ROHINI
COLLEGE OF ENGINEERING & TECHNOLOGY
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(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

ME3792 – COMPUTER INTEGRATED MANUFACTURING

Lecturer notes

ME3792 – COMPUTER INTEGRATED MANUFACTURING

COURSE OBJECTIVES

1. To provide the overview of evolution of automation, CIM and its principles.
2. To learn the various Automation tools, include various material handling system.
3. To train students to apply group technology and FMS.
4. To familiarize the computer aided process planning in manufacturing.
5. To introduce to basics of data transaction, information integration and control of CIM.

UNIT – I INTRODUCTION 9

Introduction to CAD, CAM, CAD/CAM and CIM - Evolution of CIM – CIM wheel and cycle – Production concepts and mathematical models – Simple problems in production models – CIM hardware and software – Major elements of CIM system – Three step process for implementation of CIM – Computers in CIM – Computer networks for manufacturing – The future automated factory – Management of CIM – safety aspects of CIM– advances in CIM.

UNIT – II AUTOMATED MANUFACTURING SYSTEMS 9

Automated production line – system configurations, work part transfer mechanisms – Fundamentals of Automated assembly system – System configuration, Part delivery at workstations – Design for automated assembly – Overview of material handling equipment's – Consideration in material handling system design – The 10 principles of Material handling. Conveyor systems – Types of conveyors – Operations and features. Automated Guided Vehicle system – Types &applications – Vehicle guidance technology – Vehicle management and safety. Storage system performance – storage location strategies – Conventional storage methods and equipments – Automated storage/Retrieval system and Carousel storage system Deadlocks in Automated manufacturing systems – Petrinet models – Applications in Dead lock avoidance – smart manufacturing – Industry 4.0 - Digital manufacturing – Virtual manufacturing.

UNIT – III GROUP TECHNOLOGY AND FMS 9

Part families – Visual – Parts classification and coding – Production flow analysis – Grouping of parts and Machines by rank order clustering method – Benefits of GT – Case studies. FMS – Components – workstations – FMS layout configurations – Computer control systems – FMS planning and implementation issues – Architecture of FMS – flow chart showing various operations in FMS – Machine cell design – Composite part concept, Holier method, Key machine concept – Quantitative analysis of FMS – Bottleneck model – Simple and complicated problems – Extended Bottleneck model - sizing the FMS ─ FMS applications, Benefits.

UNIT – IV PROCESS PLANNING 9

Process planning – Activities in process planning, Informations required. From design to process planning – classification of manufacturing processes – Selection of primary manufacturing processes – Sequencing of operations according to Anteriorities – various examples – forming of Matrix of Anteriorities – case study. Typical process sheet – case studies in Manual process planning. Computer Aided Process Planning – Process planning module and data base – Variant process planning – Two stages in VPP – Generative process planning – Flow chart showing various activities in generative PP – Semi generative process planning- Comparison of CAPP and Manual PP.

UNIT – V PROCESS CONTROL AND DATA ANALYSIS 9

Introduction to process model formulation – linear feedback control systems – Optimal control – Adaptive control –Sequence control and PLC& SCADA. Computer process control – Computer process interface – Interface hardware – Computer process monitoring – Direct digital control and Supervisory computer control - Overview of Automatic identification methods – Bar code technology –Automatic data capture technologies.- Quality management (SPC) and automated inspection.

TOTAL: 45 PERIODS

OUTCOMES: At the end of the course the students would be able to

1 Discuss the basics of computer aided engineering.
2 Choose appropriate automotive tools and material handling systems.
3 Discuss the overview of group technology, FMS and automation identification methods.
4 Design using computer aided process planning for manufacturing of various components
5 Acquire knowledge in computer process control techniques.

TEXT BOOK:

1. Shivanand H K, Benal M M and Koti V, Flexible Manufacturing System, New Age, 2016.

2.CIM: Computer Integrated Manufacturing: Computer Steered Industry Book by August-Wilhelm Scheer.

REFERENCES:

1. Alavudeen and Venkateshwaran, Computer Integrated Manufacturing‖, PHI Learning Pvt. Ltd., New Delhi, 2013.

1. Gideon Halevi and Ronald D. Weill, Principles of Process Planning‖, Chapman Hall, 1995.

2. James A. Retrg, Herry W. Kraebber, Computer Integrated Manufacturing‖, Pearson Education, Asia,3rd Edition, 2004.

3. Mikell P. Groover, Automation, Production system and Computer integrated Manufacturing, Prentice Hall of India Pvt. Ltd., 4thEdition, 2014.

Radhakrishnan P, Subramanian S and Raju V, CAD/CAM/CIM, New Age International Publishers, 3rd Edition, 2008.

UNIT-I INTRODUCTION

PART-A

1. Define CAD.

Computer aided design (CAD) may be defined as any design activity that involves the effective use of the computer to create, modify, or document an engineering design.

2. List any two reasons for using a CAD system. (Nov/Dec 2011)

(i) To increase the productivity of the designer
(ii) To improve the quality of the design.
(iii) To improve the communications.

3. What are the components of CAD systems? (Nov/Dec 2011)

1. Geometric modeling.
2. Design analysis and optimization,
3. Design review and evaluation and
4. Documentation and drafting

4. What are the drawing features of CAD package? (May/June 2012)

(i) Geometric modeling features.
(ii) Editing or manipulation features.
(iii) Display control features
(iii)Drafting features.

5. Mention the six phases of a Shigley's design process.

1. Recognition of need
2. Identification of problem
3. Synthesis
4. Analysis and optimization
5. Evaluation
6. Presentation

6. What are the functions of a manager/management? (MAY 2012, MAY 2016)

Planning, Organizing, Directing, and Controlling. Some people include additional roles such as Leading, Staffing, Coordinating, etc.

