td>
<td>Manufacturing.</td>
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<td>2.</td>
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<tr>
<td>Interfacing Existing</td>
<td>Integration of total</td>
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<td>System</td>
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<td>Fourth generation</td>
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**1.12. BENEFITS OF CIM:**

The following is the list of a few benefits that can be achieved by using CIM.

1. CIM improves the operational control by means of reduction in the number of uncontrollable variables, reducing dependents on human communication.

2. CIM improves the short run responsiveness.

3. CIM improves long run accommodations by means of changing product volumes.
4. CIM reduces the inventory through reducing lot sizes, improving inventory turnover for the particular company.


7. It helps quicker design & development.

8. Faster access to current and past product information.

9. CIM increases machine utilizations by means of eliminating (or) reducing machine setup, utilizing automated features.

1.13. COMPUTER INTEGRATED MANUFACTURING (CIM) AS A CONCEPT AND A TECHNOLOGY:

A number of definitions have been developed for computer integrated manufacturing (CIM). However a CIM system is commonly thought of as an integrated system that compares all the activities in the production system from the planning and design of a product through the manufacturing system, including control. CIM is an attempt to combine existing computer technologies in order to manage and control the entire business.

As with traditional manufacturing approaches, the purpose of CIM is to transform product designs and materials into salable goods at a minimum cost in the shortest possible time. CIM begins with the design of a product (CAD) and ends with the manufacture of the product (CAM). With CIM, the customary split between the design and the manufacturing functions is (supposed to be) eliminated.

CIM differs from the traditional job shop manufacturing system in the role of the computer plays on the manufacturing process. Computer integer manufacturing system are basically a network of computer system tied together by a single
integrated database. Using the information in the database, a CIM system can direct manufacturing, distribution and financial functions into one coherent system.

1.14. COMPUTERISED ELEMENTS OF A CIM-SYSTEM:

CIM Includes:

* Design parts/products
* Planning & control
* Automation
* Testing

The concept of CIM is to integrate information from Marketing, accounting, planning, control and so on as shown in Fig. 1.9.

![Fig. 1.9: Computerized elements of a CIM system](image)

* The main purpose of CIM is to enable the company to transform ideas into a high quality of products in the minimum time, cost and CIM goes beyond the scope of FMS (or) CAD/CAM system.
Network and integrated systems are tied up with CIM technologies.

The integration of data in CIM allows CAD system to link with Numerical Control, Computer Aided Manufacturing (CAM), Part programs, Manufacturing Control and Manufacturing planning.

CIM can also be linked with the automatic material handling systems to facilitate material handling.

Fully completed integrated system in CIM are not only automated but also integrated with each other and also integrated with manufacturing planning, control and scheduling.

1.15. TYPES OF PRODUCTION:

Depending upon the quantities produced in a factory, the production system can be classified into three types

(i) Job shop production (low production)
(ii) Batch production (medium production)
(iii) Mass production (high production)

Fig. 1.10: Production quantity
Fig. 1.10 shows the relation between production quantity Vs product variety for different production system.

(i) **Job shop Production:**

Job shop production is a type of manufacturing process in which small batches of a variety of custom products are made.

In the job shop process flow most of the products produced, require a unique setup and sequence of process steps.

Here the volume of production ranges from 1 to 100 units/year. This type of production system comes under low volume production.

**Examples:**

A machine tool shop, a machining centre, a commercial printing shop and other manufactures that make custom products in small lot sizes.

The following are the important characteristics of job shop type production system:

- Machines and methods employed should be general purpose as product changes are quite frequent.
- Planning and control system should be flexible enough to deal with the frequent changes in product requirements.
- Man power should be skilled enough to deal with changing work conditions.
- Schedules are actually non existent in this system as no definite data is available on the product.
- In process inventory will usually be high as accurate plans and schedules do not exist.
- Product cost is normally high because of high material and labor costs.
Fig. 1.10 shows the relation between production quantity Vs product variety for different production system.

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- Manpower should be skilled enough to deal with changing work conditions.
- Schedules are actually nonexistent in this system as no definite data is available on the product.
- In process inventory will usually be high as accurate plans and schedules do not exist.
- Product cost is normally high because of high material and labor costs.

Grouping of machines is done on functional basis (i.e. as lathe section, milling section etc.)

This system is very flexible as management has to manufacture varying product types.

Material handling systems are also flexible to meet changing product requirements.

(ii) Batch production:

Batch production is defined by American Production and Inventory Control Society (APICS) “as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing.”

Here the volume of production ranges from 100 – 10,000 units/year. This production system justified by medium volume production.

Examples:

Electrical goods, newspaper, books etc.

The following are the important characteristics of batch type production system:

- As final product is somewhat standard and manufactured in batches, economy of scale can be availed to some extent.
- Machines are grouped on functional basis similar to the job shop manufacturing.
- Semi automatic, special purpose automatic machines are generally used to take advantage of the similarity among the products.
- Labor should be skilled enough to work upon different product batches.
- In process inventory is usually high owing to the type of layout and material handling policies adopted.
Semi automatic material handling systems are most appropriate in conjunction with the semi automatic machines.

Normally production planning and control is difficult due to the odd size and non repetitive nature of order.

(iii) **Mass Production:**

Mass production refers to the process of creating large number of similar products efficiently.

This production system is justified by very large volume of production (i.e. 10,000 to millions of units per year).

Manufacturing of cars and guns are the few examples of mass production.

*The following are the important characteristics of mass production system:*

* As same product is manufactured for sufficiently long time, machines can be laid down in order of processing sequence. Product type layout is most appropriate for mass production system.

* Standard methods and machines are used during part manufacture.

* Most of the equipments are semi automatic or automatic in nature.

* Material handling is also automatic (such as conveyors).

* Semi skilled workers are normally employed as most of the facilities are automatic.

* As product flows along a pre defined line, planning and control of the system is much easier.

* Cost of production is low owing to the high rate of production.
In process inventories are low as production scheduling is simple and can be implemented with ease.

1.16. MANUFACTURING MODELS AND METRICS:

Many successful manufacturing companies use a variety of metrics to help their operations. Generally quantitative metrics provide a company with the means.

(i) To track performance in successive periods.

(ii) Tryout new technologies and new systems to determine their merits, identify problems with performance.

(iii) To compare alternative methods and to make good decisions.

The two basic categories of manufacturing metrics are

(i) Production performance measures.

(ii) Manufacturing costs.

Metrics that specify production performance include proportion uptime (or) equipment (a reliability measure), production rate, plant capacity and manufacturing lead time.

Manufacturing costs in a company includes material and labour cost, the costs of producing its products and the cost of operating a given piece of equipment.

1.17. MATHEMATICAL MODELS OF PRODUCTION PERFORMANCE:

Many features of manufacturing are quantitative. Mathematical models of production performance includes production rate, production capacity, utilization & availability and manufacturing lead time.
1.17.1. Production Rate:

Production rate for an individual processing is the number of goods that can be produced during a given period of time (i.e. work units completed/hr (or) piece/hr). Production rate is determined for the three types of production systems. (i) batch production (ii) Job shop production, (iii) mass production. For studying the above production process, we must know some basic terminology.