7. Explain CAM

Computer aided manufacturing (CAM) may be defined as an effective use of computers and computer technology in the planning management, and control of the manufacturing function.

8. List various manufacturing planning applications of CAM.

(i) Computer-aided process planning (CAPP)
(ii) Computer-assisted NC part programming
(iii) Computerised machinability data systems
(iv) Development of work standards
(v) Cost estimating
(vi) Production and inventory planning
(vii) Computer-aided line balancing

9. List the important manufacturing control applications of CAM.

1. Process monitoring and control
2. Quality control
3. Shop floor control
4. Inventory control
5. Just-in-time production systems

10. Explain CIM.

CIM is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organizational and personnel efficiency.

11. List the potential tangible and intangible benefits of CIM.

Tangible benefits	Intangible benefits
i. Higher profits ii. Improved quality iii. Shorter time to market with new products iv. Shorter vendor lead time v. Reduced inventory levels vi. Improved schedule Performance and so on.	i. Improved customer service ii. Greater flexibility iii. Greater responsiveness vi. Improved competitiveness v. Safer working environment vi. Higher employee morale. vii. More opportunities for upgrading skills.

12. What are types the production systems?

1. Job shop production,
2. Batch production,
3. Mass production, and
4. Process or continuous production.

13. List any four characteristics of batch production.

(i) A large variety of products are manufactured in lots or batches.

(ii) Both general purpose machines (for producing parts) and special purpose machines (for assembling the parts) are used.

(iii) Flow of material is intermittent.

(iv) Plant layout is process type.

14.Compare the types of production systems, in terms of product mix, types of manufacturing facilities and types of layouts employed.

Function of comparison	Job production	Batch production	Mass production	Continuous production
Product mix	Suitable for customised made to orders products	Small bits of large variety products	Standardised products	Bulk commodities
Types of manufacturing facilities	General purpose machines	Mostly general purpose and some special purpose machines	Special purpose machines dominate	Special purpose machines
Types of layout	Fixed position layout	Process layout	Process layout	Product layout

15. What are manufacturing metrics?

Manufacturing metrics are used to quantitatively measure the performance of the production facility or a manufacturing company.

16. What are the uses of manufacturing metrics?

(i) To track performance of the production system in successive periods (say in months or years);

(ii) To determine the merits, and demerits of the potential new technologies and system;

(iii) To compare alternative methods; and

(iv) To make good decisions.

17. List out the commonly used production performance measures.

1. Cycle time,
2. Production rate.
3. Plant capacity,
4. Utilization,
5. Availability.
6. Manufacturing lead time, and
7. Work-in-process.

18. Define the terms cycle time and production rate.

- ✓ The operation cycle time (Tc) is the total time from when the ope begins to the point-of-time at which the operation ends.
- ✓ Production rate for an individual production operation is nothing but number of work units completed per hour.

19. Define production capacity.

Production capacity, also known as capacity or plant capacity, is defined as the maximum rate of output that a production facility is able to produce under a given set of assumed operating conditions.

20. Differentiate between utilization and availability.

✓ Utilization of the production facility (U) is the ratio of the number of pai made by the production facility relative to its capacity. The utilization provides a measure of how well production facilities are used, given that the are available.

✓Availability is a measure of reliability for equipment and is usually expressed as a percentage. Availability provides a measure of how well the equipment in the plant are serviced and maintained.

24. Define the terms MTBT and MTTR. How are they related to availability?

✓ The **MTBT** indicates the average length of time the equipment runs between breakdowns.

✓ The **MTTR** indicates the average time required to service the equipment and put it back into operation when a breakdown occurs.

✓ The availability (A) is mathematically given by

$$A = \frac{MTBF - MTTR}{MTBF} \times 100$$

PART B & C

1. Explain the nature and role of the elements of CIM system?

Nine major elements of a CIM system are in Figure they are,

- Marketing
- Product Design
- Planning
- Purchase
- Manufacturing Engineering
- Factory Automation Hardware
- Warehousing
- Logistics and Supply Chain Management
- Finance
- Information Management

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.

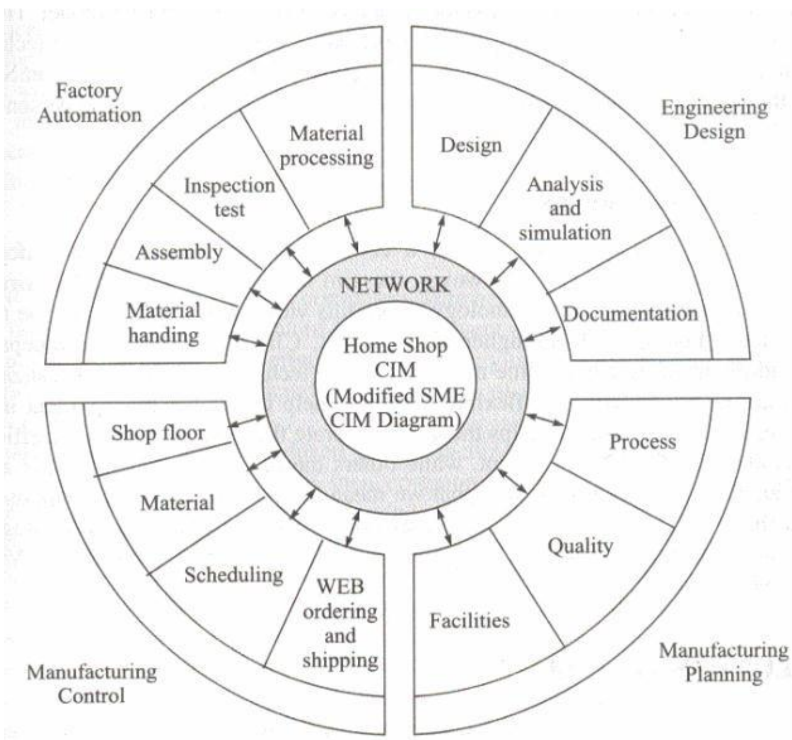
viii. Finance: Finance deals with the resources pertaining to money. Planning of investment, working capital, and cash flow control, realization of receipts, accounting and allocation of funds are the major tasks of the finance departments.