Cycle Time:

The period of time spent to complete one cycle of an operation (or) to complete a job from start to finish is called cycle time. It is given by

\[ T_c = T_0 + T_h + T_{th} \]  \hspace{1cm} \text{.... (1.1)}

where

- \( T_c \rightarrow \text{cycle time (min/piece)} \)
- \( T_h \rightarrow \text{handling time (min/piece)} \)
- \( T_0 \rightarrow \text{time of the actual processing (min/piece)} \)
- \( T_{th} \rightarrow \text{tool handling time (min/piece)} \)

1. Batch and Job shop production:

In batch production, the time to process one batch consisting of N work units is the sum at the setup time and processing time. It is given by

\[ T_b = T_{su} + NT_c \]  \hspace{1cm} \text{.... (1.2)}

- \( T_b \rightarrow \text{batch processing time (min)} \)
- \( T_{su} \rightarrow \text{setup time to prepare for the batch (min)} \)
- \( N \rightarrow \text{batch quantity (piece)} \)
If more than one part is produced in each cycle, the average production time per work unit, $T_p$ is given by

$$T_p = \frac{T_b}{N}$$

and the average production rate is given by

$$R_p = \frac{60}{T_p}$$

where,

$R_p \rightarrow$ hourly production rate (pc/hr)

$T_p \rightarrow$ average production time / minute

and the constant 60 converts minutes to hours.

**Job Shop Production:**

When $N = 1$ the production time per work unit is the sum of setup and cycle times

$$T_p = T_{su} + T_c$$

If $N > 1$, the production rate is determined as in batch production case discussed above.

**Mass Production:**

For quantity type mass production, the production rate is equal to the cycle rate of the machine (reciprocal of operation cycle time). Here the effect of setup time is insignificant i.e. $N$ becomes large, $(T_{su}/N) \rightarrow 0$.

$$R_p = R_c = \frac{60}{T_c}$$

$R_c \rightarrow$ operation cycle rate of the machine (pc/hr).

For flow line mass production, the operation of production line is complicated by interdependence of the workstations on the line. Therefore some station require longest operation time
and this station sets the pace for the entire line. The term bottleneck station is used to refer to this station. Therefore the cycle time of a production line is given by

\[ T_c = T_r + \text{Max } T_0 \]  \hspace{1cm} \text{ .... (1.7)}

\( T_r \rightarrow \) time to transfer work units between each cycle (min/cycle)

\( \text{Max } T_0 \rightarrow \) operation time at the bottleneck station.

The production rate is given by

\[ R_c = \frac{60}{T_c} \]  \hspace{1cm} \text{ .... (1.8)}

1.17.2. Production capacity:

Production capacity is defined as the maximum rate of output that a production facility is able to produce under a given operating conditions. Operating conditions refer to the number of shift/day (or) number of days in the week that the plant operates. The production capacity can be determined by the following equation

\[ PC = n S_w H_{sh} R_c \]  \hspace{1cm} \text{ .... (1.9)}

where,

\( PC \) = Weekly production capacity of the facility (output units/wk)

\( n \) = number of work centers* working in parallel producing in the facility

\( S_w \) = number of shifts/period (shift/wk)

\( H_{sh} \) = hr/shift (hr)

\( R_p \) = production rate of each work center (output units/hr)
and this station sets the pace for the entire line. The term bottleneck station is used to refer to this station. Therefore the cycle time of a production line is given by

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where,

- \( PC \rightarrow \) Weekly production capacity of the facility (output units/wk)
- \( n_s \rightarrow \) number of work centers producing in the facility
- \( w \rightarrow \) number of shifts/period (shift/wk)
- \( H_{sh} \rightarrow \) hr/shift (hr)
- \( R_p \rightarrow \) production rate of each work center (output units/hr)

Note:

*Work center is a manufacturing system in the plant typically consists of one worker and one machine. It might also be automated with no worker (or) multiple workers working together on a production line. It is capable of producing at a rate \( R_p \) units/hr.*

If we include the possibility that, each work unit requires \( n_0 \) operations in its processing sequence, with each operation requiring a new setup on either the same (or) different machine, then the plant capacity is given by

\[
PC = \frac{n_s w H_{sh} R_p}{n_0} \quad \ldots \quad (1.10)
\]

where

- \( n_0 \rightarrow \) no. of distinct operations through which work units are routed.

* Changes that can be made to increase (or) decrease plant capacity over short term are
  1. Change the number of shifts per week
  2. Change the number of hours worked per shift.

* To increase plant capacity over longer term
  (i) Increase the number of work centers in the shop.
  (ii) Increase the production rate (\( R_p \))
  (iii) Reduce the number of operation (\( n_0 \)) required per work unit by using combined operations (or) simultaneous operations.

1.17.3. Utilization:

Utilization refers to the amount of output of a production facility relative to its capacity. It is usually expressed as a percentage.
\[ U = \frac{N}{PC} \] .... (1.11)

\( N \rightarrow \) actual quantity produced by the facility during a given time period (i.e. piece/wk)
\( U \rightarrow \) utilization of the facility.
\( PC \rightarrow \) production capacity for the same period (piece/wk)

1.17.4. Availability:

Availability is a common measure of reliability for equipment. It is especially appropriate for automated production equipment. It is defined using two other reliability terms (i.e.) mean time between failures (MTBF) and mean time to repair (MTTP).

\[ A = \frac{MTBF - MTTR}{MTBF} \] .... (1.12)

where,

MTBF is the average length of time the piece of equipment runs between breakdowns (i.e. mean time between failures (hr).)

MTTR is the average time required to service the equipment and put it back into operation when a breakdown occurs [i.e. mean time repair (hr)]

1.17.5. Manufacturing lead time:

Manufacturing lead time is the time period between the placement of an order and the shipment of the completed order to the customer.

A short manufacturing lead time is a competitive advantage to the manufacturing firm because many customers want the delivery of their products as soon as possible following the placement of the order.
For batch production the manufacturing lead time (MLT) is given by

\[
MLT = n_0 \left( T_{su} + N T_c + T_{no} \right)
\]

where,

- \( n_0 \) = number of separate operations through which the work unit must be routed.
- \( T_{su} \) = Setup time
- \( T_{no} \) = non-operation time of a machine

During batch production, the term \( n_0, N, T_{su}, T_c, \) and \( T_{no} \) would vary for every product and operation.

The above equation can be adapted for job shop production and mass production by making adjustments in the parameter values. For job shop, in which the batch size \( (N = 1) \), the equation becomes

\[
MLT = n_0 \left( T_{su} + T_c + T_{no} \right)
\]

For mass production, the \( N \)-term in Eq. (1.13) is very large and dominates the other terms. In the case of quantity type mass production in which a large number of units are made on a single machine \((n_0 = 1)\), the MLT simply becomes the operation cycle time for the machine after the setup has been completed and production begins.

For flow the mass production, the entire production line is set up in advance. Also, the non-operation time between processing steps is simply the transfer time \( T_r \) to move the part or product from one workstation to the next. If the workstation are integrated so that all stations are processing their own respective work unit, then the time to accomplish all of the operations is the time it takes each work unit to progress through all of the stations on the line. The station with the longest operation time sets the pace for all stations.
1.15. Time Study:

**MLT** = **n₀** \( \left( T_r + \text{Max } T_o \right) \) = **n₀** \( T_c \) .... (1.15)

where

- **MLT** = time between start and completion of a given work unit on the line (min)
- **n₀** = number of operations on the line
- **T_r** = transfer time (min)
- **Max T_o** = operation time at the bottleneck station (min) and
- **T_c** = cycle time of the production line (min/piece)

**T_c** = **T_r** + **Max T_o** from Eq. (1.7). Since the number of stations is equal to the number of operations \((n = n_0)\). Eq. (1.15) can also be stated as

\[
\text{MLT} = n \left( T_c + \text{Max } T_o \right) = nT_c
\] .... (1.16)

where the symbols have the same meaning as above, and we have substituted \(n\) (number of workstations or machine) for number of operations **n₀**.