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.

2. Explain CASA/SME's CIM Wheel or CIM Concepts?

The CASA/SME CIM Wheel is a model developed by the Computer and Automated Systems Association (CASA) of the Society of Manufacturing Engineers (SME). It serves as a framework for understanding and implementing Computer-Integrated Manufacturing (CIM). The CIM Wheel illustrates the various components and functions that need to be integrated in a manufacturing environment to achieve a fully automated and computer-integrated production process.

The key elements of the CIM Wheel are typically grouped into the following categories:



(ii) Engineering Design

Engineering Design is the starting point of the manufacturing process, where products are conceptualized and detailed before production begins. This stage involves:

- **Computer-Aided Design (CAD)**: Engineers use CAD software to create detailed 2D or 3D models of products. CAD allows for precise design specifications, easy modifications, and simulations to test how products will perform in real-world conditions.
- **Product Lifecycle Management (PLM)**: This system manages the entire lifecycle of a product, from initial concept and design through manufacturing, maintenance, and disposal. PLM ensures that all stakeholders have access to up-to-date information, facilitating collaboration and improving efficiency.
- **Simulation and Prototyping**: Before actual production, designs are often simulated

using computer software to predict performance under various conditions. Prototyping, either virtual or physical, is used to validate designs and make necessary adjustments.

- **Design for Manufacturability (DFM)**: Engineers ensure that products are designed in a way that makes them easy and cost-effective to manufacture, considering factors like material selection, tolerances, and assembly processes.

(ii) Manufacturing Planning

Manufacturing Planning involves preparing and organizing the manufacturing process to ensure that production runs smoothly and efficiently. This stage includes:

- **Computer-Aided Process Planning (CAPP)**: CAPP systems help in planning the sequence of operations, selecting tools, and defining machine settings. It bridges the gap between design and manufacturing by translating CAD data into actionable manufacturing instructions.
- **Material Requirements Planning (MRP)**: MRP systems calculate the materials and components needed for production, ensuring that they are available when required. This system helps in managing inventory, reducing waste, and minimizing delays.
- **Production Scheduling**: This involves allocating tasks, resources, and timeframes to ensure that production meets deadlines. Effective scheduling optimizes resource use, reduces bottlenecks, and improves overall efficiency.
- **Capacity Planning**: This ensures that the manufacturing facility has the necessary resources—such as machinery, labor, and materials—to meet production demands. It involves assessing current capacity and planning for future needs.

(iii) Manufacturing Control

Manufacturing Control is the process of managing and monitoring the production process to ensure that it runs according to plan and meets quality standards. This stage involves:

- **Real-Time Monitoring**: Using sensors, software, and data analytics, real-time monitoring systems track the status of machines, processes, and products on the shop floor. This allows for immediate detection of issues and quick corrective actions.
- **Quality Control**: Systems like Statistical Process Control (SPC) and automated inspection tools are used to monitor product quality during manufacturing. This ensures that any defects are caught early, reducing waste and rework.
- **Shop Floor Control (SFC)**: SFC systems manage and track the production process on the shop floor, including work-in-progress, machine utilization, and labor productivity. These systems ensure that operations are running smoothly and that production goals are met.
- **Feedback and Adjustment**: Continuous feedback loops are established to monitor production outcomes and adjust processes as needed. This ensures that production stays on track and meets performance and quality targets.

(iv) Factory Automation

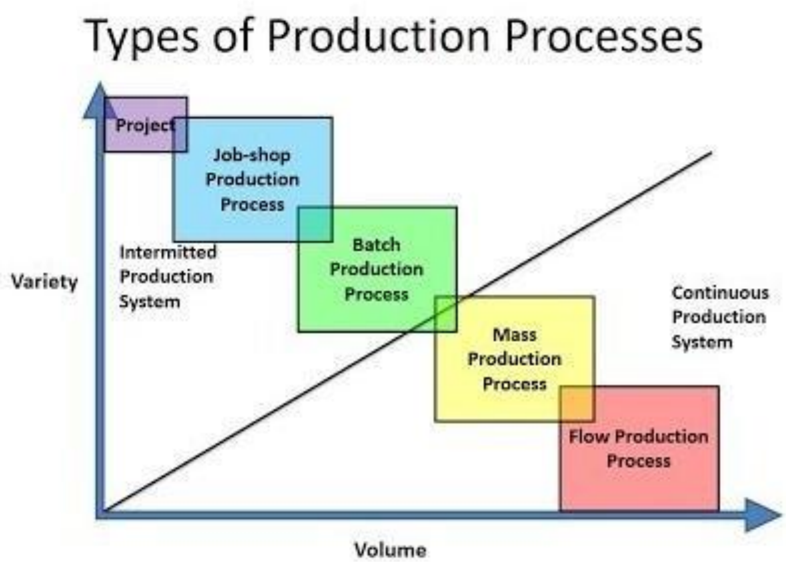
Factory Automation involves the use of advanced technologies to automate manufacturing processes, reducing human intervention and increasing efficiency. This component includes:

- **Robotics and Automated Systems**: Robots and other automated systems perform repetitive tasks with precision, consistency, and speed. They are used for tasks like assembly, welding, painting, and material handling.

- **Programmable Logic Controllers (PLCs)**: PLCs are specialized computers that control machinery and processes on the factory floor. They are programmed to perform specific tasks, such as controlling conveyor belts, managing robotic arms, or regulating temperatures.
- **Flexible Manufacturing Systems (FMS)**: These systems allow for quick reconfiguration of manufacturing processes to produce different products. FMS increases flexibility and responsiveness to changing market demands.
- **Computer-Aided Manufacturing (CAM)**: CAM software controls machine tools and related machinery, automating the manufacturing process from design to production. CAM systems convert CAD models into machine instructions, enabling precise and efficient manufacturing.

3. Explain the types of production systems

Production systems refer to the methods and processes used to create goods and services. The type of production system a company chooses depends on factors like the nature of the product, volume of production, and level of customization.



Here are the main types of production systems:

(i) Job Shop Production

Job Shop Production is a type of manufacturing system that is highly flexible and designed to handle a wide variety of products in relatively small quantities. This system is characterized by its ability to produce custom or specialized items, often tailored to individual customer specifications. It is commonly used in industries where products are made to order and not mass-produced.

- **Characteristics**:
  - Low production volume, high variety of products.
  - Highly flexible and capable of producing customized products.
  - Production is based on specific customer orders.

- **Example**: Custom furniture manufacturing, specialized machine parts.
- **Advantages**:
    - High customization.
    - Flexibility in production.
- **Disadvantages**:
    - High production costs.
    - Longer lead times.

(ii) Batch Production

Batch Production is a type of manufacturing system in which a specific quantity of a product is produced in a series of batches. Each batch moves through the production process before the next batch begins. This system is commonly used when the demand for a product is moderate, and it is not feasible to produce the product in a continuous flow or on a job shop basis.

- **Characteristics**:
    - Produces a moderate volume of similar products in batches.
    - Each batch may involve changes in the setup and process.
    - Suitable for products with moderate demand.
- **Example**: Baking bread, producing clothing.
- **Advantages**:
    - Better use of resources compared to job shops.
    - Economies of scale in each batch.
- **Disadvantages**:
    - Idle time between batches.
    - Lower flexibility compared to job shops.

(iii) Mass Production

Mass Production is a manufacturing system characterized by the large-scale production of standardized products, typically using assembly lines or automated processes. This system is designed to produce a high volume of identical items, making it highly efficient and cost-effective for producing goods with consistent quality.

- **Characteristics**:
    - High production volume, low variety of products.
    - Uses standardized processes to produce identical items.
    - Continuous production flow, often on assembly lines.
- **Example**: Automobile manufacturing, consumer electronics.
- **Advantages**:
    - High efficiency and low per-unit cost.
    - Consistent product quality.
- **Disadvantages**:
    - Inflexibility; difficult to change the product or process.
    - High initial capital investment.

(iv) Continuous Production

Continuous Production is a manufacturing system in which materials are continuously processed through a series of production stages without interruption. This type of production is used for producing large quantities of standardized products, typically in industries where stopping the process would be inefficient and costly. The system operates 24/7 to maximize output and efficiency.

- **Characteristics**:
    - Very high production volume, often 24/7 operation.
    - Produces highly standardized products in a continuous flow.
    - Often used in industries where stopping the process would be inefficient.
- **Example**: Oil refining, chemical production, steel manufacturing.
- **Advantages**:
    - Extremely high efficiency and low per-unit cost.
    - Suitable for very large-scale production.
- **Disadvantages**:
    - Very inflexible; changes to production are complex and costly.
    - High capital investment and maintenance costs.

4. Explain Manufacturing Metrices

Manufacturing metrics are quantitative measures used to assess and improve the performance of manufacturing processes. They provide insights into various aspects of production, such as efficiency, quality, and resource utilization.

The two basic categories of manufacturing metrices are

(1) Production performance measures

(2) Manufacturing costs

Here's a detailed overview of key manufacturing metrics:

(1) Production performance measures:

Production performance measures are metrics used to evaluate how effectively and efficiently a manufacturing process operates. These measures provide insights into various aspects of production, including efficiency, quality, cost, and delivery. Here's a detailed overview of key production performance measures:

(i) Cycle Time or Operation cycle time (T_c)

- **Description**: The total time required to complete one cycle of production from start to finish. It consist of
    - ✓ **Processing Time**: Time spent actively working on the product during the manufacturing process.
    - ✓ **Queue Time**: Time the product spends waiting before or between different stages of production.
    - ✓ **Setup Time**: Time required to prepare equipment or workstations for production.
    - ✓ **Transport Time**: Time taken to move materials or products between different stages of production.

Formula: Cycle Time (T_c)= $T_o + T_h + T_{th}$

T_o = Processing time or assembly (min/pc)

T_h = Handling time (min/pc) (loading or unloading time)

T_{th} = Tool handling time (min/pc) (time to change the tools)

(ii) Production Rate:

It indicates the quantity of products produced per unit of time and helps assess the efficiency and capacity of a manufacturing process.

Formula:

$$Rp = \frac{60}{Tp} \text{ (pc/hr)}$$

- For job production $T_p = T_{su} + T_c$
- For Batch production $T_p = T_{su} + Q \times T_c$
- For Mass production $T_p = T_c$ (Since setup time is zero)

T_{su} = Setup Time

Q = Batch Quantity

(iii) Production Capacity:

It refers to the maximum amount of output that a manufacturing system or facility can produce in a given period under normal operating conditions. It is a crucial metric for understanding the ability of a production system to meet demand and plan for future growth.