1.17.6. Work in-process (WIP):

Work in-process is the quantity of parts (or) products currently located in the factory that either are being processed (or) between processing operations.

WIP is determined by,

\[
\text{WIP} = \frac{\text{AU} \ (\text{PC}) \ (\text{MLT})}{S_w \ H_{sh}}
\] .... (1.17)
where,

\[
A \rightarrow \text{availability (\%)} \\
U \rightarrow \text{utilization (\%)} \\
PC \rightarrow \text{production capacity of the facility (piece/wk)} \\
MLT \rightarrow \text{manufacturing lead time (wk)} \\
S_w \rightarrow \text{number of shifts/week (shift/wk)} \\
H_{sh} \rightarrow \text{hours per shift (hr/shift)}
\]

1.18. MANUFACTURING COSTS:

Manufacturing cost, are the costs necessary to convert raw materials into products. Example of manufacturing costs include raw materials costs, salary of labours etc.

1.18.1. Fixed and variable costs:

All the costs faced by the companies can be broken into two main categories is 1. fixed costs 2. variable costs.

**Fixed cost:** A fixed cost is a cost that does not vary in the short term, irrespective of changes in production or sales levels or other measures of activity. A fixed cost is a basic operating expenses of a business that cannot be avoided such as rent, insurance, salaries etc.

**Variable cost:** A variable cost is one that varies in proportion to the level of production output. As output increases, variable cost increases. Examples of variable cost includes direct labour, raw materials and electric power to operate the production equipment.

The total cost is given by the sum of fixed cost and variable cost

\[
TC = FC + VC (Q) \quad \ldots (1.18)
\]
TC → Total cost
FC → Fixed cost
VC → Variable cost
Q → Annual quantity produced (piece/yr)

From the graph Fig. 1.11 it is noted that, the fixed cost of the automated method is high relative to the manual method and variable cost of automated method is low relative to the manual method.

1.18.2. Direct labour, Material, and overhead:

Manufacturing cost is divided into three broad categories 1. direct labour cost 2. direct material cost 3. manufacturing overhead.

Direct labour cost:

The direct labour cost is the sum of the wages and benefits paid to the workers who operate the production equipment and perform the processing and assembly tasks.
**Direct Material Cost:**

Direct material cost is the cost of the raw materials and components used to create a product. Example the cost of steel is a direct material in the manufacture of automobile.

**Overhead Cost:**

Overhead costs are all of the other expenses associated with running the manufacturing firm. Overhead divides into two categories.

1. **Factor overhead:**

   Factory overhead consists of the costs of operating the factory other than direct labour and materials, such as the factory expenses (i.e. insurance, power for machinery etc.).

   The factory overhead rate is calculated at the ratio of factory overhead expenses to direct labour expenses.

   \[
   \text{FOHR} = \frac{\text{FOHC}}{\text{DLC}} \quad \text{.... (1.19)}
   \]

   \(\text{FORH} \rightarrow \text{factory overhead rate (Rs/yr)}\)

   \(\text{FOHC} \rightarrow \text{annual factory overhead cost (Rs/yr)}\)

   \(\text{DLC} \rightarrow \text{annual direct labour costs (Rs/yr)}\)

2. **Corporate overhead:**

   It is the cost not related to the company’s manufacturing activities, such as the corporate expenses (i.e. R & D, sales & marketing).

   \* Corporate overhead rate is the ratio of corporate overhead expenses to direct labour expenses.

   \[
   \text{COHF} = \frac{\text{COHC}}{\text{DLC}} \quad \text{.... (1.20)}
   \]

   \(\text{COHR} \rightarrow \text{corporate overhead rate (Rs/yr)}\)

   \(\text{COHC} \rightarrow \text{annual corporate overhead costs (Rs/yr)}\)

   \(\text{DLC} \rightarrow \text{annual direct labour costs (Rs/yr)}\)
Note:

If material cost were used as the allocation basis, then material cost would be used as the denominator in both ratios.

Problem on Production Capacity:

Problem 1.1: The turret lathe section has 6 machines all devoted to the operation of the same part. The section operates 10 shift/wk. The number of hours / shift averages 8.0. Average production rate of each machine is 17 unit/hr. Determine the weekly production capacity of the turret lathe section.

Given:

\[ n = 6 \]
\[ Sw = 10 \text{ shift/wk} \]
\[ H_{sh} = 8 \text{ hr/shift} \]
\[ R_p = 17 \text{ units/hr} \]

Solution:

\[ PC = ns_w H_{sh} R_p \]
\[ = 6 \times 10 \times 8 \times 17 \]
\[ = 8160 \text{ output unit/week} \]

Problem on Utilization:

Problem 1.2: A production machine operates 80 hr/wk (2 shifts, 5 days) at full capacity. Its production rate is 20 unit/hr. During a certain week, the machine produced 1000 parts and was idle the remaining time. (a) Determine the production capacity of the machine. (b) What was the utilization of the machine during the week under consideration?

Solution:

(a) The capacity of the machine can be determined using the assumed 80-hr/week as follows:
PC = 80 (20) = 1600 unit/wk

(b) Utilization can be determined as the ratio of the number of parts made by the machine relative to its capacity

\[ U = \frac{1000}{1600} = 0.625 \text{ (62.5\%)} \]

(or)

The \textbf{alternative way} of assessing utilization is by the time during the week that the machine was actually used. To produce 1000 units, the machine was operated

\[ H = \frac{1000 \text{ pc}}{20 \text{ pc/hr}} = 50 \text{ hr} \]

Utilization is defined relative to the 80 hr available

\[ U = \frac{50}{80} = 0.625 \text{ (62.5\%)} \]

\textbf{Problem on Effect of Utilization and Availability on Plant Capacity:}

\textbf{Problem 1.3:} Consider Example 1.1. Suppose the same data from that example were applicable, but that the availability of the machines \( A = 90\% \) and the utilization of the machines \( U = 80\% \). Given this additional data, compute the expected plant output.

\textbf{Given:}

\[ A = 90\% = 0.90 \]
\[ U = 80\% = 0.80 \]

\textbf{Solution:}

Equation (1.9) can be altered to include availability and utilization as

\[ Q = AU \left( n S_w H_{sh} R_p \right) \]

where \( A = \) availability and \( U = \) utilization. Combining the previous and new data, we have

\[ Q = 0.90 (0.80) (6) (10) (8.0) (17) = 5875 \text{ output units/wk.} \]
Problem on Manufacturing lead time:

Problem 1.4: A certain part is produced in a batch size of 100 units. The batch must be routed through five operations to complete the processing of the parts. Average setup time is 3 hr/operation and average operation time is 6 min (0.1/hr). Average non-operation time due to handling, delays, inspections etc. is 7 hrs for each operation. Determine how many days it will take to complete the batch, assuming the plant runs 8 hr. shift/day.