Formula:

$PC_W = n \times S_w \times H_{sh} \times R_p$

n = Number of work centres working in parallel producing in the facility,

S_w = Number of shifts per period (shift/wk),

H_{sh} = Number of hours per shift (hr/shift),

R_p = Hourly production rate of each work centre (units/hr)

(iv) Utilization:

It measures how effectively a manufacturing facility or resource is being used relative to its total available capacity. It helps assess whether a production system, equipment, or workforce is operating at its optimal level and identifies areas for improvement.

Formula:

$$\text{Utilization} = \frac{\text{Maximum Possible Output}}{\text{Actual Capacity}} \times 100\%$$

$$U = \frac{Q}{PCW} \times 100\%$$

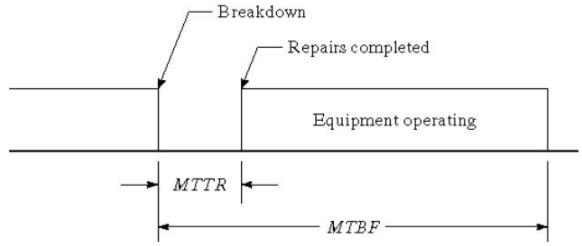
U = Utilization of the facility (percentage),

Q = Actual quantity produced by the facility during a given time period (pc/wk),

PC_W = Production capacity for the same time period (pc/wk).

(v) Availability:

The percentage of time that equipment or a production system is available for production, considering both planned and unplanned downtime.



Formula:

$$\text{Availability} = \frac{\text{Operating Time}}{\text{Scheduled Operating Time}} \times 100\%$$

$$A = \frac{MTBF - MTTR}{MTBF} \times 100\%$$

MTBF = Mean time between failures (hr)

MTTR = Mean time to repair (hr)

(vi) Manufacturing Lead Time (MLT)

The total time from when an order is placed to when the finished product is ready for shipment or delivery. It refers to the total time required to manufacture a product from the initiation of the production process to the final completion and delivery of the product. It encompasses all stages of production, including procurement of raw materials, production processes, assembly, inspection, and packaging.

Formula:

- For Job production

$$MLT = n_o(T_{su} + T_c + T_{no})$$

- For Batch production

$$MLT = n_o(T_{su} + QT_c + T_{no})$$

- For Mass production

$$MLT = T_c$$

n_o- Number of distinct operations through which work units are routed,

T_{su}- Setup time per batch (min/batch),

Q - Batch quantity (pc),

T_c - Cycle time per part (min/pc), and

T_{no}- Non-operation time associated with the machine (min).

(vii) Work-in-Process (WIP)

Items or materials that are currently undergoing manufacturing, assembly, or processing but have not yet reached the finished goods stage. It refers to the items or materials that are in various stages of the production process but are not yet complete. These items have started the manufacturing process but are not ready for sale or distribution. WIP is an essential concept in inventory management and manufacturing, representing the accumulation of partially completed goods that contribute to the overall production flow.

Formula:

$$WIP = \frac{AU(PC)(MLT)}{S_w H_{sh}}$$

WIP = work-in-process in the facility (pc)
A = availability
U = utilization
PC = production capacity of the facility (pc/wk)
MLT = manufacturing lead time (hr)
S_w = no. of shifts per week (shift/wk)
H_{sh} = hours per shift (hr/shift)

(2) Manufacturing Costs:

Manufacturing cost refers to the total expense incurred in the process of producing goods. It includes all costs associated with transforming raw materials into finished products. These costs can be broadly categorized into three main components:

(i) Prime cost or Direct Cost:

Prime cost is the total direct costs involved in producing a product or service. It consists of three primary components.

Prime Cost = Direct Materials + Direct Labor + Direct Expenses

(ii) Factory cost:

Factory cost is a broader term that encompasses all the costs incurred within a manufacturing facility. It includes both prime cost and factory overhead costs.

Factory Cost = Prime Cost + Factory Overhead Costs or Factory Expenses

(iii) Production or Manufacturing or Office cost:

Manufacturing cost refers to the total expense incurred in producing goods within a factory or production facility. It encompasses all costs associated with transforming raw materials into finished products. Manufacturing cost is crucial for determining the cost of goods sold (COGS), setting product prices, and evaluating the efficiency and profitability of the production process.

Manufacturing Cost = Factory Cost + Administrative Expenses

(iv) Total cost or Selling cost:

It includes both manufacturing costs, Selling expenses and Distribution expenses

Total Cost = Manufacturing Cost + Selling expenses + Distribution Expenses

(v) Selling price:

The selling price is typically set by considering the total cost of production, desired profit margin, market conditions, and customer demand.

Selling Price = Total Cost + Profit

5. Explain CIM Hardware and software.

CIM Hardware:

1. Manufacturing equipment
   - ✓ Workstations
   - ✓ Cells
   - ✓ Direct numerical control (DNC) systems
   - ✓ Flexible manufacturing systems (FMSs)
   - ✓ Work handling devices
   - ✓ Tool handling devices

- ✓ Storage devices
- ✓ Sensors
- ✓ Shop floor data collection devices, etc.

2. Computer related hardwares
    - ✓ Computers
    - ✓ Controllers
    - ✓ CAD/CAM systems
    - ✓ Workstation terminals
    - ✓ Printers
    - ✓ Plotters
    - ✓ Other peripheral devices
    - ✓ Modems
    - ✓ Cables
    - ✓ Connectors, etc.
3. Office equipment
4. Communication hardware
    - ✓ Remote batch terminals
    - ✓ Front end processors
    - ✓ Transmitters
    - ✓ Acoustic couplers
    - ✓ Multiplexers
    - ✓ Concentrators, etc.