Given:

\[ N = 100 \text{ units} \]
\[ T_{su} = 3 \text{ hr/operation} \]
\[ T_{no} = 7 \text{ hr/operation} \]
\[ T_c = 0.1 \text{ hr} \]
\[ n_0 = 5 \]

Solution:

\[
MLT = n_0 \left( T_{su} + NT_c + T_{no} \right)
\]
\[
= 5 (3 + 100 \times 0.1 + 7)
\]
\[
= 100 \text{ hours.}
\]

At 8 hr/day, this amounts to \( \frac{100}{8} = 12.5 \) days

Problem on determining overhead rates:

Problem 1.5: Suppose that all costs have been compiled for a certain manufacturing, firm for last year. The summary is shown in the table below the company operates two different manufacturing plants plus a corporate headquarters. Determine (a) Factory
overhead rate for each plant (b) The corporate overhead rate. These rates will be used by the firm to predict the following year’s expenses.

<table>
<thead>
<tr>
<th>Expense Category</th>
<th>Plant 1 (Rs.)</th>
<th>Plant 2 (Rs.)</th>
<th>Headquarters (Rs.)</th>
<th>Totals (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>direct labor</td>
<td>800,000</td>
<td>400,000</td>
<td></td>
<td>1,200,000</td>
</tr>
<tr>
<td>Materials</td>
<td>2,500,000</td>
<td>1,500,000</td>
<td></td>
<td>4,000,000</td>
</tr>
<tr>
<td>Factory expense</td>
<td>2,000,000</td>
<td>1,100,000</td>
<td></td>
<td>3,100,000</td>
</tr>
<tr>
<td>Corporate expense</td>
<td></td>
<td></td>
<td>7,200,000</td>
<td>7,200,000</td>
</tr>
<tr>
<td>Total</td>
<td>5,300,000</td>
<td>3,000,000</td>
<td>7,200,000</td>
<td>15,500,000</td>
</tr>
</tbody>
</table>

Solution:

(a) A separate factory overhead rate must be determined for each plant;

For plant 1,

\[ \text{FOHR}_1 = \frac{\text{Rs. } 2,000,000}{\text{Rs. } 800,000} = 2.5 = 250\% \]

For plant 2,

\[ \text{FOHR}_2 = \frac{\text{Rs. } 1,100,000}{\text{Rs. } 400,000} = 2.75 = 275\% \]

(b) The corporate overhead rate is based on the total labor cost at both plans

\[ \text{COHR} = \frac{\text{Rs. } 7,200,000}{\text{Rs. } 1,200,000} = 6.0 = 600\% \]
Problem on Estimating Manufacturing Costs and Establishing Price:

Problem 1.6: A customer order of 50 parts is to be processed through plant 1 of the previous example. Raw materials and tooling are supplied by the customer. The total time for processing the parts (including setup and other direct labour) is 100 hr. Direct labour cost is 10.00/hr. The factory overhead rate is 250% and the corporate overhead rate is 600%. (a) Compute the cost of the job. (b) What price should be quoted to a potential customer if the company use a 10% markup?

Solution:

(a) The direct labor cost for the job is (100 hr) (Rs. 10.00/hr) = Rs. 1000

The allocated factory overhead charge, at 250% of direct labor (Rs. 1000) (2.50) = Rs. 2500. The total factory cost of the job, including allocated factory overhead Rs. 1000 + Rs. 2500 = Rs. 3500.

The allocated corporate overhead charge, at 600% of direct labor is (Rs. 1000) (6.00) = Rs. 6000. The total cost of the job including corporate overhead is Rs. 3500 + Rs. 6000. = Rs. 9500

(b) If the company uses 10% markup, the price quoted to the customer would to be (1.10) (Rs. 9500) = Rs. 10,450.

1.19. MANUFACTURING CONTROL:

Manufacturing control is concerned with managing and controlling the physical operations in the factory to implement the manufacturing plan’s. As indicated in the Fig. 1.3, the flow of information is from planning to control. Informations may also flows back and forth between manufacturing control and the factory operations.

Manufacturing control includes shop floor control, inventory control and quality control.
* **Shop floor control:**

It deals with the problem of monitoring the progress of the product as it is being processed, assembled, moved and inspected in the factory.

Shop floor control is concerned with inventory in the sense that the materials being processed in the factory are work in process inventory. Thus the shop floor control and inventory control overlap to some extent.

* **Inventory control:** attempts to strike a proper balance between the risk of too little inventory (with possible stock outs of materials) and the carrying cost of too much inventory. It deals with such issues as deciding the right quantities of materials to order and when to reorder a given item when stock is low.

* **Quality Control:** The function of quality control is to ensure that the quality of the product and its components meet the standards specified by the product designer. To accomplish its mission, quality control depends on inspection activities performed in the factory at various times during the manufacture of the product. Also, raw materials and component parts from outside sources are sometimes inspected when they are received, and final inspection and testing of the finished product is performed to ensure functional quality and appearance. Quality control also includes data collection and problem solving approaches to address process problems related to quality. Examples of these approaches are statistical process control (SPC) and Six Sigma.

1.20. **BASIC ELEMENTS OF AN AUTOMATED SYSTEM:**

Automation is the technology by which a process (or) procedure is accomplished without human assistance. An automated system consists of three basic elements.
1. Power – To accomplish the process and to operate the automated system.
2. Program of instructions – To direct the process.
3. Control system – To actuate the instructions.

![Diagram of an automated system](image)

**Fig. 1.12: Elements of an automated system:**
1. Power, 2. Program of instructions and 3. Control systems

1.20.1. Power to accomplish the automated process:

In automated system, the power is required to drive the process as well as controls. The primary source of power in automated system is electricity. Other power source for automation includes fossil fuels, solar energy, water and wind energy.

**Power for the process:**

The term process refers to the manufacturing operation that is performed on a work unit. The **table 1.2** shows the common manufacturing process and their power requirements. Power is also required for the following material handling functions.

**Table 1.2: Common manufacturing processes and their power requirements**

<table>
<thead>
<tr>
<th>Process</th>
<th>Power form</th>
<th>Action Accomplished</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting</td>
<td>Thermal</td>
<td>Melting the metal before pouring into a mold cavity where solidification occurs.</td>
</tr>
</tbody>
</table>
### Table 1.2: Common manufacturing processes and their power requirements

<table>
<thead>
<tr>
<th>Process</th>
<th>Power form</th>
<th>Action Accomplished</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric discharge machining (EDM)</td>
<td>Electrical</td>
<td>Metal removal is accomplished by a series of discrete electrical discharges between electrode (tool) and workpiece. The electric discharges cause very high localized temperatures that melt the metal.</td>
</tr>
<tr>
<td>Forging</td>
<td>Mechanical</td>
<td>Metal work part is deformed by opposing dies. Work parts are often heated in advance of deformation, thus thermal power is also required.</td>
</tr>
<tr>
<td>Heat treating</td>
<td>Thermal</td>
<td>Metallic work unit is heated to temperature below melting point to effect microstructural changes.</td>
</tr>
<tr>
<td>Injection molding</td>
<td>Thermal and mechanical</td>
<td>Heat is used to raise temperature of polymer to highly plastic consistency, and mechanical force is used to inject the polymer mold into a mold cavity.</td>
</tr>
<tr>
<td>Laser beam cutting</td>
<td>Light and thermal</td>
<td>A highly coherent light beam is used to cut material by vaporization and melting.</td>
</tr>
<tr>
<td>Machining</td>
<td>Mechanical</td>
<td>Cutting of metal is accomplished by relative motion between tool and workpiece.</td>
</tr>
<tr>
<td>Sheet metal punching and blanking</td>
<td>Mechanical</td>
<td>Mechanical power is used to shear metal sheets and plates.</td>
</tr>
<tr>
<td>Process</td>
<td>Power form</td>
<td>Action Accomplished</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Welding</td>
<td>Thermal (may be mechanical)</td>
<td>Most welding processes use heat to cause fusion and coalescence of two (or more) metal parts at their contacting surfaces. Some welding processes also apply mechanical pressure to the surfaces.</td>
</tr>
</tbody>
</table>

**Loading and unloading the work unit:**

The processes listed in the table 1.2 are accomplished on discrete parts. These parts are loaded and unloaded in the proper position and orientation which requires power.

**Material transport between operations:**

For moving the work units from one operation to another operation, power is required.

**Power for automation:**

Apart from the basic power requirements for the manufacturing operations, the additional power is also required for automation.

**Controller Unit:**

Controller unit requires electrical power to read program of instructions, make the control calculations and execute the instructions by transmitting the proper commands to actuating devices.

**Power to actuate the control signals:**

The commands sent by the controller unit are generally transmitted by means of low-voltage control signals. To accomplish the commands, the actuators require more power and so the control signals must be amplified to provide the proper power level for the actuating devices.
Data acquisition and information processing:

In most control systems, data must be collected from the process and used as input to the control algorithms. The additional requirement of the process may include keeping records of process performance (or) product quality. These data acquisition and record keeping functions require power.

1.20.2. Program of instructions:

The action performed by an automated process are defined by a program of instructions. In the manufacturing operation, part (or) product requires one or more processing steps that are unique to that part or product. These processing steps are performed during a work cycle. A new part is completed during each work cycle. The particular processing steps for the work cycle are specified in a work cycle program. Work cycle programs are called part program in Numerical Control (NC).

Work cycle Programs:

In the simplest automated processes, the work cycle consists of essentially one step which is to maintain a single process parameter at a defined level. Example: maintaining the temperature of a furnace at a designated value for the duration of a heat treatment cycle. In this case, programming involves setting the temperature dial on the furnace. To change the program the operator simply changes the temperature setting.

In more complicated systems, the process involves a work cycle consisting of multiple steps that are repeated with no deviation from one cycle to the next. Most discrete part manufacturing operations are in this category.

There are sequence of steps involved in manufacturing operations, during each step there are one or more activities involve changes in one or more process parameters.
Features of a Work Cycle Program:

- Number of steps in the work cycle
- Manual participation in the work cycle (e.g., loading and unloading work parts)
- Process parameters – how many must be controlled?
- Operator interaction – does the operator enter processing data?
- Variations in part or product styles
- Variations in starting work units – some adjustments in process parameters may be required to compensate for differences in starting units.

Decision making in the programmed work cycle:

Many automated manufacturing operations require decisions to be made during the programmed work cycle to cope with variations in the cycle. The following are examples of automated work cycles in which decision making is required.

Operator interaction:

Although the program of instruction intended to be carried out without human interaction, the controller unit may require input data from human operator in order to function.

Example: Automated Teller Machine (ATM)

Different part (or) product styles processed by the system:

In this instance the automated system is programmed to perform different work cycles on different part or product styles.

Example: Robot welding cycle for two door versus four door car models.
Variations in the starting work units:

In some manufacturing operations the starting work units are not consistent.

Example: Additional machining pass for oversized sand casting.

1.20.3. Control System:

In many systems, it is not enough just to measure a parameter. It is also required to control the parameter. A parameter is either maintained as constant or varied in a pre-programmed way. To control a parameter, say pressure, the following is required to be considered:

1. To control any parameter, the first requirement is the real-time reading of the parameter. Hence the first requirement is to know the pressure level in the system under observation to control that.

2. Once that parameter is measured, it must be compared to a standard. After measuring the pressure of system in bars or pascals, it must be compared to a standard to know if the pressure is high or low in the system.

3. After comparison, if the parameter is within the desired range, then it is maintained otherwise control action is taken. There are numerous ways to control the variable parameters.

A general control system is illustrated in Fig. 1.13.
1.20.4. Basic Terminology used in Control System:

(a) **Reference Variable or Input:** Reference variable is that benchmarked variable which is used to compare with the system output to know if the output is in the specified desired level. It is like when petrol is bought from the bunk, the operator types the amount say Rs. 100/- in the counter. The counter runs a dispensing petrol until it reaches Rs. 100/-. The Rs. 100/- amount is ‘Reference Variable’ of the System.

(b) **Output:** It refers to the actual response of the system as per the input fed to the system.

(c) **Feedback:** The output of a system is measured. This measure is in the form of a signal which is fed to the control circuit. This path from the output to the control unit is considered as feedback. Refer Fig. 1.15.

(d) **Error:** The difference between the reference variable and the system output is called error.

(e) **Disturbance:** Those signals which disturb the system by affecting the reference variable or other control features are considered as ‘Disturbance’.

(f) **Actuating Signal:** The response signal due to the error which actuates the system to change the output is called “Actuating signal”.

(g) **Control or feed forward Elements:** The components which are connected between control unit and the output unit are considered as the feed forward elements.

(h) **Controlled Output:** The parameter (Pressure, Temperature, etc.) which is regulated/Guided/controlled for the system is called “Controlled Output”.

(i) **Feedback element:** The elements which are used to generate feedback in the system are the feedback elements.

1.20.5. Types of Control System:

Fig. 1.13 illustrates a general control system. It has not mentioned how the controlling is done. There are two basic ways in which a system is controlled and they are
(a) **Open Loop Control System:**

In this system, the control parameter is simply regulated. Just like a fan regulator which merely regulates the speed of fan with various settings. Here the output is only regulated as per the pre-programmed set up. An open loop control system can be illustrated as shown in **Fig. 1.14.**

![Fan Control System](image-url)

**Fig. 1.14: Open Loop Control System**

**Table 1.3: Advantages and Disadvantages of Open Loop Control System**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Manufacturing cost in low as it is very simple.</td>
<td>(a) Control is limited as per the pre-programming.</td>
</tr>
<tr>
<td>(b) Ease of control and Maintenance.</td>
<td>(b) Control is manually operated and hence it is slow and subjected to human error.</td>
</tr>
<tr>
<td>(c) Pre-programmed as per the requirement.</td>
<td>(c) Output optimization is not possible as there is no feedback.</td>
</tr>
<tr>
<td>(d) Very useful in application where the output is difficult to measure or economically not feasible.</td>
<td>(d) This system cannot be automated.</td>
</tr>
<tr>
<td>(e) It is very economical to use in applications where the control output requirement levels are clear.</td>
<td>(e) Cannot be used in complex applications where the control output has to be monitored and maintained even with all variations.</td>
</tr>
</tbody>
</table>
(b) Closed Loop Control System:

In this system, as illustrated in Fig. 1.15, the control parameter is instantaneously controlled. This is achieved by the means of a feedback. From the output a feedback is generated. This generated signal is compared with the set conditions in the control system. If there is a difference, an error is generated. To compensate the error, control is activated and output is varied to match the set condition. This process continues till the error is nil or zero.