CIM software: CIM software comprises the following computer programmes.

- ✓ Management information system (MIS) program
- ✓ Sales program
- ✓ Marketing program
- ✓ Finance program
- ✓ Database management system (DBMS) program
- ✓ Design program
- ✓ Analysis program
- ✓ Simulation program
- ✓ Communications program
- ✓ Monitoring program
- ✓ Production control program
- ✓ Manufacturing area control program
- ✓ Job tracking program
- ✓ Inventory control program
- ✓ Bar code program
- ✓ Order entry program
- ✓ Conveyor program
- ✓ Device drivers program
- ✓ Process planning programs

- ✓ Manufacturing facilities program, etc.

6. Describe the three-step process for implementation of CIM.

The three-step process for implementing Computer Integrated Manufacturing (CIM) that you've outlined is a practical approach focused on ensuring a smooth transition to automated and integrated manufacturing systems. Here's a more detailed explanation of each step:

(i). Assessing the Company:

- **Objective**: To gain a comprehensive understanding of the company's current state, including its strengths, weaknesses, opportunities, and threats (SWOT analysis).
- **Activities**:
  - **Evaluate Current Capabilities**: Analyze the existing manufacturing processes, technologies, and workflows. Identify what the company does well and where it may fall short, particularly in areas like production efficiency, quality control, and technology usage.
  - **Identify Gaps**: Pinpoint areas where the company's current operations are not aligned with the goals of implementing CIM. This could include outdated machinery, lack of automation, or inefficient communication systems.
  - **Set Objectives**: Based on the assessment, define what the company needs to achieve with CIM—such as reducing production costs, increasing throughput, or improving product quality.

(ii). Simplifying the Process:

- **Objective**: To streamline manufacturing operations by identifying and eliminating waste, making processes more efficient, and preparing them for automation.
- **Activities**:
  - **Process Mapping**: Create detailed maps of current manufacturing processes to visualize workflows and identify inefficiencies.
  - **Identify Waste**: Use methodologies like Lean Manufacturing or Six Sigma to identify sources of waste, such as overproduction, excessive inventory, or unnecessary movement of materials.
  - **Simplify Operations**: Eliminate or reduce unnecessary steps in the production process, standardize procedures, and ensure that processes are as efficient as possible. Simplification may also involve consolidating tasks, reducing setup times, or improving material handling systems.
  - **Prepare for Automation**: Ensure that the simplified processes are suitable for automation and integration with CIM technologies. This includes ensuring compatibility with the software and hardware that will be used.

(iii). Training Employees:

- **Objective**: To equip employees with the skills and knowledge they need to effectively operate and maintain CIM systems, and to foster a culture of continuous improvement.
- **Activities**:
  - **Technical Training**: Provide hands-on training for employees on the new CIM technologies, including how to operate machinery, use software, and perform routine maintenance.

- **Problem-Solving Skills**: Train employees to identify potential problems early, troubleshoot issues, and make necessary adjustments to prevent errors. This can include training on quality control techniques and data analysis.
- **Continuous Learning**: Encourage a culture of continuous learning and improvement. Employees should be updated on new technologies and best practices regularly.
- **Change Management**: Support employees through the transition to CIM by addressing concerns, providing clear communication, and involving them in the implementation process. This helps in reducing resistance to change and ensures smoother adoption.

7. Describe computer and computer networks used in CIM.

Computers in Computer-Integrated Manufacturing (CIM) play a crucial role in automating and streamlining the entire production process. Here are some key aspects:

1. **Design and Engineering**: Computers are used for Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE) to create detailed 3D models and simulations of products. This helps in optimizing designs before actual production.
2. **Manufacturing Planning**: Computer-Aided Manufacturing (CAM) systems generate the necessary instructions for manufacturing equipment, such as CNC machines, ensuring precision and efficiency.
3. **Production Control**: Computers monitor and control the production process in real-time, using data from sensors and other input devices to adjust operations as needed.
4. **Quality Control**: Automated inspection systems use computers to check the quality of products at various stages of production, ensuring consistency and reducing defects.
5. **Inventory Management**: Computers track inventory levels, manage orders, and optimize stock levels to ensure that materials are available when needed without overstocking.

Computer Networks for Manufacturing are essential for integrating various components of CIM. Here's how they contribute:

1. **Data Communication**: Networks enable seamless communication between different systems, such as CAD, CAM, and Enterprise Resource Planning (ERP) systems. This ensures that data flows smoothly across the entire manufacturing process.
2. **Real-Time Monitoring**: Networks connect sensors, machines, and control systems, allowing for real-time monitoring and control of the production process. This helps in quickly identifying and addressing any issues.
3. **Remote Access and Control**: With networked systems, engineers and managers can access and control manufacturing processes remotely, improving flexibility and responsiveness.
4. **Integration of Supply Chain**: Networks facilitate the integration of supply chain management, linking suppliers, manufacturers, and distributors to optimize the flow of materials and products.
5. **Security and Data Integrity**: Robust network security measures ensure that sensitive manufacturing data is protected from unauthorized access and cyber threats.

8.Explain the future automated factory and management of CIM.

The future automated factory represents a significant shift in how manufacturing operations are conducted, driven by advancements in technology such as robotics, artificial intelligence (AI), the Internet of Things (IoT), and big data. Computer Integrated Manufacturing (CIM) plays a central role in this transformation, providing the framework for integrating these technologies into a cohesive, efficient, and flexible manufacturing system.