![Fig. 1.15: Closed Loop Control System](image)

A closed loop control system can be explained from the working principle of a compressor in an Air conditioning unit. On turning on an AC unit, an user sets the temperature as 21°C. Now thermostat measures the temperature of the room and converts it to a signal. This signal is compared analogously with the set temperature 21°C. If the temperature of the room is more said 26°C then the error is positive. This results in activating or switching on the compressor which is a key component in the AC unit for regulating the temperature. The comparison of room temperature with the set temperature is continuous. As soon as the temperature of the room drops to 21°C the error becomes zero. Depending on the programing of the AC unit, the compressor will be switched off. Hence the compressor will cut-in or cut-off as per the fluctuations of the room temperature.

1.20.6. Basic terms used in Closed Loop Control System:

* **Process element:** It is the element of the system which is to be controlled. It can be a room where the
temperature is controlled or a tank where water level is controlled etc.

* Measurement Element: The element which is used to measure the state of the process element is called Measurement Element.

* Reference point or Set point: It is the standard signal which is set in the system to control the output.

* Comparison Element: This element compares the reference value to the measured value. The difference between them is considered as error. (Error = Reference value − Measured value)

* Control Element: This element reads the error signal and produces a signal to correct the error.

* Correction element: It is that element which receives a signal from the control element and makes changes in the output accordingly.

* Controlled Variable: It is that parameter which is controlled by the control system. It is the temperature of the room which is controlled.

* Manipulated Variable: to control the output or the controlled variable there is a variable which is changed and it is called manipulated variable.

For Air conditioning Compressor system Example:

<table>
<thead>
<tr>
<th>Process Element</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Element</td>
<td>Thermostat</td>
</tr>
<tr>
<td>Reference Point</td>
<td>Set Cooling Temperature</td>
</tr>
<tr>
<td>Comparison Element</td>
<td>Electronic control circuit (It compares the signals)</td>
</tr>
</tbody>
</table>
Control Element | Electronic control (as per the program generates the signal to correct)
Correction Element | Compressor on/off switch
Manipulated Variable | Temperature of the AC unit
Controlled Variable | Temperature of the room

1.20.7. Comparison between Open Loop and Closed Loop Control System:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Open Loop system</th>
<th>Closed Loop system</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cost</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>2. Feedback</td>
<td>No feedback is there</td>
<td>Feedback is there</td>
</tr>
<tr>
<td>3. Accuracy</td>
<td>Limited to pre-programing</td>
<td>As per the efficiency of feedback</td>
</tr>
<tr>
<td>4. Construction</td>
<td>Simple</td>
<td>Complex</td>
</tr>
<tr>
<td>5. Non-linearity</td>
<td>System can malfunction</td>
<td>Well within the specified range of non-linearity</td>
</tr>
<tr>
<td>6. Stability</td>
<td>Stable as per the pre-program condition</td>
<td>Continuously active with feedback</td>
</tr>
<tr>
<td>7. Response time</td>
<td>Slow as it is manually operated</td>
<td>Instantaneous as it is automated</td>
</tr>
<tr>
<td>8. Output Optimization</td>
<td>Not possible</td>
<td>Possible within the limits of the control system</td>
</tr>
<tr>
<td>9. Maintenance</td>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>10. Disturbance Handling</td>
<td>Chances of having a disturbance are limited.</td>
<td>Depends on the systems failsafe’s and signal filters efficiency.</td>
</tr>
</tbody>
</table>
1.21. LEVELS OF AUTOMATION:

In many factory operations, the concept of automated system can be applied to various levels. The level of automation can be defined as an amount of the manning level with focus around the machines, which can be either manually operated, semi-automated or fully automated. There are five possible levels of automation in a production plant and their hierarchy is shown in the Fig. 1.16.

1. Device level:

This is the lowest level in automation hierarchy. It includes sensors, actuators and other hardware components that comprise the machine level. The devices are combined into the individual control loops of the machine, example: the feedback control loop for one axis of a CNC machine.

2. Machine level:

The hardware from device level is assembled into individual machines. Control functions at this level include performing the sequence of steps in the program of instructions in the right order and making sure that each steps is properly executed. Example: Industrial robots, powered conveyors and automated guided vehicles (AGV).

3. Cell (or) System level:

This is the manufacturing cell or system level, which operates under instructions from the plant level. The system level is a group of machine (or) workstations connected and supported by a material handling system, a computer and other equipments needed for a manufacturing process.

Functions:

* parts dispatching and machine loading.
* coordination among machines and material handling system
* collecting and evaluating inspection data.
4. **Plant level:**

This is the production system level and it receives instructions from the corporate information system and translate them into operation plan for production.

**Functions:**

- Order processing
- Process planning
- Inventory control
- Purchasing
- Material requirements planning
- Shop floor control etc.

5. **Enterprise level:**

This is the highest level and it is concerned with all functions necessary to manage the company includes marketing and sales, accounting, design research, aggregate planning and master production scheduling (MPS).

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**Fig. 1.16: Five levels of automation and control in manufacturing**
1.22. LEAN MANUFACTURING:

Lean production also known as lean manufacturing, is a systematic method for the elimination of waste within a manufacturing system.

Lean production began as a manufacturing technique to enhance efficiency and profitability. Its primary focus is speed of output by waste elimination, (waste is anything that doesn’t add value to the end product.)

It is a management philosophy derived mostly from Toyota production system (TPS), and this concept was originated at Toyota motors in Japan after World War II.

Manufacturing operations often includes many wasteful activities, that is activities that don’t really add value to the product. Manufacturing activities can be divided into three categories according to the value they contribute to the part (or) product being made.

(i) Value – adding activities:

These are work activities which are contributing to the value of product.

(ii) Auxiliary activities:

There are activities that support the value-adding activities but don’t themselves contribute value to the part (or) product.

(iii) Wasteful activities:

These are activities which don’t add any value to the part (or) product.

Wastes can be classified into seven categories:

1. Waste of overproducing: Producing components that are neither intended for stock nor planned for sale immediately.
2. **Waste of waiting:** Refers to the idle time between operations.

3. **Waste of transport:** Moving material more than necessary.

4. **Waste of processing:** Doing more to the product than necessary and the customer is willing to pay.

5. **Waste of Inventory:** Excess of stock from raw materials to finished goods.

6. **Waste of motion:** Any motion that is not necessary to the completion of an operation.

7. **Waste of defects and spoilage:** Defective parts that are produced and need to be reworked.

### 1.22.1. Objectives of lean production:

The objectives of implementing a lean production system is to achieve a competitive advantage through cost reduction and efficient service of customer demands.

1. **Quality:**

   Increasing the quality level of a production system i.e. reducing the number of errors, repairs and rejects. The main objective of lean manufacturing is to attain optimum level in quality without any fluctuation in operating cost.

2. **Inventory:**

   Inventory levels must be minimized because carrying inventory consumes space, adds considerable logistics costs and consumes significant amount of financial resources.

3. **Labour productivity:**

   The idle time of workers must be reduced inorder to improve the labour productivity.
(iv) **Optimum utilization of resources:**

Lean manufacturing aims at optimum (or) full utilization of resources (time, money, machines, workers etc.) by eliminating bottlenecks and minimizing machine down time.

(v) **Standardizing:**

Adopting lean manufacturing results in standardizing of resources like place for everything and everything in its right place. This makes performance of operations smooth and steady.

(vi) **Thorough checking:**

It involve in deep examination of the process as soon as the task is over. As a result, short comings are sought out at the very first stage before moving to next stage and thus the efficiency is maintained at every stage.

**1.22.2. Principles of Lean Manufacturing:**

1. Continuous Flow  
2. Lean Machines/Simplicity.  
3. Workplace Organization  
4. Parts Presentation  
5. Reconfigurability  
6. Product Quality  
7. Maintainability.

1. **Continuous Flow:**

The preferred shape of the lean workcell is U-shaped. Each subprocess is connected to the next in order of process. With the worker in the interior of the U, minimum movement is required to move the workplace or assembly from one workstation to the next.

**Benefits:** Elimination of non-value added movements, work in process, and inventory.

2. **Lean Machines/Simplicity:**

Since continuous-flow, one-at-a-time manufacturing is another goal of lean manufacturing, it is important that each workstation or machine be designed to fit within a minimal envelope. The minimal envelope ensures the elimination of
excess flat space at the workstation or machine. This is done to avoid the possibility of storing parts or subassemblies at the machine. Storing parts increases work in process and results in “batch” processing, which subsequently defeats the purpose of lean manufacturing.

**Benefits:** One-at-a-time manufacture, quick production changeover, reduced WIP, easily modified, customizable production.

### 3. Parts Presentation:

Naturally, during the average work shift, additional parts will be required for the workcell. Traditional methods of resupplying workstations are not useful in a lean workcell. Each worker should go about his work with the minimum number of interruptions. Therefore, all parts should be supplied to each workstation from outside the workcell. The use of gravity feed conveyors or bins fits the simplified design of the lean workcell.

**Benefits:** Easy reconfigurartion, reduce wasted motion, uninterrupted production, quick changeover

### 4. Reconfigurability:

A properly designed lean workcell must be easy to reconfigure. In fact, the ability to change the process and go from good part to good part as quickly as possible is a must. The faster the changeover, the less production time is lost.

**Benefits:** Minimize downtime, quick changeover, uninterrupted workpiece flow.

### 5. Quality:

One of the results of one-at-a-time manufacturing is a decrease in quality problems. As each part is produced, visual inspection by the worker can verify that it is correctly
assembled. If verification is required through gages, they should be mounted to the machine or workstation and be easily replaced. Quick release of fixtures using star knobs or locking levels is a necessity.

**Benefits:** Immediate feedback on quality as workers inspect parts; platform for continuous improvement; eliminate rework areas, encourage changeover to solve “minor” quality problems; greater quality assurance by giving the responsibility to the assembler; rapid change of quality gages as assembled product or process changes.

6. **Maintainability:**

Ease of service is another requirement of a lean cell. Long down times cannot be tolerated in a pull through system. When customer demand exists, the product must be produced. A modular structural framing system provides the ultimate in maintainability. Components can be replaced or reconfigured in a matter of minutes.

**Benefits:** Minimum down time, easy-to-source replacement parts, quick service.

1.22.3. **Benefits of Implementing Lean:**

The benefits of implementing Lean can be broken down into three broad categories; Operational, Administrative, and Strategic Improvements. Even to this day, most organizations that implement Lean do so for the operational improvements, primarily because of the perception that Lean only applies to the operations side of the business.

1.22.4. **Operational Improvements:**

* Lead Time (Cycle Time) reduced by 90%

* Productivity increased by 50%
Work-in-Process Inventory reduced by 80%

Quality improved by 80%

Space Utilization reduced by 75%.

1.22.5. The five steps of lean Implementation:

* **Step 1: Specify value**
  Define value from the perspective of the final customer. Express value in terms of a specific product which meets the customer’s needs at a specific price and at a specific time.

* **Step 2: Map the value stream**
  Identify the value stream, the set of all specific actions required to bring a specific product through the three critical management tasks of any business, the problem-solving task, the information management task, and the physical transformation task. Create a map of the current state and the future state of the value stream, Identify and categorize waste in the current state, and eliminate it.

* **Step 3: Create Flow**
  Make the remaining steps to the value stream flow. Eliminate functional barriers and develop a product focused organization that dramatically improves lead-time.

* **Step 4: Establish Pull**
  Let the customer pull products as needed, eliminating the need for a sales forecast.
**Step 5: Seek Perfection**

There is no end to the process of reducing effort, time, space, cost, and mistakes. Return to the first step and begin the next lean transformation.

---

**Fig. 1.17**

Fig. 1.17. Shows the steps involved in lean implementation.

**Comparison between the traditional manufacturing and lean manufacturing**

**Table 1.5**

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Traditional Manufacturing</th>
<th>Lean Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of equipment and people</td>
<td>High</td>
<td>Less</td>
</tr>
<tr>
<td>Factory space for same output</td>
<td>High</td>
<td>Less</td>
</tr>
<tr>
<td>Work in progress (WIP)</td>
<td>High</td>
<td>Less</td>
</tr>
<tr>
<td>Defects</td>
<td>High</td>
<td>Less</td>
</tr>
<tr>
<td>Aspects</td>
<td>Traditional Manufacturing</td>
<td>Lean Manufacturing</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Operational availability</td>
<td>Less</td>
<td>High</td>
</tr>
<tr>
<td>Production Lead time</td>
<td>High</td>
<td>Less</td>
</tr>
<tr>
<td>Inventory</td>
<td>Inventory is good</td>
<td>Inventory is waste</td>
</tr>
<tr>
<td>System schedule</td>
<td>Push system scheduled internally</td>
<td>Pull system scheduled by Customer Requirements</td>
</tr>
<tr>
<td>Focus</td>
<td>Focus on Value Add improvement (5%)</td>
<td>Focus on Non-value-Add Waste Elimination (95%)</td>
</tr>
<tr>
<td>Direct labor cot</td>
<td>High direct labor cost</td>
<td>Direct labor cost is a small percentage of total labor cost</td>
</tr>
<tr>
<td>Cycle time</td>
<td>Long cycle time</td>
<td>Short cycle time</td>
</tr>
<tr>
<td>Production</td>
<td>Production for inventory (Just in Case-JIC)</td>
<td>Production on demand (Just in Time-JIT)</td>
</tr>
<tr>
<td>Inventory level</td>
<td>High inventory levels (Raw, WIP, Finished)</td>
<td>Inventory levels are radically reduced.</td>
</tr>
<tr>
<td>Production system</td>
<td>Assembly line flow (Each worker performs one function)</td>
<td>Cell production (Each operator performs multiple operations – multi skilled operators)</td>
</tr>
</tbody>
</table>
**Table:**

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Traditional Manufacturing</th>
<th>Lean Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleanliness</td>
<td>Messy, cluttered and dirty shop floor</td>
<td>Spotless shop floor with visual management</td>
</tr>
<tr>
<td>Quality management</td>
<td>Quality management through inspection and rework</td>
<td>Management of quality through prevention</td>
</tr>
<tr>
<td>Changes in production practice</td>
<td>Infrequent changes in production practice</td>
<td>Continuous changes to improve efficiency and productivity</td>
</tr>
<tr>
<td>Management layer</td>
<td>Many layers of management</td>
<td>Fewer layers of management</td>
</tr>
<tr>
<td>Structure</td>
<td>Not exactly team based structure</td>
<td>Strong team based structure</td>
</tr>
</tbody>
</table>

**1.23. JUST IN TIME APPROACH (JIT APPROACH):**

JIT is a philosophy of manufacturing based on planned elimination of all wastes and continuous improvement of productivity.