- **Advanced Robotics and Automation**
  - **Robots and Cobots**: The factory will be equipped with advanced robots and collaborative robots (cobots) that can work alongside human workers. These machines will handle a wide range of tasks, from assembly to packaging, with high precision and speed.
  - **Autonomous Systems**: Autonomous vehicles and robots will navigate the factory floor, transporting materials and components without human intervention.
- **Artificial Intelligence and Machine Learning**
  - **Predictive Maintenance**: AI will be used to predict equipment failures before they happen, allowing for proactive maintenance and reducing downtime.
  - **Smart Manufacturing**: AI-driven systems will optimize production processes in real-time, adjusting to changing conditions and demand.
- **Internet of Things (IoT)**
  - **Connected Devices**: IoT will connect machines, sensors, and devices, enabling real-time data collection and analysis across the entire manufacturing process.
  - **Smart Sensors**: Sensors will monitor every aspect of the production environment, including temperature, humidity, and machine performance, ensuring optimal conditions for manufacturing.
- **Big Data and Analytics**
  - **Data-Driven Decisions**: The future factory will generate vast amounts of data, which will be analyzed to improve decision-making, optimize production, and enhance product quality.
  - **Supply Chain Integration**: Big data analytics will be used to optimize the supply chain, ensuring that materials and products are delivered just-in-time.
- **Additive Manufacturing (3D Printing)**
  - **Rapid Prototyping**: 3D printing will enable the quick production of prototypes, accelerating the product development cycle.
  - **On-Demand Production**: Factories will be able to produce customized products on demand, reducing the need for large inventories.
- **Sustainability and Energy Efficiency**
  - **Green Manufacturing**: The future factory will focus on sustainability, using energy-efficient processes and renewable energy sources. Waste reduction and recycling will be integral parts of the manufacturing process.

9. Management of CIM in the Future Automated Factory:

Managing CIM in the future automated factory will require a comprehensive approach to ensure that all systems and technologies work together seamlessly. Here are the key aspects of

CIM management:

(i) Integration and Interoperability

- **System Integration**: Managers will need to ensure that all manufacturing systems, from robots to IoT devices, are integrated into a single, cohesive system. This involves ensuring that different software and hardware components can communicate and work together effectively.
- **Interoperability**: The future factory will likely use a variety of technologies from different vendors. Ensuring that these technologies are interoperable—able to work together without compatibility issues—will be a critical management task.

(ii) Data Management and Security

- **Big Data Management**: The vast amount of data generated by an automated factory will need to be managed effectively. This includes collecting, storing, and analyzing data in a way that supports decision-making and process optimization.
- **Cybersecurity**: With increased connectivity comes increased risk. CIM management must prioritize cybersecurity to protect the factory's data and systems from cyber threats. This includes implementing robust security protocols and regular monitoring for potential vulnerabilities.

(iii) Human-Machine Collaboration

- **Skill Development**: As automation increases, the role of human workers will shift. CIM management will need to invest in training and upskilling workers to enable them to work effectively alongside advanced machines and technologies.
- **Change Management**: The transition to a highly automated factory will require careful management of change. CIM leaders will need to address potential resistance to change and ensure that employees are engaged and motivated.

(iv) Real-Time Monitoring and Control

- **Real-Time Decision Making**: CIM systems will provide real-time data and analytics, allowing managers to make informed decisions quickly. This will be crucial for responding to issues on the production line or adjusting to changes in demand.
- **Automated Control Systems**: CIM management will involve overseeing automated control systems that manage everything from production schedules to inventory levels, ensuring that operations run smoothly and efficiently.

(v) Continuous Improvement and Innovation

- **Process Optimization**: Continuous improvement will be a key focus, with CIM systems providing the data and tools needed to identify areas for improvement and implement changes quickly.
- **Innovation Management**: As new technologies emerge, CIM managers will need to evaluate and integrate these innovations into the factory's operations, ensuring that the factory remains competitive and efficient.

10. Explain in detail Safety aspects of Computer Integrated Manufacturing

1. Machine safety: Safeguards for robots, CNC machines, and other automated equipment.

2. Operator safety: Protection from hazardous materials, noise, and ergonomics.

3. Cyber security: Protection of computer systems and data from unauthorized access.
4. Electrical safety: Safe installation and maintenance of electrical systems.
5. Fire safety: Prevention and suppression systems for electrical and chemical fires.
6. Emergency response planning: Procedures for accidents, spills, and other incidents.
7. Training and education: Operators, maintenance personnel, and management.
8. Safety protocols for additive manufacturing (3D printing).
9. Safety considerations for collaborative robots (cobots).
10. Compliance with safety standards and regulations (e.g., OSHA, ISO 9001).

Example 1.6 *A certain part is routed through six machines in a batch production plant. The setup and operation times for each machine are given in Table 1.8.*

Table 1.8.

Machine	Setup Time (hr)	Operation Time (min)
1	4	5
2	2	3.5
3	8	10
4	3	1.9
5	3	4.1
6	4	2.5

The batch size is 100 and the average non-operation time per machine is 12 hours.

(a) Determine the manufacturing lead time.

(b) Determine the production rate for operation 3.

⊗ ***Given data:***

Number of distinct operations/machines through which work units are routed, $n_o = 6$

Batch size, $Q = 100$

Average non-operation time per machine, $T_{no} = 12 \text{ hr} = 12 \times 60 = 720 \text{ min}$

To find: (a) Manufacturing lead time (MLT), and

(b) Production rate for operation 3 (R_p).