JIT approach involves a continuous commitment to the pursuit of excellence in the manufacturing system design and operation. JIT seeks to manufacture 100% good products JIT seeks to produce only required items, at the required time and in the required quantities. JIT seeks to achieve the following goals.

1. Zero defects
2. Zero setup time
3. Zero inventory
4. Zero handling
5. Zero breakdown
6. Zero lead time
7. Lot size of one

1. Zero defects:

There is a belief that a certain level of defective product is unavoidable. But this is contradicted by JIT approach which aims to eliminate, once and for all, the causes of defects and seeks to achieve excellence at all stages of the manufacturing process. It tells. ‘Do it once and do it right. No excuse.’

2. Zero inventories:

Normally, inventories are needed when there is uncertainty in supply of raw materials by the outside suppliers. Outside suppliers are not reliable and most of the time, they do not supply in time. Hence, a buffer stock is necessary, so inventory is essential to manage the uncertain availability of raw materials and unexpected customer order.

But as per JIT approach, inventory is an evidence of poor design, poor coordination and poor operation of the production system. In JIT, there is no inventory, since there is no uncertain supplier and there are so many facilities to manage unexpected customer order.

3. Zero Setup time and a lot size of one:

If there is zero setup time, then there is no advantage in producing goods in batches. So a single product (a lot size of one) can be produced since setup time is zero. So the zero setup time and a lot size of one are interrelated.

In inventory control, the EOQ (Economic Order Quantity) is as follows:

$$EOQ = \sqrt{\frac{2DS}{H}}$$
where \( D \) – annual demand for the item.

\[ S \] – setup cost or ordering cost per order

\[ H \] – annual holding cost of stock

This EOQ is used to minimise the total cost of inventory by trading off between the annual holding costs of stock and setup costs. Very large batches need high inventory cost (holding cost) and very small batches need lower inventory cost (holding costs) but involve a larger setup costs.

But in JIT, the setup time is zero thus the setup cost is zero. So very smaller batch i.e. a lot size of one is economic in JIT approach.

4. **Zero lead time:**

Longer lead time make the manufacturing system to rely on forecasts and anticipation of customer orders. Short lead time make the manufacturing system to be adapted to short-term fluctuations in market demand. Zero lead time approach makes the manufacturing system to operate with greater flexibility than its competitors.

5. **Zero parts handling:**

Manufacturing and assembling operations include a large number of non-value adding activities as given below.

1. Component feeding
2. Component handling
3. Parts making
4. Parts Inspection

If the components, manufacturing and assembling systems are designed to minimise the feeding and handling operations, one can reduce manufacturing and assembling time. The product-based (Group technology layout) is often preferred than process layout, because the material flow is smooth and material handling effort is less.
By using JIT approach, the Japanese manufacturers identified the following wastes.


2. **Waste of overproduction**: Make only what is needed.

3. **Waste of processing itself**: Analyse each process for a product and eliminate unnecessary processes.

4. **Waste of stock**: Reduce the inventory cost for investing and carrying the stock uneconomically.

5. **Waste of motion**: By studying motion study, eliminate all unnecessary motions.

6. **Waste of producing defective products**: At each and every stage, quality control and inspection should be carried out to minimise (or) to make the defective products zero.

### 1.23.1. Key elements in JIT approach:

The following are the three important elements of the JIT approach for product and manufacturing system design.

1. A match of product design to market demand

2. Product families and flow based manufacturing (Group Technology)

3. The relationship with suppliers in JIT environment.

#### (i) A match of product design to market demand:

Even with a sophisticated and versatile manufacturing technology, the companies are not able to provide customized products at an economic price to the market. So the products should be designed (or) the manufacturing system should design a range of products anticipating the market requirement. It should manufacture and deliver a sufficient variety of products to meet customer’s expectation with a price affordable by the market.
By using JIT approach, the Japanese manufacturers identified the following wastes.

1. **Waste of waiting:** Eliminate waiting for workers, machine and raw materials.
2. **Waste of overproduction:** Make only what is needed.
3. **Waste of processing itself:** Analyse each process for a product and eliminate unnecessary processes.
4. **Waste of stock:** Reduce the inventory cost for investing and carrying the stock uneconomically.
5. **Waste of motion:** By studying motion study, eliminate all unnecessary motions.
6. **Waste of producing defective products:** At each and every stage, quality control and inspection should be carried out to minimise (or) to make the defective products zero.

1.2. **Key elements in JIT approach:**

The following are the three important elements of the JIT approach for product and manufacturing system design.

1. **A match of product design to market demand:** Even with a sophisticated and versatile manufacturing technology, companies are not able to provide customized products at an economic price to the market. So the products should be designed (or) the manufacturing system should design a range of products anticipating the market requirement. It should manufacture and deliver a sufficient variety of products to meet customer's expectation with a price affordable by the market.

   To achieve this objective, the products should be designed in a modular fashion. If there is wide variety of product styles, the manufacturing and assembly costs will be more. So the greater the flexibility, costlier will be the manufacturing system.

(ii) **Product families and flow based manufacturing:**

(******Group Technology******)

The Group Technology is used in JIT approach to define part families. In JIT, the Group Technology is used to help the design process and to reduce unnecessary product variety and duplication in product design. The part families of product and components can be manufactured in well-defined manufacturing cells. These manufacturing cells replace the process based layout into product based layout (Flow based layout). By using Group Technology, the JIT achieves shorter lead time, reduced work in progress and finished goods inventories, simplified production planning and control and increased job satisfaction.

(iii) **The relationship with suppliers in a JIT environment:**

The JIT idea is not only implemented to the manufacturing plant but also to the customers and back to the vendor companies who supply the company with raw materials and purchased items. The JIT approach builds strong and enduring relationships with a limited number of suppliers.

It provides idea to these suppliers so that they can be cost effective, they can overcome the problems, they can improve the components quality and they can implement new manufacturing technology on doing the processes. The JIT execution (or) implementation used for purchasing (i.e. **Kanban system**) increases the frequent orders with frequent deliveries. Practically, delivery of ‘lot size of one’ is not possible. But it can be approached, by making a lot size...
as small as possible. So the delivery of the goods (or) components by the supplier is become frequent. The JIT approach advises the supplier to be more close to the buyer’s plant so that it is easy to make frequent deliveries of small lots. Also, the supplier can implement JIT system in his own company.

1.23.2. Kanban:

The ‘Kanban’ is a system which executes JIT delivery on the shop floor level. The cards used in the ‘Kanban’ system is known as ‘Kanban’ cards. ‘Kanban’ was developed at the Toyota car plants in Japan. It is a system (or) a programme to smoother the flow of products throughout the production process. It improves the system productivity and increases the operator involvement and participation in achieving this high productivity Kanban system is also used as an information system to monitor and control the production quantities at every stage of the manufacturing and assembly process. Kanban system is normally used in a repetitive manufacturing environment.