☺ ***Solution:***

(a) To find manufacturing lead time (MLT):

First let us calculate the average setup time per machine (T_{su}) and the average operation time per machine (T_c) using the data given in Table 1.8.

$$\therefore \quad \text{Average setup time per machine, } T_{su} = \frac{4+2+8+3+3+4}{6}$$

$$= 4 \text{ hr} = 4 \times 60 = 240 \text{ min}$$

$$\text{and average operation time per machine, } T_c = \frac{5+3.5+10+1.9+4.1+2.5}{6}$$

$$= 4.5 \text{ min}$$

We know that the MLT for batch production,

$$\text{MLT} = n_o (T_{su} + Q \cdot T_c + T_{no})$$

$$= 6\,[240 + (100 \times 4.5) + 720]$$

$$= \mathbf{8460\ min} \text{ or } \mathbf{141\ hr} \quad \textbf{Ans.}$$

(b) To find production rate for operation 3:

In batch production, the batch processing time (T_b) for operation 3 is given by

$$T_b = T_{su} + Q \cdot T_c$$

Here $\quad T_{su} = 8 \text{ hr} = 8 \times 60 = 480 \text{ min};$

and $\quad T_c = 10$ min for operation 3, from Table 1.8

$$\therefore \quad T_b = 480 + 100 \times 10 = 1480 \text{ min}$$

The average production time (T_p) for the machine 3 is given by

$$T_p = \frac{T_b}{Q} = \frac{1480}{100} = 14.8 \text{ min}$$

∴ The hourly production rate (R_p) for operation 3 is given by

$$R_p = \frac{60}{T_p} = \frac{60}{14.8} = \mathbf{4.05\ hr} \quad \textbf{Ans.}$$

Example 1.7 *The average part produced in a certain batch manufacturing plant must be processed sequentially through six machines on average. There are 20 new batches of parts launched each week. Other pertinent data are as follows:*

Average operation time = 6 minutes

Average setup time = 5 hours

Average batch size = 25 parts

Average non-operation time per batch = 10 hr/machine

There are 18 machines in the plant working in parallel. Each of the machines can be set up for any type of job processed in the plant. The plant operates an average of 70 production hours per week. Scrap rate is negligible.

(a) Determine the manufacturing lead time for an average part.

(b) Determine the production rate.

(c) Determine the plant capacity.

(d) Determine the plant utilization.

(e) Determine the average level of work-in-process (number of parts-in-process) in the plant.

Given data:

Number of distinct operations/ machines through which work units are routed, $n_o = 6$

Average operation time, $T_c = 6$ min

Average setup time, $T_{su} = 5 \text{ hr} = 5 \times 60 = 300$ min

Average batch size, $Q = 25$ units

Average non-operation time per batch, $T_{no} = 10 \text{ hr} = 10 \times 60 = 600$ min

(d) To find the plant utilization (U):

We know that the plant utilization,

$$U = \frac{Q}{PC_w} \times 100$$

where Q = Actual output during the week

= Number of batches × Batch size

= 20 × 25 = 500

$$\therefore \quad \text{Utilization, } U = \frac{500}{700} \times 100 = \mathbf{71.43\%} \quad \textbf{Ans.}$$

(e) To find the average level of work-in-process in the plant (WIP):

The work-in-process is given by

$$WIP = \frac{A \cdot U \cdot (PC_w) \cdot (MLT)}{S_w \cdot H_{sw}}$$

$$= \frac{1 \times 0.7143 \times 700 \times \left(\frac{105}{70}\right)}{70} \quad [\because \text{Availability, } A = 100\% \text{ is assumed}]$$

$$= 10.71 \simeq \mathbf{11\ parts} \quad \textbf{Ans.}$$

Example 1.8 *A certain piece of work is produced by a firm in batches of 100. The direct materials cost for that 100 piece work is Rs. 160 and the direct labour cost is Rs. 200. Factory on cost is 35% of the total material and labour cost. Overhead charges are 20% of the factory cost. Calculate the prime cost and factory cost. If the management wants to make a profit of 10% on the gross cost, determine the selling price of each article.*

☹ ***Given Data:*** n = 100; Direct material cost = Rs. 160; Direct labour cost = Rs. 200; Factory on cost = 35% of total material and labour cost; Overhead charges = 20% of factory cost; Profit = 10%.

☺ ***Solution:*** Factory on cost $= \frac{35}{100} \times$ (Rs. 160 + Rs. 200) = Rs. 126

To find prime cost and factory cost:

$$\text{Prime cost} = \left\{\begin{matrix}\text{Direct}\\\text{material}\\\text{cost}\end{matrix}\right\} + \left\{\begin{matrix}\text{Direct}\\\text{labour}\\\text{cost}\end{matrix}\right\} + \left\{\begin{matrix}\text{Direct}\\\text{expenses,}\\\text{if any}\end{matrix}\right\}$$

$$= \text{Rs. } 160 + \text{Rs. } 200 + 0 = \textbf{Rs. 360} \quad \textbf{Ans.}$$

Factory cost = Prime cost + Factory on-cost

= Rs. 360 + Rs. 126 = **Rs. 486 Ans.** ☜

To find the selling price of each article:

Given that, Overhead charges = 20% of the factory cost

$$= \frac{20}{100} \times (\text{Rs. } 486) = \text{Rs. } 97.20$$

∴ Total cost = Factory cost + Overhead charges

= Rs. 486 + Rs. 97.20 = Rs. 583.20

We know that, Selling price = Total cost + Profit

or Selling price = Rs. 583.20 + (10% of gross cost)

or Selling price = Rs. 583.20 + (0.1 × Selling price)

or $$\text{Selling price} = \frac{\text{Rs. } 583.20}{0.9} = \text{Rs. } 648$$

The calculated selling price of Rs. 648 is for 100 articles.

$$\therefore \text{Selling price per article} = \frac{\text{Rs. } 648}{100} = \textbf{Rs. 6.48}$$ **Ans.** ☜